Prashasan July 2025, Vol. 57, Issue 1, No. 141, 158-166

https://doi.org/10.3126/prashasan.v57i1.80664
www.mofaga.gov.np/prashasanjournal
ISSN: 2565-5043 Print / ISSN: 2822-1974 Online

Causes and Effects of Variation Orders in Water Supply Projects in Nepal

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Abstract

In Nepal's construction industry, variation orders remain a major concern. They are inevitable in nearly every construction project and carry significant implications for project outcomes. If not managed properly, variation orders can negatively impact cost, schedule, and quality. This study examines the causes and effects of variation orders in water supply projects in Nepal. The research is based on a review of variation order documents from 19 water supply projects and a questionnaire survey involving clients, consultants, and contractors. A total of 52 participants contributed to the study. Data were analyzed using the Likert Scale, Relative Importance Index (RII), and Severity Index (SI). The five major causes identified are: (i) design changes during implementation, (ii) inadequate site investigation during project preparation, (iii) inaccurate cost estimation by consultants, (iv) additional work demands from user committees/beneficiaries, and (v) unforeseen site conditions, with RII values of 0.862, 0.858, 0.854, 0.838, and 0.835, respectively. The primary effects identified include cost overruns, time overruns, and increased overhead expenses.

Keywords: variation orders, design changes, site investigation, cost overrun, time overrun.

Introduction

Project cost is a critical component of construction management, especially when public funds are involved. However, a range of factors can lead to deviations from the original budget. In construction, variation orders are common and occur when changes are made to the initial project scope (Halwatura & Ranasinghe, 2013). Such changes can significantly affect project management outcomes (Ali & Majeed, 2020). Variations may involve additions, omissions, or revisions to project scope and usually impact cost, duration, and quality (Ibbs et al., 2001; Enshassi et al., 2010). They often result in delays, cost escalations, and disputes (Burati et al., 1992). A formal variation order legally modifies the contract between the employer and contractor (Ezeldin et al., 2016).

In the context of Nepal, variation orders are a persistent issue in the construction sector, which plays a pivotal role in national development. These variations often lead to cost and time overruns, strained stakeholder relationships, and project disputes. A contributing factor is the limited experience of many contractors, consultants, and clients (Ghimire et al., 2023). The Department of

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Water Supply and Sewerage Management (DWSSM) is currently implementing over 200 water supply projects across Nepal, with budgets ranging from NPR 5 million to NPR 500 million. Most of these projects have experienced variation orders. This paper aims to explore the root causes and consequences of such variations.

Objective of the Study

The objective of this study is to identify the causes and effects of variation orders in water supply projects in Nepal. It aims to offer insights, practical knowledge, and recommendations that may help reduce the occurrence of variation orders in future projects.

Literature Review

Cost is a crucial factor in construction projects, from inception to completion. Despite careful planning, unexpected issues frequently lead to cost deviations from the original contract. While variation orders are often unavoidable, efforts are typically made during design and implementation phases to minimize their occurrence. Multiple studies have investigated their causes and consequences.

Ijaola and Iyagba (2012) conducted a comparative study of change orders in public construction projects in Nigeria and Oman. They found that most variations were client-related, particularly due to owner requests for additional work. The effects included disputes, time delays, and cost overruns. The authors recommended the enforcement of building codes, periodic registration reviews, and proper feasibility studies to mitigate these issues.

Ismail et al. (2012) identified scope changes, design errors and omissions, and the financial incapability of owners as critical causes of variation in roadway projects in southern Iran. These factors led to time and cost overruns and project disputes. The authors suggested engaging specialists during the planning and execution phases.

In Sri Lanka, Halwatura and Ranasinghe (2013) found poor estimation to be the primary cause of variation orders in road construction projects, followed by unforeseen site conditions, political influences, and inadequate site investigations.

Similarly, Alaryan et al. (2014) identified the top five causes of variation orders in Kuwait's construction projects as employer-initiated changes, project scope deviations, site-related issues, design errors and omissions, and insufficient working drawing details. The consequences included project delays, cost overruns, increased financial liabilities, and deferred contractor payments. The authors advocated for thorough contract and design document reviews and improved communication among stakeholders.

Alshdiefat and Aziz (2018) examined variation orders in Jordan’s construction sector and found client-related issues, such as poor communication and delays between design and construction phases, as the most severe causes. These were followed by design errors and material shortages.

Pokharel and Joshi (2020) studied a land pooling project in Kathmandu and found that contract document conflicts and additional work demands were major sources of variation. Their study reported a 26.5% cost overrun from the original contract price. Recommendations included careful consultant selection, thorough site investigation, and ensuring contractor capacity.

Mishra et al. (2021) investigated building construction projects in Nepal and found that client-related causes included scope changes, delayed decisions, and financial constraints. Consultant-related issues involved errors in bills of quantities, design flaws, and poor judgment. Contractor-related issues included a lack of skilled managers and poor participation in the design phase. The study recommended better coordination among all stakeholders.

Ghimire et al. (2023) explored variation orders in Bharatpur Metropolitan City and highlighted major causes such as design errors, changing owner requirements, scope alterations, and poor working drawings. Their recommendations emphasized thorough planning, complete design documentation during tendering, detailed site investigations, and consultant accountability.

Research Methodology

A comprehensive literature review was conducted, during which numerous research papers on the causes of variation/change orders were analyzed. In addition, documents related to change orders from 19 water supply projects implemented by the Department of Water Supply and Sewerage Management (DWSSM), Nepal, were examined. Project managers and engineers from DWSSM were interviewed to identify the underlying causes of variation orders. Furthermore, designers/consultants and contractors were consulted to gather insights into the frequent causes and impacts of variation orders in water supply projects. Based on the document analysis, eighteen primary causes of variation orders were identified, among which twelve significant causes were selected for this study.

Table 1

The 12 major causes of variation orders in the water supply projects in Nepal selected for study purpose

S.N.	Causes of Variation Orders
1	Design changes during project implementation
2	Additional work demands from users' committees/beneficiaries
3	Unforeseen site conditions
4	Poor estimation by consultants
5	Poor site investigation during the project preparation phase
6	Natural disasters
7	Inadequate scope of work defined for the contractor
8	Conflicts between contract documents
9	Inadequate project planning
10	Errors and omissions in design
11	Political pressure during the construction phase
12	Obstacles to work from local residents

Population Size

For the purpose of this study, a total of 52 respondents were selected. These respondents included Project Directors (Superintending Engineers), Project Managers (Senior Divisional Engineers), Engineers, Consultants/Designers, and Contractors. The distribution of respondents is illustrated in Figure 1. Selection was based on their professional backgrounds and extensive experience in the design, implementation, monitoring, and supervision of water supply projects. The respondents' professional experience is presented in Figure 2.

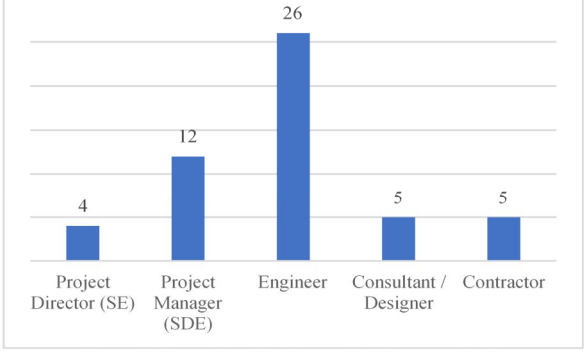

Figure 1: Occupational background of the respondents.

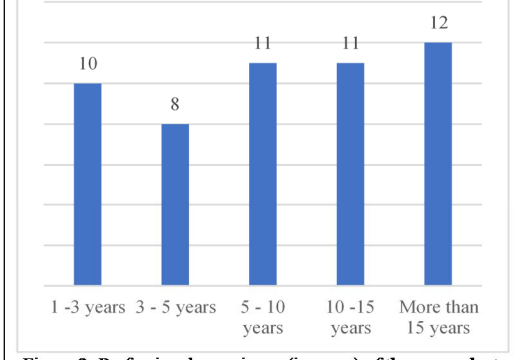

Figure 2: Professional experience (in years) of the respondents

Data Analysis

The data obtained from the questionnaire survey were processed, and the Relative Importance Index (RII) was used as shown in the Equation 1.

$$RII = \frac{\sum W}{A*N} \quad \text{..... Equation (1)}$$

Where,

W is the scale used by respondents to rate a factor, ranging from 1 to 5.
A is the highest weight in the scale. N is the total number of respondents.
Here, $W=1N_1+2N_2+3N_3+4N_4+5N_5$,
where N_1, …, N_5 are the frequencies of respondents in the 5-point Likert scale.

Furthermore, Severity Index (Alshdiefat & Aziz, 2018) was calculated using the data as indicated in equation 2.

$$\text{Severity Index (SI)} = \sum_{i}^{5}(Wi * fi) * 100/N \quad \text{.....Equation (2)}$$

$$Wi = i/N$$

Where,
SI = Severity Index; computed as the summation of importance ratings.

i = the rating from 1 to 5.
Wi = the weight of each rating.
fi = the frequency of responses for a particular rating point.
N = the total number of respondents rating a particular factor in the survey.

Result and Discussion

The respondents were asked to express their level of agreement on a five-point Likert scale ("Strongly Disagree," "Disagree," "Neither Agree nor Disagree," "Agree," and "Strongly Agree") regarding twelve identified causes of variation orders in water supply projects in Nepal. Subsequently, the Relative Importance Index (RII) was calculated for each factor to determine its relative significance. The summarized results are presented in Table 2 below.

Table 2
Causes of Variation Orders in water supply projects in Nepal

S.N.	Causes of Variation Orders in Water Supply Projects	RII	Rank
1	Design changes during project implementation	0.862	1
2	Poor site investigation during the project preparation phase	0.858	2
3	Poor estimation by the consultants	0.854	3
4	Additional work demand from users' committees/beneficiaries	0.838	4
5	Unforeseen site conditions	0.835	5
6	Inadequate project planning	0.800	6
7	Errors and omissions in design	0.796	7
8	Natural disasters	0.765	8
9	Obstacles in work from local residents	0.765	9
10	Conflicts between contract documents	0.746	10
11	Inadequate scope of work for the contractor	0.719	11
12	Political pressure during the construction phase	0.681	12

Table 2 demonstrates the ranking of variation orders in water supply projects in Nepal, as determined from the respondents' views. The results show that the major causes of variation orders in these projects are: design changes during project implementation, poor site investigation during the project preparation phase, poor estimation by the consultants, additional work demands from the users' committees/beneficiaries, and unforeseen site conditions, with RII values of 0.862, 0.858, 0.854, 0.838, and 0.835 respectively. The least important cause of variation orders, as indicated by this study, is political pressure during the construction phase.

Since design changes during project implementation are identified as the key cause of variation orders in water supply projects, it suggests that the designs prepared by consultants and reviewed by clients are either insufficient, not aligned with actual site conditions, or not developed in accordance with proper design guidelines and norms. This indicates that the design of structural components in these projects is either overlooked or prepared on weak engineering foundations.

Poor site investigation during the project preparation phase is the second most significant cause of variation orders, which is closely related to project design. If the site is not properly investigated, an accurate project design cannot be expected. Conversely, even if the design is adequate, if the site is not thoroughly investigated, the design may prove ineffective and require modifications during construction.

The Severity Index (SI) was calculated using Equation (2). The most significant cause of variation orders, design changes during project implementation, has the highest severity index (SI) of 86.15, while political pressure during the construction phase has the lowest severity index (68.08), implying a lower impact on variation orders in water supply projects in Nepal. The results are illustrated in Figure 3.

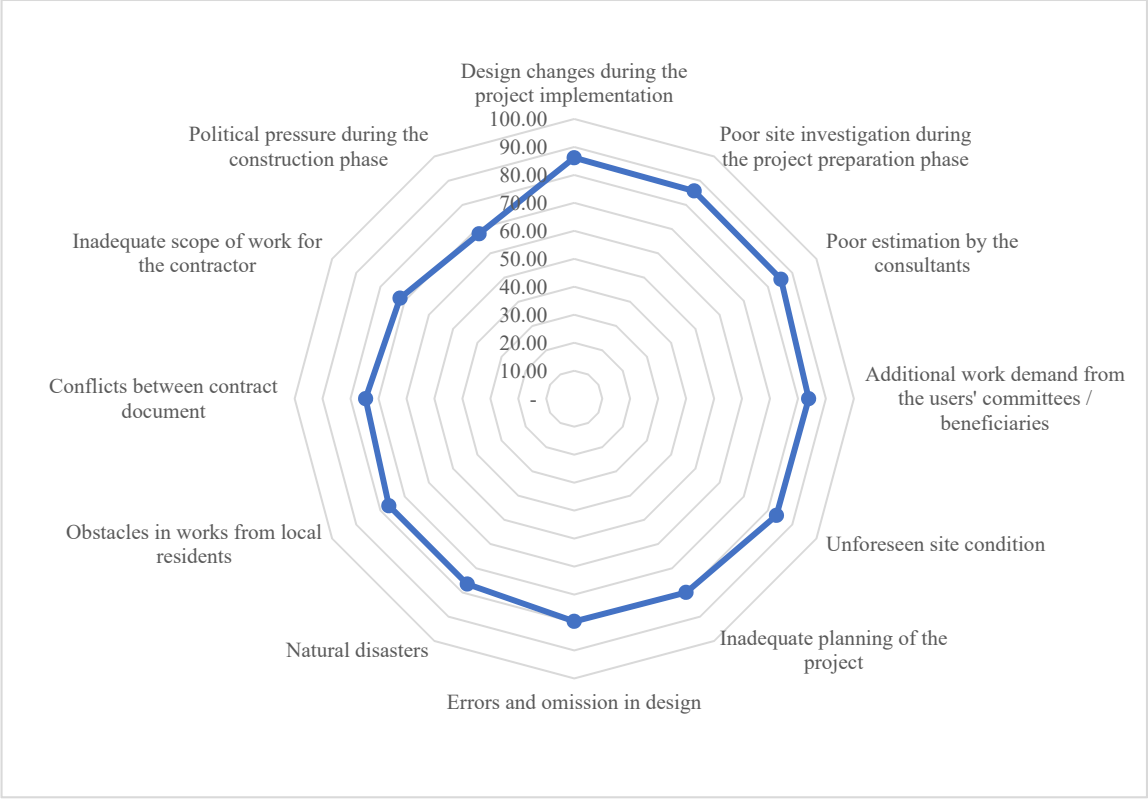

Figure 3 *Severity Index for the causes of variation orders in Water Supply Projects in Nepal*

Furthermore, the respondents were asked about the consequences of variation orders throughout the project life cycle. A total of six effects were identified based on the literature review and an analysis of documents from projects where variation orders had occurred. The results, calculated using the Relative Importance Index (RII), are presented in Table 3 below.

Table 3
Effects of the Variation Orders in the Water Supply Projects in Nepal

S.N.	Effects of variation orders	RII	Rank
1	Cost Overrun of the project	0.854	1
2	Time Overrun of the project	0.838	2
3	Increase in overhead expenses	0.815	3
4	Claims & Disputes	0.758	4
5	Poor performance relationships between client, consultant and contractor	0.692	5
6	Quality deterioration of the project	0.573	6

Table 3 illustrates that cost overrun is the major effect of variation orders in water supply projects in Nepal, with an RII of 0.854. The respondents believe that quality deterioration is the least significant effect, with an RII of 0.573. In most cases, a variation order means additional work; therefore, it is obvious that due to additional work, cost overruns and time overruns are normal phenomena. Furthermore, additional work naturally leads to an increase in overhead expenses in the project, as indicated by this study.

Conclusion and Recommendations

This study focuses on the causes and effects of variation orders in water supply projects in Nepal. From the study, it is concluded that among the twelve causes of variation orders, the top five causes are design changes during project implementation, poor site investigation during the project preparation phase, poor estimation by the consultants, additional work demands from the users' committee/beneficiaries, and unforeseen site conditions, with RII values of 0.862, 0.858, 0.854, 0.838, and 0.835 respectively, as analyzed using the Likert scale and Relative Importance Index (RII) method. The top three effects of variation orders were cost overruns of the project, time overruns of the project, and increases in overhead expenses. Variation orders have very detrimental effects on the project life. Therefore, in order to avoid or minimize the occurrence of variation orders in water supply projects in Nepal, the study suggests the following points:

- The design of the project should be prepared very carefully and reviewed critically by design experts, consultants, and the client's design engineers.
- All geological, hydrological, geotechnical, environmental, and socio-political investigations shall be conducted critically. Moreover, these studies shall be carried out by well-qualified and experienced professionals.
- The feasibility study, environmental study, and detailed engineering design shall be prepared by well-experienced and professional consultants with long-standing goodwill.

- Adequate and reasonable time and care should be given during the project preparation phases (feasibility study, environmental study, detailed design, cost estimation, and project appraisal).
- Adequate consultation meetings and discussions should be held with stakeholders and the users' committee/beneficiaries, because involving stakeholders and beneficiaries in the execution phase of the project will help minimize additional work demands.

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