

Assessment of the Cause of Variation and Extension of Time in Water Supply Projects

Mohan Regmi¹, Rajib Pokhrel^{1*}

¹ School of Engineering, Faculty of Science and Technology, Pokhara University, Pokhara, Nepal

*rajibp@pu.edu.np

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Abstract

Public water supply projects in Nepal frequently face cost overruns and schedule delays. It mostly investigates the causes and extent of Variation Orders (VO) and Extensions of Time (EOT) in water supply projects implemented under the Department of Water Supply and Sewerage Management (DWSSM) in Gandaki Province, Nepal. Primary data were collected through questionnaires from clients, contractors, and water user committees, while secondary data were obtained from EOT and VO approval reports. Relative Importance Index (RII) and Severity Index (SI) were used to rank and prioritize the causes of VO and EOT. Among 25 identified causes, inadequate coordination among stakeholders with RII 0.785 and communication delay from the project manager with SI 78.889 were found to be the most significant causes of EOT. It reflected different ranking orders using different tools. Similarly, among 13 identified causes of VO, mistakes in the bill of quantities with RII 0.852 and incomplete design with SI 85.185 were the most influential causes of VO. Spearman's rho correlation analysis showed a strong positive correlation between the causes of VO and EOT, with a correlation coefficient of 0.805 and a significance value of $p = 0.000$ (<0.01). The Kruskal-Wallis test confirmed that all respondent groups shared similar perceptions regarding these causes. Reliability tests yielded Cronbach's alpha values above 0.8, validating the internal consistency of the survey data. Improper communication among the stakeholders and technical errors in designing and quantifying the quantities were the major causes of the water supply project delay and variation.

Keywords: Variation Order, Extension of Time, Water Supply Projects, Relative Importance Index, Severity Index

1. Introduction

Water supply projects are essential components of public infrastructure, supporting public health, socio-economic development, and Sustainable Development Goal (SDG) targets. In Nepal, the Department of Water Supply and Sewerage Management (DWSSM) and its provincial/municipal offices are responsible for planning and implementing water supply schemes across diverse geographical and socio-political contexts. Despite growing investments, many projects experience scope deviations and schedule delays, often resulting in cost escalation, reduced service efficiency, and weakened institutional credibility.

The Asian Development Bank reports that only 15% of Nepal's public construction projects are completed within the intended schedule, with an average completion time of 37 months instead of the planned period. This delay has led to increased costs, reduced benefits, and the failure to achieve development goals (Bhattarai, 2023). Project variations and delays are frequent on most projects in Nepal. Across the globe, infrastructure projects, particularly in the public sector, often experience cost and time escalations due to a multitude of internal and external factors. Basically, variations will cause problems for

everyone involved in the project. Variations can originate from numerous factors pertinent to the construction projects (Arain, 2005).

Although Variation Order (VO) and Extension of Time (EOT) have been widely studied in building, road, and utility projects, limited empirical research specifically examines these issues within Nepal’s water supply sector. This study addresses this gap by quantifying the extent of VO and EOT in DWSSM-implemented projects and identifying the underlying causes from multi-stakeholder perspectives.

2. Methodology

A comprehensive literature review was conducted to identify recurring causes of EOT and VOs in construction projects. EOT and VO approval records from 17 water-supply projects implemented over the last five years under the Water Supply and Sanitation Management Office (WSSMO), Pokhara, and WSSMO Lamjung were collected and analyzed. Additionally, structured questionnaires were administered to contractor representatives, Water User and Sanitation Committee (WUSC) representatives, and client representatives. Based on literature review and field consultations, 25 causes of EOT and 13 causes of VO were identified for analysis, as in Table 1 and 2.

Table 1: Major causes of EOT in water supply projects in Gandaki Province are considered in this study.

S.N.	Cause of EOT	Notation
1	Slow decision by clients	F 1
2	Delay in fund release from the government	F 2
3	Unavailability of fund	F 3
4	Political/Bureaucratic influences	F 4
5	Unrealistic time frame allocation for the project	F 5
6	Frequent design during construction	F 6
7	Delay in instruction from the project manager	F 7
8	Poor site investigation before the project start	F 8
9	Mismatch between design and field conditions	F 9
10	Inefficient project planning and scheduling	F 10
11	Low financial capability of the contractor	F 11
12	Incompetent professionals in construction site	F 12
13	Improper cash flow management	F 13
14	Mistake during construction that needs reconstruction	F 14
15	Low quality of work	F 15
16	Construction method and technology	F 16
17	Limited technical capacity of WUSC	F 17
18	Inadequate coordination among stakeholders	F 18
19	Poor performance of the contractor (delays in mobilization, shortage of equipment, lack of skilled manpower)	F 19
20	Social issues at the construction site	F 20
21	Government regulation	F 21
22	Variation order	F 22
23	Unavailability of labor force and materials	F 23

S.N.	Cause of EOT	Notation
24	Natural disaster (flood, landslide, earthquake)	F 24
25	Unfavorable weather condition	F 25

Table 2: Major causes of VO in water supply projects in Gandaki Province are considered in this study.

S.N.	Cause of VO	Notation
1	Incomplete or inaccurate design	VF 1
2	Frequent design modification after construction start	VF 2
3	Errors or omissions in the Bill of Quantities	VF 3
4	Poor site investigation to project implementation	V F 4
5	Mismatch between field condition and design assumption	V F 5
6	Changes in scope by client/WUSC	V F 6
7	Political interference or changes in project priorities	V F 7
8	Additional work request by the local community/WUSC	V F 8
9	Additional work due to unforeseen site conditions	V F 9
10	Inefficient procurement and contract management procedures	VF 10
11	Natural disasters	VF 11
12	Legal or regulatory changes during construction	VF 12
13	Land issue and local protest	VF 13

2.1 Study area

The study focused on DWSSM water supply projects managed by WSSMO Pokhara and WSSMO Lamjung, covering Kaski, Tanahun, Parbat, Syangja, Nawalpur, Gorkha, and Lamjung districts as shown in Fig. 1. Primary data were collected through a structured set of questionnaires administered to 20 client representatives, 17 contractor representatives, and 17 WUSC representatives. Similarly, secondary data were collected from variation order approvals, extension of time approvals, progress reports, and project documentation.

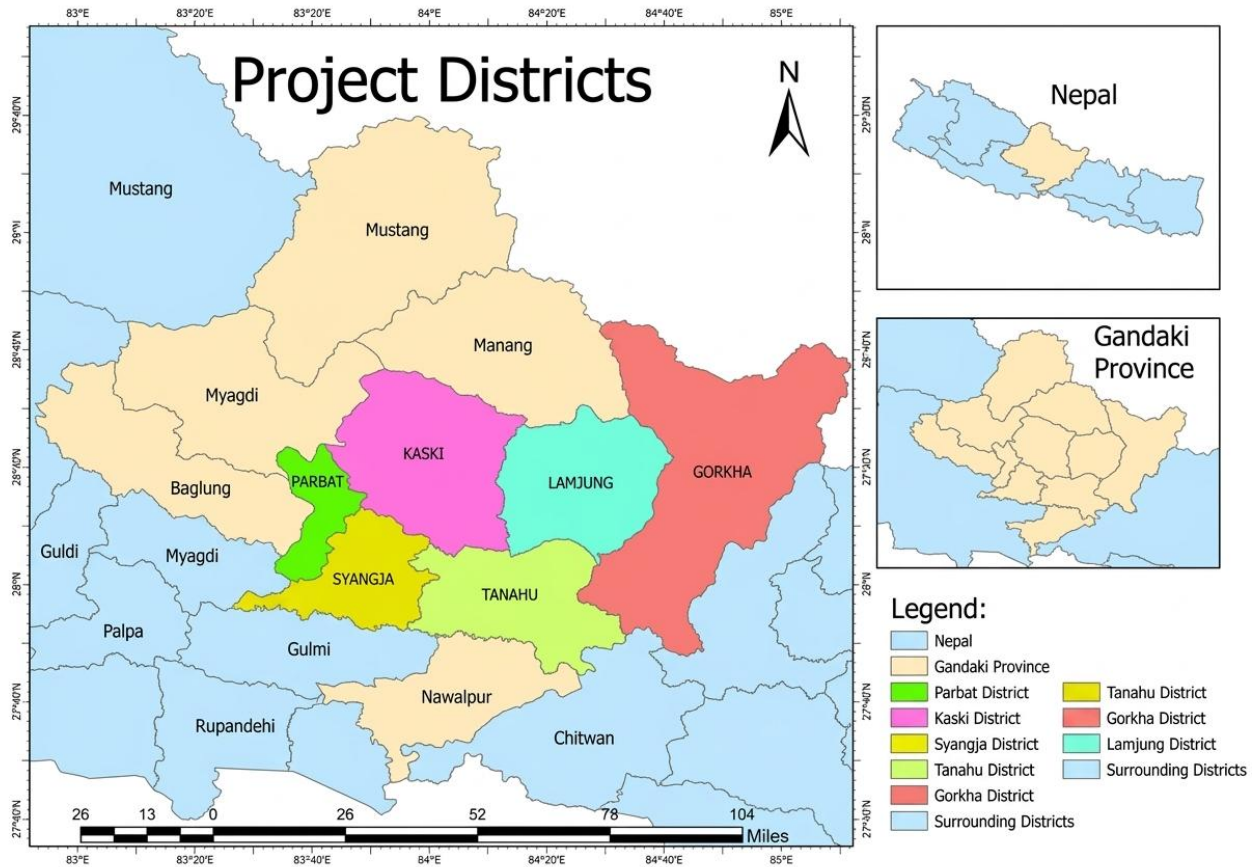


Fig. 1: Study Area: water supply projects operated in different districts of Gandaki Province.

2.2 Sampling procedure and sample size

All the water supply projects that are implemented by WSSMO Pokhara and WSSMO Lamjung that needed either EOT or Variation or both in the last five years were taken as the population of this study. Altogether, there were seventeen water supply projects. Participants of the study include the client/consultant, representative from the contractor, and the water user’s committee. The whole population, covering every stakeholder, was selected from 17 water supply projects. Stakeholders, i.e., client/consultant, representative from the contractor, and the water user’s committee, were considered in this study.

The Sampling procedure carried out for the determination of the objective was non-random/non-probability sampling, in which basically judgmental sampling or purposive sampling was applied. The sample size consisted of client/consultant, contractor, and user committee member representatives involved in the DWSSM Water Supply Project in Gandaki Province, and was selected as the total population. Moreover, data were collected using a census approach.

Table 3: Sampling procedure and sample size

Organization	Total Population	Sample Size
Client/consultant	20	20
Contractor	17	17
WUSC	17	17

Total	54	54
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2.3 Data analysis

Data obtained from the questionnaire survey were processed and analyzed to calculate the relative importance index (RII) using Eq. (1).

$$\text{Relative Importance Index (RII)} = \frac{\sum W}{(A \times N)} \tag{1}$$

Where W is the weightage given to each factor by the respondents, A is the highest possible rating, and N is the total number of responses. The RII values range from 0 to 1, with higher values indicating greater importance.

Moreover, severity Index (SI) was calculated using the Likert data according to the Eq. (2). as calculated by:

$$\text{Severity Index (SI)} = \sum_i^5 (W_i \times f_i) \times \frac{100}{N} \tag{2}$$

Where,

SI = Severity Index

i = rating of 1 to 5

W_i = weightage of individual rating

f_i = Particular rating point frequencies

N = total number of respondents rating a particular factor in the survey

Reliability analysis was carried out using the Cronbach's Alpha which is represented by Eq. 3.

$$\text{Cronbach's } \alpha = \frac{K}{K-1} \left(1 - \frac{\sum S_y^2}{S_x^2} \right) \tag{3}$$

Where;

α = Cronbach's Alpha

K = no. of items

∑ S_y² = sum of item variance

S_x² = variance of total score

Similarly, the Kruskal-Wallis test was applied to examine whether the perspectives of the client, contractors, and WUSC towards the cause of variation order and extension of time are the same or different. Correlation analysis between the mean VO (causes of variation order) and mean EOT (Extension of time) was also conducted using IBM SPSS version 27 software.

3. Result and Discussion

3.1 Respondent Profile

Among 54 respondents, 48% had less than five years of experience, 33% had five to ten years, and 19% had more than ten years of experience. Likewise, 41% had participated in one to five projects, while 28% had been involved in more than ten projects, as in Fig. 2.

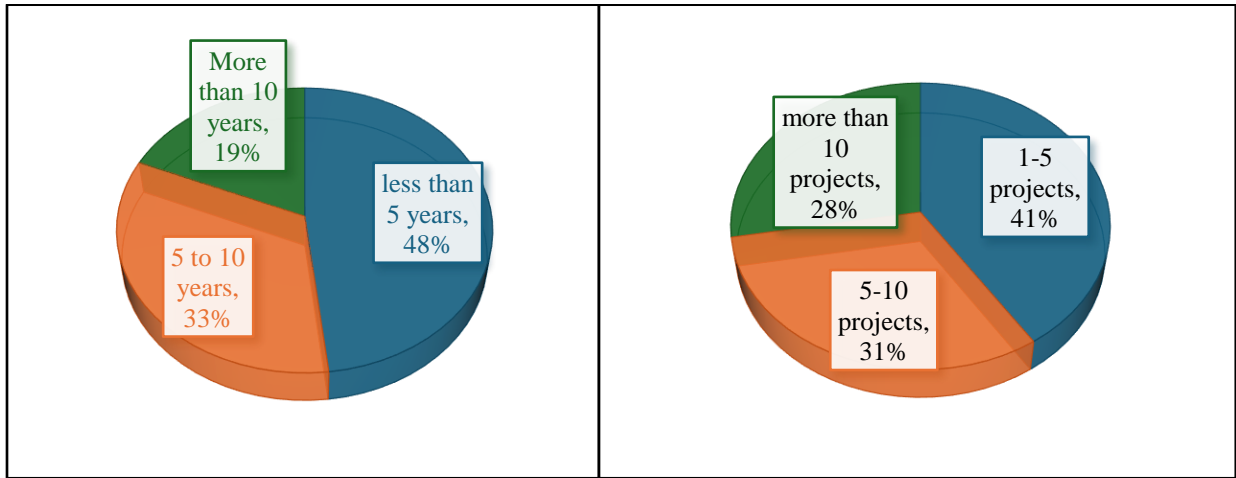


Fig. 2: Respondents' experience in years and the number of their involvement in water supply projects.

The histogram, as in Fig. 3, the response rate was 100% for all three stakeholder groups, such as clients, contractors, and WUSC representatives. This complete response from each category ensures balanced and reliable representation of perceptions for this study.

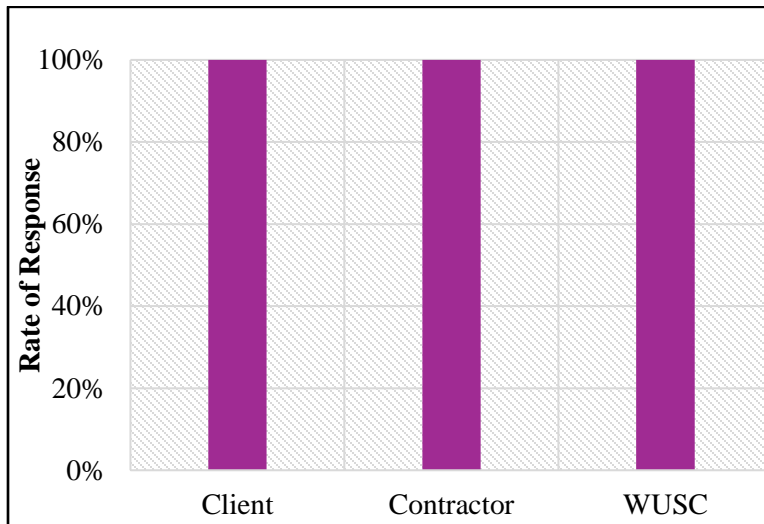


Fig. 3: Rate of response to the set of questionnaires administered.

3.2 Analysis of extension of time

3.2.1 Relative Importance Index Analysis

The data collected from the survey was analyzed using Microsoft Excel. Respondents were asked to rate each potential factor contributing to the extension of time on a scale such that strongly disagree=1, disagree=2, neutral=3, agree = 4, and strongly agree=5. The potential factors contributing to EOT were asked in the survey. Table 4 shows the major factors contributing to the extension of time based on the RII.

Table 4: Rank of the cause of extension of time in total using the RII method

Cause of extension of time	RII	Rank
Inadequate coordination among stakeholders	0.789	1
Inefficient project planning and scheduling	0.785	2

Cause of extension of time	RII	Rank
Mismatch between design and field conditions	0.781	3
Variation order	0.781	3
Improper cash flow management	0.770	5
Social issues at the construction site	0.763	6
Poor site investigation before the project started	0.759	7
Unrealistic time frame allocation for the project	0.756	8
Poor performance of the contractor (delays in mobilization, shortage of equipment, lack of skilled manpower)	0.756	8
Frequent design during construction	0.733	10
Natural disaster (flood, landslide, earthquake)	0.715	11
low financial capability of the contractor	0.707	12
Construction method and technology	0.707	12
Unavailability of labor force and materials	0.707	12
Unfavorable weather condition	0.693	15
Slow decision by clients	0.678	16
unavailability of fund	0.670	17
Delay in instruction from the project manager	0.659	18
Incompetent professionals on a construction site	0.659	18
Delay in the fund release from the government	0.656	20
Political/Bureaucratic influences	0.652	21
Government regulation	0.652	21
Limited technical capacity of WUSC	0.633	23
Mistake during construction that needs reconstruction	0.589	24
Low quality of work	0.507	25

From the analysis, it was found that inadequate coordination among stakeholders with RII 0.79 was the top-ranked factor contributing to the extension of time. Similarly, inefficient project planning and scheduling with RII 0.79, Mismatch between design and field condition with RII 0.78, Variation order with RII 0.78, and improper cash flow management with RII 0.77, were ranked second, third, fourth, and fifth factors contributing to EOT. While low-quality work with RII 0.507 was ranked last.

The ranking results revealed that inadequate coordination among stakeholders (RII = 0.789) was the most influential factor contributing to project delays. In DWSSM-implemented water supply projects, responsibilities are distributed among several entities-DWSSM and its offices (WSSMO) on the client side, Water Users’ and Sanitation Committees (WUSC) at the community level, and private contractors for execution. This multi-tiered structure often results in fragmented communication, overlapping authority, and delayed decision-making. For instance, when design clarifications or approvals must pass through both the central department, which is DWSSM, and the implementing office, which is WSSMO, the response time increases, causing idle resources at the site.

3.2.2 Severity index analysis

A Severity Index (SI) analysis was conducted to evaluate the relative impact of various factors contributing to the time extension of construction projects. Each factor was assessed through a structured

questionnaire survey, where respondents rated the significance of identified causes based on their field experience. The collected data were analyzed statistically to compute the severity index for each factor.

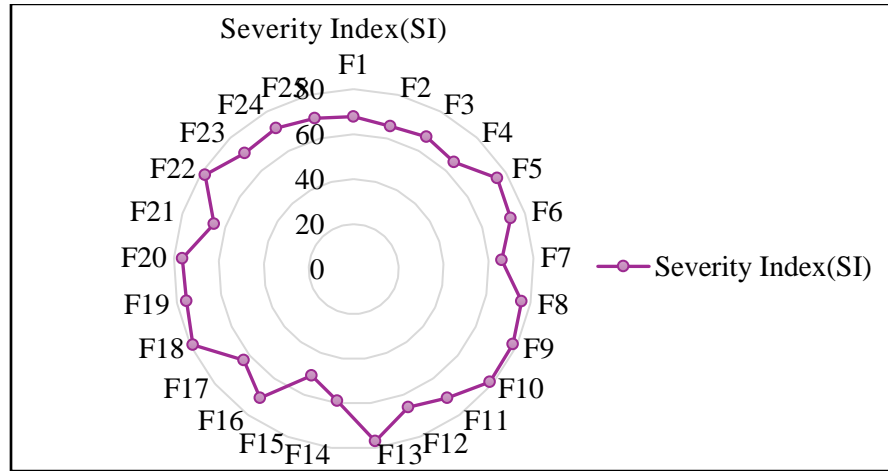


Fig. 4: Severity index for the causes of extension of time

The results showed that delay in instruction from the project manager (SI = 78.889), frequent design changes during construction (SI = 78.519), poor contractor performance (SI = 78.148), Government regulation (SI=78.148), construction method and technology (SI=77.037) were found to be the top five causes of extension of time. While the Unfavorable weather condition (SI=50.741) was ranked last.

The variation in rankings between the RII and SI results indicates that the frequency and impact of delay factors differ. From the RII results, factors like inadequate coordination and inefficient planning are perceived as the most frequent and common contributors to project delay. However, the SI ranking shows that when issues such as delay in instruction, frequent design changes, and poor contractor performance occur, their severity or consequence on project time is higher, even if they happen less often. In summary, RII highlights commonly occurring causes, while SI emphasizes those with the most severe time impact, explaining the difference in their ranking orders.

A study by Timilsina et al. (2020) in bridge construction in Nepal also revealed similar causes of extension of time as identified by this study. Not only in the context of Nepal, but also in the context of other countries and different projects, the causes of extension of time are similar across different countries and different projects (Frimpong et al., 2003).

3.3 Analysis of variation order

3.3.1 Relative importance index analysis

Table 5: Rank of cause of variation order in total using RII

Cause of variation order	RII	Rank
Errors or omissions in the Bill of Quantities	0.852	1
Mismatch between field condition and design assumption	0.852	1
Incomplete or inaccurate design	0.848	3
frequent design modification after construction start	0.811	4
Poor site investigation prior to project implementation	0.811	4

Cause of variation order	RII	Rank
Additional work due to unforeseen site conditions	0.789	6
Additional work request by the local community/WUSC	0.752	7
Land issue and local protest	0.748	8
Changes in scope by client/WUSC	0.737	9
Natural disasters	0.685	10
Political interference or changes in project priorities	0.637	11
Inefficient procurement and contract management procedures	0.626	12
Legal or regulatory changes during construction	0.593	13

For variation orders, the RII analysis identifies error or omission in the bill of quantities (BOQ) (RII = 0.852) as the most significant factor, followed by incomplete or inaccurate design and changes in the scope of work by the client. This pattern points toward design-stage weaknesses rather than construction-stage inefficiencies. The recurrence of BOQ-related errors indicates that pre-tender documentation is not being adequately reviewed or validated. Such discrepancies often lead to contractual disputes, cost escalation, and re-measurement requirements during construction. The finding reinforces the necessity for DWSSM to institutionalize independent design and quantity verification prior to tendering. In addition, the frequent ranking of unforeseen site conditions and changes in material specification highlights the lack of comprehensive site investigations during the planning phase.

3.3.2 Severity index analysis

Table 6: Rank of the cause of variation in total using SI

Cause of variation order	Severity index (SI)	Rank
Incomplete or inaccurate design	85.185	1
Poor site investigation prior to project implementation	85.185	1
Errors or omissions in the Bill of Quantities	84.815	3
Mismatch between field condition and design assumption	81.111	4
frequent design modification after construction start	81.111	4
Changes in scope by client/WUSC	78.889	6
Land issue and local protest	75.185	7
Legal or regulatory changes during construction	74.815	8
Additional work due to unforeseen site condition	73.704	9
Political interference or changes in project priorities	68.519	10
Additional work request by local community/WUSC	63.704	11
Natural disasters	62.593	12
Inefficient procurement and contract management procedures	59.259	13

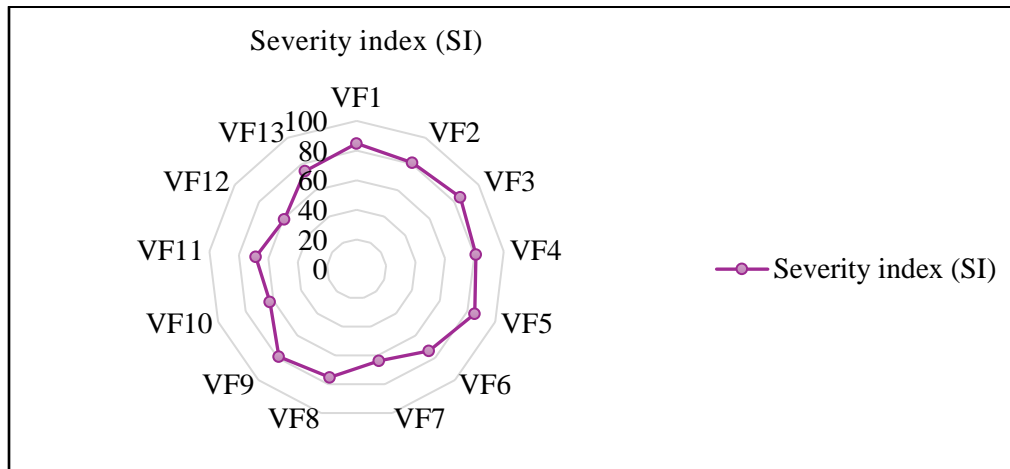


Fig. 5: Severity index for the cause of variation order.

According to the SI results, incomplete or inaccurate design (SI = 85.185) emerges as the most severe cause of variation. This suggests that design-related lapses, though not always frequent, have disproportionately large financial impacts. Other high-severity causes, such as errors in BOQ and changes in work scope, further confirm that weaknesses at the design and planning stage propagate into significant cost variations downstream.

The findings from both the Relative Importance Index (RII) and Severity Index (SI) analyses showed a strong consistency in identifying the major causes of variation orders. In both methods, incomplete or inaccurate design, poor site investigation, and errors or omissions in the Bill of Quantities ranked among the top factors. This close alignment between RII and SI results reinforces the reliability of the responses and indicates that design- and planning-related deficiencies are universally perceived by all stakeholder groups as the dominant contributors to variation in DWSSM water-supply projects. This study showed similar results as identified by Koirala (2021), who focused on building projects in Nepal, and Kandel (2025), who focused on water supply projects in Nepal. Similarly, a study by Berihu et al. (2023) in water supply projects in Ethiopia, Gardezi et al. (2014) on construction projects in Pakistan, and Aziz (2013) on construction projects in Egypt also found causes and rank of variation order similar to this study. This revealed that the cause of variation in projects is similar across the globe and across different construction projects.

3.4 Reliability analysis

The calculated value of Cronbach's Alpha was 0.84. According to standard reliability criteria, a value above 0.70 indicates acceptable reliability, while values above 0.80 are considered good. Therefore, the obtained value ($\alpha = 0.84$) demonstrates high internal consistency and reliability. The calculated value of Cronbach's Alpha was 0.82. According to standard reliability criteria, a value above 0.70 indicates acceptable reliability, while values above 0.80 are considered good. Therefore, the obtained value ($\alpha = 0.82$) demonstrates high internal consistency and reliability.

Table 7: Cronbach’s alpha for the cause of the extension of time

Variables	Description	Values
K	Item number	25
ΣS^2y	sum of item variance	20.44
S^2x	variance of total score	107.72
α	Cronbach’s alpha	0.84

Table 8: Cronbach’s alpha for the cause of variation order

Variables	Description	Values
K	Item numbers	13
ΣS^2y	sum of item variance	8.71
S^2x	variance of total score	35.40
α	Cronbach’s alpha	0.82

3.5 Group comparison

To determine whether there is a significant difference among the perspectives of the three respondent groups, that is, clients, contractors, and water users' committees, towards the causes of variation and extension of time, the Kruskal–Wallis test was applied as in Fig. 6 and 7. This non-parametric test is suitable for comparing the mean responses of more than two independent groups using Likert scale data, as the mean responses did not follow normality. The test results indicate whether the differences in perceptions among the three groups are statistically significant. A *p*-value less than 0.05 suggests that at least one group’s perception significantly differs from the others, while a *p*-value greater than 0.05 indicates that all groups share a similar perspective regarding the causes of variation and time extension in water supply projects.

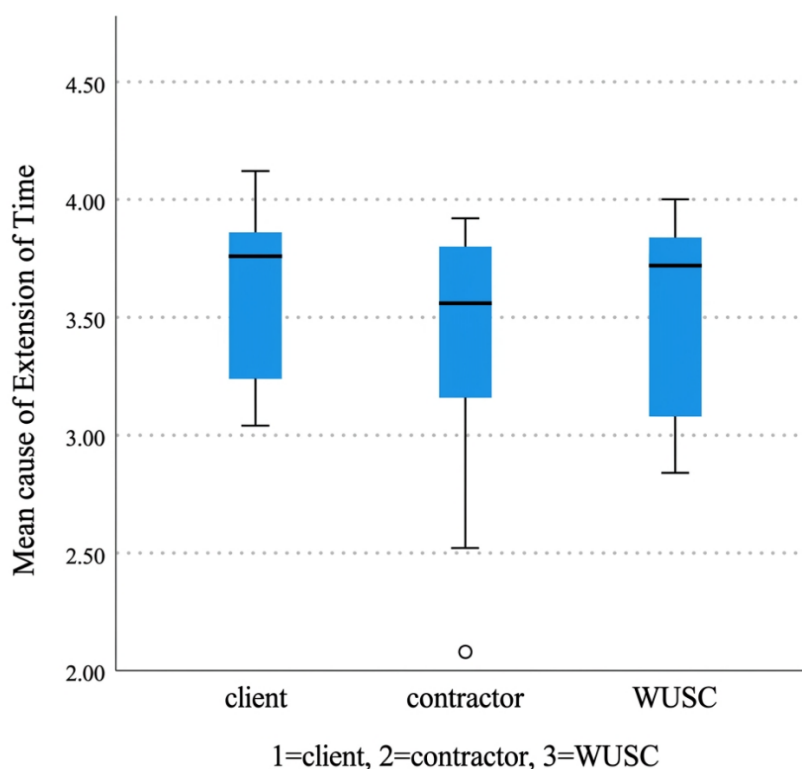


Fig. 6: Independent samples Kruskal -Wallis test for mean cause of EOT.

Table 9: Hypothesis test summary for EOT

S.N.	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The distribution of Mean EOT is the same across categories of 1=client, 2=contractor, 3=WUSC.	Independent-Samples Kruskal-Wallis Test	0.567	Retain the null hypothesis.

a. The significance level is .050

b. Asymptotic significance is displayed

Table 10: Hypothesis test summary for Mean VO.

S.N.	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The distribution of Mean VO is the same across categories of 1=client, 2=contractor, 3=WUSC.	Independent-Samples Kruskal-Wallis Test	0.482	Retain the null hypothesis.

a. The significance level is .050.

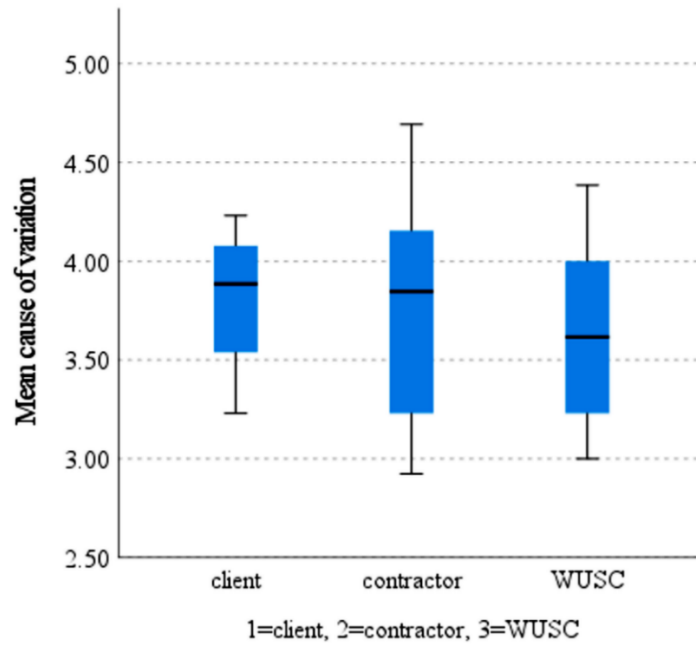


Fig. 7: Independent samples Kruskal-Wallis Test of mean cause of variation

The Kruskal–Wallis test was conducted to examine whether there were significant differences among the three respondent groups, clients, contractors, and water users’ committees (WUSC) in their perceptions of the causes of variation (Mean VO) and extension of time (Mean EOT) in water supply projects. The results showed that for both Mean EOT ($p = 0.567$) as in Table 9 and Mean VO ($p = 0.482$) as in Table 10, the p -values are greater than the significance level of 0.05. Therefore, the null hypotheses were retained, indicating that there was no statistically significant difference in perceptions among the three respondent groups. This suggests that clients, contractors, and WUSC share similar views regarding the causes of variation and time extension in water supply projects.

3.6 Correlation analysis

Examining if there is a meaningful correlation between the reasons for variance and time extensions in water supply projects was crucial. The non-parametric Spearman's rank-order correlation test was chosen since the data did not follow a normal distribution and were gathered using a Likert scale. This test may be used to determine how strongly and in which direction two ordinal variables are associated. In order to ascertain if a rise in variation-related factors is linked to a comparable increase in time extension factors across the projects that were evaluated, an analysis was conducted.

Table 11: Spearman's rho correlation among mean EOT and mean VO

Correlations				
Spearman's rho	Mean EOT	Correlation Coefficient	1.000	.805**
		Sig. (2-tailed)		0.000
	Mean VO	N	54	54
		Correlation Coefficient	.805**	1.000

	Sig. (2-tailed)	0.000
N	54	54

** . Correlation is significant at the 0.01 level (2-tailed).

To examine the relationship between the causes of variation and extension of time in water supply projects, a Spearman’s rank-order correlation analysis was performed. The result shows a strong positive correlation between Mean VO (causes of variation) and Mean EOT (causes of extension of time), with a correlation coefficient of 0.805 and a significance value of $p = 0.000 (< 0.01)$ as shown in Table 11. This indicates that as the factors contributing to variation increase, the likelihood of time extension also increases. In other words, variation and extension of time are closely interrelated issues in water supply projects, suggesting that effective control of variation factors can help minimize project delays.

4. Conclusion

This study assessed the causes and extent of Variation Orders (VO) and Extension of Time (EOT) in water supply projects implemented under the Department of Water Supply and Sewerage Management (DWSSM) in Gandaki Province. A total of 17 projects were analyzed. Among the 25 identified causes, inadequate coordination among stakeholders (RII = 0.789), inefficient project planning and scheduling (RII = 0.785), mismatch between design and field condition (RII = 0.781), variation order (RII = 0.781), and improper cash flow management (RII = 0.770) were ranked as the top five most influential factors contributing to extension of time, while low quality of work (RII = 0.507) was ranked the lowest based on the Relative Importance Index. Similarly, according to the Severity Index, delay in instruction from project manager (SI = 78.889), frequent design changes during construction (SI = 78.519), poor performance of contractor (SI = 78.148), government regulation (SI = 78.148), and construction method and technology (SI = 77.037) were identified as the top five most severe causes of delay, while Unfavorable weather condition (SI = 50.741) ranked the lowest. From the study, it was observed that a distinct order of causes cannot be fixed, as the two indicators (RII and SI) ranked the factors in different orders. However, both indicators consistently revealed that the identified factors significantly influence the extension of time in construction projects.

Among the 13 identified causes, error or omission in bill of quantities (RII = 0.852), mismatch between field condition and design assumption (RII = 0.852), and incomplete or inaccurate design (RII = 0.848) were ranked as the top three most influential causes of variation orders based on the Relative Importance Index. Similarly, according to the Severity Index, incomplete or inaccurate design (SI = 85.185), poor site investigation before project implementation (SI = 85.185), error or omission in bill of quantities (SI = 84.185) were ranked as the most severe causes. From the study, it was observed that a distinct order of causes cannot be fixed, as the two indicators (RII and SI) produced slightly different rankings. Nevertheless, both measures consistently indicate that design-related and pre-construction deficiencies have a major influence on the occurrence of variation orders. Spearman’s rho correlation analysis showed a strong positive correlation between causes of variation and extension of time, with a coefficient of 0.805 and a significance value $p=0.000 (<0.01)$. The results of the Kruskal-Wallis tests confirmed that all stakeholder groups, clients, contractors, and WUSC share similar perceptions regarding these causes. Reliability tests yielded Cronbach’s alpha values above 0.8, validating the internal consistency of the survey data.

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