Everest Advances in Science and Technology (EAST), Vol. 1, No. 1, 2025
ISSN: 3102-0410(print), 3102-0429(online)

Analysis of Cost deviation in civil works of selected hydropower projects of Province No. 1 and Gandaki Province

AARSHIKA K.C.[1*]

Abstract. Cost of construction project is one of the major concerns of the parties involved in the project. The percentage of difference between the initial cost and final cost is known as cost deviation. In the context of developing countries like Nepal, inadequate planning often leads to significant cost deviation in construction projects. A case study has been done observing four hydropower projects: Rudi Khola A, Hewa Khola HEP, Midim Khola HEP and Mistri Khola HEP. The objective was to analyze the current scenarios of cost deviation, identifying underlying causes and suggesting remedial measures to mitigate such deviations. Data were collected through the bill of quantities, final Interim Payment Certificates (IPCs), and questionnaire survey. The qualitative response from the questionnaire survey has been quantified with five point ranking Likert scale for analysis.

The study revealed that the percentage deviation in cost lies between 18 % to 42 %. The main causes of cost deviation were identified separately .i.e. In Rudi Khola A HEP and Hewa Khola HEP, quantity overrun was the main cause. In Midim Khola HEP, change in design, quantity over run were identified as the major causes. In case of Mristi Khola HEP, seepage water management inside tunnel and price escalation were main causes of cost deviation.

Based on the feedback of the parties involved, the remedial measures suggested are to review and improve bid documents such as technical specifications, drawings, bill of quantities by the consultant; contractor should have enough cash before beginning of any project, frequent preventive maintenance of equipment by hiring full time skilled mechanics; client should ensure quality design of the project and other measures as effective strategic planning, geological investigation should be done

Keywords: Quantity over run, change in design, price escalation, preventive maintenance, technical specifications, geological investigation, cost deviation, Bill of quantities, quality design, bid document.

---

[1]Nepal Engineering College, Bhaktapur, Nepal
E-mail: kcrcka@gmail.com
[*] Corresponding author
Manuscript received: 27 July, 2025; revised: 13 August 2025; accepted: 5 September, 2025.
Everest Advances in Science and Technology (EAST), Vol. 1, No. 1, 2025

1. Introduction

1.1. **Background.** A successful project is one which has been completed as per the technical specification, the schedule, and within the budget. The cost of a construction project is one of the foremost imperative aspects in the construction industry. Due to numerous reasons, the total cost of a project notably deviates from the initially estimated cost [33]. The major concern of professionals in the construction industry is the wide gap between final account figures and the preliminary estimates arrived before the contract stage [23]. In the context of developing countries like Nepal, due to various reasons such as changes in scope of work, specifications, differing site conditions, increase in quantity of works, and unforeseen conditions, cost deviation exists [11].
Upper Trishuli 3A (60 MW), Middle Marsyangdi (70 MW), and Kulekhani-III (14 MW) are large hydropower projects having installation capacity greater than 10 MW, which were also completed with considerable deviation in project cost [29]. Similarly, in other small hydropower projects having installation capacity less than 10 MW, such as Lower Piluwa Hydropower Project and Hadi Khola Hydropower Project, there was deviation in the original cost by the time the project was completed [36]. Despite the size and nature of the project, deviation was seen in the cost of hydropower projects.
Also, the largest share of installed costs for hydropower projects is usually taken up by civil works for the construction of the hydropower plant, such as headworks, dam, tunnels, canal, and powerhouse [21].
Therefore, it is necessary to study the construction phase of hydropower projects in order to identify the causes of deviation so that the negative impact of deviation can be minimized in future hydropower projects.

1.2. **Statement of the Problem.** In the Nepalese construction industry, hydropower construction projects are being implemented without proper planning, estimation, and detailed study, which results in cost deviation of the projects by the time they are completed [31]. The final project cost of completed hydropower projects has considerable deviation from the original cost [28].
National pride projects like Middle Marsyangdi Hydropower Project (70 MW) and Kulekhani-III Hydroelectric Project (14 MW) faced cost deviation of more than 50% [29]. Delay and cost overrun occur in all phases of a project's life span. However, significant cost deviations usually occur during the construction phase [38].
Identifying the factors that lead to cost deviation is a way to control project costs. Very few studies have been done to identify cost deviation in the hydropower sector of Nepal. Therefore, studies in this field are very important to explore matters related to project cost deviation and make possible recommendations based on findings so that the parties involved in the projects can benefit.

1.3. **Research Objectives.** The general objective of this study is to analyse cost deviation in selected hydropower projects of Nepal.
The specific objectives of the study are as follows:

(1) To analyse the current scenarios of cost deviation of selected hydropower projects.
(2) To find out the major causes of cost deviation in selected hydropower projects.
(3) To find out the remedial measures of cost deviation of hydropower projects.

1.4. **Significance of the Study.** This study identifies the causes of cost deviation and recommends remedial measures for cost deviation in the construction of hydropower projects. Hence, all parties involved in the project—such as clients, consultants, and contractors—will benefit from the study.

The developers (clients) of hydropower projects will be able to minimize the wide gap between final and initial estimated costs. The consultants involved in the projects can gain better insight for proper estimation during the feasibility study stage. Contractors of hydropower construction projects will be able to clearly identify the possible causes of deviation during construction and will incorporate the rate of major works accordingly so that the negative impact of deviation can be avoided.

1.5. Scope and Limitation.

Scope. This study mainly focuses on major activities of civil works to analyse the current scenario of cost deviation in hydropower projects. In addition, it also focuses on analysing the causes and remedial measures of cost deviation in selected hydropower projects of Nepal.

Limitation. This research is limited to the civil construction works of hydropower projects, as civil works cover a major percentage of total project cost. Furthermore, the research only covers hydropower projects developed by Independent Power Producers (IPPs).

2. Literature Review

2.1. **General background.** Cost deviation may be expressed as a percent difference between the final cost of the project (actual cost) and the contract award amount (estimated cost). Generally, the success of project is defined by accomplishing it within specified cost, time and quality. However, the construction industry is full of projects that were completed with significant time and cost overruns [3]. The cost deviation can be either positive or negative (i.e., the final cost is above, or below the initial one). When it is positive, there is a cost overrun.

2.2. **Causes of cost deviation in construction projects.** From the preliminary survey conducted in water drilling projects in Ghana attributed the cost overruns to irregular monthly payment, the escalation of material prices, inadequate cash flow during construction, deficiencies in cost estimates prepared [38]. Some researchers like [25] and [5] have criticized bill of quantities lacking precision as one of the major reason for cost deviation. A fuzzy model was developed for forecasting the probability of cost overrun risk for Indian construction project. Among major factors shortage of construction material, fluctuation in price of material, inappropriate government policies and laws, unrealistic contract duration, differing site (ground) conditions, inflation, contractor' lack of experience and frequent design change are commonly occurred cost deviation factors [34]. Similarly, research done in delay and cost overrun in Vietnam construction project identified cost overrun factors such as financial difficulties of owner and contractor, , slow payment of completed works by owner, slow inspection of completed works by consultant and delay of works etc. [26].

2.3. **Causes of Cost Deviation in Hydropower Construction Projects.** In order to identify the various causes of variation orders in the construction of hydropower projects in Pakistan, a survey questionnaire was conducted. The most significant factors identified were:

(1) Change of scope,
(2) Omission and mistakes in design,
(3) Change in design,
(4) Owner's financial problems, and

(5) Unavailability of equipment [18].

The impact of such variation orders on time and cost of the project was reported as 20% time overrun and 31% cost overrun with respect to the planned schedule and budget [19]. A study of the construction of the underground powerhouse at the Dagachhu Hydropower Project in Bhutan revealed challenges such as seepage water management during construction. According to another study carried out on small hydropower projects, the main causes of cost deviation were time overrun and variation in quantity in civil and hydromechanical works [10].

A newspaper article published in the *Himalayan Times* regarding construction delays mentioned contractor-, client-, and employer-related factors, as well as external factors, as primary causes of delay and cost overrun in construction projects of Nepal [31]. Contractor-related factors included shortage of manpower. Consultant-related factors included delays in approving major changes in the scope of work, discrepancies in design documents, unclear and inadequate details in drawings, and insufficient data collection and survey before design.

Similarly, external factors included problems of land acquisition, tree cutting, price escalation, labour disputes, government regulations, slow permit approval by government agencies, and unforeseen ground conditions. According to [30, 31], construction delays lengthen project schedules, increase project costs, and hinder economic growth.

A paper published by [30] in *Hydro Nepal* analyzed the following major contractual problems faced by hydropower construction projects in Nepal:

- Payment disputes between contract parties in construction,
- Changed circumstances during construction,
- Unforeseeable conditions such as rugged terrain and varying geology, and
- Force majeure conditions.

A paper on predicted versus actual rock mass conditions for tunnel projects in the Nepal Himalaya revealed discrepancies between predicted and actual rock mass conditions, which affected the overall cost and construction time of projects [24]. Studies of tunnel projects in Nepal showed that the ground conditions encountered were quite different from what was anticipated during pre-construction phase planning and design. This mismatch caused additional cost, considerable delay, and led to claims and contractual disputes. The study of hydropower projects such as Khimti I and Modi Khola revealed that rock mass quality assessment, stability analysis, and rock support quantity predictions were mainly based on desk studies, aerial photo interpretation, and surface geological mapping.

2.4. **Remedial Measures of Cost Deviation in Hydropower Construction Projects.** As cost deviation is inevitable in any project, it is necessary to adopt certain measures to minimize its impact in construction projects. A research article published by [1] recommended several measures to be adopted by contractors, clients, and consultants to minimize deviation in civil construction projects.

Contractors, being the main builders of the project, are recommended to have sufficient cash flow before beginning any project to minimize financial problems. Owners are advised to review and improve bid documents such as technical specifications, drawings, and bills of quantities, and to ensure the quality design of the project. Consultants are advised to hire qualified technical staff, provide timely instructions to contractors, and promptly

resolve any issues raised by the contractors, as delays in resolution can directly or indirectly affect project costs (either positively or negatively) [1].
[38] also suggested that appropriate funding levels should always be determined at the planning stage of a project so that regular payments can be made to contractors for the work completed.
In addition, mitigation measures to control cost overrun factors in construction projects in Malaysia have been identified as follows [6]:

(1) Proper project planning and scheduling,
(2) Effective site management and supervision,
(3) Frequent progress meetings,
(4) Use of experienced subcontractors and suppliers,
(5) Utilization of up-to-date technology,
(6) Clear information and communication channels,
(7) Frequent coordination between the parties,
(8) Comprehensive contract administration, and
(9) Systematic control mechanisms.

Furthermore, [24] suggested maintaining a minimum level of geological investigation to improve the predictability of geological conditions. This helps reduce the discrepancy between predicted and actual rock mass conditions to an acceptable level, thereby minimizing unexpected cost deviations.

3. Methodology

3.1. **Study Area.** The study area of the research was selected as hydropower construction projects developed by Independent Power Producers (IPP). There are altogether 42 hydropower projects developed by IPPs in Province No. 1 and Province No. 4 which have already started generation and are under operation. Among the 42 hydropower projects, only four hydropower projects were purposively selected for the study. The selected projects for the study are mentioned in Table 1 below:

Table 1. List of Selected Hydropower Projects with Key Details

S.N.	Name of Project	Installed Capacity / Type	Location	Project Commencement Date / Start Date	Status of the Project / Civil Works Completion Date
1	Rudi Khola A Small Hydropower Project	8.8 MW / RoR project with pipe	Lamjung District, Province 4 (Gandaki Pradesh)	March 24, 2016	May, 2019
2	Hewa Khola ‘A’ Hydroelectric Project	14.9 MW / RoR Project with Tunnel	Panchthar District, Province 1	September 30, 2012	February 4, 2017
3	Midim Khola Hydropower Project	3 MW / RoR Project with Tunnel	Lamjung District, Province 4 (Gandaki Pradesh)	April 15, 2016	August, 2017
4	Mistri Khola Hydroelectric Project	42 MW / RoR Project with Tunnel	Myagdi District, Province 4 (Gandaki Pradesh)	June 30, 2016	July, 2021

3.2. **Study population and Sample selection.** The parties related to the project such as client, consultant and contractor were interviewed on the subject.

3.3. **Data Collection.** To fulfil the purpose of study both primary as well as secondary data were collected.

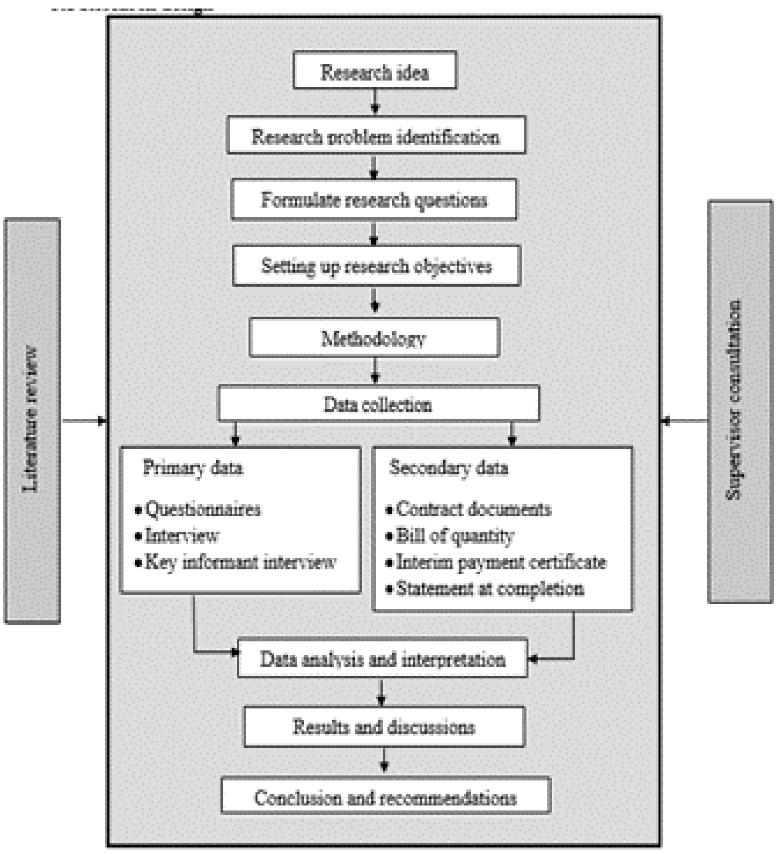

FIGURE 1. Research methodology flow chart

TABLE 2. Details of Respondents from Different Target Groups

S.N.	Target Group	Total No. of Respondents
1	Client's Representative	10
2	Consultant's Representative	10
3	Contractor's Representative	20
	Total	**40**

TABLE 3. Response Rate by Target Group

S.N.	Target Group	No. of Respondents	Responses Received	Non-response Rate
1	Client's Representative	10	8	20%
2	Consultant's Representative	10	8	20%
3	Contractor's Representative	20	16	20%
	Total	**40**	**32**	**20%**

3.3.1. *Primary Data Collection.* Primary data refers to the first-hand data gathered by the researcher himself. Various sources of primary data are surveys, observations, questionnaires, and interviews [2].

3.3.2. *Questionnaire Method.* Questionnaires is an observational technique which comprises series of items presented to a respondent in a written form, in which the individual is expected to respond in writing [2]. In this research, a set of questionnaires was developed which was provided to all the concerned parties (Client, Consultant and Contractor) who were directly involved in the projects.
The factors related to causes and remedial measures for the selected hydropower project were identified from the literature review.
The respondents were asked to rate the factors in a 5-point Likert scale. However, the numbers assigned to the agreement or degree of influence (1, 2, 3, 4, 5) do not indicate that the interval between scales is equal, nor do they indicate absolute quantities. The ranking detail is as shown below:

- E.S. = extremely significant (5 marks)
- M.S. = moderately significant (3 marks)
- V.S. = very significant (4 marks)
- S.S. = slightly significant (2 marks)
- N.S. = not significant (1 marks) [36]

3.3.3. *Key Informant Interview (KII).* Interviewing is a technique that is primarily used to gain an understanding of underlying reasons [2]. Key informant interview of managing director of hydropower construction company and design team leader of reputed consultant for hydropower projects who have experience in hydropower sector for more than 10 years was done to identify the challenges faced by hydropower sector which results in cost deviation. In total KII of three personnel were taken.

3.3.4. *Secondary Data Collection.* Secondary data are those which have already been collected by someone else earlier [2]. For the purpose of the study, secondary data were collected from the final interim payment certificate or statement at completion certified by the client after the work completion and Bill of Quantity agreed at the time of contract agreement and signed by the authorized representative of client and consultant were collected from the concerned authorities to get the information regarding actual cost and final cost of the project.

3.4. **Validity and Reliability.**

3.4.1. *Validity of Research Tools.* Validity refers to the degree to which an instrument measures what is supposed to be measured [26]. In order to establish content validity, literature reviews and then follow-ups with the evaluation by expert needs to be done [7]. The questionnaire developed for this study was based on Likert 5-point scale. Similar type of questionnaire was used in similar research by [20, 32, 33, 36, 22]. Similarly, in order to rank the factors, RII was used in similar research done by [20, 32, 33, 36, 22]. The results obtained in the research done by the previous researchers were also in agreement with the findings obtained after the analysis of questionnaire survey in this study.
In order to fulfil the objective of this research, questionnaire for the research were prepared with the help of literature review and concerned engineer having experience of more than 10 years in hydropower construction. Prior to the questionnaire survey, the questionnaire was thoroughly discussed and consulted with the supervisor for the validity of the research.

3.4.2. *Reliability of Research Tools.* Reliability concerns the extent to which a measurement of a phenomenon provides stable and consistent result [7]. The most commonly used internal consistency measure is the Cronbach Alpha coefficient [37]. Cronbach's alpha (α)

developed by Lee Cronbach in 1951, measures reliability of multiple questions to see if multiple surveys are reliable.
The formula for Cronbach's alpha is:

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\sum s_y^2}{s_x^2}\right) \tag{1}$$

where,
k = number of test items
Σs_y^2 = sum of item variance
s_x^2 = variance of total score

TABLE 4. Cronbach's Alpha and Internal Consistency Levels

Cronbach's Alpha (α)	**Internal Consistency**
$0.9 \le \alpha \le 1.0$	Excellent
$0.8 \le \alpha < 0.9$	Good
$0.7 \le \alpha < 0.8$	Acceptable
$0.6 \le \alpha < 0.7$	Questionable
$0.5 \le \alpha < 0.6$	Poor
$0.0 \le \alpha < 0.5$	Unacceptable

Cronbach's alpha test was carried out in MS-Excel, for the purpose of analysis, responses from questionnaire sets were tabulated in MS- Excel. There were 93 items in questionnaire of which the reliability of its measurements needs to be measured. Using the formula, the value of Cronbach's alpha was calculated for the causes and remedial measures which is presented in the table 5:

TABLE 5. Cronbach's Alpha Values for Different Sections of the Study

S.N.	**Description**	**Cronbach's Alpha Value (α)**	**Remarks**
1	Causes of cost deviation in selected hydropower projects of Nepal	0.982	Excellent
2	Remedial measures to mitigate the cost deviation	0.980	Excellent

As per prescribed values and range illustrated in table above, the consistency of questions within the questionnaire was found to be excellent.

3.5. **Data Analysis.** The data collected from both primary and secondary sources were summarized, classified, tabulated, and categorized in various categories. The method used in data analysis was primarily focused on calculating Relative Importance Index (RII), ranking the factors based on obtained RII, and checking the correlation between the views of respondents. To achieve the research goal, Microsoft Excel was used for analyzing the data.

Likert's scale is used for the ordinal scale measurement for the study. In this research, the scales are represented as not significant = 1 to extremely significant = 5.

3.6. **Relative Importance Index (RII).** Relative Importance Index has been widely used in construction research for measuring attitudes [13]. Many researchers like [1, 14, 35] used the relative importance index in their analysis.
Likert scaling was used to rank the causes of cost deviation and remedial measures to mitigate cost deviation [36]. After the ranking of the causes and remedial measures by the respondents, the combined ranking of client, consultant, and contractor was used to calculate the Relative Importance Index (RII) value using the following equation [15]:

$$\text{RII} = \frac{\sum_{i=1}^{5} W_i \times X_i}{A \times N} \tag{2}$$

where,
RII = Relative Importance Index
W_i = Weighting given to each factor by the respondents and ranges from 1 to 5
X_i = Frequency of i-th response given for each cause
A = Highest weight (i.e., 5 in this case)
N = Total number of respondents
The value of RII ranges from 0 to 1. Higher the value, more important is the factor that is responsible for the causes of cost deviation and remedial measures to mitigate cost deviation.

3.7. **Spearman's Rank Order Correlation.** According to Glen [35], Spearman's correlation coefficient is a statistical measure of the strength of a monotonic relationship among paired data. It means that if one variable increases (or decreases), then the other one also increases (or decreases). It is denoted by r_s or simply r and is constrained as $-1 \leq r \leq 1$. The formula for calculating Spearman's rank order correlation given by Charles Spearman in 1904 is:

$$\rho = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)} \tag{3}$$

where,
d_i = difference between two ranks of each observation
n = number of observations
It is interpreted based on the strength of correlation as follows:

- -1 = a perfect negative correlation between ranks
- 0 = no correlation between ranks
- 0 to 0.19 = very weak
- 0.2 to 0.39 = weak
- 0.4 to 0.59 = moderate
- 0.6 to 0.79 = strong
- 0.8 to 1.0 = very strong
- +1 = a perfect positive correlation between ranks

In a similar study done by Khanal [22] for the study of impact of variation order on project cost and time of building construction, Spearman rank correlation coefficient was calculated to determine the correlation among the control measures to minimize variation orders.

In this research study, correlation coefficient was calculated to find the correlation among the rank given by the respondents for the factors causing deviation and remedial measures to mitigate cost deviation.

3.8. **Research Matrix.** Following research matrix was used to meet the objective of the proposed research.

Table 6. Research Matrix

S.N.	Objectives	Data Required	Data Source	Analysis Tools	Outcome
1	To analyse the current scenario of cost deviations of selected hydropower projects	Percentage deviation in cost of major activities of civil works due to quantity overrun	Bill of quantities, interim payment certificates, contract documents, correspondences with client and consultant	Descriptive statistics	The cost deviation scenario that exists in selected hydropower projects
2	To find out the major causes of cost deviation in hydropower projects	Major causes resulting in cost deviation	Questionnaire survey, key informant interviews (KII)	Relative Importance Index (RII), Spearman's rank correlation	Various major causes of cost deviation in selected hydropower projects
3	To find out the remedial measures of cost deviation	Various remedial measures adopted to avoid cost deviation	Questionnaire survey, key informant interviews (KII)	Relative Importance Index (RII), Spearman's rank correlation	Mitigation measures to minimize the gap between final and initial cost

4. Results and Discussion

In order to study the current scenarios of cost deviation in construction of civil structures of selected hydropower projects, the contract document, interim payment certificated (IPC) and final certified bills and correspondence documents (i.e. , letters from client, consultant and contractor, minutes of meetings) were studied. The result of the selected project is tabulated below (Table 7):

Table 7. Current scenarios of cost deviation of selected hydropower projects

S.N.	Description	Rudi Khola A HPP (8.8 MW)	Hewa Khola 'A' HEP (14.9 MW)	Midim Khola (Karapu) HPP (3 MW)	Mistri Khola HEP (42 MW)
1	Contract Agreement Date / Project Commencement Date	March 24, 2016 / March 31, 2016	September 30, 2012	January 8, 2015	May 8, 2015 / June 30, 2016
2	Initial Project Completion Date	September 15, 2017	November 19, 2014	April 15, 2016	December 17, 2018
3	Actual Completion Date	May 30, 2019	February 4, 2017	November 16, 2017	July 8, 2021
4	Time Overrun	1.7 years	2.25 years	2.67 years	2.58 years
5	Original Contract Amount / Revised Contract Amount (Including VAT)	NRs. 320,920,000	NRs. 1,008,584,059.45 / 1,039,619,696.02	NRs. 244,975,338.29 / 323,943,814.38	NRs. 1,382,942,393.38
6	Final Certified Amount (Including VAT)	NRs. 458,984,846.00	NRs. 1,203,113,550.00	NRs. 433,991,644.47	NRs. 1,634,042,758.93
7	Cost Overrun	43.02%	15.73%	33.97%	18.16%

The percentage deviation in cost of major activities due to quantity variation is presented in the table 8 below separately for all projects:

Table 8. Percentage of Cost Deviation in Rudi Khola A HEP

S.N.	Item of Works	% Deviation in Cost due to Quantity Variation
1	Excavation of earth soil / common material / boulder mix	10.14%
2	Excavation in hard rock without blasting	63.48%
3	M10 Concrete	28.86%
4	M15 Concrete	15.72%
5	M20 Concrete	-69.47%
6	Plum M15/40	50.06%
7	M25 Concrete	747.15%
8	Formworks	37.99%
9	Reinforcement	4.62%

Table 9. Percentage of Cost Deviation in Hewa Khola HEP

S.N.	Item of Works	% Deviation in Cost due to Quantity Variation
1	Excavation of Common Material / Boulder	18.54%
2	Hard Rock Excavation	104.89%
3	Rock Excavation by Drilling and Blasting	-1.25%
4	75 mm thick C15 Blinding Concrete	8.76%
5	C25 Concrete	98.54%
6	Formwork	-8.76%
7	Reinforcement	101.83%
8	Fiber Reinforced Shotcrete	-3.63%
9	Rock Bolt and Spilling Rod	-3.63%
10	Steel Rib	193.37%

Table 10. Percentage of Cost Deviation in Midim Khola HEP

S.N.	Item of Works	% Deviation in Cost due to Quantity Variation
1	All types of Excavation	7%
2	Formwork	35.3%
3	Various Grades of Concrete	10.93%
4	Reinforcement Works	43%
5	Tunnel Support Works	-16%

Table 11. Percentage of Cost Deviation in Mistri Khola HEP

S.N.	Item of Works	% Deviation in Cost due to Quantity Variation
1	All types of Excavation	-8%
2	Formwork	2%
3	Various Grades of Concrete	54%
4	Reinforcement Works	18%
5	Tunnel Support Works	-27%

4.0.1. *Causes of cost deviation in the selected hydropower project.* Based on the combined views of all the parties involved and analysis of causes of cost deviation, the value of RII given to the following factors were most significant:

5. Relative Importance Index (RII) for Selected Hydropower Projects

Table 12. RII Values for Rudi Khola - A HEP

Factor	**RII**
Quantity overrun of the various activities of the project due to site condition	0.88
Additional work / New Item	0.825
Inadequate cash flow during construction / Cash flow problem / Financial difficulties faced by the contractor / Poor cost control	0.775
Bill of quantities lacking precision	0.775

Table 13. RII Values for Hewa Khola - A HEP

Factor	**RII**
Quantity overrun of the various activities of the project due to site condition	0.7
Strikes, bandhs	0.7
Inadequate cash flow during construction / Cash flow problem / Financial difficulties faced by the contractor / Poor cost control	0.675

Table 14. RII Values for Midim Khola HEP

Factor	**RII**
Change in design	0.93
Quantity overrun of the various activities of the project due to site condition	0.83
Insufficient data collection and survey before design / Inadequate detail study before execution of works	0.825
Strikes, bandhs	0.825

Table 15. RII Values for Mistri Khola HEP

Factor	**RII**
Seepage water management inside tunnel	0.95
Fluctuation in price of construction materials	0.9
Provision for price escalation	0.83

5.0.1. *Remedial measures of cost deviation in selected hydropower project.* Based on the combined views of all the parties involved and analysis of remedial measures of cost deviation, the value of RII given to the following factors were most significant:

Table 16. RII Values for Remedial Measures - Rudi Khola HEP

Remedial Measure	RII
Review and improve bid documents such as technical specifications, bill of quantities	0.825
Minimize change orders, design to reduce any time and cost overruns	0.775
Frequent preventive maintenance of equipment to avoid sudden breakdown	0.775

Table 17. RII Values for Remedial Measures - Hewa Khola HEP

Remedial Measure	RII
Review and improve bid documents such as technical specifications, bill of quantities	0.775
Hire full time skilled mechanics for proper maintenance of equipment	0.775
Frequent preventive maintenance of equipment to avoid sudden breakdown	0.75

Table 18. RII Values for Remedial Measures - Midim Khola HEP

Remedial Measure	RII
Review and improve bid documents such as technical specifications, bill of quantities	0.875
Ensure quality design of project	0.85
Minimize change orders, design to reduce any time and cost overruns	0.8

Table 19. RII Values for Remedial Measures - Mistri Khola HEP

Remedial Measure	RII
For the geophysical studies, seismic refraction, reflection seismic and electrical resistivity should be done to get more accurate information regarding weathering depth, ground water conditions	0.825
Minimum level of geological investigation to improve the predictability of geological conditions	0.8
Effective strategic planning by all parties involved	0.775
Realistic prediction and evaluation of rock mass quality	0.775

6. Conclusions and Recommendations

6.1. **Conclusions.** Based on the results and discussions, the following conclusions are made: From the study of all 4 hydropower projects, it was found that in all hydropower projects except Mistri Khola HEP, there was quantity overrun of major activities of the construction which resulted in cost deviation of civil construction works of the project. Besides that various client related factors such as irregular monthly payment; consultant related factors such as bill of quantities lacking precision, change in design, insufficient data collection and survey before design; contractor related factors such as inadequate cash flow during construction/ cash flow problem/ financial difficulties faced by contractor; project related factors such as quantity overrun of the various activities of the project due to site condition, additional work, new item, seepage water management inside tunnel, provision for price escalation; external factors such as strikes, bandhs, natural disaster (landslide and flood triggered by heavy rainfall); equipment related factors such as frequent equipment breakdown/ frequent maintenance of equipment ; material related factors such as fluctuation in price of construction materials were some of the significant factors that led to cost deviation of the selected hydropower project.

6.2. **Recommendations.** From the analysis of the result of the questionnaire survey, it is observed that in order to minimize the cost deviation of hydropower project, the remedial measures to be adopted by client is to ensure quality design of the project, have appropriate funding levels so that contractor can be regularly paid; consultant related factor such as review and improve bid documents such as technical specifications, drawings, bill of quantities, minimize change orders, detail and comprehensive site investigation during the preparation of bill of quantities; contractor related measures are contractor should have enough cash before beginning of any project, frequent preventive maintenance of equipment to avoid sudden breakdown . Besides that the remedial measures to be adopted by all parties involved are effective strategic planning by all parties in order to find appropriate way to tackle various problems that arise during construction.

References

[1] A. Enhassi and J. A.-N., "Delays and cost overruns in the construction projects in the Gaza Strip," *Journal of Financial Management of Property and Construction*, vol. 14, no. 2, pp. 126–151, 2009.
[2] V. Ajayi, "Primary sources of data and secondary sources of data," 2017.
[3] A. M. Belay and O. T., "Do longer projects have larger cost deviation than shorter construction project," Elsevier Ltd, Primosten, Croatia, 2017.
[4] S. Assaf and H., "Causes of delay in large construction projects," *International Journal of Project Management*, pp. 349–357, 2006.
[5] A. Razali and A. T., "Applicability of Bill of Quantities in Construction Procurement," *International Journal of Engineering Science Invention*, vol. 3, no. 4, pp. 31–34, 2014.
[6] A. Azis et al., "Controlling Cost Overrun Factors in Construction Projects in Malaysia," *Research Journal of Applied Sciences, Engineering and Technology*, pp. 2621–2629, 2013.
[7] E. Carmines et al., *Reliability and validity assessment*, SAGE, Newbury Park, CA, 1979.
[8] M. M. Chabota Kaliba, "Cost escalation and schedule delays in road construction projects in Zambia," *International Journal of Project Management*, pp. 522–531, 2009.
[9] D. Chan et al., "Comparative Study of Causes of Time Overruns in Hong Kong Construction Projects," *International Journal of Project Management*, vol. 15, no. 1, pp. 55–63, 1996.
[10] K. Chiluwal, "Factors affecting construction performance and its impact on profitability of small hydropower projects," MSc thesis, Nepal Engineering College, CPS, Pokhara University, Bhaktapur, Nepal, 2017.
[11] S. L. Dahal, "Cost Variation in Construction Projects (A Case Study on Road Projects of RSDP in Department of Roads)," MSc thesis, Nepal Engineering College, CPS, Pokhara University, Bhaktapur, Nepal, 2015.
[12] E. Drost, "Validity and Reliability in Social Science Research," 2011.
[13] M. Egemen et al., "Different approaches of clients and consultants to contractors' qualification and selection," *Journal of Civil Engineering and Management*, 2005.
[14] M. El-Razek, "Causes of Delay in Building Construction Projects in Egypt," *Journal of Construction Engineering and Management*, 2008.
[15] O. Fagbenle, "Factor affecting the performance of labour in Nigeria Construction," 2004.
[16] S. Glen, "StatisticsHowTo," 2013. [Online]. Available: https://www.statisticshowto.com/probability-and-statistics/correlation-coefficient-formula/spearman-rank-correlation-definition-calculate/. [Accessed Feb. 2022].

[17] T. Hamed, "Validity and Reliability of the Research Instrument," *International Journal of Academic Research in Management*, pp. 28–36, 2016.

[18] M. B. Hashim Hanif, "Causes of Variation Orders in Construction of Hydropower Projects in Pakistan," in *International Conference on Management and Engineering*, Pakistan, 2014.

[19] M. B. Hashim Hanif, "Impact of Variation Orders on Time and Cost in Mega Hydropower Projects of Pakistan," *Journal of Construction in Developing Countries*, vol. 21, no. 2, pp. 37–53, 2016.

[20] S. R. Hillis, "Delay Management in Construction Projects in the Gaza Strip Clients perspectives," The Islamic University- Gaza, 2010.

[21] B. 36, "Clean Leap," 2015. [Online]. Available: https://cleanleap.com/4current-cost-hydropower/42-breakdown-hydropower-costs-source. [Accessed Jan. 30, 2015].

[22] S. Khanal, "Study of Impact of Variation Order on Project Cost and Time of Building Construction (A Study of Building Projects Inside Tribhuvan University Premises, Kathmandu)," 2020.

[23] L. C. Kofi Offei-Nyako, "Deviations between Contract Sums and Final Accounts: The Case of Capital Projects in Ghana," *Journal of Construction Engineering*, vol. 2016, p. 8, 2016.

[24] B. N. Krishna Kanta Panthi, "Predicted versus actual rock mass conditions: A review of tunnel projects in Nepal Himalaya," *Tunnelling and Underground Space Technology*, vol. 22, pp. 173–184, 2007.

[25] K. M. L.S. Pheng, "Formulating a strategic marketing mix for quantity surveyors," *Marketing Intelligence & Planning*, vol. 15, no. 6, pp. 273–280, 1997.

[26] Y. D. Long Le-Hoai, "Delay and Cost Overrun in Vietnam Large Construction Projects: A Comparison with Other Selected Countries," *KSCE Journal of Civil Engineering*, vol. 12, no. 6, pp. 367–377, 2008.

[27] Ministry of Energy, Water Resources and Irrigation, Department of Electricity Development, "Department of Electricity Development," 2020. [Online]. Available: https://www.doed.gov.np/license/54. [Accessed Aug. 23, 2020].

[28] Nepal Electricity Authority, *A Year in Review, Fiscal Year 2011/12*, Kathmandu, Nepal, 2012.

[29] Nepal Electricity Authority, *A Year in Review - Fiscal Year 2018/19*, Kathmandu, Nepal, 2019.

[30] A. Neupane, "Contractual Issues for Hydropower Construction in Nepal," *HYDRO NEPAL*, no. 23, pp. 56–57, 2018.

[31] U. Neupane, "Construction delay: poor planning to blame," *Himalayan Times*, Sep. 11, 2019. [Online]. Available: https://thehimalayantimes.com/opinion/construction-delay-poor-planning-to-blame.

[32] S. Sharma and P. G., "Cost overrun factors and project cost risk assessment in construction industry - a state of the art review," *Internal Journal of Civil Engineering*, pp. 139–154, 2014.

[33] S. Ahmed and I. B., "Deviation in the Cost of Projects," in *Construction Maeconomics Conference 2014*, p. 10, 2014.

[34] P. K. Savita Sharma, "Forecasting the Probability of Cost Overrun Risk of Indian Construction Projects using Fuzzy Model," *International Journal on Emerging Technologies*, vol. 14, 2019.

[35] G. Sweis, "Factors Affecting Time Overruns in Public Construction Projects: The Case of Jordan," *International Journal of Business and Management*, 2013.

[36] S. 29, "Time Overrun and Its Impact on Cost of Construction of Small Hydropower Projects," MSc thesis, Nepal Engineering College, CPS, Pokhara University, Bhaktapur, Nepal, 2014.

[37] B. Whitley, *Principals of Research and Behavioural Science*, Boston: McGraw-Hill, 2002.

[38] J. O. Yaw Frimpong, "Causes of delay and cost overruns in construction of groundwater projects in a developing countries; Ghana as a case study," *International Journal of Project Management*, pp. 321–326, 2003.