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Research Article

Causes, Effects, and Mitigation Measures of Time and Cost Overruns in Water Supply Projects: Case of Tigrai Region, Northern Ethiopia

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Project cost overrun and schedule delay are major and widespread problems in the construction industry. In Tigrai, most water supply construction projects are not completed within the predetermined contract time and planned budget. Hence, this research was carried out to investigate the causes and effects of time and cost overrun in water supply projects in Tigrai, northern Ethiopia and further recommend effective mitigation measures. A total of 87 questionnaires were distributed, 50 of them were collected, and desk study of 12 water supply projects were conducted. Data were analyzed using relative importance index and statistical software SPSS version 20. Results showed that the most important causes of time overrun were design errors and changes, lack of consistency between bill of quantities and drawings, and change order. Similarly, the most important causes of cost overrun were design errors and changes, lack of consistency between bill of quantities and drawings, and shortage of construction materials and electromechanical equipment in local market. The most effective mitigation measure of the overruns was complete and proper design. Time and cost overrun of the projects ranged between 0 and 203% and between 0 and 25%, respectively. The regression model showed that time overrun was estimated well ($r^2 = 0.95$) using delays caused by design errors and changes and material import. Similarly, cost overrun was estimated well ($r^2 = 0.98$) using factors that affect cost. Overall, the major cause for the overruns was design problem, hence clients and consultants should give due attention for the design process.

1. Introduction

Construction projects in general are complex and are subjected to time and cost overruns. Water supply projects are not an exception. Even though all project managers want to complete their construction projects with high quality, low cost, and least time, almost all construction projects are subjected to time and cost overruns in project execution due to different factors [1]. A global study by [2] concluded that a project is said to be successful if it is completed on the planned budget. [2] further emphasized that construction cost overrun is a major challenge, where 9 out of 10 construction projects encounter cost overrun which commonly ranges from 50 to 100% of the contract amount. Similarly, Ansar et al. [3] acknowledged that 8 out of every 10 large dams suffered time overrun, and an increase in estimated time of 1 year contributes to an increase in cost overrun of approximately between 5 and 6% depending on the country whilst holding the inflation rate constant.

Construction time and cost overruns of public projects have negative impact in government's infrastructure development and can affect the communities' benefit as well. The rate of the overruns may be related with the contract amount. For example, in India, Shete and Kothawade [4] found that an average cost overrun between 10 and 30% of the project's estimated cost was experienced in building construction projects. Similarly, in Madhya Pradesh, Prajapati et al. [5] discovered that 15 out of 44 public building construction projects suffered cost overrun and the rate of cost overrun ranged from a minimum of 0 to the maximum of 120% of the contract amount for individual projects [5]. Furthermore, it was emphasized that the rate of cost overrun decreases with an increase in contract amount. Additionally, in Saudi Arabia, Assaf and Al-Hejji [6] found that only 30% of construction projects were completed within schedule, in which the average time overrun was between 10 and 30%. The problem of cost overrun in construction projects is very common in both developed and developing countries, but it is very severe in developing countries where the overrun sometimes exceeds 100% of the estimated amount [7].

Overruns are common throughout the world, but more Severe in developing countries [8]. For example, in Ethiopia, Koshe and Jha [9] carried out research to find out the causes of time overrun, and their study reveals that only 8.25% of projects have been finished to the original planned completion date and the remaining 91.75% projects delayed 352% of their contractual time. Similarly, Taye [10] investigated ten completed construction projects in Addis Ababa and revealed that 100% of the construction projects suffered time and cost overruns. The rate of time overrun for these projects ranged from a minimum of 13 to the maximum of 181% of the contract time. Similarly, the cost overrun for these projects ranged from a minimum of 1 to the maximum of 47% of the contract amount.

In Ethiopia, the construction industry, especially public construction projects, is the highest recipient of government budget [11]. From the government's capital budget, about 60% of it is allocated to public projects [12, 13]. According to the Tigrai Bureau of Water Resources (TBoWR), about 30–35% of the capital budget is allocated to the water sector of the region for project implementation [14, 15]. The majority of water construction projects were not completed within the contract time and budget. The time and cost performance of water supply construction projects is also similar to other water works in Tigrai region.

The risk factors that cause overruns are different in different countries, different stages, and project types, which are the outcomes of the complexity and dynamic nature of construction projects. Several researchers identified the factors that affect time and cost performance in different types of construction projects [1, 6, 16, 17]. Similarly, Nega [11] found that 67 out of 70 public building construction projects in Ethiopia suffered from cost overrun. The rate of cost overrun ranged from a minimum of 0 to the maximum of 126% of the contract amount for individual projects [11]. Gasasira et al. [18] revealed that most studies on project overruns are heavily skewed towards identifying the causative factors in building and road construction projects with little or no attention to water works.

The main responsible parties for the causes of construction overruns are mostly the key construction stakeholders, namely clients, contractors and consultants, and external factors [10, 19]. Similarly, Matin [20] revealed that the most significant impact for the overruns in water works is caused by the actions of the government followed by clients and consultants. Furthermore, Perera and Halwatura [21] added that inclement weather conditions, contractors' financial difficulties, shortage of labor, rules and regulations of authorities, delays in subcontractors' work, material import delays, and ineffective planning and scheduling of projects by contractors were among the most important factors causing time overrun in medium scale drinking water supply projects.

Hence, it is important to assess the causative factors of the overruns in water supply projects in order to use effective mitigation measures. Despite that cost and time overruns are common in Tigrai water supply projects, there is almost no information on the causes of the overruns and their effect on the performance of the projects. Thus, the first and most important step is to identify and understand the factors that cause the overruns in order to mitigate the problem [1]. Therefore, the objective of this study was to investigate the causes, effects, and mitigation measures of time and cost overrun of water supply projects in Tigrai.

2. Materials and Methods

2.1. Description of the Study Area. The research was conducted in Tigrai region, which is located in the northern part of Ethiopia, one of the 9 regional states of Ethiopia (Figure 1). The total area of Tigrai region is about 54,569.25 km^2. It is bordered in the north by Eritrea, in south by Amhara region, in the east by Afar and in the west by Sudan. Tigrai is administratively divided into 6 zones, 1 capital city, 46 woredas (12 urban and 34 rural woredas) and 763 Kebeles (702 rural and 61 urban). The region's climatic zones are lowland, temperate, and highland. According to the projected census of 2007, the region has a total population of 4,806,843 (3,787,667 in rural and 1,019,176 in urban areas) in 2010 [22].

2.2. Data Collection

2.2.1. Questionnaire. A detailed literature review was carried out to identify the previous studies in the research area and found the major causes, effects, and mitigation measures of time and cost overrun in water supply projects in different countries. Furthermore, a careful identification of the factors related to the research were conducted to develop the questionnaire survey prepared using the standard 5-point Likert scale as used by [20].

(1) Questionnaire Design. The factors, effects, and mitigation measures of water supply project overruns that were categorized under seven major groups, namely owner/consultant related, contractor related, project related, design related, equipment and labor related, and external factors identified from previous studies were randomly distributed to selected clients, consultants, and contractors that have direct involvement in water supply construction projects. This helped to select the most important factors that are related with causes, effects, and mitigation measures of overruns of water supply projects in Tigrai region. Therefore, from the listed factors, 38 causes of time overrun, 44 causes of cost overrun, 8 effects of time overrun, 10 effects of cost overrun, 15 mitigation measures of time overrun, and 12 mitigation measures of cost overrun were selected. List of all factors, effects, and mitigation measures analyzed in the study are shown in the Tables 1–3.

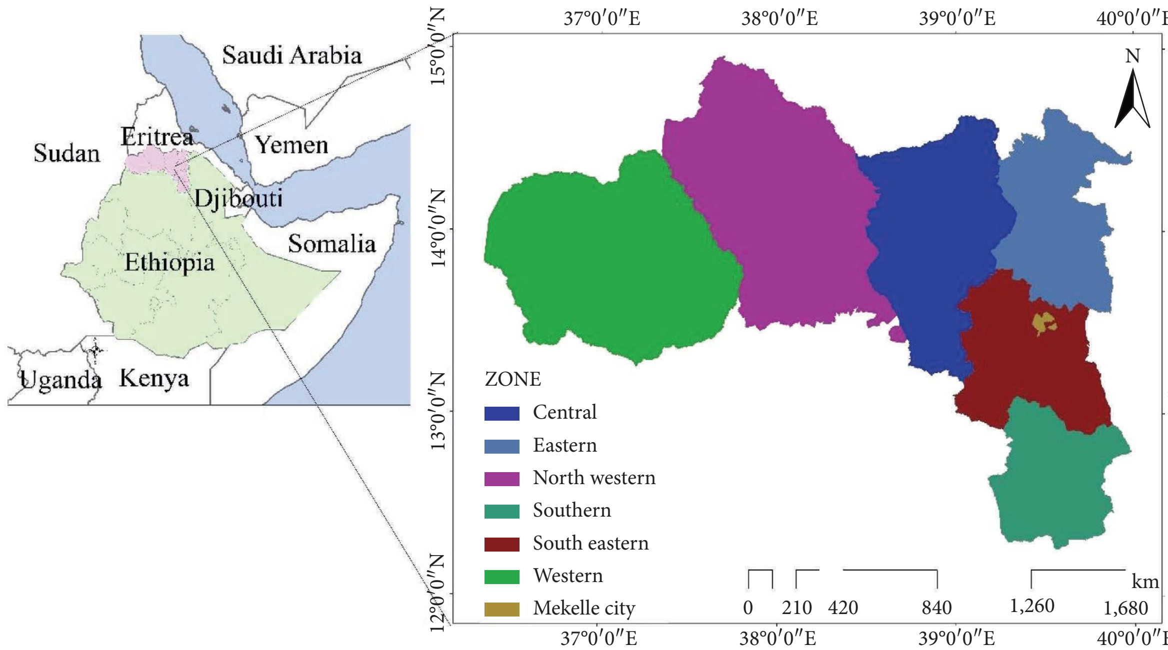

Figure 1: Location map of Tigrai regional state.

(2) Questionnaire Validation. The questionnaire was initially tested on 10 pilot respondents purposefully selected from contractors, clients, and consultants who were directly involved in water supply projects. The questionnaire test responses were then assessed to ensure that they were clearly stated and meaningful to the respondents. The result of the pilot test was analyzed and later used to improve the questionnaire by correcting ambiguous statements. Finally, the main questionnaire was physically distributed to the respondents.

2.2.2. Sample Size Distribution. The total population of the research was 31 water supply construction projects which were constructed by contractors of Grade 1 and 2. Contractors of Grade 1 and 2 were selected to get full data for the study as they own high capital, machinery, and manpower. According to the manual of Minister of Water and Energy of Ethiopia, they should own 7.5 million Ethiopian Birr (ETB) capital or equivalent machinery, 7 professionals with specific experience of above 15 years and 4 professional engineer with at least 10 years of specific experience and a graduate engineer.

The sample size was estimated using equation (1) suggested by [31] to avoid selection bias and ensure that the sample is representative of the population for accurate results.

$$\mathrm{SS} = \frac{N}{1 + N(e)^2}, \quad (1)$$

where SS is sample size, N is population size, and e is desired level of precision (±%), usually taken at 95% confidence level.

Considering 31 contractors of Grade 1 and 2 in Tigrai region working on water supply projects (population size) and 5% level of precision, the estimated sample size was 29. Therefore, the study was project based, in which 87 questionnaires were distributed to 29 contractors, 29 clients, and 29 consultants that had direct participation in the projects.

2.3. Data Analysis. Data were analyzed using descriptive and inferential statistics. A five-point Likert scale was used to categorize the frequency of occurrence and severity. The collected data were then analyzed using relative importance index (RII), determined for each individual factor, as a function of both frequency and degree of severity for cause and effect of time and cost overrun factors. Moreover, RII was used to rank the methods of minimizing time and cost overruns. Statistical software SPSS version 20 was used to test if significant differences existed among variables and to determine correlation between the factors involved. The degree of correlation between factors and the degree of agreement among the respondents was also determined by the spearman's rank correlation. The responses to the questionnaires were analyzed from clients, contractors, consultants, and overall perspectives based on severity and frequency of occurrence of the factors, effects, and mitigation measures of time and cost overruns. Ranking of the factors were made using the relative importance index formula.

2.3.1. Ranking Factors of Time and Cost Overruns. The ranking of the factors of causes, effects, and mitigation measures of time and cost overruns from the perspectives of the contractual parties was undertaken using RII (equation (2)) as a function of frequency index (FI) and severity index (SI) as adopted in other similar studies [6, 32].

Table 1: List of time and cost overrun factors [1, 6, 11, 17, 18, 20, 21, 23–25].

Nos	Factor description	
	Causes of cost overrun	Causes of time overrun
I	Owner/consultant related	
1	Late hand over of construction sites	Late hand over of construction sites
2	Late approval of design documents	Delay in progress payments
3	Change order	Delay in approval of shop drawings and samples
4	Faulty design documentation	Slow decision-making
5	Additional agreement	Change order
6	Client's shortage of finance or delayed payments to contractors	Incomplete estimation of the project
7	Executive bureaucracy in the client's organization	Additional agreement
8	Inadequate design supervision	Failure to choose appropriate contractor
9	Cost underestimation	The weakness of the consultant in terms of planning and supervising
10	Lack of sufficient experience of consultants	Lack of the consultant's knowledge about the location of the project
11	Acceleration required by owner	Poor contract management of the owner/consultant
12	Need to update the design solutions as a result of technological progress	
13	Mistakes and discrepancies in contract documents	
II	Contractor related	
14	Inexperienced contractor	Offering low price in tender
15	Failure to identify timely design and programming changes	Contractor's financial difficulties
16	Contractor's bankruptcy	Mistakes during construction and rework
17	Cost underestimation	Poor communication b/n contractor and other parties
18	Difficulties in finding construction materials in the local market	Ineffective planning and scheduling of projects by contractor
19	Poor communication b/n contractor and other parties	Improper construction methods
20	Mistakes during construction and rework	Delays in subcontractor's work
		Insufficient delegation of power to the site management team
III	Project related	
21	Complexity of construction projects	Complexity of construction projects
22	Size of project	Size of project
23	Location of project	Location of project
IV	Design related	
24	Design errors and changes	Lack of consistency between bill of quantities and drawings
25	Lack of consistency between bill of quantities and drawings	Design errors and changes
		Poor specifications of materials
V	Material related	
26	Shortage of materials and electromechanical equipment in local market	Shortage of construction materials and electromechanical equipment in market
27	Delay in material delivery	Delays in material import (pipes, fittings, etc.)
28	Inconstancy of the price of materials	Noncompliance of imported materials with the contract specifications
29	Inappropriate/misuse of material	Changes in material types and specifications during construction
30	Poor procurement programming of materials	Restrictions on issuing permits to transport material
VI	Equipment and labor related	
31	Equipment availability and failure	Shortage of equipment and frequent breakdown
32	Low productivity and efficiency of equipment	Low productivity and efficiency of equipment
33	Fluctuation in the cost of labor	Lack of qualified production labors

Table 1: Continued.

Nos	Factor description	
	Causes of cost overrun	Causes of time overrun
34	Lack of qualified production labor	
35	Weak motivation	
VII	External factors	
36	Inflation	Inflation
37	Severe weather conditions	Severe weather conditions
38	Unexpected ground conditions	Delay in obtaining permits and services from local authorities and other organizations such as electricity board
39	Changes in foreign exchange rate (for imported materials)	Changes in government laws and regulations
40	Effect of social and cultural factors	Force majeure (such as war, hostilities, riot, strike, political and economic instability, explosive materials, contamination, and earthquake)
41	Corruption	
42	Fossils or discovery of things of geological or archaeological interest	
43	Changes in government laws and regulations	
44	Force majeure (such as war, terrorism, riot, strike, explosive materials, radiation, and earthquake)	

Table 2: List of effects of time and cost overruns [5, 11, 21, 26–30].

Nos	Effects of cost overrun	Effects of time overrun
1	Delay	Cost overrun
2	Additional cost and budget shortfall	Dispute
3	Dispute	Litigation/goes to court case
4	Litigation/goes to court case	Total abandonment
5	Total abandonment	Termination of contracts
6	Termination of contracts	Funding difficulties
7	Supplementary agreement	Delay in commissioning other related projects
8	Funding difficulties	Develop bad relationship with construction team
9	Delay in commissioning other related projects	
10	Develop bad relationships with other organizations	

$$\mathrm{RII} = \frac{\mathrm{SI} \times \mathrm{FI}}{100}, \quad (2)$$

where RII is relative importance index (%), SI is severity index (%), and FI is frequency index (%).

(1) Frequency Index (FI). Frequency index of the causes and effects of time and cost overrun was calculated based on frequency of occurrence of the factors using the following equation:

$$\mathrm{FI} = \sum a\left(\frac{n}{N}\right) \times \frac{100}{4}, \quad (3)$$

where FI is frequency index (%), a is a constant expressing weight given to each response (1 to 5), n is frequency of responses, and N is the total number of responses. Frequency of occurrence was categorized as always (5), often (4), sometimes (3), rarely (2), and very rarely (1).

(2) Severity Index (SI). Severity index of the causes and effects of time and cost overrun was calculated based on severity of the factors using the following equation:

$$\mathrm{SI} = \sum a\left(\frac{n}{N}\right) \times \frac{100}{4}, \quad (4)$$

where SI is severity index (%), a is a constant expressing weight given to each response (1 to 5), n is frequency of responses, and N is the total number of responses. Degree of severity was categorized as extreme (5), great (4), moderate (3), little (2), and very little (1).

(3) Relative Importance Index (RII). Relative importance index was used to determine the importance of the mitigation measures of time and cost overrun using the following equation:

$$\mathrm{RII} = \frac{\sum W}{(A \times N)}, \quad (5)$$

where RII is relative importance index (%), W is weight given to each mitigation measure by respondents (1 to 5), A is the highest weight (5), and N is total number of respondents. Importance index was categorized as very highly effective (5), highly effective (4), moderately effective (3), lowly effective (2), and less effective (1).

The pairwise Mann–Whitney *U*-test was used to determine if the measured variable differed significantly among the overall ranked top ten causes of time and cost overruns and top five effects and mitigation measures of time and cost overruns.

2.4. Regression Analysis. Multiple linear regression analysis was performed after confirming linearity of the relationships between the dependent and independent variables, multicollinearity, independence of errors, homoscedasticity, and normality of predictor errors. The degree of multicollinearity among predictor variables was also tested using tolerance and variance inflation factor (VIF). Multicollinearity refers to a near perfect linear combination between independent variables. VIF and tolerance were calculated by the following equations as explained by [33]:

$$\mathrm{VIF} = \frac{1}{1 - R^2}, \quad (6)$$

$$\mathrm{Tolerance} = 1 - R^2, \quad (7)$$

where VIF is variance inflation factor and R^2 is the coefficient of determination of a regression predictor variable on all other predictor variables. VIF<10 indicates no multicollinearity and tolerance<0.1 implies that further assessment is required. Multicollinear predictor variables were excluded from the regression analysis. A Durbin–Watson test was also evaluated to test statistical independence between predictor variables. While testing the normality of the dependent variables, time overrun was positively skewed and hence violated the normality. So, the time overrun data was transformed to a logarithm to normalize the skewed data.

Shapiro–Wilk's test ($p > 0.05$) and a visual inspection using histograms, normal Q-Q plots, and box plots showed that cost overrun and the transformed time overrun data were approximately normally distributed for all predictors. All assumptions of multiple linear regression were satisfied, hence multiple regression was performed for predicting time and cost overrun, similar to a method by [34] using the statistical software SPSS version 20.

The regression models were formulated to predict time overrun using predictor variables such as design errors and changes, change order, and delay in material import.

Table 3: List of mitigation measures of time and cost overruns [20, 23, 28, 30].

Nos	Mitigation measures of time overrun	Mitigation measures of cost overrun
1	Complete and proper design at the right time	Accurate estimation of the initial cost of the project
2	Accurate estimation of the initial cost of the project	Complete and proper design at the right time
3	Decision makers should have technical awareness about water supply projects	Decision makers should have technical awareness about water supply projects
4	Obtaining permissions from concerned organizations before starting to work	Contractors must consider their financial capabilities before bidding and should employ a qualified staff for the financial management of projects
5	The owner should select a reliable contractor and experienced in water supply projects	The owner should select a reliable contractor and experienced in water supply projects
6	The project site ownership before doing tender by the owner	Reduce change orders during construction
7	Reduce change orders during construction	Effective strategic planning
8	Effective strategic planning	The initial time of the contract should be determined based on the geographical location of the project
9	The initial time of the contract should be determined based on the geographical location of the project	Planning completely and accurately the project by the consultant engineers
10	Planning completely and accurately the project by the consultant engineers	Frequent progress meeting
11	Frequent progress meeting	Ensure timely delivery of materials
12	Ensure timely delivery of materials	Proper site management and supervision
13	Proper site management and supervision	
14	Proper emphasis on past experience	
15	Absence of bureaucracy	

Similarly, cost overrun was predicted using predictor variables such as design errors and changes, lack of consistency between bill of quantities and drawings and inconsistency of price of materials. The predictor variables were the top most causes of time and cost overrun obtained from the analysis based on the RII values. The data of the independent variable and predictor variables, which were used to develop the regression models were obtained from the contract documents of water supply projects. The following multiple regression model was used to estimate the overruns:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots + \beta_n X_n + \varepsilon, \quad (8)$$

where Y is the dependent variable, β_0 is a constant, β_1, β_2, β_3, and β_n are parameter estimates, X_1, X_2, X_3, and X_n are the predictor variables, and ε is prediction error.

The performance of the regression models was evaluated using the coefficient of determination (R^2), which describes how well the regression line of predicted data pass through each data. R^2 ranges from 0 to 1, with 0 indicating no correlation and 1 indicating good fit between model predictions and observations.

2.5. Agreement between Respondents. Correlation analysis on the attitudes of respondents towards the ranking of the variables of time and cost overruns in water supply projects was carried out after testing the normality of the data used in the analysis. Most of the data were not normally distributed. Hence, Spearman's rank correlation coefficient with the hypothesis tested at 5% level of significance was used to determine the degree of agreement among the parties, because of its advantages of not requiring the assumption of normality and or homogeneity of variances [35, 36].

The value of Spearman correlation coefficient varies between +1 and −1. Where +1 implies a perfect positive agreement, while −1 implies a perfect negative relationship. Correlation coefficients close to 1 imply good correlation, while values approaching zero implies little or no correlation [6, 36]. According to [37], the values of correlation coefficients between 0.1 and 0.4 represent weak correlation, and a value above 0.5 represents strong correlation. To calculate the Spearman rank correlation coefficient, the following equation was used:

$$\rho = 1 - \frac{6\sum_{i=1}^{n} \mathrm{di}^2}{n\left(n^2 - 1\right)}, \quad (9)$$

where ρ is Spearman's rank correlation coefficient, di is the difference in ranking between any two parties, and n is the number of observations.

2.6. Case Study. Purposive selection of 12 water supply projects was taken as case study to obtain actual information and validate the findings from the questionnaire survey from various documents of water supply projects such as contract documents, payment letters, variation orders, progress reports, supplementary agreement letters, delay justification, request for time extension letters, completion reports, and claim documents. Similarly, time overrun of nine water supply projects and cost overrun of seven water supply projects were identified from the contract documents; and from the available data, multiple linear regression models were developed for both dependent variables of time and cost overruns.

3. Results and Discussions

3.1. Causes of Time and Cost Overruns. Results discussed in this section included frequency index and severity index for the factors responded by clients, contractors, consultants, and overall of the respondent's perspectives. Results of the relative importance index of causes of time and cost overrun were also discussed in this section.

3.1.1. Clients' Views. Clients' ranked ineffective planning and scheduling of projects by contractor as the first cause of time overrun with RII of 107.4%. This result showed the importance of effective planning and scheduling of projects to complete projects within the schedule. A study by [20] in Iran, however, showed that ineffective planning and scheduling of projects by contractor was ranked 13th as the cause of time overrun. This difference in ranking between this study and a study by [20] shows that the contractors in Iran follow effective plan and schedule to execute construction activities compared to contractors in Tigrai. The second important factor (RII = 105.1%) as a cause of time overrun was change order. Change order refers to the changes made due to different reasons, such as design change, scope change by the owner, and changes in laws and regulations. In order to undertake these changes, it consumes extra time and leads the project to time overrun. These results coincided with the results found in [20, 30].

Clients, moreover, ranked design errors and changes as the first cause of cost overrun with RII of 89.7%. Similarly, Rybka et al. [30] ranked faulty design documentation as the first cause of cost overrun in water supply projects. Design changes may result from the errors occurred during design or the client may need additional work or omission of some works. Hence, design problem is one of the factors that causes project cost overrun which should be given more emphasis in water supply construction projects [30].

The second important factor (RII = 85.6%) that caused cost overrun as ranked by clients was lack of consistency between bill of quantities and drawings. This factor describes the lack of evenness of the items in the drawing with the items in the bill of quantities. Hence, the modification of this error leads the project to supplementary agreements and project cost overrun. Inadequate design supervision was ranked as the tenth cause of cost overrun with RII of 69.8%. Poor design supervision by consultants causes design error and the need to solve the problem contribute to project cost overrun.

3.1.2. Contractors' Views. Contractors ranked lack of consistency between bill of quantities and drawings as the first cause of time overrun with RII of 114.2%. This reference shows that when there is inconstancy of items in the design with the items in the bill of quantities or specification, it takes additional time to solve the problem. A study by [21], however, ranked lack of consistency between bill of quantities and drawings as the 12th factor that caused time overrun in water supply projects in Sri Lanka. Design errors and changes was ranked as the second important factor of time overrun by contractors with RII of 112.6%. This result is similar with the clients' view, which shows design change would significantly affect the project time.

The first important factor that caused cost overrun according to contractors was design errors and changes with RII of 90.9%. This result coincided with the clients' result. Similarly, Rybka et al. [30] ranked faulty design documentation as the first cause of cause overrun in water supply projects. Lack of consistency between bill of quantities and drawings was the second cause of cost overrun ranked by contractors with RII of 90%. This result also coincided with the clients' result. Therefore, proper design and drawings in accordance with the bill of quantities play an important role in completing projects within budget.

3.1.3. Consultants' Views. The consultants ranked design errors and changes as the first factor of time overrun with RII of 121%. Lack of consistency between bill of quantities and drawings was the second factor of time overrun ranked by consultants with RII of 120.9%. Perera and Halwatura [21] ranked lack of consistency between bill of quantities and drawings as the 12th cause of time overrun in water supply projects in Sri Lanka. This shows that the factors design errors and lack of consistency between bill of quantities and drawings are significant causes of time overruns in water supply projects in Tigrai.

Consultants ranked lack of consistency between bill of quantities and drawings as the first cause of cost overrun with RII of 95%. Design errors and changes was ranked as the second important factor with RII of 89.7%. Similarly, Rybka et al. [30] ranked faulty design documentation as the first cause of cost overrun in water supply projects.

The top 10 factors analyzed using the relative importance index (RII), determined for each factor, as a function of both frequency and degree of severity for the factors of time and cost overrun are ranked and summarized in the Tables 4 and 5.

3.1.4. Overall View. Figures 2 and 3 show the top ten causes of time and cost overrun, respectively, ranked by the overall respondents namely clients, contractors, and consultants with their RII numerical value and their statistical significance differences.

The letters *a* and *b* in Figure 2 show the significant differences ($p < 0.05$) between the factors. The factors having the same letter represent factors that have statistically the same importance. The factors with the greater letter are statistically ranked as the most important factors. The results of the analysis show that there are several important factors of underlying causes of time overrun in construction of water supply projects in Tigrai.

Design errors and change was ranked as first major factor of time overrun by overall with RII of 109.2%. Design errors and changes have severe impact on the project time which should be given much attention. Lack of consistency between bill of quantities and drawings was ranked as the second factor of time overrun ranked by overall with RII of 109.1%. Lack of consistency between bill of quantities and drawings has severe impact on project time if some items were missed during design. Change order was ranked as third cause of time overrun by overall with RII of 108.2%. Change order was also identified as one of the top ten causes of time overrun in water supply projects in Iran and Sri Lanka [20, 21].

Shortage of construction materials and electromechanical equipment in local market was ranked as the 4th cause of time overrun with RII of 93.6%. Whereas, it was ranked as the 28th cause of time overrun in Sri Lanka [21]. This shows that this factor has significant effect in project time overrun in Ethiopia than other countries. Unavailability of electromechanical equipment in local market has high impact on project time as these are the basic gears for water supply construction projects.

The overall rank shows that severe weather condition and force majeure were ranked as the least factors that causes time overrun with RII of 41.8% and 29.8%, respectively. This is due to their rare occurrence in Tigrai. Similarly, Frimpong et al. [25] found that bad weather and geological conditions were not very important factors in Ghana. Whereas, other studies [19, 21] identified severe weather conditions as the highest cause of time overrun in construction of dams in Oman and water supply projects in Sri Lanka. This difference shows that construction projects are site specific.

Even though the factors were ranked numerically based on their RII values, the statistical difference of the factors for this study showed that factors such as design errors and changes, lack of consistency between bill of quantities and drawings, change order, shortage of construction materials and electromechanical equipment in local market, delays in material import, and ineffective planning and scheduling of projects by contractor does not show significant difference ($p > 0.05$). This means that these six factors have statistically equal importance as major causes of time overrun. Factors such as slow decision-making, contractor's financial difficulties, poor contract management of the owner and consultant and delay in progress payments doesn't show significant difference ($p > 0.05$) or have statistically equal importance in time overrun as the second major cause of time overrun.

The letters *a*, *b*, and *c* in Figure 3 show the significant differences ($p < 0.05$) between the factors. The factors having the same letter represent factors that have statistically the similar importance. The factors with the greater letter are statistically ranked as the most important factors.

Design errors and changes was ranked as the first major cause of cost overrun by overall with RII of 90.3%. Similarly, Rybka et al. [30] ranked faulty design documentation as the first cause of cost overrun in water supply and sewerage system projects. The authors further proposed that attention

Table 4: Top ten causes of time overrun ranked by respondents.

Nos	Causes of time overrun	Client's view		Contractors' view		Consultants' view		Overall view	
		RII	Rank	RII	Rank	RII	Rank	RII	Rank
1	Design errors and changes	99.9	5	112.6	2	121.0	1	109.2	1
2	Lack of consistency between bill of quantities and drawings	97.9	6	114.2	1	120.9	2	109.1	2
3	Change order	105.0	2	107.6	3	115.5	3	108.2	3
4	Shortage of construction materials and electromechanical equipment in local market	101.0	4	76.3	10	107.3	5	93.6	4
5	Delays in material import (pipes, fittings, etc.)	93.7	7	87.8	4	97.5	8	92.1	5
6	Ineffective planning and scheduling of projects by contractor	107.4	1	70.1	15	90.0	10	88.2	6
7	Slow decision-making	87.8	9	80.9	6	102.5	6	87.9	7
8	Contractor's financial difficulties	104.7	3	77.7	8	68.0	20	86.0	8
9	Poor contract management of the owner/consultant	86.4	10	69.1	16	110.3	4	83.7	9
10	Delay in progress payments	90.3	8	82.0	5	70.0	17	82.8	10

Table 5: Top ten causes of cost overrun ranked by respondents.

Nos	Causes of cost overrun	Clients' view RII	Contractors' view Rank	Consultants' view RII	Overall view Rank	RII	Rank	RII	Rank
1	Design errors and changes	89.7	1	90.9	1	89.7	2	90.3	1
2	Lack of consistency between bill of quantities and drawings	85.6	2	90.0	2	95.0	1	89.8	2
3	Shortage of construction materials and electromechanical equipment in local market	72.7	5	80.9	3	83.3	11	78.1	3
4	Inconstancy of the price of materials	72.2	6	80.8	4	76.6	15	76.5	4
5	Change order	75.6	3	71.3	10	87.8	5	76.3	5
6	Delay in material delivery	68.8	13	76.5	5	87.8	5	75.7	6
7	Inadequate design supervision	69.8	10	63.8	12	87.9	3	70.8	7
8	Executive bureaucracy in the client's organization	66.0	15	72.0	9	76.6	15	70.6	8
9	Poor communication b/n contractor and other parties	73.1	4	60.9	15	85.3	8	70.5	9
10	Client's shortage of finance or delayed payments to contractors	70.1	9	62.8	14	87.9	3	70.5	10

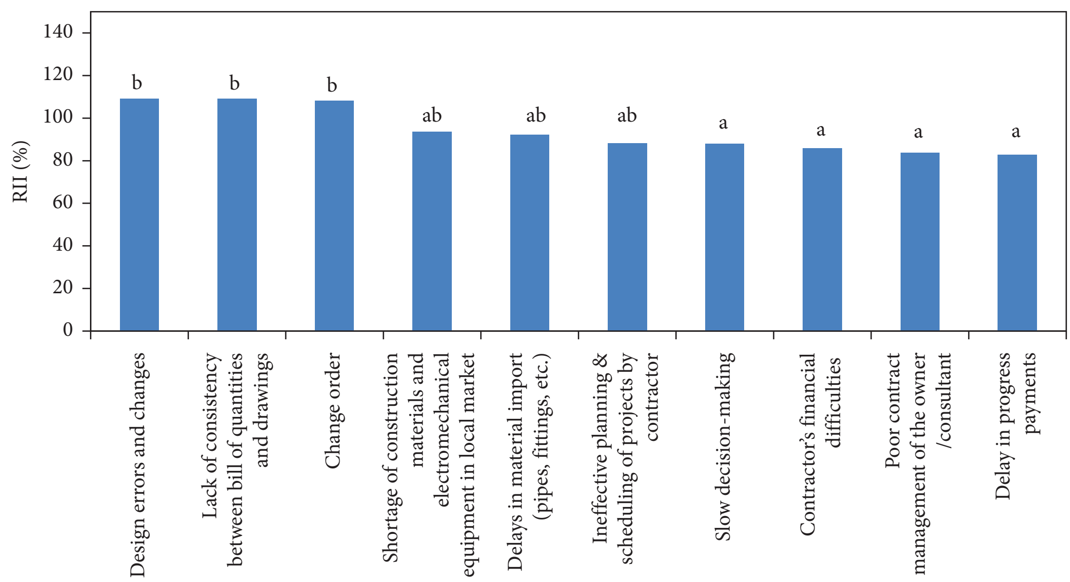

Figure 2: Overall view on the top ten causes of time overrun. Different letters show significant (Mann–Whitney U-test, $p < 0.05$) differences between factors; $a < b < c$.

should be given to the design phase as part of the cost risk management plan to minimize cost overrun in construction of water supply projects.

Lack of consistency between bill of quantities and drawings was ranked as the second most important cause of cost overrun with RII of 89.8%. This factor has severe impact on project cost leading to other variations for the missing items in design and for the underestimated quantities. If any item is missed during design phase, even if it can be constructed by supplementary work, it will cost higher than the first cost due to market fluctuations.

Shortage of construction materials and electromechanical equipment in local market was ranked as the 3rd cause of cost overrun with RII of 78.1%. This factor has high impact on project cost in Tigrai since the materials used in water supply projects are mostly imported. Hence, availability of the equipment in local market and using locally manufactured equipment will solve the problem. Inconstancy of the price of materials was ranked as the fourth cause of cost overrun by the overall rank with RII of 76.5%. Similarly, inconsistency of price of materials was identified as the fourth cause of cost overrun in water construction projects in Iran [20]. It was, however, ranked as the eleventh cause of time overrun in construction of water supply projects in Tehran [23]. This is due to the fact that Ethiopia and Iran have different market conditions, in which price of materials is expected to be different due to variable inflation rates.

Force majeure and fossils or discovery of things of geological or archaeological interest were ranked as the least factors that causes cost overrun with RII of 30.8% and 30.5%, respectively. This shows that the factors have low chance of occurrence in Tigrai. A research by [30] revealed that

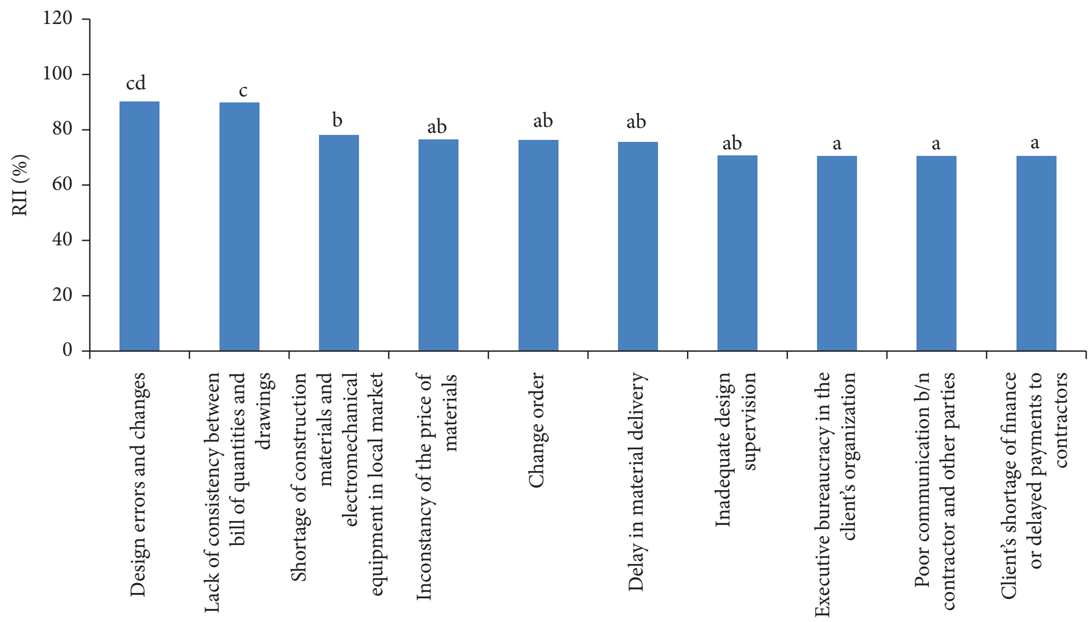

FIGURE 3: Overall view on the top ten causes of cost overrun. Different letters show significant (Mann–Whitney U-test, $p < 0.05$) differences between factors; $a < b < c < d$.

unforeseen physical conditions and adverse weather and ground conditions were among the top five causes of cost overrun in construction of water supply projects. This is due to the difference of the location of the projects.

Although design errors and changes were ranked first, it was not, however, significantly different ($p > 0.05$) from lack of consistency between bill of quantities and drawings. This means both factors have equal importance on cost overrun.

3.2. Linear Regression Models for Estimating Time and Cost Overruns

3.2.1. Establishing Multiple Regression to Estimate Time Overrun. Multiple regression was used to determine if time overrun could be predicted using design errors and changes, lack of consistency between bill of quantities and drawings, change order and delays in material import. The problem of multicollinearity was examined using the magnitude of the tolerance in the regression analysis. The multiple linear regression analysis for estimating time overrun from the measured design errors and changes, change order, and delays in material import resulted in a significant ($p < 0.05$) overall model fit. The regression model performed well for time overrun prediction, with r^2 of 0.95 and is shown in Table 6.

Lack of consistency between bill of quantities and drawings was excluded from the regression model since it was highly multicollinear (tolerance near 0) with the other predictors. The parameter estimates for design errors (*Der*) and changes and delays in material import (*Dmi*) were positive and significant ($p < 0.05$). The parameter estimates for change order was positive but not significant ($p > 0.05$). Design errors and changes and delays in material import were thus positively correlated with logarithm of time overrun, indicating that time overrun tend to increase as these predictor variables increased. The regression model for the time overrun performed well ($r^2 = 0.95$) and was statistically significant ($p < 0.05$) as shown in the following equation:

$$\log(\text{time overrun}) = 1.66 + 0.005 \times Der + 0.004 \times \text{Dmi}, \tag{10}$$

where logarithm of time overrun is in days, Der is number of design errors and changes and Dmi is number of delays in material import.

The regression equation indicated that time overrun can basically be predicted using design errors and changes and delays in material import. Change order, however, showed little effect on time overrun.

3.2.2. Establishing Multiple Regression to Estimate Cost Overrun. Multiple regression was used to determine if cost overrun could be predicted using design errors and changes, lack of consistency between bill of quantities and drawings, inconsistency of the price of materials and change order. The problem of multicollinearity was examined using the magnitude of the tolerance in the regression analysis.

The multiple linear regression analysis for estimating cost overrun from the measured design errors and changes, lack of consistency between bill of quantities and drawings, and inconsistency of the price of materials resulted in a significant($p < 0.05$) overall model fit. The regression model performed well for cost overrun, with r^2 of 0.98 as tabulated in Table 7.

Change order was excluded from the regression model since it was highly multicollinear (tolerance near 0) with the other predictor variables. The parameter estimates for design errors and changes (*Der*), lack of consistency between bill of quantity and drawings (Lcs), and inconsistency of price of

Table 6: Linear regression for time overrun and model parameter estimates. Regression model: Log (time overrun) = $\beta_0 + \beta_1 \times \text{Der} + \beta_2 \times \text{Lcs} + \beta_3 \times \text{Cho} + \beta_4 \times \text{Dmi}$.

Predictor variable	Parameter estimate
Constant, β_0	1.658[a]
Design errors and changes (*Der*), (days), β_1	0.005[a]
Inconsistency between bill of quantity and drawings (*Lcs*), (days), β_2	—
Change order (*Cho*), (days), β_3	0.06
Delays in material import (*Dmi*), (days), β_4	0.004[a]
r^2	0.95*

Note: [a]Parameter estimate significance ($p < 0.05$). *Model fit significance ($p < 0.05$).

Table 7: Linear regression for cost overrun and model parameter estimates regression model: cost overrun = $\beta_0 + \beta_1 \times \text{Der} + \beta_2 \times \text{Lcs} + \beta_3 \times \text{Inc} + \beta_4 \times \text{Cho}$.

Predictor variable	Parameter estimate
Constant, β_0	0.015
Design errors and change (*Der*), (millions), β_1	1.054[a]
Inconsistency between bill of quantity and drawings (*Lcs*), (millions), β_2	1.136[a]
Inconsistency of price of materials (*Inc*), (millions), β_3	1.316[a]
Change order (*Cho*), (millions), β_4	—
r^2	0.98*

Note: [a]Parameter estimate significance ($p < 0.05$); *model fit significance ($p < 0.05$).

materials (*Inc*) were positive and significant ($p < 0.05$). Design errors and changes, lack of consistency between bill of quantity and drawings, and inconsistency of price of materials were thus positively correlated with cost overrun, indicating that cost overrun tend to increase as these predictor variables increased. The regression model for the cost overrun performed well ($r^2 = 0.98$) and was statistically significant ($p < 0.05$). The developed model to predict cost overrun was shown with the following equation:

$$\text{Cost overrun} = 1.05 \times \text{Der} + 1.14 \times \text{Lcs} + 1.316 \times \text{Inc}, \tag{11}$$

where cost overrun is in days, Der is design errors and changes (no.), Lcs is lack of consistency between bill of quantity and drawings (no.), Inc is inconsistent price of materials (millions, ETB), and *Cho* is change orders (million, ETB).

The regression equation indicated that cost overrun can basically be predicted using design errors and changes, lack of consistency between bill of quantity and drawings, and inconsistency of price of materials.

3.3. Effects of Time and Cost Overruns on Project Performance.

Analysis of this section consisted of calculation of the frequency index and severity index for the effects of time and cost overrun.

3.3.1. Overall Respondents' View on the Effects of Time Overrun.

The letters *a* and *b* in Figure 4 show the significant differences ($p < 0.05$) between the factors. The factors with the same letters represent factors that have statistically equal importance. The factors with the greater letter are statistically ranked as the most important factors.

Cost overrun was ranked the first by both contractors and consultants with similar RII of 70%. The clients ranked it second with RII of 60.56%. Similarly, in Sri Lanka, cost overrun was identified among the most common effects of time overrun in construction of water supply projects [20]. If excessive cost overrun occurs, it may probably lead to additional budget which affects the limited financial resources of the country. This consequently results in budget shortfall for construction of other water supply projects which prevent the plan to address clean water to the society. Hence, cost overrun does not affect only the parties involved, but the society and the national economy of the country as a whole.

Funding difficulties was ranked first by clients with RII of 63.4%, third by consultants with RII of 58.1%, and fourth by contractors with RII of 50.6%. Dispute was ranked third by clients with RII of 52.4%, whereas it was ranked second by both contractors and consultants with RII of 53.4% and 63.8%, respectively. Similar result was obtained in Sri Lanka, in which water supply projects were severely affected due to delay in construction [21]. Time overrun could lead to inability to secure project fund from public authorities and could also be a source of dispute and bad relationship among the parties.

Statistical analysis revealed that the effect of time overrun on cost overrun and funding difficulties did not result in significant differences ($p > 0.05$) between these two factors (Figure 4). Time overrun had, however, statistically significant ($p < 0.005$) effect on cost overrun compared to the effect on other factors. Similarly, factors such as termination of contracts and bad relationship with construction team had statistically similar effects on time overrun.

The letters *a* and *b* in Figure 5 show the significant differences ($p < 0.05$) between the factors in which letter *b* is greater than a. The factors with the same letters represent factors having statistically the same importance. The factors

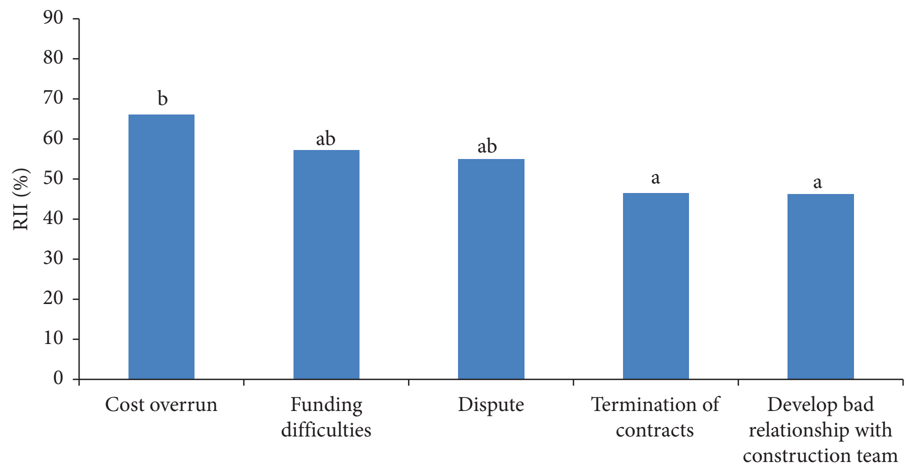

Figure 4: Overall view on the top 5 effects of time overrun. Different letters show significant (Mann–Whitney *U*-test, $p < 0.05$) differences between factors; $a < b < c$.

with the greater letter are statistically ranked as the most important factors.

Delay was identified as the first most important effect of cost overrun in construction of water supply projects by all clients, consultants, and contractors with RII of 87.8%, 90%, and 72.8% respectively. Delay of the projects has severe effect on the parties and most importantly on the society.

Additional cost or budget shortfall was ranked second by both clients and consultants with RII of 69.9% and 69.4%, respectively. Contractors ranked it third with RII of 56.88%. Supplementary agreement was ranked as the third effect of cost overrun by both clients and consultants with RII of 57.2% and 61.9%, respectively. Contractors ranked it as the second effect of cost overrun with RII of 62.3%. This showed that devoting additional cost has severe impact on the client, government, and the community as a whole as there will be difficulties for funding other water supply construction projects.

Statistical analysis on the effect of cost overrun on delay and additional cost did not result in significant difference ($p > 0.05$). The effect of cost overrun on project delay was, however, statistically significant ($p < 0.05$) compared to the other effects on the need for supplementary agreement, dispute, and funding difficulty. The effects of cost overrun on dispute, funding difficulties, and supplementary agreement did not result as statistically significant ($p > 0.05$) difference.

3.4. Mitigation Measures of Time and Cost Overrun. Analysis of this section consists calculation of importance index for the mitigation methods of time and cost overrun responded by clients, contractors, consultants, and overall, the respondent's perspectives.

3.4.1. Overall Respondents' View. The letter *a* in Figure 6 shows the significant differences ($p < 0.05$) between the factors. The factors with the same letter represent factors having the equal importance which are all statistically ranked as the most important methods.

The results of the analysis show that complete and proper design at the right time was ranked first by clients with RII of 0.89, whereas it was ranked fifth by both contractors and consultants with RII of 0.78. Design problem was identified as the most important factor of time overrun, so complete and proper design at the right time is necessary to minimize time overrun. This result is in agreement with other previous studies elsewhere in the world [30].

Selection of a reliable and experienced contractor in water supply projects was ranked the first mitigation method of time overrun by consultants with RII of 0.88 while it was ranked second by contractors with RII of 0.79. Clients, however, ranked it the fourth important method with RII of 0.79. Effective strategic planning was identified as the most effective method by contractors with RII of 0.81. Consultants ranked it third with RII of 0.82 and clients ranked it fourth with RII of 0.79. Effective strategic planning is important to accomplish the activities based on schedule. This result is in agreement with the study by [20].

Statistical analysis, however, did not result in significant difference among the mitigation measures. All mitigation measures having high RII means that they are equally important in minimizing time overrun of water supply projects in Tigrai region.

The letter a in Figure 7 shows the significant differences ($p < 0.05$) between the factors. The factors with the same letter represent factors having the equal importance which are all statistically ranked as the most important methods.

The results of the analysis showed that complete and proper design at the right time was identified as the first most effective mitigation measure of cost overrun in construction of water supply projects by clients with RII of 0.82, contractors ranked it fourth with RII of 0.78, and consultants ranked it sixth with RII of 0.82. As design error was identified as the most important factor causing cost overrun in this study, complete and proper design at the right time is important to minimize cost overrun.

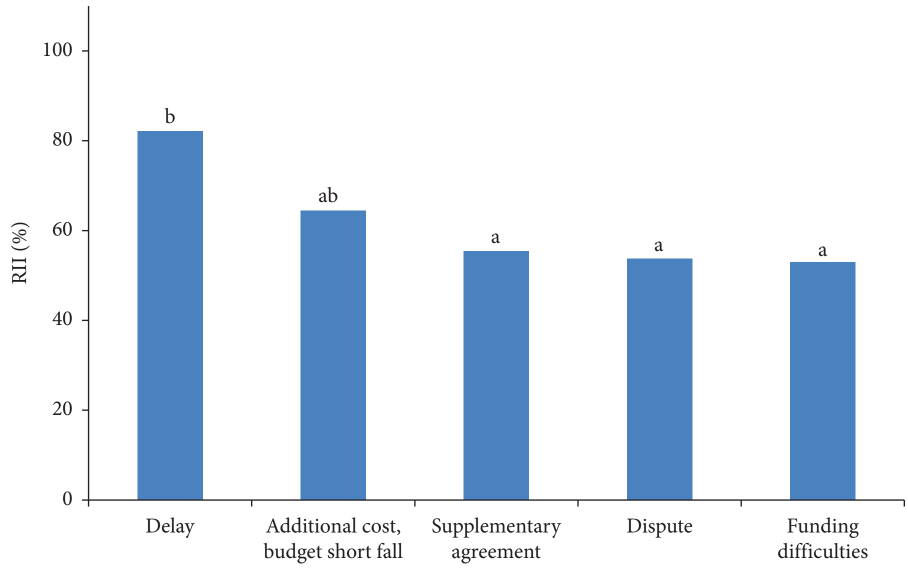

Figure 5: Overall view on the top 5 effects of cost overrun. Different letters show significant (Mann–Whitney U-test, $p < 0.05$) differences between factors; $a < b < c$.

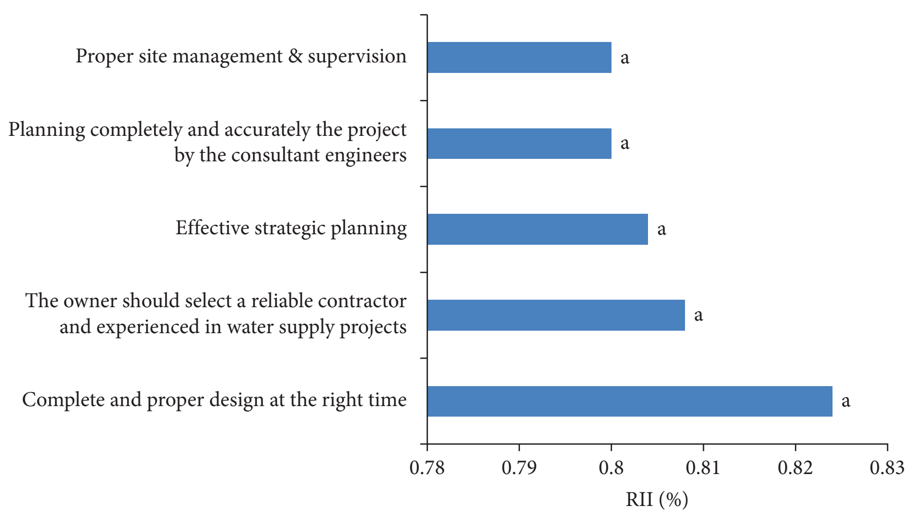

Figure 6: Overall view on the mitigation measures of time overrun. Different letters show significant (Mann–Whitney U-test, $p < 0.05$) differences between factors; $a < b < c$.

Technical awareness about water supply projects was ranked as the first most important mitigation measure of cost overrun by both contractors and consultants with RII of 0.8 and 0.88, respectively. Clients, on the other hand ranked it seventh with RII of 0.77. Selection of a reliable and experienced contractor in water supply projects was ranked as the first effective mitigation measure of cost overrun by consultants with RII of 0.88 and second by contractors with RII of 0.79 and fifth by clients with RII of 0.78.

Experience of the contractor in water supply construction projects is important to minimize underestimation and to stay on planned budget as suggested by [24]. Although there is some difference in RII among the factors in Figure 7, there is statistically significant difference among the factors, indicating that all the factors are equally important in reducing cost overrun. Therefore, these factors should be seriously considered in future water supply interventions to at least minimize cost overruns.

3.5. Tests for Agreements among Respondents. The Spearman's rank correlation among respondents about the top ten identified causes, effects, and mitigation measures of time and cost overrun (Table 8). Result indicated that the level of agreement between responses of clients and contractors about the causes of time overrun is significantly ($p < 0.01$) high ($r = 0.707$, $n = 200$). Similar results were obtained from the responses of consultants and contractors, in which the agreement was significantly high ($r = 0.568$, $n = 100$). The level of agreement between clients and consultants was, however, significant but weak ($r = 0.365$, $n = 100$).

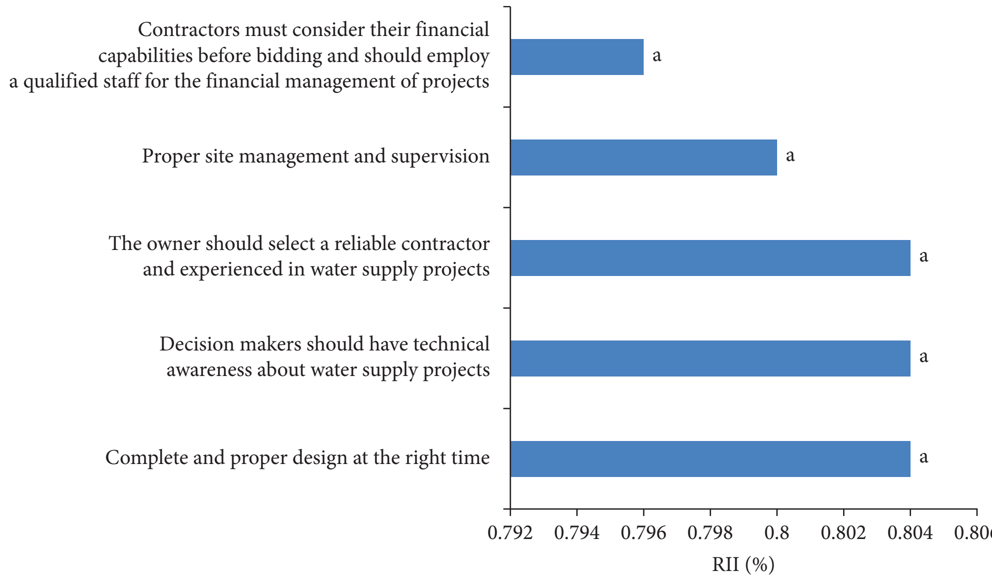

Figure 7: Overall view of the mitigation measures of cost overrun. Different letters show significant (Mann–Whitney U-test, $p < 0.05$) differences between factors; $a < b < c$.

Table 8: Correlation among the respondents.

Variables	Respondents	Client	Contractor	Consultant
Causes of time overrun	Client	—		
	Contractor	0.707**	—	
	Consultant	0.365**	0.568**	—
Causes of cost overrun	Client	—		
	Contractor	0.857**	—	
	Consultant	0.738**	0.674**	—
Effect of time overrun	Client	—		
	Contractor	0.853**	—	
	Consultant	0.630**	0.691**	—
Effect of cost overrun	Client	—		
	Contractor	0.871**	—	
	Consultant	0.723**	0.802**	—
Mitigation measures of time overrun	Client	—		
	Contractor	0.769**	—	
	Consultant	0.359**	0.675**	—
Mitigation measures of cost overrun	Client	—		
	Contractor	0.764**	—	
	Consultant	0.443**	0.782**	—

Note: *Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).

The level of agreement between responses of clients and consultants about the causes of cost overrun was significantly ($p < 0.01$) high ($r = 0.738$, $n = 100$). Similar level of agreement about causes of cost overrun was obtained between responses of clients and contractors, with significant and high ($r = 0.857$, $n = 200$) correlation. Moreover, the level of agreement between the responses of contractors and consultants about the causes of cost overrun is significantly high ($r = 0.674$, $n = 100$). Generally, the overall spearman correlation result showed that there was sound level of agreement among the responses of contractors, consultants, and clients about the identified top causes, effects, and mitigation measures of time and cost overrun in water supply projects.

3.6. Case Studies. To see the validity of the questionnaire survey result, case studies of 12 water supply projects were analyzed about their contractual documents, variation letters, claims, and justification documents (Table 9). The selection criteria used were 4 projects that have experienced high rate of time and cost overrun, 4 projects that have experienced medium rate of time and cost overrun, and 4 projects that had good performance in time and cost. From

Table 9: Findings of the case studies.

Project	Contract signed date	Contract completion date	Actual completion	Time overruns (day)	Initial contract amount (ETB)	Actual cost (ETB)	Cost overruns (ETB)	Cost overrun, (%)
A	07-08-07	19-08-08	Ongoing	741	135,202,397.4	150,901,250.7	15,698,853.3	12
B	09-07-07	13-04-08	21-10-09	553	17,556,161.1	19,401,165.9	1,845,004.8	10.5
C	11-02-09	25-07-09	10-01-10	165	5,403,696.5	6,645,094.2	1,241,397.7	23
D	17-04-07	22-01-09	14-08-09	142	15,183,028.5	16,357,182.9	1,174,154.4	7.7
E	20-11-08	14-03-09	07-12-08	−97	5,549,151.5	5,715,598.9	166,447.4	3
F	27-10-08	08-09-09	20-08-09	−18	16,375,502.9	16,364,176.6	−11,326.3	0
G	22-04-06	10-02-09	Ongoing	571	136,892,950.5	171,116,180.5	34,223,230	25
H	08-07-07	09-04-08	Ongoing	870	75,113,281.6	84,106,477.8	8,993,196.2	12
I	12-04-08	05-04-10	Ongoing	145	125,850,628.3	251,700,979.6	27,592,776.8	22
J	22-10-08	25-09-09	03-11-09	37	9,440,495.20	8,608,284.90	−832,210.20	−8.8
K	05-08-08	15-01-09	15-02-09	39	6,089,668.30	5,729,844.80	−359823.4	−6

Note: ETB = Ethiopian birr.

the reviewed documents, projects that had time overrun of above 500 days and cost overrun of above 23% were taken as projects that had suffered high time overrun and cost overrun, respectively. Projects that had time overrun of from 140 up to 200 days and cost overrun of from 10% up to 22% were taken as projects that had medium time and cost overrun, respectively. Projects that were completed without time and cost overrun were taken as projects that had good performance.

The major causes of time and cost overrun identified from the contractual documents, claims, delay justification, and variation agreements of the reviewed water supply projects were design problem and change, variations, lack of consistency, late compensation, under estimation, and late delivery of electromechanical equipment. The result found from the existing data of projects coincided with the outcomes obtained from the questionnaire survey. The causes of time and cost overrun of projects were caused by among the top ten causes of time and cost overrun identified in the research findings. This covers above 90% of the reviewed documents, which showed very good agreement with the research findings.

The most common effects of time and cost overrun found in the case studies were delay, community problem of access to clean water, funding difficulties, and the need for supplementary agreement. The desk study result showed, more than 90% of the projects incurred additional time and cost from the initial estimated amount. The first and most victims from the time and cost overrun were the society of Tigrai due to shortage of water which still is a basic problem. Moreover, the effect of time and cost overrun can affect national economy of the country. From the limited financial resource of the country, it is difficult to allocate additional budget when cost overrun occurs and this result in budget shortfall for constructing other water supply projects. The overrun also result dispute and bad relationship among the parties involved.

From the existing reviewed data of the projects, it was found that the rate of time and cost overruns ranged from 0 up to 203% of the contract time and the cost overrun ranged from 0 up to 25% of the contract amount. Similarly, the effects of time and cost overrun identified from the case studies were also similar with these research findings.

4. Conclusion

The case study indicated that the actual time overrun ranges between 0 and 203% of the contract time and cost overrun ranges between 0 and 25% of the contract amount. The most important causes of time and cost overrun were design errors and changes and lack of consistency between bill of quantities and drawings. Moreover, the major effect of time overrun was cost overrun, resulting in additional budget and eating up of the limited financial resources of Tigrai region. The most common effect of cost overrun was delay; this in turn affects the key stakeholders and the society leading to shortage of access to drinking water. Time and cost overruns affect all the parties involved and the society. Hence, the most effective mitigation measure to reduce time and cost overruns was complete and properly designed at the right time. Regression model was also able to predict time overrun based on available delay data caused by design errors and changes and late material import with good model performance. Similarly, cost overrun could be predicted well using additional cost incurred by design errors and changes, lack of consistency between bill of quantity and drawings, and inconsistency of price of materials. These regression models hence can help to estimate time and cost overrun based on available data on factors that affect the overruns.

This study was limited on water supply projects which were constructed over the period of 2005–2009 E.C. Moreover, the groups of respondents for this research were the contractual parties: client (Tigrai Bureau of Water Resources), consultants, and Grade 1 and 2 contractors. Future studies should be conducted on delay and cost minimization of water work construction projects, which involve community participation to come up with more general solutions and hence develop a model to mitigate the predicted time and cost overruns.

Data Availability

The data related to contract documents and construction history are available at Tigrai Water Resource Bureau and Tigrai Water Utility Offices.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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