Assessing the causes of project overruns in tunnel construction projects in Pakistan

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Abstract

Tunnel construction is considered a bottleneck point in mega construction projects because of higher associated risks and uncertainties. This study is an attempt to identify and rank the causes project overruns in tunnel construction projects in Pakistan and propose a mitigation strategy to minimize their effects. For the given purpose, a total of 32 key causes were obtained from the literature and discussion with a team of experts and practitioners. A web-based questionnaire survey was used for data collection. About 55 complete responses were received from the practitioners working as clients, consultants, and contractors in Pakistan. The identified causes were ranked using frequency, severity, and relative importance indexes. The most important causes were found to be inexperienced and incompetent contractors, ignoring consultants' instructions by contractors, inadequate project estimates, delay in issuance of funds to the contractors, and low bids. This study can be employed for controlling the leading causes of overruns in tunnel construction projects. Moreover, it can serve as a guide in further investigation of the causes of project overruns in tunneling in different countries.

Keywords: Causes of Project overruns, relative importance index, tunnel construction projects

1 Introduction

Construction industry plays an important role in the infrastructure development (Azhar et al., 2008, Endut et al., 2009) and economic growth of any country (Sambasivan and Soon, 2007). Despite its importance, a large number of construction projects suffer from overruns severely, which carries harsh consequences for both contractors and clients (Al-Momani, 2000).

Many studies investigated the causes of project overruns in construction projects in various countries such as , United State (Shrestha et al., 2013), United Kingdom (Olawale and Sun, 2010), Australia

(Love et al., 2013), Saudi Arabia (Elawi et al., 2016), South Korea (Lee, 2008), Malaysia (Karunakaran et al., 2018), Nigeria (Aibinu and Odeyinka, 2006) Vietnam(Long et al., 2004), and Pakistan (Haseeb et al., 2012, Batool and Abbas, 2017). Studies also investigated causes of overruns in different types of construction projects such as buildings (Abd El-Razek et al., 2008), highways (Sohu et al., 2016), groundwater (Frimpong et al., 2003), transportation including tunnel construction (Flyvbjerg et al., 2004), and power plant construction, such as nuclear, thermal, and hydroelectric construction projects (Schneider et al., 2016, Sovacool et al., 2014). The detailed review of the literature suggests different level of significance for different reasons of project overruns in various civil construction projects because of external and internal factors and the nature of the projects.

Tunnel construction projects are growing as a result of increasing world population, which leads to the importance of using confined spaces. Therefore, it is essential to investigate the critical factors of tunnel construction projects for their successful completion. The factors related to design and geological construction methods severely affect these projects (Paraskevopoulou and Boutsis, 2020). The design and procedures of tunneling and underground excavations are based on the estimated mechanical and/or physical properties of the rock mass, which is a natural geological material (Stille and Palmström, 2008). Unlike civil construction materials, the rock mass is generally anisotropic, discontinuous, non-elastic, and non-homogeneous (Harrison et al., 2002). It creates uncertainties during construction and consequently the actual construction deviates from the design. A good knowledge to understand the complexity of the ground or rock characteristics is imperative for tunneling projects (Stille and Palmström, 2008). During tunnel design, the precise estimation of rock mass properties and qualitative picture of rock mass structure is also essential (Yan-jun et al., 2017). Tunnel construction projects experienced higher overruns as compared to other sector projects because of various factors such as higher risks, uncertainties (Isaksson, 2002). Some of the important factors are summarized as under:

1. Geotechnical problems and instability due to adverse structural geology, excessively high rock stress, weathering or swelling rock, instability due to excessive groundwater pressure or flow (Riedmüller and Schubert, 2000).

2. The complexity of design, and incomplete information of the rock structure (Brown and Hoek, 1980)
3. Requirement of specialized earth excavation equipment due to limited spacing (Sinha, 2012)
4. A single point for all the cyclic operations

It is pertinent to note that the significance of causes of overruns can vary for different projects at different geographical locations (Flyvbjerg et al., 2003). The critical review of the previous literature show that several studies have been carried out to identify significant factors causing project overruns in various types of construction projects in Pakistan including building construction (Sohu et al., 2018, Kamal et al., 2019), highways construction (Zafar et al., 2019, Sohu et al., 2017), and power plants construction projects (Batool and Abbas, 2017). However, there is a lack of study to investigate specifically the causes of project overruns in tunnel construction projects in Pakistan. Tunneling projects involve higher risks and uncertainties as compared to other types of construction projects (Isaksson, 2002) because of the complex nature of underground excavation (Reilly and Arrigoni, 2005). Higher associated risks, inadequate information, and changing ground conditions make tunneling projects difficult and more susceptible for overruns (Senent and Jimenez, 2015, Wang et al., 2012). This shows the necessity for a comprehensive study to investigate the causes of project overruns in tunnel construction projects. Hence, the primary purpose of this study is to identify the factors causing overruns in tunnel construction projects in the context of Pakistan.

The study has the following objectives:

- identify the key causes of project overruns in tunnel construction projects;
- evaluate the perspectives of clients, consultants, and contractors about overruns separately for getting a broader view of the subject; and
- draw a mitigation plan for minimizing the effects of project overruns.

This paper is organized in sections. The paper draws on evidence from literature about the causes of overruns in construction projects. The subsequent section discusses questionnaire development, validation, data gathering, and analysis techniques followed by results and discussion. Thereafter,

mitigation measures are discussed. In the last section, the study is concluded the study with its application both for practitioners and researchers.

2 Literature review

Tunnel construction involves a large number of technical parameters, associated high risk of collapse, and uncertainties to the geological condition of the construction site, which makes it practically unique and difficult to estimate the time and cost of construction (Flyvbjerg et al., 2004). Tunnel constructions have multiple similarities in general processes and activities with civil construction process. Therefore, the magnitude of project overruns in tunnel construction projects can be understood by studying various infrastructure projects (Isaksson, 2002).

2.1 Causes of overruns in civil construction project

Several researchers have investigated the severity and frequency of various causes of overruns in construction projects (Sambasivan et al., 2017, Ogwueleka, 2011, Batool and Abbas, 2017). Despite a strong effort from both the researchers and practitioners to control the causes of project overruns, the track record of project overruns is extremely poor across the world. The following subsections discuss the causes of overruns in construction projects at different geographic locations across the globe.

2.1.1 *Causes of overruns in Global construction projects*

The key factors responsible for project overruns vary in different countries (Shah, 2016). For instance, the important causes of project overruns in Egypt were found as slow decision making, frequent change orders, unrealistic scheduling, poor contract management, financial issues with the contractors, and bidding (Abd El-Razek et al., 2008). In South Africa, the significant causes of project overruns were revealed as financial issues with the contractors, slow decisions, poor planning, and frequent scope changes (Khabisi et al., 2019). A study of the Thailand construction industry reported shortage of resources, poor contractor management, shortage of labor, delay in design, inadequate planning, and frequent change orders as critical factors of project overruns (Toor and Ogunlana, 2008). Cost issues, late payment and other financial issues, increase in prices, contract related issues, poor planning, and mismanagement and

discrepancies were reported as fundamental factors of project overruns in India (Venkateswaran and Murugasan, 2017). Shah (2016) compared the causes of time and cost overruns in Australia, Malaysia, and Ghana. It was concluded that poor planning, methods of construction, and monitoring and feedback processes were major factors in Australia, where late payment, underestimating or ignoring the effect of project cost, project complexity, and project size were the major causes in Ghana. However, poor planning, site management issues, and inexperienced contractors were the most important causes in Malaysia. In United States construction industry, the key factor of project overruns were found as change in order, slow decision making, design error, delay in approval of design documents, and errors in contract documents (Tafazzoli and Shrestha, 2017). In short, studies carried out across the globe to investigate project overruns in construction projects and have concluded various sets of critical factors for different countries.

2.1.2 *Causes of overruns in construction projects in Pakistan*

Researchers have carried out a number of studies to investigate causes of overruns in various type of construction projects in Pakistan. For instance, Batool and Abbas (2017) have explored the causes of delays in hydropower projects in Pakistan. They found the emerging causes of project overruns as poor project time management, legal issues, non-compliance by contractor with contractual provision, intentional delay by contractor for personal motives, lack of control of contractor activities. In an another study, inadequate project management, late funding, rework due to error, poor supervision, poor site management, late delivery of material, lack of adequate machinery, poor management were found as the highest risk factors in building construction projects (Kamal et al., 2019). Further, Sohu et al., (2019) investigated highway construction projects, and identified inadequate planning, frequent design changes, financial difficulties faced by the client, owner interference, delays in decision making, fluctuation of material prices, and poor contract management as the influential causes of project overruns. Shaikh et al., (2020) have examined the financial issues in project schedule of building construction projects and identified weak cash flow administration, delay payment by client, inadequate fiscal assets and financial market flux as the frequent occurred financial causes of project delay. The above discussion indicates that different kind of projects occurred in the same country have different significant factors of overruns.

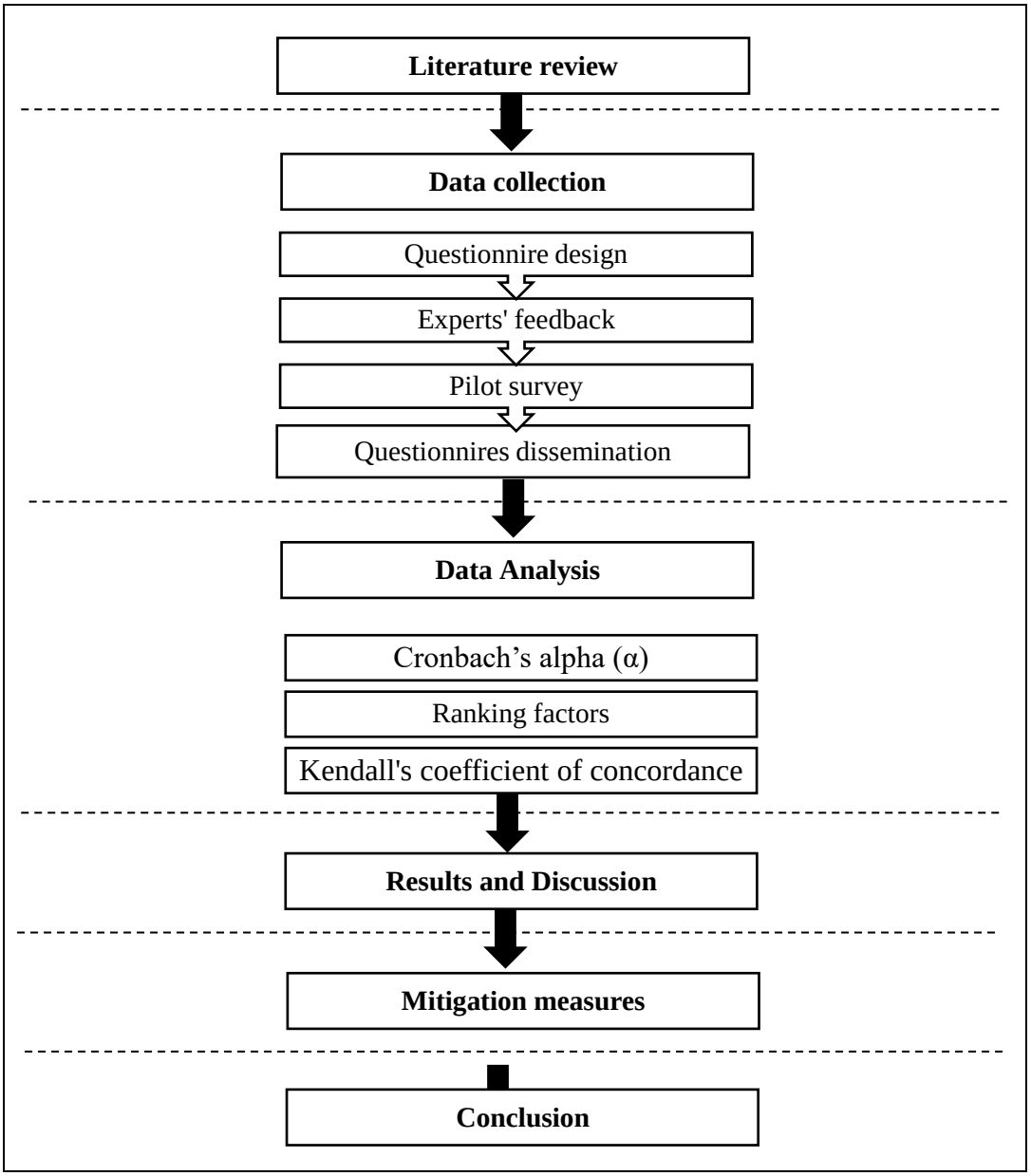
2.2 Causes of overruns in Tunnel construction projects

Tunnel construction has higher level of risk and uncertainties as compared to other construction projects (Isaksson, 2002). Because of the associated uncertainties and inadequate information obtained from site investigation, tunneling/ underground excavation are complex (Hoek et al., 1998, Reilly and Arrigoni, 2005), and involve high risks, which have direct impact on the project schedule, cost and performance (Sarkar and Dutta, 2011). The complexity, higher risk of failure, and limited knowledge of geological condition make tunneling difficult to estimate and more susceptible for project overruns (Senent and Jimenez, 2015, Wang et al., 2012). Efron and Read (2012) examined around 158 tunnel projects from 35 countries, and note that none of the examined case was completed within the initial estimations. Researchers identified different causes of project overruns in tunnel construction projects. Flyvbjerg, (2014) found that the key factors affecting cost and time overruns in tunnel construction projects are frequent changes in schedule, changes in design and scope, poor procurement process, complexities in design and construction methods, poor estimates, and contractual disputes. In another study, geological surprises, lack of competition, price fluctuation and inflation, public concerns and unforeseen events were found as the influential factors of overruns in tunnel construction projects (Membah and Asa, 2015). The cost and time overruns in tunnel construction projects are correlated with prevailing geological, technological and economic conditions (Isaksson, 2002). In a study of modeling risk, lack of resources, changes in work, defective design, inefficient machines, lack of adequate material, inflation, accidents, changes in regulations, funding issues, geological conditions, natural disasters etc., were identified as key risk factors that lead to project overruns in hydropower and tunnel construction projects (Charoenngam and Yeh, 1999).

3 Research Methodology

In this study, the identified causes project overruns were investigated using a web based semi-structured questionnaire. For assessing the authenticity of the questionnaire, validity and reliability have been checked prior to data collection in line with previous study (Mohajan, 2017). In this study, experts' review and pilot survey was used for validity and Cronbach's alpha (α) test for assessing the reliability of

188 the questionnaire. It is important to mention it here that the word “practitioners” in this study refers to those
189 who have worked in tunnel construction projects in Pakistan and the word “expert” refers to those who
190 have doctoral degree in the relevant field and have good understanding of quantitative methodologies and
191 tunnel construction activities. The following subsections discuss the components of research methodology
192 as shown in Figure 1.
193



194 Figure 1 Research flow diagram of the study

3.1 Questionnaire Development

A comprehensive list of causes and effects of overruns in construction projects was populated from previous literature. The list was modified after discussion with experts and practitioners to make it suitable for the nature of tunnel construction projects in the context of Pakistan. The designed questionnaire was shared first with a group of five experts to select the suitable terms, to ensure the validity of knowledge measurement, and the completeness of the questions. The questionnaire was edited according to their feedback and sent to a group of ten practitioners for pilot survey and for their feedback to make the questionnaire simpler to understand and more effective in measuring the intended objectives. The procedure of validation of questionnaire through experts and practitioners is in line with previous studies (Famiyeh et al., 2017).

The questionnaire consists of four main sections. It starts with a consent form, followed by definitions of the key terminologies, the demographic data of the respondents, and information related to the associated projects. The next section comprises the key factors responsible for project overruns in tunnel projects in Pakistan. The respondents were asked to rank the frequency and severity of each factor on a linear scale from 1-5. The last section consists of open ended questions about mitigation measures for reducing the effect of project overruns. The practitioners recommended a number of mitigation measures based on their experiences and expertise for controlling overruns in tunneling construction projects.

3.2 Data collection

The questionnaires were sent to around 80 practitioners having working experience in tunnel construction projects as clients, consultants, or contractors in Pakistan. About 65 questionnaires were received back from different respondents working in public, private, and semi-government organizations. The collected data were filtered, and unengaged responses were removed. A sample of 55 respondents was considered for further statistical analysis. The response rate was around 68.75%, which was good enough to show the true representation of the target sample.

The respondents participated in this study have experiences around 12 years at average in construction industry on a management position, which increases the reliability of the data. It is also

important to mention here that several studies in the literature have used sample sizes ranging from 30 to 60 for ranking causes of project overruns using similar quantitative techniques (Famiyeh et al., 2017, Sohu et al., 2018, Azhar et al., 2008, Gündüz et al., 2013). Therefore, the sample size (n=55) used in this study is appropriate for ranking techniques.

3.3 Ranking Indexes

In this study, the causes and effects of project overruns have been ranked by their frequency of occurrence, severity, and relative importance. Relative frequency index (RFI) indicates the frequency of occurrence of each factor, where the relative severity index (RSI) shows the impact of the factor on project overruns (Assaf and Al-Hejji, 2006). Relative importance index (RII) can be calculated with the help of RSI and RFI. The three ranking indexes were computed by using equations (1-3). Its value ranged from 0 (0 = no importance) to 1 (1= Very high importance).

Frequency index has been computed using equation (1)

$$RFI = \sum_{i=1}^{5}(n_{i.}\ F\,i)/A_5\ .N \qquad (1)$$

Similarly, the severity index has been calculated by using equation (2)

$$RSI = \sum_{i=1}^{5}(n_{i.}\ S\,i)/A_5\ .N \qquad (2)$$

RII for each factor was calculated from the values obtained from equation (1) and equation (2)

$$RII = \sum_{i=1}^{5}(n_{i.}\ W\,i)/A_{25}\ .N \qquad (3)$$

Where

F_i = Weight given to the i^{th} response about the frequency of each factor: i = 1, 2, 3, 4, 5

(*F_1 = Very low; F_2 = Low; F_3 = Medium; F_4 = High; and F_5 = Very high)*

N = Total number of respondents (in this study N = 55)

n_i = Frequency of i^{th} response: i = 1, 2, 3, 4, 5

A = The largest score in the selected scale which is 5 for RFI and RSI equations *(A_5)*, and 25 for RII equation A_{25}

S_i = Weight of severity / impact of each factor given to the i^{th} response

$W_i = F_i * S_i$

The frequency and severity indexes for any cause have value greater than 0.599 will be considered significant as used by previous studies (Famiyeh et al., 2017, Muhwezi et al., 2014). It is also important to explain that weight of RII (Wi) is the product of weight of severity (Si) and weight of frequency (Fi) in this study. Therefore, the values of RII will not be read as significant or insignificant in this study. It only explains the relative importance and position of each cause on priority scale (Assaf and Al-Hejji, 2006, Batool and Abbas, 2017).

3.4 Reliability of Questionnaire

In this study, a commonly used statistical test known as Cronbach's alpha (α) has been applied for measuring the reliability or inner consistency of the questionnaire. In Cronbach's alpha (α) test, α indicates the degree of relatedness of items, which ranges from 0.0 (no correlation) to 1.0 (perfect correlation) and is considered adequate if ranged from 0.70 to 0.95 (Terwee et al., 2007). It can be calculated by using equation (4) as given below:

$$Cronbach \propto = (n/(n-1)) \times [1-(\sum V\_i\hat{}2)/(V\_sum\hat{}2)] \quad (4)$$

Where

V_i^2 = Variance of the sample (respondents)

V_{sum}^2= Variance of the sum of all respondents

n = Number of factors (causes), (in this study n= 32)

The results of Cronbach's alpha (α) test show that the value of alpha for all factors is greater than 0.90. The overall Cronbach's alpha value for frequency and severity of the factors were also found 0.921 and 0.935, respectively. The highest value of alpha for the individual factors and group of factors confirmed the high reliability of the collected data. The table consisting of Cronbach's alpha (α) values for each variable have been attached in Appendix A.

3.5 Kendall's coefficient of concordance

In this study, the respondents were clustered in three groups namely clients, consultants, and contractors to find out their opinions about the importance of each identified factor. Kendall's coefficient of concordance (W) is used to check agreement among the three groups in line with previous studies (Lundin et al., 2015, Frimpong et al., 2003, Assaf and Al-Hejji, 2006). The value of Kendall's (W) ranged from 0.0 (no agreement) to 1.0 scale (very high agreement) (Frimpong et al., 2003). It can be calculated by using equation (5) as given below:

$$W = 12 \times S/((m\text{^}(2)\,(n\text{^}(3) - n))) \quad (5)$$

where

m = Number of groups (clients, consultants, and contractors), (in this study m=3)

n = Number of factors (causes), (in this study n= 32)

R_i = Sum of all the ranked value of each factor

$\overline{R} = (m(n+1))/2$

$S = \sum_{n=1}^{n} \left(R_i + \overline{R}\right)^2$: [i = Factors 1,2,3,4…..n]

The following test hypothesis was developed for the test.

Null hypothesis (H_0): There is no convincing evidence of agreement in ranking among three groups

Alternative hypothesis (H_1): There is convincing evidence of agreement in ranking among three groups

Since n =32, much greater for the table of critical value, we computed Friedman's chi-square (χ^2) statistic from W by the formula

$$\chi^2 = \mathrm{m}(n-1)\mathrm{W} \quad (6)$$

Thus, using χ^2critical table for n= 32 and α = 0.05, the $\chi_{\alpha}^{2(n-1)} = \chi_{0.05}^{2(32)} = 43.77$

The computed value (χ^2) is given below:

Computed valued of Chi-square = $\chi^2 = 52.181$

p-value = $P = 0.010$

As the above values show that the computed value ($\chi^2 = 52.181$) is greater than the value of the critical table ($\chi_{0.05}^{2(32)}$ = 43.77). Therefore, it is accepted that there is convincing evidence of an association among the project groups. This indicates the reliability and unbiasedness of the given results.

4 Results and Analysis

Demographic data of respondents, information about organizations, projects, and project teams are shown in Table 1. Respondents were classified based on gender, professional background, and experience. The data show that questionnaire was assessed by experienced respondents, which reflects the importance of the results of the study. It also shows that majority of the respondents were from private organizations and were from consultants employing party. However, clients and contractors also have adequate representation in the sample. Further, the data show that project team members have diverse backgrounds. Again, it can be observed from Table 1 that 41.81% of the respondents were associated with projects valued more than 20 million USD, where just 12.72% were associated with the projects value less than 1 million USD. This indicates that the tunnel construction projects are highly money intensive, and minimizing project overruns can be translated into a big financial benefit. It was found from the data that tunneling is a part of large projects, not a separate project by itself.

Table 1: The profiles of organization, project, and respondents

Characteristics			**Number**	**Percentage**
Respondents	Gender	Male	53	96.36%
		Female	02	3.64%
	Professional background	Executive	7	12.72%
		Managers	8	14.54%
		Geologists	8	14.54%
		Engineers	24	43.63%
		Other	8	14.54%
	Years of experience	Less than 5	5	9.09%
		5-10	24	43.63%
		11-20	17	30.90%
		Above 20	9	16.36%
Organization	Type	Public	10	18.18%
		Private	42	76.36%
		Other	03	5.45%
	Category	Client	13	23.63%
		Consultant	25	45.45%
		Contractor	17	30.90%
Project size	Project Budget (million USD)	Less than 1	7	12.72%
		1-5	11	20%
		6-10	4	7.27%
		11-20	10	18.18%
		Above 20	23	41.81%
Project team	Team diversity	Ethnicity	23	**NB:** A team may have members of different ethnicities, religions, or country
		Religion	24	
		Country	29	
		Other	12	

4.1.1 *Ranking of overruns causes*

Three ranking indexes were used in this study for assessing the importance of the identified causes as given in Table 2. RII in this study indicates the relative importance of the causes, where RFI and RSI show the significance of the causes of overruns. The results show that there are 16 causes which were significant on both indexes (RFI and RSI). Their values were above the defined threshold value (0.599) on both RFI and RSI.

Table 2: Ranking of causes of project overruns

S.No.	Causes of Overruns	RFI	Rank	RSI	Rank	RII	Rank
1	Design and scope changes	0.633	6	0.702	12	0.471	12
2	Delay in issue of fund to the contractors	0.655	2	0.749	5	0.513	4
3	Slow decision making by owners	0.582	14	0.702	12	0.438	18
4	Poor supervision and management	0.553	17	0.658	17	0.374	25
5	Delay in approval of drawing	0.633	6	0.662	16	0.441	17
6	Delay in quality control	0.567	15	0.636	19	0.359	28
7	Planning and schedule deficiencies	0.651	3	0.713	10	0.483	9
8	Inadequate project estimates or budgets	0.640	5	0.760	4	0.516	3
9	Ineffective project monitoring	0.596	12	0.684	15	0.430	19
10	Accidents at construction sites	0.487	21	0.578	22	0.316	30
11	Inexperienced and incompetent contractors	0.644	4	0.785	1	0.529	1
12	Ignoring consultant instruction by contractors	0.673	1	0.775	3	0.520	2
13	Poor communication	0.618	9	0.691	13	0.462	14
14	Ineffective procurement planning	0.625	8	0.709	11	0.477	11
15	Material shortage	0.604	11	0.691	13	0.452	15
16	Geological surprises	0.640	5	0.724	9	0.493	8
17	Complexities and ambiguities of project design	0.596	12	0.662	16	0.410	21
18	Unavailability of adequate equipment	0.629	7	0.735	7	0.465	13
19	Long breakdown time of critical machines	0.604	11	0.687	14	0.481	10
20	Lack of awareness of modern equipment & technology	0.560	16	0.684	15	0.449	16
21	Unviability of competent project manager	0.585	13	0.684	15	0.405	22
22	Shortage of skillful manpower	0.585	13	0.640	18	0.416	20
23	External factors such as natural disaster, protest, change of government	0.640	5	0.742	6	0.398	24
24	Price fluctuation	0.473	22	0.556	23	0.503	7
25	Court decision and stay orders	0.567	15	0.658	17	0.303	31
26	Poor infrastructure and logistics system	0.545	18	0.636	19	0.399	23
27	Contractual dispute	0.651	3	0.731	8	0.366	27
28	Low bid	0.629	7	0.782	2	0.508	5
29	Corruption within government or organization	0.524	20	0.596	21	0.505	6
30	Government / political interference	0.451	23	0.509	24	0.352	29
31	Changes in law and regulation	0.527	19	0.618	20	0.255	32
32	Delay in regularity approval	0.633	6	0.702	12	0.367	26

To see the perception of the three project groups (client, consultant, and contractor) about the importance of identified factors, RII were computed separately for each project group (rater group) as given in Table 3. The results show that the most important causes as perceived by clients were price fluctuations,

corruption within government and organization, inexperienced and incompetent contractor, and low bids. Consultants perceived ignoring consultant instruction by consultants, geological surprises, delay in issuing funds to the contractor, and inadequate project estimates or budgets as the most important factors. Similarly, the important causes of overruns as perceived by contractors were inadequate project estimates or budget, delay in issuing funds to the contractors, and design and scope changes. Nevertheless, some factors which lead to project overruns are related to the responsibilities of any of the groups who rated the factors of project overruns. Unconsciously, the responses may lead to biased answers against factors related to the respondents' responsibilities. Therefore, Kendall's coefficient of concordance test has been used in this study to see the association among the raters. The results of the test, as discussed in the previous section, suggest a high degree of association and agreement among clients, consultants, and contractors in ranking the causes of project overruns.

351 Table 3: Ranking of causes of project overruns for clients, consultants, and contractors

S.No.	Causes of Overruns	Overall		Client		Consultant		Contractor	
		RII	Rank	RII	Rank	RII	Rank	RII	Rank
1	Design and scope changes	0.471	12	0.452	4	0.448	15	0.438	3
2	Delay in issue of fund to the contractors	0.513	4	0.452	4	0.533	3	0.459	2
3	Slow decision making by owners	0.438	18	0.415	8	0.410	18	0.407	11
4	Poor supervision and management	0.374	25	0.308	20	0.360	24	0.381	17
5	Delay in approval of drawing	0.441	17	0.388	11	0.451	14	0.416	8
6	Delay in quality control	0.359	28	0.323	17	0.374	22	0.311	26
7	Planning and schedule deficiencies	0.483	9	0.425	7	0.522	5	0.391	14
8	Inadequate project estimates or	0.516	3	0.409	9	0.533	3	0.527	1
9	Ineffective project monitoring	0.430	19	0.434	6	0.390	21	0.376	18
10	Accidents at construction sites	0.316	30	0.255	22	0.336	26	0.287	27
11	Inexperienced and incompetent contractors	0.529	1	0.554	2	0.506	9	0.428	6
12	Ignoring consultant instruction by contractors	0.520	2	0.449	5	0.560	1	0.414	9
13	Poor communication	0.462	14	0.369	14	0.514	7	0.332	23
14	Ineffective procurement planning	0.477	11	0.372	13	0.499	10	0.431	5
15	Material shortage	0.452	15	0.452	4	0.426	16	0.405	12
16	Geological surprises	0.493	8	0.452	4	0.536	2	0.395	13
17	Complexities and ambiguities of project design	0.410	21	0.388	11	0.390	21	0.388	15
18	Unavailability of adequate equipment	0.465	13	0.363	15	0.507	8	0.339	21
19	Long breakdown time of critical machines	0.481	10	0.372	13	0.520	6	0.438	3
20	Lack of awareness of modern equipment & technology	0.449	16	0.378	12	0.475	12	0.369	19
21	Unviability of competent project manager	0.405	22	0.406	10	0.402	20	0.334	22
22	Shortage of skillful manpower	0.416	20	0.348	16	0.424	17	0.367	20
23	External factors such as natural disaster, protest, change of government	0.398	24	0.369	14	0.366	23	0.386	16
24	Price fluctuation	0.503	7	0.575	1	0.480	11	0.391	14
25	Court decision and stay orders	0.303	31	0.265	21	0.278	28	0.322	25
26	Poor infrastructure and logistics system	0.399	23	0.249	23	0.403	19	0.409	10
27	Contractual dispute	0.366	27	0.323	17	0.403	19	0.275	28
28	Low bid	0.508	5	0.468	3	0.526	4	0.421	7
29	Corruption within government or organization	0.505	6	0.575	1	0.464	13	0.435	4
30	Government / political interference	0.352	29	0.314	19	0.339	25	0.329	24
31	Changes in law and regulation	0.255	32	0.215	24	0.246	29	0.271	29
32	Delay in regularity approval	0.367	26	0.317	18	0.328	27	0.369	19

5 Discussion of results

This section presents analysis of the results and comparison of the results of this study with previous studies.

5.1 Analysis of the results

The results obtained from ranking and analyzing the causes of project overruns in tunnel construction projects in Pakistan are discussed in this section. We discussed the important causes for project overruns briefly in the following subsections.

5.1.1 *Inexperienced and incompetent contractors*

Due to the complexity, large size, and higher risk associated with tunnel construction projects, it is crucial to have competent and experienced contractors**.** In this study, inexperienced and incompetent contractors was ranked by respondents as highly critical factors of project overruns. All three groups agree on the importance of this factor for project overruns. It can be linked with the bidding procedure, where the contract is awarded to the lowest bidder. An inexperienced and incompetent contractor despite being the lowest bidder, cannot manage complicated projects properly, which can lead to terrible consequences.

5.1.2 *Ignoring consultants' instruction by contractors*

Lack of collaboration among project groups in tunnel construction projects, which have various types of engineering and construction complexities can lead to serious issues. In this study, ignoring consultants' instruction by contractors also emerged as the second most significant cause and the most frequently occurring cause of project overruns. The results further show that it is the greatest concern of consultants that contractors do not act upon on their instructions. They ranked it the topmost important factor. It can lead to diverse problems, including safety and environmental issues, re-work, and disputes among parties.

5.1.3 Inadequate project estimates or budgets

Due to unforeseen underground condition, project estimates are difficult to make in tunnel construction projects as compared to above ground infrastructure projects. Further, there is no standardized guidelines are available for estimators to follow in computing initial cost for tunnel construction projects. Therefore, the cost in tunnel construction projects are commonly underestimated (Membah and Asa, 2015). In this study, inadequate project estimate emerged as an important cause of project overruns. Contractors have ranked it the topmost reason for project overruns. Clients use project estimates to allocate budget to the projects. It is in the client's interest to achieve the lowest possible overall project cost. Contractors utilize cost estimates as an important input for deciding about participating or not participating in the bidding process of a project.

5.1.4 Delay in issuing of funds to the contractors

Tunnel construction needs a heavy amount of money to continue the process. Delay in the release of funds to contractors can impede project progress. In this study, it has emerged as second frequently occurring cause of project overruns and a great concern of contractors. Contractors ranked it the second most important cause. It can lead a project to the worst situation in the case of financially weak contractors.

5.1.5 Low bid

Low bidding emerged as the fifth important factor attributing to the causes of project overruns in this study. It was ranked third by the client, fourth by consultants, and seventh by contractors. Low bidding is attributing to the methods of awarding contracts. Projects are awarding to those contractors who give the lowest bid. The lowest bidding contractors may lack project experiences, required skills and capacities, and resources.

5.1.6 Corruption within government or organization

Corruption within the government or organization is an important but a complex factor to be controlled. The correspondents in this study considered it as the second most severe cause of project overruns. Furthermore, clients ranked it first and contractors as the fourth most important factor of project

overruns. According to Transparency International, Pakistan is on 120th position out of 180 countries on the index of least corrupt countries (https://www.transparency.org/cpi2019#closer-look). Therefore, the result is logical, given the corruption environment inside the country.

5.1.7 Price fluctuation

Increase in prices of materials is another important factor considered by respondents for project overruns in tunnel construction projects. Clients have ranked price hike on the top of all factors of project overruns. This result is understandable given the recent price hike in Pakistan. The annual inflation rate in Pakistan increased to 12.42 percent in December 2019, which is the highest in the last ten years (https://tradingeconomics.com/pakistan/inflation-cpi).

5.1.8 Geological surprises

There are various imaging technologies used to determine rock type and water penetration. These technologies give some confidence, but they are neither fully reliable nor comprehensive (Efron and Read, 2012). Therefore, tunnel construction process faces frequent geological surprises, which lead to project overruns. It is one of the most uncertain and difficult factors to be controlled. In this study, consultants and clients ranked it as the second and fourth significant factor attributing to the causes of project overruns respectively. As discussed in the above section, around 57% of the tunneling projects carried out in Pakistan allocated just 1-2% of their total budget for geological exploration. The allocation of less funding for geological exploration is one of the obvious reasons for greater geological surprises.

5.1.9 Planning and schedule deficiencies

The uncertainties associated with the underground conditions and difficulties in comprehensive investigation make the planning more difficult and complex in tunnel construction projects. In this study, planning and schedule deficiencies are the third most frequently occurring factor attributing to the causes of project overruns. Poor planning at the start has a bad impact throughout the project and leads to re-work and a waste of time and resources at different stages.

5.1.10 Long breakdown time of critical machines

Tunnel construction projects involve working in a single confined space in complex dimensions, which require complicated machineries. Many contractors do not have enough machines for their construction work. Generally, they rent the machines when required. The contractors also do not have the necessary technical skills to do the scheduled maintenance of the machinery and repair them if any breakdown occurs during the construction process. The breakdown of critical machines in the absence of the redundant system will cause delays to project progress.

5.1.11 Ineffective procurement planning

Ineffective procurement planning is another important cause of project overruns emerged in this study. Procurement process in construction sector is a complex phenomenon requires innovation, expertise, certain regulation, financial and governance instruments. In a developing country like Pakistan, there are certain challenges to adopt modern procurement methods. They are primarily based on traditional form of procurement (lowest competitive bidding), which have certain limitations (Khalfan, 2013). Poor procurement planning lead to cost as well as time overruns in construction projects.

5.1.12 Design and scope changes

Design changes in tunnel construction are serious issue because of the complexity and high uncertainty associated with the tunneling construction projects. The design and scope changes appeared in this study as the sixth frequent cause of project overruns. Clients ranked it fourth, where contractor ranked it third important cause of overruns in tunnel construction projects in Pakistan. The uncertainty and complexity of design in tunnel construction has been widely discussed in the literature (Paraskevopoulou and Boutsis, 2020, Stille and Palmström, 2008) that lead to project overruns (Flyvbjerg, 2014). Other importance causes of overruns were found as unavailability of adequate equipment, poor communication, material shortage, and lack of awareness of modern equipment & technology.

5.2 Comparison of current vs. previous studies

The significant factors causing overruns in tunnel construction projects are compared with the significant factors of overruns identified in previous studies. The previous studies given in Table 4 have investigated causes of overruns in building construction projects, highway construction projects, and hydro-power construction projects in the context of Pakistan (Batool and Abbas, 2017, Sohu et al., 2018, Zafar et al., 2019). The comparison of the factors show that factors related to financial issues, poor planning, poor accountability, and price fluctuation are included in the list of important factors of previous studies as well as current study. However, some factors such as difficulty in land acquisition, natural disaster, and bad law and order situation have been identified as significant factors of overruns in previous studies only.

Besides, some factors such, as ignoring consultants' instructions by contractors, low bid, geological surprises, and long breakdown time of critical machines, are emerged as important in the current study. This indicates that despite of similarities in tunneling construction and other types of civil construction projects, the tunneling construction projects face different set of challenges and environment. The factors identified in the previous studies for other types of civil construction projects may not be efficient for dealing the issue of overruns in tunneling construction projects. Therefore, the practitioners need to consider different set of factors identified in this study for controlling overruns in tunneling construction projects.

Table 4. Comparing of significant factors of project overruns of previous studies vs. current study

Ranking	Building construction projects (Sohu et al., 2018)	Highway construction projects (Zafar et al., 2019)	Hydro-power projects (Batool and Abbas, 2017)	Tunnel construction projects (Current study)
1	Financial issues faced by client	Suspension of work due to insecurity and terrorist threat	Lack of political will	Inexperienced and incompetent contractors
2	Slow information between parties	Unrealistic planning and scheduling due to a hostile environment	Delay in civil work	Ignoring consultants' instruction by contractors
3	Change in material price	Lack of local community support	Delays in release of funds by Government	Inadequate project estimates or budgets
4	Delay in design	Poor project design due to insufficient data collection & survey	Bad law and order situation	Delay in issue of funding to the contractors

5	Poor site management	Low productivity due to unskilled workforce	Project start without proper site investigation	Low bid
6	Payment problem faced by contractors	Difficulty in land acquisition	Poor project time management	Corruption within government or organization
7	Delay in decision making	Limited contractor's financial capacity to undertake	Unrealistic estimates while preparing PC-1	Price fluctuation
8	Natural disaster	Delayed payment for completed work	Lack of accountability	Geological surprises
9		Forced selection of inexperienced contractors due to tribal compulsion	Force majeure	Planning and schedule deficiencies
10		Lack of reward and punishment in contract terms and conditions	Delays in land acquisition by Land department	Long breakdown time of critical machines

6 Mitigation measures

This study identified a set of important causes leading to project overruns in tunnel construction projects in Pakistan. A detailed mitigation strategy has been proposed based on the findings of the study, and participants' recommendations as given below:

- The underground geological conditions should be studied precisely through comprehensive site investigation before the execution of work for proper design and underground support requirements. Appropriate funds should be allocated for geological exploration.
- The unpredictability of geological formation put serious challenges for designing construction projects. Accurate prediction of geological condition increases the ability of engineers to appropriately design the project. Moreover, changes in design and scope can be minimize by through early involvement of the key project group including clients in project design and planning phases to have clarity of objectives and requirements. Further, consultant must ensure site investigation during feasibility and conceptual design to address all the design challenges properly.

- The stakeholders must be trained to raise their consciousness to the level of higher morality and ethical conduct. Moreover, organizations must deal firmly and decisively with those getting kickbacks for giving illegal favor.
- Procurement process for construction is a fairly complex phenomenon. There is a dire need to innovate the process, design new policies and regulations, and develop expertise for smooth procurement process in construction sector in Pakistan. Further, strict quality assurance checklist should be applied to avoid the use of any defective material.
- For controlling the issue of Inadequately experienced and incompetent contractors, following steps are recommended.
    1. Being the lowest bidder must not be the only sole criterion of awarding a contract. The awarding of contracts needs to be carefully considered.
    2. For improving the managerial skills and project management techniques, continuous training programs for the contractors is recommended.
- Contractors must listen to the instructions of consultants; otherwise, specific penalties must be put on the contractors. Further, the contractors need to be well equipped with modern machineries. They also must develop the skills to repair critical machines in case of breakdown and have a redundant system to make sure smooth work progress
- A proper level of funding leading to regular payment to the contractor must be defined in planning phase. Further, contractors should have enough cash before starting the projects to minimize financial issues.
- Clear communication is essential when it comes to large scale contracting work. Making sure everyone is fully updated about the situation. For example, changes to the design plan, and even potential setbacks such as weather forecasts, supply issues, and inadequate manpower should be communicated clearly to all the necessary parties.

7 Conclusion

This study investigated the causes project overruns in tunnel construction projects in Pakistan and proposed a detailed mitigation strategy. The topmost causes of project overruns were: (1) inexperienced and incompetent contractors, (2) ignoring consultants' instructions by contractors, (3) inadequate project estimates, (4) delay in issue of funds to the contractors, (5) low bid, (6) corruption within government or organization, (7) price fluctuation, (8) geological surprises, (9) planning and schedule deficiencies, and (10) long breakdown time of critical machines. Further, this study presented a detail set of recommendations to improve efficiency of the projects. The most important among them are the need of urgent reforms in contract awarding methods. It is important to award project to the competent contractor, who has enough capacity to carry out the projects successfully. Further, strong coordination among main project parties namely clients, consultants, and contractors, continuous capacity building training for contractors, detailed geological exploration, and heavy punishment on kickbacks are recommended for reducing project overruns in tunnel construction projects in Pakistan. This study will help the practitioners to control the critical causes of project overruns. Researchers can extend this study to other countries to identify more specific set of causes for each country.

7.1 Limitation of the study

Although this study has valuable contributions, there are some limitations of the study as well.

- Firstly, 76.3 % of the respondents were from private organizations. The results may closely represent the situation of private organizations than public sector organizations.
- Secondly, the findings of this study well interpreted in the context of Pakistan. Caution is warranted in generalizing these results because different countries have their own socio-economic, political, cultural, and behavioral factors and industrial infrastructures. Therefore, other countries may have a different set of causes of project overruns in tunnel construction projects**.**

- Thirdly, the findings of this study is based on the opinions of 55 practitioners (namely clients, consultants, and contractors) about causes and effect of project overruns, which tends to be vary based on their experiences and expertise.

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