ESCUELA DE CONSTRUCCIÓN CIVIL
FACULTAD DE INGENIERÍA
Revista de la Construcción
Journal of Construction

Research Article

Cost overrun estimation in the construction of high-rise buildings using fuzzy inference model

Ali Paydar[1, *], Yaser Khademi Fahraji[2], Abbas Tajaddini[3], Zahra Sabzi[4]

[1] Department of Civil Engineering, Malard branch, Islamic Azad University, Tehran (Iran)
[2] Department of Civil Engineering, Karaj branch, Islamic Azad University, Karaj (Iran)
[3] Department of Civil Engineering, Karaj branch, Islamic Azad University, Karaj (Iran)
[4] Department of Civil Engineering, Karaj branch, Islamic Azad University, Karaj, (Iran)
*Correspondence: Ap.paydar@gmail.com, a.paydar@iaumalard.ac.ir

Received: 19.05.202; **Accepted:** 10.06.2023; **Published:** 31.08.2023

Citation: Paydar, A., Fahraji, Y., Tajaddini, A., Sabzi, Z. (2023). Cost overrun estimation in the construction of high-rise buildings using fuzzy inference model. Revista de la Construcción. Journal of Construction, 22(2), 382-406. https://doi.org/10.7764/RDLC.22.2.382.

Abstract: Proper cost forecasting is a major parameter in the success of construction projects, and has a significant impact on various phases of a project, including its budget approval phase. Project managers usually look for solutions to reduce costs. It needs to identify the cost-rising factors, and to exclude them from projects. This study principally aimed at forecasting cost increase of high-rise building construction, using a neuro fuzzy inference model. In fact, the model is able to quantify cost overrun, resulted from each influencing factor, based on fuzzy logic. Through a vast literature review, 43 cost-influencing factors were identified, which then were reduced to 13, using the principal component analysis method, and experts' opinions. The construction cost was then predicted by the inference model created, based on each factor. The results showed that the factor of "lack of commitment of the Ministry of Housing" had the greatest impact, while the factor of "not considering measures to resolve potential disputes" had the least impact on the estimation of cost overrun in high-rise buildings.

Keywords: Construction, cost overrun prediction, high-rise buildings, ANFIS model, PCA method.

1. Introduction and significance

The economic and social growth of any country is highly dependent on its construction industry as it provides infrastructures such as dams, power plants, roads, and buildings. Organizations always look for suitable ways to promote productivity, to reduce costs, and to maximize project profitability. To achieve these objectives, the concept of cost management has been introduced, that deals with collecting and analyzing cost information to more effectively plan for budget and cost controlling. Annually, a considerable proportion of the world's budget is spent on construction projects. Increase of the costs and time in construction projects could cause severe damage to private sectors, and customers. In addition to diminishing financial resources, this could cause irreparable damage to this industry in the long run.

In many countries, attempts have been made to assess the scale of cost overruns in construction projects. As an example, it was found that a mean overrun value of 7.9% to 9% is normal in road construction projects (Odeck, 2004). Also, it was found that 54% and 72% of Qatari projects experience increase in cost and time, respectively (Senouci *et al.*, 2016). In Malaysia, more than half (55%) of construction projects experience cost overruns, and public sectors perform better than private sectors (Larsen *et al.*, 2016). In general, previous studies indicate that the problem of cost increase is common in many countries, and that the causes are recurrent.

As a developing country, the Iranian construction industry contributed to 4% of the GDP in 2015 (Parchami & Shoar, 2019). Its share of the total country's budget increased from 17.5% in 2003 to 24% in 2006, and to 28.8% in 2008 (Samarghandi *et al.*, 2016), and nearly 15% of Iranian male employees work in the construction industry (Parchami & Shoar, 2019), which indicates the pivotal role of this sector in Iran's economy. Also, between the years 2002 and 2012, the direct cost of delays in building projects was about US$21 Billion (Shoar & Chileshe, 2021). Nearly 30% of Iranian building projects experience a minimum of 25% cost overrun (Heravi & Mohammadian, 2021). The annual report provided by the Central Bank of Iran indicates that more than US$13 Billion is spent on construction projects (Samarghandi *et al.*, 2016). All these conclude that it is imperative to adopt initiatives to ensure all construction projects are completed successfully.

The increasing size and complexity of construction projects rises the risks in general (Nieto-Morote & Ruz-Vila, 2011). By definition, any building higher than 23 meters is considered a high-rise building (Alsuliman, 2019a; Puncreobutr *et al.*, 2018; Puncreobutr & Mon Khin, 2017). Because of the complexity and dynamic nature of their environments, high-rise projects face higher risks and more time-consuming constraints (Basari, 2017). As such, cost overruns are more severe than time overruns in high-rise buildings (Fernando *et al.*, 2017), and the risks related to their management and designs are quite significant compared to other building types (San Santoso *et al.*, 2003a, 2003b). The high risks are mostly related to fire emergencies, high occupant density, design configuration and excessive loads (Hassanain, 2009).

Since building construction play a vital role in development of a country, the management of its risks is important in reaching the highest socio-economic and market value (El-Sayegh, 2014). High-rise building construction itself poses high risks and uncertainties, as it requires considerable investments (especially to supply the materials and equipment). Moreover, various permits, sophisticated construction methods are required, and several project parties should be involved (San Santoso *et al.*, 2003a, 2003b).

There will be a growing need for erecting more buildings in cities in the near future, specifically high-rise buildings due to land access limitation, as cities accommodate a major part of the world's population (World Health Organization, 2019). The issue of cost overrun, if persists, will have negative effects on national economics and people's life quality. These all show that cost overrun is a complex problem especially in high-rise buildings, causing this context to be a sound case for assessment, and the results will be useful for the scholars worldwide.

The current research tried to examine the construction cost of high-rise buildings in District 22 of Tehran (Iran), since they have been significantly developed in the mentioned area in the recent decade, and most of the projects have encountered time delays and cost increase. Moreover, no similar study has investigated cost overrun estimation, exclusively in high-rise building context in a developing country in this way. Any building having 20 floors or more has been considered as a high-rise building in this survey. In summary, this study aimed at identifying the reasons for cost overrun, and how to estimate it properly, based on the influential factors, by creating a suitable fuzzy forecasting model.

This article structurally consists of different sections including: 1. Introduction (describing the research aims and significance); 2. Theoretical Background (explaining the definitions, and reviewing the literature and previous studies in the research field, and analysis models); 3. Methods (explaining the methodology employed here to create a FIS model, and to collect and analyze the data); 4. Results & Discussions (demonstrating the outcomes of the analysis, and discussion & comparison of the research findings); 5. Implication for practice (providing some managerial and practical recommendations for developers and stakeholders to prevent cost overrun); and, 6. Conclusions (summarizing the entire work and findings).

2. Theoretical background

2.1. Cost overrun definition

As defined by Flyvbjerg *et al.* (2018): “Cost overrun is the amount by which the actual cost exceeds the estimated cost, with cost measured in the local currency, constant prices and against a consistent baseline”. In addition, Derakhshanalavijeh (2017) described project cost overrun as the positive difference between the actual cost upon project completion and the agreed estimation of the project budget at the time of contract. Flyvbjerg *et al.* (2002) and Odeck (2004) interpreted cost overrun as the difference between the forecasted and actual construction costs. In line with the conventional methodology, the inaccuracy of cost estimates is considered as the size of cost overruns. Cost overrun is directly calculated by subtraction of the actual out-turn costs from the estimated costs, as a percentage of estimated costs. Actual costs are defined as real, accounted construction costs determined at the time of project completion, while estimated costs are defined as budgeted or forecasted construction costs determined at the time of decision to build. This definition is used in this study.

2.2. Previous studies on cost overrun

Construction cost overrun has been already studied to some extent. Some of them are reviewed in this section. Alsuliman (2019a, 2019b) examined the factors that cause construction cost rising in Saudi Arabia. He found that lengthy delays and cost increase were among the main challenges in construction projects. He also classified the influential factors into four general categories of pre-tender, during-tender, post-tender, and general factors. Focusing on financial analysis and awarding a contract to the lowest bidder were among the most important factors influencing cost increase and delays. Al-Hazim *et al.* (2017) investigated the factors leading to cost increase in engineering projects in Jordan. The results revealed that the most important factors contributed to the cost increase of infrastructure projects were related to the terrain and weather conditions.

Niazi & Painting (2017) acknowledged that one criterion for judging the success of a project is whether it is completed within the estimated budget. According to them, construction cost overrun is a major problem in the construction industry in Afghanistan. Aiming at identifying the factors leading to cost increase, the results revealed that financial corruption, delayed payment, financing problems, social security, change order by the owner, and financial inflation are the major reasons.

A conceptual model of delay-causing factors was proposed by Alfakhri *et al.* (2017) through examining construction projects in Libya. They paid special attention to road construction projects and the outcomes indicated that the most effective factors include: delays in conversion and transfer of utility services by competent authorities, difficulty in budget availability, short duration of contracts, delayed payment, and effects of underground conditions. In another study, Gebrehiwet & Luo (2017) studied the causes of delays in a construction process, and their impact on projects in Ethiopia. The data were collected using a questionnaire containing 52 identified causes and five consequences of delay. The methods adopted were the relative importance index (RII) and correlation coefficient. The causes of delay were evaluated in three stages of pre-construction, construction, and post-construction. It was shown that the major factors: corruption, unavailability of site utilities, lack of access to local services, lack of quality materials, delay in approving, poor management, and ineffective performance and planning.

As Shah Kapur (2016) points out, delay and cost overrun are considered as the main problems of construction projects, exerting a negative impact on the economic growth of any country. His study aimed to ascertain the most important factors causing cost increase in Australia, Malaysia, and Ghana, using the RII method. The findings showed that the most effective factors in Australia included: planning deficiencies, construction methods, and monitoring, whereas in Ghana they comprised delayed payment, underestimating project cost, and the complexity and size of projects. Moreover, improper planning, poor site management, and insufficient experience of the contractor were major factors causing delay and cost increase in Malaysia.

According to Bekr (2016), most of construction projects in Iraq are exposed to cost overrun. He reviewed the literature and extracted the effective factors using a questionnaire-based survey, including security measures, regulation changes, official and non-official holidays, poor performance of contractors, changes in order, delayed payment, local community problems, lack of experience, and economic conditions. Cheng (2014) ranked the key factors through employing the modified Delphi (MDM) and Kawakita Jiro (KJ) methods to strengthen the experts' opinions. Among the most important items were "defining the project scope in the contract", and "method of resolving contract disputes". Li *et al.* (2015) demonstrated that transaction costs include costs of drafting, negotiating, and enforcing contracts, as well as administrative expenses and costs of security obligations. They identified and classified the major factors into four categories, including role of the owner, role of contractor, characteristics of transaction environment, and also project management efficiency.

Lengthy delays in India's projects were examined by Doloi *et al.* (2012). Factor analysis (FA) method and a regression model were used to investigate the delay-causing factors. The results showed that slow decision-making, poor labor productivity, and architects' unwillingness to correct construction mistakes were among the causes significantly prolonging project delay. Overall, literature review in construction cost overrun indicates that various aspects are addressed, such as 'lack of proper planning', 'limited financial resources', 'corruption in tendering', and 'delayed payment', as well as the factors related to the 'poor performance of employers, consultants, and contractors in projects', 'environmental factors', and 'contract regulations. In addition, time delay itself is also considered as one of factors leading to cost overruns (Chen & Hu, 2019).

The risk of cost overrun was examined by Plebankiewicz, *et al.* (2020) under input variables of share of element, predicted changes in work numbers and expected changes in the unit price of construction. According to Cantarelli *et al.* (2018), four categories of explanations for cost overrun can be distinguished including: technical, economic, psychological, and political. Furthermore, Huo *et al.* (2018) conducted a research on the cost performance of mega transport projects in Hong Kong. No significant statistical relation to cost overruns was found between project size and the time of decision to build. According to Andri´c (2019), the key causes of cost overruns are the increasing cost of resources (construction materials, equipment, and labor), construction works, changes in design specifications, land acquisition and resettlement, and changes in currency exchange. Chen & Hu (2019) identified that the main reasons for cost overruns include: 'delay in construction period', 'engineering quantity increase', and 'lack of technical skill/experience'. Aziz *et al.* (2013) found that the main reasons for cost overruns in Malaysia are the 'variation of materials prices', 'cash flow', and 'financial difficulties'.

In addition, 11 factors affecting cost overrun were determined by El-Kholy (2015), including: 'financial condition', 'cash flow', 'method of procurement', 'material cost increase due to inflation', 'competition at tender stage', 'currency fluctuations', 'project size', 'delay in design and approval', 'risk retained by client for quantity variations', 'drawings', and 'inaccurate material estimating'. According to Larsen *et al.* (2016) the factors that have the greatest effect on project budget are: 'errors in consultant material', 'errors in project documents', 'late user changes', 'lack of preliminary examination', and 'inexperienced or newly qualified consultants'. Many studies revealed that most cost overruns occur in the planning stages up to the final design (Derakhshanalavijeh *et al.*, 2017; Cantarelli *et al.*,2012). They are related to design changes, and tend to increase in the number of inputs needed because of technical and administrative problems (Lind *et al.*, 2015). Chen & Hu, (2019) proposed a methodology named cost overrun risk propagation network (CORPN). They indicated that CORPN presents the topological property of heterogeneity. A large number of risk paths can be blocked through preventing the CORs with large total degree, like delay in construction period and quantity increase.

In another study, Gunduz & Maki, (2018) showed that cost overrun is directly related to inaccurate cost estimation, improper planning, unrealistic contract duration and requirements, frequent work and design changes, inadequate labor/skill availability, and inflation on costs of machinery, labor, material and transportation. Huo *et al.* (2018) explored three independent explanatory variables (i.e., project type, project size, and length of the project implementation period) to analyze cost performance of mega-transport infrastructure projects in Hong Kong. The results indicate a cost escalation of 39.2%, an average cost overrun of 34.8% for rails, 32.5% for road projects, and 37.5% for fixed-link projects. Cost overruns have no significant relationship with project size, but for road projects, projects with smaller scale tend to be more prone to larger cost overruns.

As Kamaruddeen *et al.*, (2020) describes, most of the projects in Malaysia experience cost overrun of 5 to 10% of the total contract sum central. Descriptive statistics and the RII method were used in their study to analyze the data. Commitments to finish the projects in time in Nepal was found as primary reason for time overrun, caused by easily postponing practices by the authority on the request of concerned contractors. In contrast, capital cost rise due to price escalation was the major reason for cost overrun (Khanal & Ojha, 2020). According to Susanti (2020) major reasons for cost overrun include: 'land acquisition delay', 'site location', 'local objection', 'changes in design', 'rework', 'vendors performance', 'delay in approval', 'inaccurate budgeting', 'price escalation', 'regulations of government', 'owners additional required', 'inflation', 'payment delay', 'weak cash flow' and 'bad weather'. The result showed that, from owners' viewpoint, additional required is the most important factor, while from contractors' viewpoint the main reason is rework.

In another study (Mary *et al.*, 2018), a concurrent mixed-method approach, utilizing a questionnaire and an interview with UAE construction professionals, was employed to analyze the major causes of poor time and cost performance. The top five causes of cost overrun were summarized as 'design variation', 'poor cost estimation', 'delay in client's decision-making process', 'financial constraints of client' and 'inappropriate procurement method'. The factors analyzed by various researchers across different countries point out that some causes for delays and cost overruns are common in all areas, but some may vary due to changing culture and practices followed within the country (Dolage & Rathnamali, 2013).

Pham *et al.*, (2020) assessed the impact of cost overrun causes in construction projects, using factor analysis and a regression model. It was concluded that risks, resources, incompetence of parties, and components, transportation and machinery cost are the four main causes of cost overrun. Although cost increases and time delays have the same sources of causative factors, the focus of the current research is on factors causing cost increases. The reason is that the cost is tangible, and the time delay itself is an introduction to the increase in costs in buildings, especially high-rise buildings.

2.3. High-rise building studies

A few studies have been conducted on cost management in high-rise buildings. To ascertain the major financial risks affecting high-rise building contractors in Sri Lanka, Fernando *et al.* (2017) investigated the suitability of available hedging techniques as remedial solutions in managing such financial risks. As per the findings, the most serious financial risk affecting contractors was found to be associated with variations in material prices. Research (Kaming *et al.*, 1997) showed that many variables have an impact upon high-rise construction time and cost overruns in Indonesia. The variables identified were ranked according to their importance and frequencies of occurrence. Using factor analysis, it was indicated that inflationary increases in material cost, inaccurate material estimating and project complexity are the main causes of cost overruns.

Another study (Santoso *et al*., 2003a) showed that the risks related to management and design are the most significant items in high-rise construction projects. The findings obtained by Perera *et al.* (2020) demonstrated that 'financial problems arising from errors in estimating' is the major risk factor faced by high-rise building developers, while 'poor contract management' is the main factor faced by the contractors.

2.4. Iran cost overrun studies

In a survey, Derakhshanalavijeh *et al.* (2016) revealed that the main causes of cost overrun in this industry include inaccurate cost estimations, improper planning, frequent design changes, inadequate labor/skill availability, inflation of costs of machinery, labor, raw material and transportation prices. According to Ghahramanzadeh (2013), the first three risks for Iranian construction projects are cost overrun, foreign exchange and convertibility, and inflation and interest rate.

The causes of cost overrun were analyzed by Shoar (2021) using interpretive structural modeling. The results showed that price fluctuation, claims, execution delay, delay in payment and change order are positioned at the highest level of effectiveness, resulting in cost overrun. Additionally, corruption and poor contract management are two major root causes of cost overruns. In a research (Balali *et al*., 2020), cost overrun factors in mega Iranian projects were ranked using Delphi-SWARA method. The results illustrated that the most crucial factors in contractor, employer and consultant groups are: unacceptable quality of work, not allocating sufficient budget from the government, and lack of supervisors' technical knowledge, respectively. Delay causes in Iran's gas pipeline projects were investigated by Fallahnejad, (2013). According to the results, the 10 major delay factors are: imported materials, unrealistic project duration, client-related materials, land expropriation, change orders, contractor selection methods, payment to contractor, obtaining permits, suppliers, and contractor's cash flow.

Cost overruns and delay in Iran's urban projects were also investigated by Heravi & Mohammadian, (2019). This study showed that large urban projects are faced higher cost overruns and delay. The findings offered descriptive statistical cost and time performance information to support realistic time and cost estimation in urban projects.

In general, it is known that delay and cost overruns are usual issues in construction projects in both developing and developed countries (Sweis *et al.*, 2013; Cheng, 2014; Shehu *et al.*, 2014), and similarly, a large number of Iran's urban construction projects encounters cost overruns and delay as well (Najafabadi & Pimplikar, 2013). According to Pourrostam & Ismail (2012), the 10 most delay-causing reasons are: (1) delay in payment, (2) change orders, (3) poor site management, (4) slow decision making, (5) financial difficulties, (6) late design approvals, (7) problems with subcontractors, (8) ineffective planning, (9) design mistakes, and (10) bad weather.

In research conducted by Mohammad *et al.* (2016), reasons for delay and cost overrun in Iran's construction Projects were studied. The statistical model categorizes the delay factors under four major classes, and determines the most significant delay factors in each class, including: owner defects, contractor defects, consultant defects and, regulation defects. Moreover, their regression models demonstrated that a significant difference exists between the initial and final project duration and cost. According to the models, the average delay per year is 5.9 months, and the overall cost overrun is 15.4%.

2.5. Models for cost overrun analysis

As already described, previous studies have used various methodologies to solve the problem of how to predict cost overrun in construction projects (CAR-PUŠIĆ *et al.*, 2020). The major methods used previously could be summarized as: (1) statistical methods, like multiple regression analysis (as reported by Abu Hammad *et al.*, 2008; Lowe *et al.*, 2006); (2) a combination of regression and artificial neural network (ANN) models (Doğan *et al.*, 2008; Attala & Hegazy, 2003; Hegazy & Ayed , 1998; Smith & Mason, 1997); (3) analogical methods, such as case-based reasoning (CBR), (Kim *et al.*, 2010; Ji *et al.*, 2011); (4) predictive models (El-Kholy, 2015); (5) data mining as a key business tool to assist in transforming information embedded in the construction data into decision support systems (Ahiaga-Dagbui & Smith, 2014); and (6) relative importance index (RII) to scale the influence of major factors (França & Haddad, 2018; Kamaruddeen *et al.*, 2020).

To more explain, Kim *et al.* (2004) examined three different models including regression, ANN, and CBR by collecting 530 cost historical data set. They used a total of 9 cost factors in their study, such as floor area, finishing grades, duration, etc. The performance of these three approaches was measured on MAER criteria, indicating better performance by the ANN estimation compared to the regression as well as CBR model. Liu *et al.* (2006) discussed an approach of fuzzy ANNs for real estate cost prediction based on hedonic price theory. Lowe *et al.* (2006) designed a framework using a linear regression model to predict the construction cost of buildings. They developed the best regression model indicating a better coefficient of determination (R2) of 0.661 along with 19.3% of mean absolute percentage error. Shehab *et al.* (2010) applied an ANN approach versus regression for early and accurate prediction of water and sewer network rehabilitation projects cost. It was observed that the performance of the ANN approach was better compared to that of the regression. Wang *et al.* (2012) contributed a comparative study of ANN and support vector machine for prediction of project cost and schedule success. Naik & Kumar (2015) developed an ANN trained with the backpropagation algorithm for prediction of housing projects utilizing 512 data sets. A study on cost overruns in transport projects was conducted by Flyvbjerg *et al.* (2002, 2018). The performance of 258 projects located in Europe and North America were investigated and different probabilistic and statistical tools (such as, F-test, Welch T-test, regression analysis etc.) were applied.

2.6. Discussion of the literature review

Based on the literature review, it is found that cost overrun in construction project is predominant, and it is still critical to conduct further studies. Although the success and failure of a project is mainly dependent on time and cost, this study aims to quantify the effectiveness of the influencing factors only on cost overrun. The reason is that all time-dependent factors are implicitly considered as critical causative factors in cost overrun. A detailed description of the sub-relevant factors and their corresponding studies are listed in APPENDIX A, Table A-1. The influencing factors together with other parameters obtained by unconstructed interview and a survey questionnaire will be further discussed in the methodology section. To explore how cost overrun could be effectively estimated, this research first assess the contributing factors, and then, cost overrun will be estimated using a soft computing technique.

3. Materials and methods

The overall stages of how this research was conducted is illustrated in Figure 1. As observed, a field visit was performed, and the existing documents were inspected to predict the construction cost of high-rise buildings. The major factors were first identified by interviewing a number of Iranian construction experts, that were then evaluated both quantitatively and qualitatively. Afterwards, a standard questionnaire was designed. The analysis data collected was performed in two stages. First, 43 factors were adopted using experts' opinions and reviewing the literature, and then, their numbers were reduced to 13 using the PCA[1] method. Finally, a cost forecasting model was created using the ANFIS [2] method.

[1] Principal component analysis
[2] Adaptive Neuro-Fuzzy Inference System

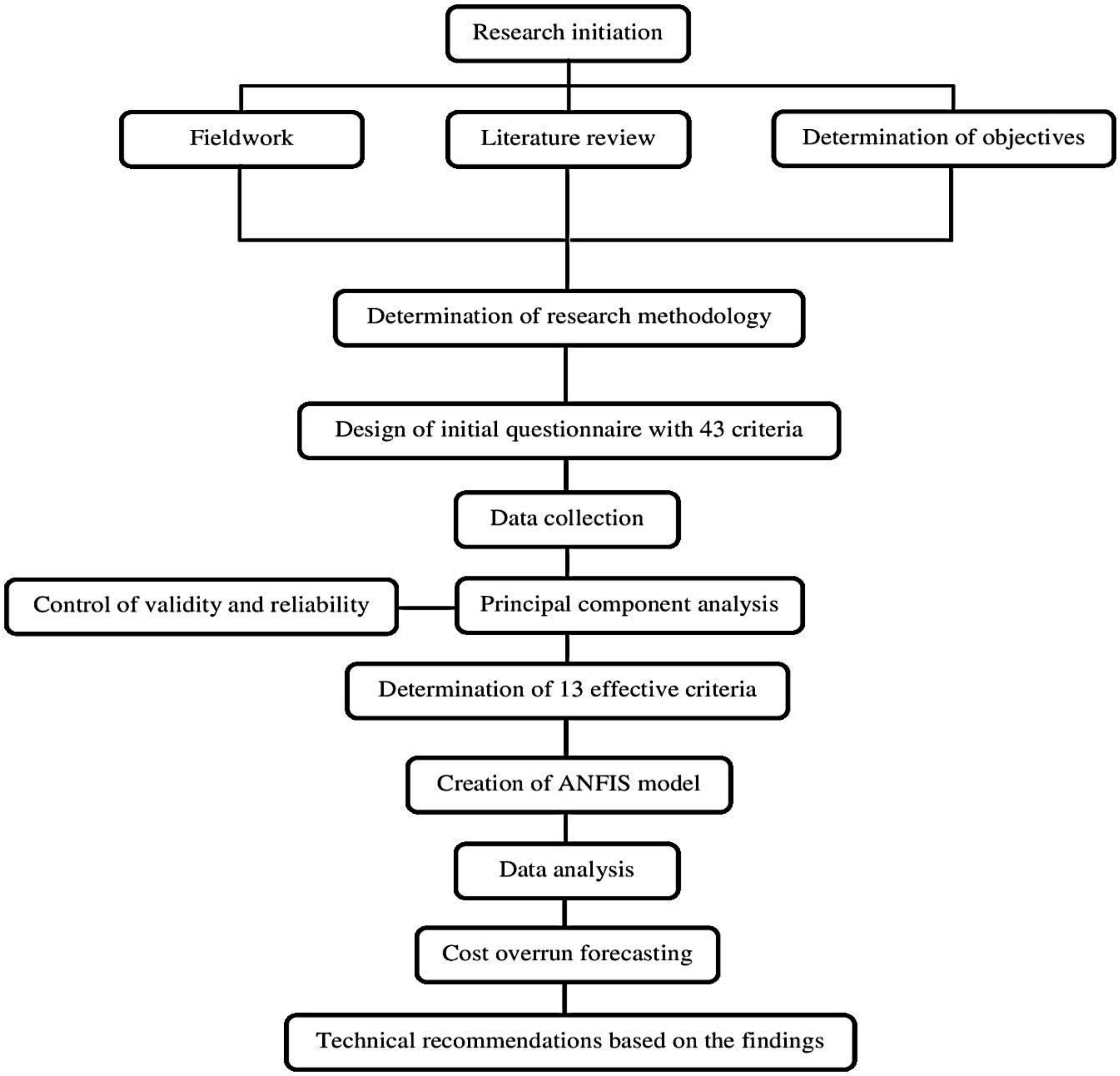

Figure 1. Flowchart of research method.

To collect the data in the best form, the research questionnaire was modified and standardized in several stages, during which, minor questions were excluded, and the major factors were eventually specified. To interpret the questions and to determine their importance, a 5-point Likert scale was employed, and the respondents were asked to determine the effectiveness of each factor by choosing the appropriate option. A typical description of the Likert scale is provided in Table 1.

Table 1. A typical Five-point Likert scale.

Response categories	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Numerical value	1	2	3	4	5

The initial questionnaire and its content are presented in APPENDIX B, Table B-1. As previously mentioned, the items were adopted based on previous studies and experts' opinions. In total, 43 important factors were identified. The number of factors was then reduced using the results, the PCA and ANFIS methods. Accordingly, a model was created to predict the construction cost increase of high-rise buildings.

The statistical population of the current research included 50 experts from the employers, consultants, and contractors working in high-rise building projects in District 22 of Tehran, Iran. Accordingly, the experts' opinions were collected by the questionnaire and structured interviews, which were next analyzed. As the exact size of the total statistical population could not be specified, simple random sampling and the Cochran formula, Eq. (1), were used to calculate the required/adequate sample size (Adam, 2020; Asl, 2019):

$$n = \frac{Nt^2 pq}{Nd^2 + t^2 pq}$$
Eq. (1)

where, 'n' is the sample size, 'N' is the population size, 't^2' is the normal distribution value, 'q' and 'p' represent the proportion of absence and presence of an attribute in the statistical population, respectively, and 'd^2' is the error level. The statistical population was equal to 50 individuals here, the error level was considered 5% (i.e., 95% confidence level), the normal distribution value in the area under the normal curve with 95% confidence level was equal to 1.96, and 'p' and 'q' values were considered to be 50% based on previous data. According to Eq. (2), 44 experts were randomly selected to answer the questionnaire.

$$n = \frac{50 \times 1.96^2 \times 0.5 \times 0.5}{50 \times 0.05^2 + 1.96^2 \times 0.5 \times 0.5} = 44$$
Eq. (2)

The data were first analyzed in the SPSS software, in which descriptive analysis, and factor analysis were performed. This method follows two main rules in analysis. First, an efficient data analysis tool is provided for identifying and expressing data patterns that also determines data similarities and differences. Second, a data compression is enabled through minimizing the data set dimensionality which is constituted of numerous interrelated variables with almost zero information loss (Forghani *et al.*, 2018).

In the next step, a model was created using the ANFIS method. Neural algorithm and fuzzy logic were applied to design a nonlinear mapping between the input and output spaces. In the neural-fuzzy system, the membership degree of output membership functions (MF) is selected in accordance with the input data. Hybrid systems are becoming the next generation of artificial intelligence systems due to their ability to provide solutions to complex real-life problems. Artificial intelligence techniques (Akinade & Oyedele, 2019) such as ANNs, fuzzy logic, support vector machines, genetic algorithms, and expert systems could be applied to a variety of problems. Fuzzy logic was first proposed in the 1960s as an alternative to Aristotelian binary logic. This method enables us to describe and identify any vague idea.

There are two main approaches to fuzzy logic: Mamdani and Sugeno. The "maximum-minimum" composition is applied in Mamdani's fuzzy approach, in which the uncertain results are obtained. This approach uses the fuzzy inference system and requires significant computational processing. Sugeno fuzzy approach in contrast is particularly effective in numerical control systems operating with adaptive control systems, as well as in optimizing nonlinear dynamic systems. The ANFIS method was first proposed by Jang (Bekr, 2016).

As displayed in Figure 2, an ANFIS model consists of five layers (Cheng, 2014). The first layer is known as the input layer. Modeling operations are performed in the second to fourth layers. In the second layer, the input values to each node are multiplied to obtain the rule weight. In the third layer, each node calculates the relative rule weight. In the fourth layer, also known as the rule layer, the volume of operations on the input signals to this layer is obtained. The fifth layer has only one node that is fixed, and calculates the main output of the network by collecting the inputs to this node (Li *et al.*, 2015).

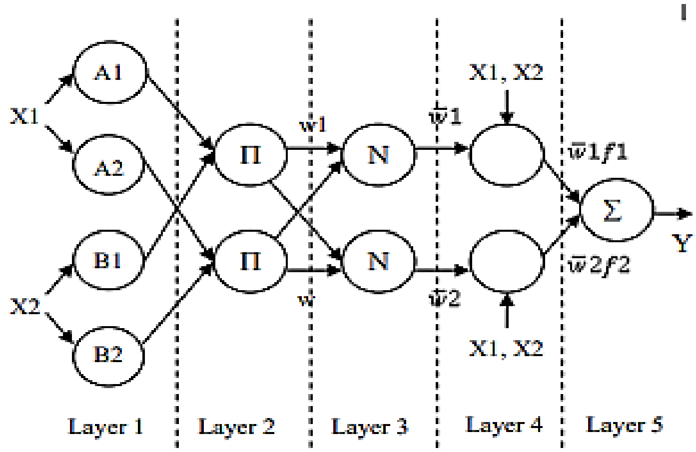

Figure 2. The structure of an ANFIS model (Cheng, 2014).

4. Results and discussions

4.1. Initial analysis

In terms of work activity, 36.4% of the respondents were employers, 29.6% were contractors, and 34% were consultants in this research. Moreover, 22.7% of the participants had an Associate degree, 31.8% had a Bachelor's degree, 29.6% had a Master's degree, and 15.91% had a PhD. The primary data were analyzed in SPSS 17.0. Based on the initially designed questionnaire, the results of the principal component analysis were calculated. To avoid prolonging, the calculation details are provided in Table C-1, APPENDIX C. They were calculated at the significance level of 0.05, which means there was a significant correlation between the correlation matrices of the questionnaire items. The Kaiser-Meyer-Olkin (KMO) index here was obtained as 0.77. It should be noted that the KMO index measures the sampling adequacy, which shows whether the partial correlation between the variables is small. The KMO index varies between '0' and '1'. The closer it is to '1', the more suitable the sample data are for the PCA method. This index should be above 0.7; however, values between 0.5 and 0.7 are also acceptable with caution (Forghani *et al.*, 2018).

Table C-1, which is based on the SPSS output, shows that some factors (from F1 to F43) were correlated in the correlation matrix of the questionnaire. In other words, some factors had a common factor causing them to be highly correlated, and could be combined together. On the contrary, some others had only one factor with the max variance, which were selected as the main factors of the questionnaire. Therefore, the highly correlated items were removed from the questionnaire (as seen in Table 2). As a result, items F1, F5, F7, F8, F9, F25, and F35 were selected as the major factors of the research using the PCA method. In addition, according to the experts' opinions, items F2, F11, F12, F26, F31, and F36 were also added to the set of factors in the final questionnaire, leading the final number of factors to be 13 in total. As seen in Table 2, the major factors are called C1 to C13 from now on.

Table 2. Modified questionnaire and the final selected factors.

No.	Major research factors
C1	Inaccurate estimation of work volume
C2	Submitting unrealistic financial offers by contractors in competitive bidding conditions
C3	Lack of attention to the existing financial inflation in the country
C4	Not considering measures to resolve potential disputes when concluding the contract
C5	Lack of commitment of the Ministry of Housing and Urban Development as the senior supervisor to holding the tender properly
C6	Non-compliance of plans with urban development criteria of the intended area
C7	Lack of attention to the financial capacity of contractors
C8	The employer's desire for a particular contractor to win, and the existence of economic rent and corruption in the plan
C9	The employer's delay in arranging the import of project materials and equipment
C10	Delay in timely equipping of the workshop by the contractor
C11	The contractor's failure to observe HSE
C12	Exchange rate variations during the project
C13	Size of the project

The reliability of all 13 selected factors was assessed in SPSS 17.0 through determining the Cronbach's alpha coefficient. A value of 0.7 was obtained accordingly, which was desirable, indicating that the items were consistent. Therefore, the results were reliable and the factors were adequately correlated. In other words, there was a logical consistency and coordination in the questionnaire that could help to properly evaluate the variables.

4.2. The ANFIS results

The ANFIS model was created in MATLAB software, and 43 input data were used as the dependent and independent variables. The input data were the effectiveness of the variables on the construction cost of high-rise buildings. Its level was considered in a fuzzy form with scales of: 'very low = 0.1', 'low = 0.3', 'medium = 0.5', 'high = 0.7', and 'very high = 0.9'. The output data included the rate of increase in construction cost per square meter, calculated by the ANFIS model. To clarify, it was assumed here that the basic construction price of a property is 45 million Iranian Rials (IRR) per square meter in Tehran, in 2019-2020. Note that at the time of doing this research, each US$ was roughly equivalent to 150,000 IRR.

The data were next normalized by the ANFIS model. Accordingly, the computational neurons were generated. In each operational phase, the data in the network were trained and tested with a ratio of 80% to 20%, respectively. Accordingly, 35 (out of 44) sets of the inputs were utilized for training, and the rest 9 sets were used for testing the model. To determine the best model among the existing possible models, the coefficients of determination (R2) and root-mean-square error (RMSE) values were calculated for each model, and then compared to those of others. In this technique, the best model is the one that has the lowest RMSE value and the highest R2 value in calculations. Here, 26 ANFIS models with various MFs and layers were created and compared. The models were screened and deleted based on R2 and RMSE values of the testing network. Finally, 13 models that had the most suitable R2 and RMSE values of the testing network were specified. The model results for predicting the construction cost are listed in Table 3. To create the models and achieve the best results, the 'gbellmf' MF and hidden layers of '3' and '9' were employed, because of their optimal functions.

Table 3. Results of the ANFIS model for predicting the construction cost.

Factor	MF type	Number of MF	Train RMSE	Train R^2	Test RMSE	Test R^2
C1	Gbellmf	3	4.704	0.537	2.638	0.629
C2	Gbellmf	3	10.106	0.496	3.227	0.631
C3	Gbellmf	3	10.142	0.473	2.455	0.711
C4	Gbellmf	9	10.340	0.507	3.618	0.467
C5	Gbellmf	3	4.617	0.534	1.515	0.838
C6	Gbellmf	9	8.322	0.501	4.098	0.566
C7	Gbellmf	9	7.234	0.558	7.738	0.471
C8	Gbellmf	9	5.604	0.568	4.263	0.546
C9	Gbellmf	9	9.982	0.585	5.851	0.588
C10	Gbellmf	9	9.666	0.572	5.224	0.546
C11	Gbellmf	3	8.603	0.588	3.386	0.729
C12	Gbellmf	3	14.522	0.501	2.795	0.479
C13	Gbellmf	3	9.253	0.537	3.657	0.653

According to Table 3, factor C5, i.e., *lack of commitment of the Ministry of Housing and Urban Development as the senior supervisor*, with a gbellmf MF and hidden layer of 3, showed the best answer with the lowest RMSE (=1.515) and greatest 'R^2' values (= 0.838). In contrast, factors C4 (i.e., *not considering measures to resolve potential disputes when concluding the contract)*, and C7 (i.e., *Lack of attention to the financial capacity of contractors*) with a gbellmf MF and hidden layer of 9 were the most insignificant factors for predicting the construction cost. Their RMSE and 'R^2' values were 3.618 and 0.467, for C4, and 7.738 and 0.471, for C7, respectively. For a better comparison, the influence levels of all factors are graphically illustrated in Figure 3.

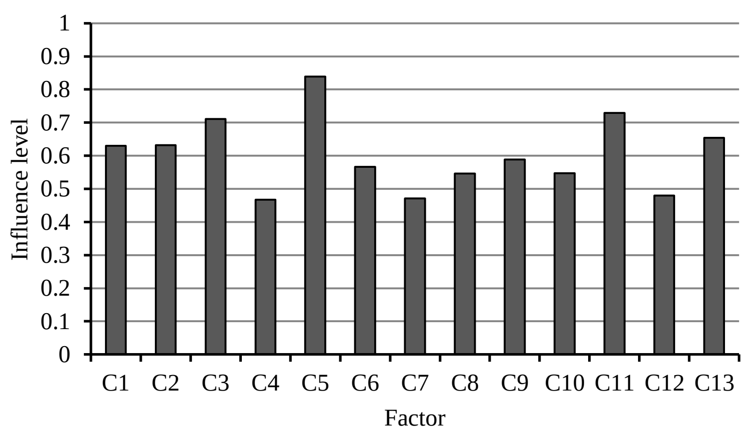

Figure 3. Comparison of the influence level of all factors.

According to the chart illustrated above, project management tools and financial-related factors play an important role in the effective cost management of a project. A proper cost/project management will result in an efficient cost performance through efficient project planning and execution within the limited budget of the project. The results confirms the causes of cost overrun related to management reported in the literature (Albtoush, & Doh, 2019) including: poor site management and supervision, poor contractor management, and lack of project management support. In addition, as seen, the results are consistent with those reported in the literature (Albtoush, & Doh, 2019) regarding to financial-related factor, including: inadequate funds for project financing, delay in progressive payment, economic instability, inconsistent cash flows, payment problems faced by contractor, foreign currency fluctuations, and monthly payment difficulties. The results of current study indicate that various sources of the causes of cost overrun exist, and then, suitable decisions must be taken to reduce or avoid cost overrun within its sources in construction projects.

Furthermore, to better clarify, a scatter plot is provided to better visualize the relationship between variables in Train and Test conditions separately. A scatter plot in fact uses dots to represent values for two different numeric variables. The position of each dot on the horizontal and vertical axis indicates values for an individual data point. For example, Figure 4 depicts a diagram for the Train data of factor C5, in which the relationship between the experimental and analytical data, the scatter of data set, and a trend line are observed. In addition, a line with a 45^0 slope (i.e., Line Y=X) is drawn on the diagram to better represent the distribution of numerically simulated points by the ANFIS model. It should be noted that Trend line equation is a formula that finds a line that best fits the data points. Figure 5 also depicts the corresponding results and data for the Test data of factor C5. As the output values, i.e., the predicted increase of construction cost per square meter, ranged from 45-90 million IRR (equivalent to 300-600 US$), the data are illustrated in ranges of ‘0’ to ‘9’ on the vertical and horizontal axes of the diagrams.

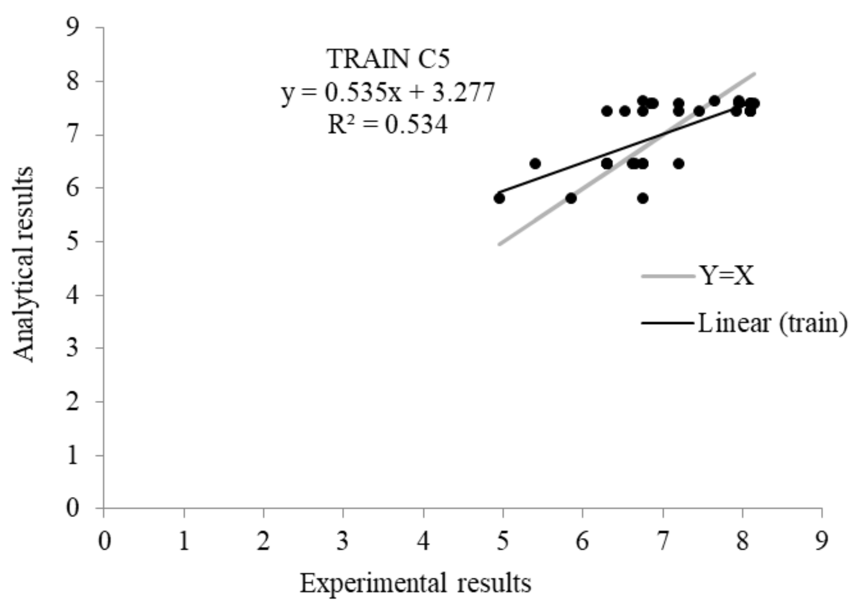

Figure 4. Relationships between the experimental and analytical data for factor C5 in Train mode.

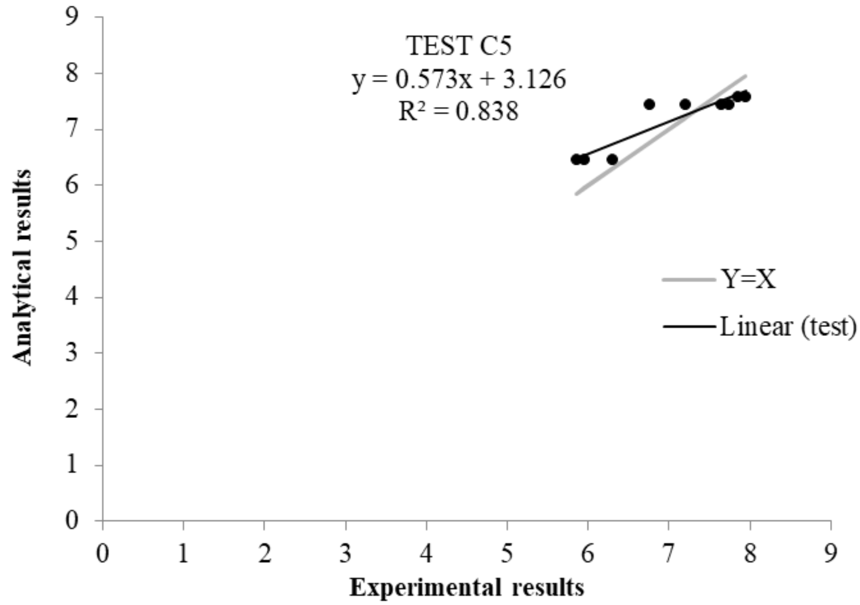

Figure 5. Relationships between the experimental and analytical data for factor C5 in Test mode.

Similarly, scatter plots for the Train and Test data of factor C4 are illustrated in Figures 6 and 7, respectively.

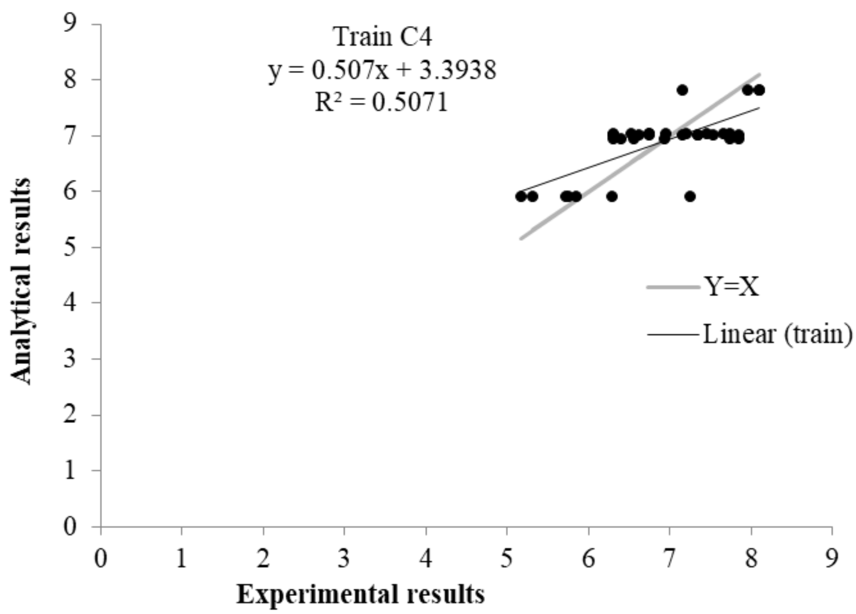

Figure 6. Relationships between the experimental and analytical data for factor C4 in Train mode

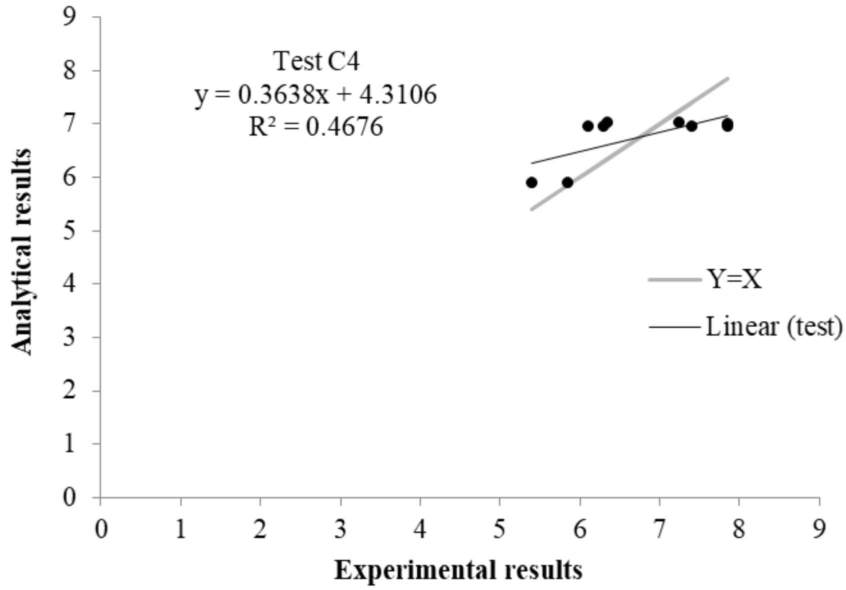

Figure 7. Relationships between the experimental and analytical data for factor C4 in Test mode

5. Implications for practice

According to the research findings, the following solutions are proposed to prevent the construction cost overrun of high-rise buildings:

- Full supervision during construction and careful consideration of the tenders to prevent corruption in winning of inefficient/unskilled contractors; It should be noted that poor construction outcomes in low-income countries is majorly relevant to mismanagement, but corruption is also a vital issue that has to be considered. The construction industry is widely reported as one of the most corrupted sectors globally, leading to huge cost overrun. As such, the practices inducing corruption especially in tendering phase could be prevented by applying tighter regulation, perhaps also with more transparency and civil society oversight.

- Paying sufficient attention to the contractor's financial capacity for implementing the project properly, and carefully reviewing the contractor's financial turnover and resume; The literature (Zubair & Ataguba, 2019; Akali, & Sakaja, 2018) has clearly shown that contractors' financial capacity is essential for evaluating potential performance of construction contractors' during prequalification and tender evaluation. It is therefore recommended that the financial capability of contractors must be considered to determine their level of insolvency.

- Appointing an HSE manager from the beginning of the project, and investigating all the potential risks; HSE managers facilitate the maintenance and management of environmental health, safety and well-being through systems, inspection and the establishment of high standards and expectations on employees of service excellence and safety awareness behaviors/performance. A safe and healthy workplace not only protects workers from injury and illness, it can also lower injury/illness costs, reduce absenteeism and turnover, increase productivity and quality, and raise employee morale. In other words, safety is beneficial for business. Plus, protecting workers is the right thing to do, especially reduces cost overrun.

- IV) Selecting an experienced consultant to estimate construction costs at the beginning of the project, and to submit a proper bid; Cost estimating is one of the most important steps in project management. A cost estimate establishes the base line of the project cost at different stages of development of the project, providing a detailed description of the project and the costs involved to it. The estimates assist in finding an idea about costing and plan accordingly to complete the project efficiently. An accurate estimation preserves all parties focused on delivering a project on time and under proper budget. It holds a developer and construction company accountable for increased costs and overruns.

- V) Appointing an experienced financial consultant in the contractor's technical team, and conducting a careful review of exchange rate variations during the project; Exchange rate fluctuations can have a significant impact on the costs, revenues, and risks of international projects. As reported, any project is exposed to foreign exchange risks in form of transaction risk, economic risk exposure as well as translation risk. Exchange rates fluctuations affect the revenue and profits, financial performance, and the market value of the organization. It also negatively affects cash flows, that leads to deviations from project budgets, resulting in high adjustment costs and in turn, the performance of projects.
- VI) Holding monthly meetings among the contractors, employers, and consultants to resolve potential disputes during the construction; These meetings are important as they provide the managers with insight into the employees' performances and how on track, they are to submitting the entire project by the client's expected due date.

6. Conclusions and comments

Cost estimation in large construction projects can extensively contribute to project success. This study investigated the influence of various factors on the construction cost of high-rise buildings, using fuzzy logic. To accomplish this and accordingly:

1. An ANFIS model was created to accurately predict and manage the construction cost of high-rise buildings per square meter by evaluating the impact of various factors. To create the model, 43 factors affecting cost overrun were first identified by reviewing the literature. Then, their number was reduced to 13 using the PCA method, and collecting construction experts' opinions through designing a standard questionnaire;
2. The results showed that the factor of '*lack of commitment of the Ministry of Housing and Urban Development as the senior supervisor*' with a gbellmf membership function and hidden layer of 3 reflected the highest influence, whereas, the factors of '*not considering measures to resolve potential disputes when concluding the contract*', and '*Lack of attention to the financial capacity of contractors'* with a gbellmf membership function and hidden layer of 9 reflected the lowest effectiveness for predicting the construction cost;
3. The major practical implications of this study are that decision makers should focus on the tender period, and pay more attention to possible delays, and precise supervision should be undertaken in high-rise building projects to reduce any cost overruns.

Author contributions: **Ali Paydar** (Served as scientific supervisor, Critically reviewed the study proposal, Conceived and designed the analysis, Wrote the paper cooperatively); **Yaser Khademi Fahraji** (Collected the data, Contributed data or analysis tools, Performed the analysis); **Abbas Tajaddini** (Wrote the paper cooperatively, Served as scientific advisor, Critically reviewed the study proposal, Revised the manuscript); **Zahra Sabzi** (Served as scientific advisor, Critically reviewed the study proposal);

Funding: None.

Acknowledgments: None.

Conflicts of interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.
.

References

Abu Hammad, A.A.; Ali, S.M.A.; Sweis, G.J.; Basher, A. Prediction Model for Construction Cost and Duration in Jordan. Jordan J. Civ. Eng. 2008, 2, 250–266.

Adam, A. M. (2020). Sample Size Determination in Survey Research. 26(5), 90–97. https://doi.org/10.9734/JSRR/2020/v26i530263

Ahiaga-Dagbui, D.D.; Smith, S.D. Dealing with construction cost overruns using data mining. Constr. Manag. Econ. 2014, 32, 682–694. doi:10.1080/01446193.2014.933854

Akali, T., & Sakaja, Y. (2018). Influence of contractors' financial capacity on performance of road construction in Kakamega county. *American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)*, *46*(1), 34-50.

Akinade, O. O., & Oyedele, L. O. (2019). Integrating construction supply chains within a circular economy : An ANFIS-based waste analytics system (A-WAS). Journal of Cleaner Production, 229, 863–873. https://doi.org/10.1016/j.jclepro.2019.04.232

Albtoush, A. F., & Doh, S. I. (2019). A Review on causes of cost overrun in the construction projects. *International Journal of New Innovations in Engineering and Technology*, *12*(3), 15-22.

Alfakhri, A. Y. Y., Ismail, A., Khoiry, M. A., Arhad, I., & Irtema, H. I. M. (2017). A conceptual model of delay factors affecting road construction projects in Libya. Journal of Engineering Science and Technology, 12(12), 3286–3298.

Al-Hazim, N., Salem, Z. A., & Ahmad, H. (2017). Delay and Cost Overrun in Infrastructure Projects in Jordan. Procedia Engineering, 182, 18–24. https://doi.org/10.1016/j.proeng.2017.03.105

Alsuliman, J. A. (2019a). Causes of delay in Saudi public construction projects. Alexandria Engineering Journal, 58(2), 801–808. https://doi.org/10.1016/j.aej.2019.07.002

Alsuliman, J. A. (2019b). Causes of delay in Saudi public construction projects. Alexandria Engineering Journal, 58(2), 801–808. https://doi.org/10.1016/j.aej.2019.07.002

Andri´c, J.M.; Mahamadu, A.; Wang, J.; Zou, P.X.W.; Zhong, R. The cost performance and causes of overruns in infrastructure development projects in Asia. J. Civil Eng. Manag. 2019, 25, 203–214

Asl, S. R. (2019). Assessing the Impacts of human needs on Enhancing of urban Tourism development (Case study ; Shahrekord , Iran). Advances in Engineering Research, 156 (Senvar 2018), 141–146.

Attala, M.; Hegazy, T. Predicting Cost Deviation in Reconstruction Projects: Artificial Neural Networks Versus Regression J. Constr. Eng. Manag. 2003, 129, 405–411

Aziz, A.A.A.; Memon, A.H.; Rahman, I.A.; Karim, A.T.A. Controlling cost overrun factors in construction projects in Malaysia. Res. J. Appl. Sci. Eng. Technol. 2013, 5, 2621–2629

Shoar, S. (2021). Modeling cost overrun in building construction projects using the interpretive structural modeling approach : a developing country perspective. *Engineering, Construction and Architectural Management*. https://doi.org/10.1108/ECAM-08-2021-0732

Shehu Z, Endut IR, Akintoye A, Holt GD. 2014. Cost over- run in the Malaysian construction industry projects: a deeper insight. Int J Project Manage. 32(8):1471–1480. http://dx.doi.org/10.1016/j.ijproman.2014.04.004

Balali, A., Moehler, R. C., & Valipour, A. (2020). Ranking cost overrun factors in the mega hospital construction projects using Delphi-SWARA method: An Iranian case study. International Journal of Construction Management, 1-9.

Basari, I. (2017), "Estimation risk of high risk building project on contractor", IPTEK Journal of Engineering, Vol. 3 No. 2, pp. 29-34.

Bekr, G. A. (2016). Causes of delay in public construction projects in Iraq Causes of Delay in Public Construction Projects in Iraq. Jordan Journal of Civil Engineering, June.

Cantarelli, C. C., Flybjerg, B., Molin, E. J. E., & Wee, B. Van. (2018). Cost Overruns in Large-Scale Transport Infrastructure Projects. *Automation in Construction*, *2*(1), 19.

Cantarelli, C.C.; Molin, E.J.E.; van Wee, B.; Flyvbjerg, B. Characteristics of cost overruns for Dutch transport infrastructure projects and the importance of the decision to build and project phases. Transp. Policy 2012, 22, 49–56

CAR-PUŠIĆ, D., TIJANIĆ, K., MAROVIĆ, I., & MLADEN, M. (2020). Predicting buildings construction cost overruns on the basis of cost overruns structure. Scientific Review Engineering and Environmental Sciences, 29(3), 366–376. https://doi.org/10.22630/PNIKS.2020.29.3.31

Chen, Y.; Hu, Z. Exploring the properties of cost overrun risk propagation network (CORPN) for promoting cost management. J. Civil Eng. Manag. 2019, 25, 1–18.

Cheng, Y. M. (2014). An exploration into cost-influencing factors on construction projects. International Journal of Project Management, 32(5), 850–860. https://doi.org/10.1016/j.ijproman.2013.10.003

Doloi, H., Sawhney, A., Iyer, K. C., & Rentala, S. (2012). Analysing factors affecting delays in Indian construction projects. International Journal of Project Management, 30(4), 479–489. https://doi.org/10.1016/j.ijproman.2011.10.004

Derakhshanalavijeh, R.; Teixeira, J.M.C. Cost overrun in construction projects in developing countries, Gas-Oil industry of Iran as a case study. J. Civil Eng. Manag. 2017, 23, 125–136

Doğan SZ, Arditi D, Murat Günaydin H. Using Decision Trees for Determining Attribute Weights in a Case-Based Model of Early Cost Prediction. J Constr Eng Manag 2008;134:146–52. doi:10.1061/(ASCE)0733-9364(2008)134:2(146)

Dolage D, Rathnamali D. 2013. Reasons of time overrun in construction phase of building projects: a case study on Department of Engineering Services of Sabaragamuwa Provincial Council. Engineer: J Inst Engineers Sri Lanka. 63(3): 9–18

El-Kholy, A.M. Predicting Cost Overrun in Construction Projects. Int. J. Construct. Eng. Manag. 2015, 4, 95–105

El-Sayegh, S.M. (2014), "Project risk management practices in the UAE construction industry", International Journal ofProject Organisation andManagement, Vol. 6 Nos 1/2, pp. 121-137.

Fallahnejad, M. H. (2013). Delay causes in Iran gas pipeline projects. *JPMA*, *31*(1), 136–146. https://doi.org/10.1016/j.ijproman.2012.06.003

Fernando, C.K., Hosseini, M.R., Zavadskas, E.K., Perera, B.A.K.S. and Rameezdeen, R. (2017), "Managing the financial risks affecting construction contractors: implementing hedging in Sri Lanka", International Journal ofStrategic Property Management, Vol. 21 No. 2, pp. 212-224

Flyvbjerg, B., Ansar, A., Budzier, A., Buhl, S., Cantarelli, C., Gar- buio, M., Glenting, C., Skamris Holm, M., Lovallo, D., Lunn, D., Molin, E., Rønnest, A., Stewart, A., & van Wee, B. (2018). Five things you should know about cost overrun. Transporta- tion Research Part A: Policy and Practice, 118, 174-190. https://doi.org/10.1016/j.tra.2018.07.013

Flyvbjerg, B.; Holm, M.S.; Buhl, S. Underestimating Costs in Public Works Projects: Error or Lie? J. Am. Plan. Assoc. 2002, 68, 279–295

Forghani, A., Sadjadi, S. J., & Moghadam, B. F. (2018). A supplier selection model in pharmaceutical supply chain using PCA , Z-TOPSIS and MILP : A case study. PLoS ONE, 13(8), 1–17. https://doi.org/10.1371/journal. pone.0201604

França, A., & Haddad, A. (2018). Causes of Construction Projects Cost Overrun in Brazil. *International Journal of Sustainable Construction Engineering & Technology (ISSN:*, *9*(1), 69–83. https://doi.org/https://10.30880/ijscet.2018.09.01.006

Ghahramanzadeh, M. 2013. Managing risk of construction projects: a case study of Iran: unpublished PhD. university of east London

Gebrehiwet, T., & Luo, H. (2017). Analysis of Delay Impact on Construction Project Based on RII and Correlation Coefficient: Empirical Study. Procedia Engineering, 196(June), 366–374. https://doi.org/10.1016/j.proeng.2017.07.212

Gunduz, M.; Maki, O.L. Assessing the risk perception of cost overrun through importance rating. Technol. Econ. Dev. Econ. 2018, 24, 1829–1844

Hassanain, M.A. (2009), "On the challenges of evacuation and rescue operations in high-rise buildings", Structural Survey, Vol. 27 No. 2, pp. 109-118.

Hegazy, T.; Ayed Neural Network Model for Parametric Cost Estimation of Highway Projects. J. Constr. Eng. Manag. 1998, 124, 210–218.

Heravi, G. and Mohammadian, M. (2021), "Investigating cost overruns and delay in urban construction projects in Iran", International Journal of Construction Management, Vol. 21, pp. 958-968

Huo, T.; Ren, H.; Cai, W.; Shen, G.Q.; Liu, B.; Zhu, M.; Wu, H. Measurement and dependence analysis of cost overruns in megatransport infrastructure projects: Case study in Hong Kong. J. Construct. Eng. Manag. 2018, 144, 05018001

Ji, S.H.; Park, M.; Lee, H.S. Cost Estimation Model for Building Projects Using Case-Based Reasoning. Can. J. Civ. Eng. 2011, 38, 570–581.

Kamaruddeen, A. M., Sung, C. F., & Wahi, W. (2020). A study on factors causing cost overrun of construction projects in Sarawak, Malaysia. *Civil Engineering and Architecture*, *8*(3), 191–199. https://doi.org/10.13189/cea.2020.080301

Kaming, P. F., Olomolaiye, P. O., Holt, G. D., & Harris, F. C. (1997). Factors influencing construction time and cost overruns on high-rise projects in Indonesia. *Construction Management and Economics*, *15*(1), 83–94. https://doi.org/10.1080/014461997373132

Khanal, B. P., & Ojha, S. K. (2020). Cause of time and cost overruns in the construction project in Nepal. *Advances in Science, Technology and Engineering Systems*, *5*(4), 192–195. https://doi.org/10.25046/aj050423

Kim, K.J.; Kim, K. Preliminary Cost Estimation Model Using Case-Based Reasoning and Genetic Algorithms. J. Comput. Civ. Eng. 2010, 24, 499–505.

Kim G-H, An S-H, Kang K-I. Comparison of construction cost estimating models based on regression analysis, neural networks, and case-based reasoning. Build Environ 2004;39:1235–42. doi:10.1016/j.buildenv.2004.02.013.

Larsen, J.K.; Shen, G.Q.; Lindhard, S.M.; Ditlev, T. FactorsAffecting Schedule Delay, Cost Overrun, and Quality Level in Public Construction Projects. J. Manag. Eng. 2016, 32, 1–29

Li, H., Arditi, D., & Wang, Z. (2015). Determinants of transaction costs in construction projects. Journal of Civil Engineering and Management, 21(5), 548–558. https://doi.org/10.3846/13923730.2014.897973

Lind, H.; Brunes, F.; Lind, H.; Brunes, F. Explaining cost overruns in infrastructure projects: Anew framework with applications to Sweden. Construct. Manag. Econ. 2015, 33, 554–568

Liu J-G, Zhang X-L, Wu W-P. Application of Fuzzy Neural Network for Real Estate Prediction, 2006, p. 1187–91. doi:10.1007/11760191_173

Lowe, D.J.; Emsley, M.W.; Harding, A. Predicting Construction Cost Using Multiple Regression Techniques J. Constr. Eng. Manag. 2006, 132, 750–758.

Mary, J. R., Robin, B., & Ipe, I. (2018). Time and cost overruns in the UAE construction industry : a critical analysis. *International Journal of Construction Management*, *0*(0), 1–10. https://doi.org/10.1080/15623599.2018.1484864

Mohammad, S., Tabatabaei, M., Taabayan, P., Hashemi, A. M., & Willoughby, K. (2016). Studying the Reasons for Delay and Cost Overrun in Construction Projects : The Case of Iran. *Journal of Construction in Developing Countries*, *21*(1), 51–84. https://doi.org/10.21315/jcdc2016.21.1.

Najafabadi EA, Pimplikar SS. 2013. The significant causes and effects of delays in Ghadir. IOSR-JMCE. 7(4):75–81.

Naik MG, Kumar DR. Construction Project Cost and Duration Optimization Using Artificial Neural Network. AEI 2015, Reston, VA: American Society of Civil Engineers; 2015, p. 433–44. doi:10.1061/9780784479070.038

Niazi, G. A., & Painting, N. (2017). Significant Factors Causing Cost Overruns in the Construction Industry in Afghanistan. Procedia Engineering, 182, 510–517. https://doi.org/10.1016/j.proeng.2017.03.145

Nieto-Morote, A. and Ruz-Vila, F. (2011), "A fuzzy approach to construction project risk assessment", International Journal ofProject Management, Vol. 29 No. 2, pp. 220-231

Odeck, J. Cost overruns in road construction: What are their sizes and determinants? Transp. Policy 2004, 11, 43–53

Parchami Jalal, M. and Shoar, S. (2019), "A hybrid framework to model factors affecting construction labour productivity: case study of Iran", Journal of Financial Management of Property and Construction, Vol. 24 No. 3, pp. 630-654, doi: 10.1108/JFMPC-10-2018-0061

Perera, B. A. K. S., Samarakkody, A. L., & Nandasena, S. R. (2020). Managing financial and economic risks associated with high-rise apartment building construction in Sri Lanka. Journal of Financial Management of Property and Construction, 25(1), 143–162. https://doi.org/10.1108/JFMPC-04-2019-0038

Pham, H., Luu, T. Van, Kim, S. Y., & Vien, D. T. (2020). Assessing the Impact of Cost Overrun Causes in Transmission Lines Construction Projects. *KSCE Journal of Civil Engineering*, *24*(4), 1029–1036. https://doi.org/10.1007/s12205-020-1391-5

Plebankiewicz, E., & Wieczorek, D. (2020). Prediction of Cost Overrun Risk in Construction Projects. *Sustainability*, *12*(9341).

Pourrostam, T., & Ismail, A. Bin. (2012). Causes and Effects of Delay in Iranian Construction Projects. *International Journal of Engineering and Technology*, *January*. https://doi.org/10.7763/IJET.2012.V4.441

Puncreobutr, V., & Mon Khin, M. M. (2017). Cost Management of the High-Rise Buildings in Thailand. SSRN Electronic Journal, 1–11. https://doi.org/10.2139/ssrn.2963521

Puncreobutr, V., Pengsa-ium, V., Khamkhong, Y., & Kriengsantikul, T. (2018). Identifying and Analyzing Risks in the Construction of High Rise Buildings Along the Sky Train Rails in Bangkok. SSRN Electronic Journal, 1–9. https://doi.org/10.2139/ssrn.3179360

Samarghandi, H., Tabatabaei, S.M.M., Taabayan, P., Hashemi, A.M. and Willoughby, K. (2016), "Studying the reasons for delay and cost overrun in construction projects: the case of Iran", Journal of Construction in Developing Countries, Vol. 21 No. 1, pp. 51-84, doi: 10.21315/jcdc2016. 21.1.4

San Santoso, D., Ogunlana, S.O. and Minato, T. (2003a), "Assessment of risks in high-rise building construction in Jakarta", Engineering, Construction and Architectural Management, Vol. 10 No. 1, pp. 43-55

San Santoso, D., Ogunlana, S.O. and Minato, T. (2003b), "Perceptions of risk based on level of experience for high-rise building contractors", International Journal of Construction Management, Vol. 3 No. 1, pp. 49-62.

Senouci, A.; Ismail, A.; Eldin, N. Time Delay and Cost Overrun in Qatari Public Construction Projects. Proc. Eng. 2016, 164, 368–375

Shah Kapur, R. (2016). An Exploration of Causes for Delay and Cost Overruns In Construction an exploration of causes for delay and cost overrun in construction projects : a case study of Australia , Malaysia &. Journal of Advanced College of Engineering and Management, July. https://doi.org/10.3126/jacem.v2i0.16097

Shehab T, Farooq M, Sandhu S, Nguyen T-H, Nasr E. Cost Estimating Models for Utility Rehabilitation Projects: Neural Networks versus Regression. J Pipeline Syst Eng Pract 2010;1:104– 10. doi:10.1061/(ASCE)PS.1949-1204.0000058

Shoar, S. (2021). Modeling cost overrun in building construction projects using the interpretive structural modeling approach : a developing country perspective. *Engineering, Construction and Architectural Management*. https://doi.org/10.1108/ECAM-08-2021-0732

Shoar, S. and Chileshe, N. (2021), "Exploring the causes of design changes in building construction projects: an interpretive structural modeling approach", Sustainability, Vol. 13, 9578, doi: 10.3390/ su13179578

Smith AE, Mason AK. cost estimation predictive modeling: regression versus neural network. Eng Econ 1997;42:137–61. doi:10.1080/00137919708903174

Susanti, R. (2020). Cost overrun and time delay of construction project in Indonesia. *Journal of Physics: Conference Series*, *1444*(1). https://doi.org/10.1088/1742-6596/1444/1/012050

Sweis GJ, Sweis R, Rumman MA, Hussein RA, Dahiya SE. 2013. Cost overruns in public construction projects: the case of Jordan. J Am Sci. 9:134–141

Wang Y-R, Yu C-Y, Chan H-H. Predicting construction cost and schedule success using artificial neural networks ensemble and support vector machines classification models. Int J Proj Manag 2012;30:470–8. doi:10.1016/j.ijproman.2011.09.002.

World Health Organization (2019), "Global health observatory (GHO) data", available at: http://www. who.int/gho/urban_health/en/ (accessed 14 August 2019).

Zubair A., and Ataguba, J O., (2019). Impact of Contractors' Financial Capability on Construction Project truction Project Delivery in Nigeria. *International Journal of Environmental Studies and Safety Research.* Volume 4, Number 2, June 2019.

Appendix A:
Sub-relevant factors reported in the literature

Table A-1

No.	Sub-relevant factors	References
1	Delayed payment of the contractor's statements	Aljohani (2017); Niazi & Painting (2017); Shah Kapur (2016); Tayefeh Hashemi *et al.* (2020)
2	Delay in making changes during the project	Chen & Hu (2019); Flyvbjerg *et al* (2018); Huo *et al.* (2018); Kamaruddeen *et al.* (2020); Shoar, (2021)
3	Delay in timely equipping of the workshop by the contractor	Billa *et al.* (2019); Niazi & Painting (2017); Tayefeh Hashemi *et al.* (2020)
4	Delay in site delivery to the contractor	Alsuliman (2019*b*); Billa *et al.* (2019); Niazi & Painting (2017); Tayefeh Hashemi *et al.* (2020)
5	Technical, economic, psychological and political aspects of cost overrun	Cantarelli *et al.*; Niazi & Painting (2017); Aziz *et al.* (2013); Dolage & Rathnamali (2013); Pham *et al.*, (2020); Fallahnejad, (2013); Pourrostam & Ismail, (2012); Cantarelli *et. al.*; Niazi & Painting; Aziz *et al.*(2013); Dolage & Rathnamali (2013); Pham *et al.* (2020); Fallahnejad (2013); Pourrostam & Ismail, (2012)
6	Dividing the factors into two categories of Pre-construct phase (appropriate planning and contract issues) and construct phase	Chandanshive & Kambekar (2019); Shoar (2021); Gebrehiwet & Luo (2017)
7	Cost damage in high-rise buildings will result in a larger scale of loss	Nieto-Morote & Ruz-Vila (2011); Basari, (2017); San Santoso *et al.* (2003a, 2003b)
8	Drawbacks related to contracts and holding tender	Al-Hazim *et al.* (2017); Aljohani (2017); Alsuliman (2019b); Tayefeh Hashemi *et al.* (2020); El-kholy (2015); Perera *et al.*, (2020)
9	Inaccurate estimation of work	Alsuliman (2019b); Gebrehiwet & Luo (2017); Puncreobutr *et al.* (2018); Seddeeq *et al.* (2019); Tayefeh Hashemi *et al.* (2020); Chen & Hue (2019); Gunduz & Maki, (2018); Mary *et al.* (2018); Derakhshanalavijeh *et al.*, (2016)
10	Payment issues such as delay of payment to the contractor	Aljohani (2017); Perera *et al.* (2020); Pg *et al.* (2017); Tayefeh Hashemi *et al.* (2020); El-Kholy,(2015); Niazi and Painting (2017); Susanti, (2020); Dolage & Rathnamali (2013)
11	Design change or change order of work	Chen & Hu; Flyvbjerg *et al.* (2018); Huo *et al.* (2018); Kamaruddeen *et al.* (2020); Shoar (2021); Billa *et al.* (2019); Tayefeh Hashemi *et al.* (2020), Chen & Hu (2019); Khanal & Ojha (2020); Balali *et al.* (2020)
12	Financial issues related to inflation or exchange rate which is frequent, in developing countries	Haslinda *et al.* (2018); Musarat *et al.* (2020); Niazi & Painting (2017); Puncreobutr *et al.* (2018); Rafiei & Adeli (2018); Tayefeh Hashemi *et al.* (2020);

		Khoy (2015); Shoar (2021)
13	Project size and type	Badawy (2020); Meharie *et al.* (2019); Rafiei & Adeli (2018); Sindaka & Simanjuntak (2018); Tayefeh Hashemi *et al.* (2020); Huo *et al.* (2018); Badawy (2020); Canesi & Marella (2017); Le & Juszczyk (2018); Meharie *et al.* (2019); Rafiei & Adeli (2018); Tayefeh Hashemi *et al.* (2020); Andrić *et al.* (2019)

APPENDIX B
Initial questionnaire and the selected factors

Table B-1

No.	Criteria	References
F1	Inaccurate estimation of work volume	Alsuliman (2019b); Gebrehiwet & Luo (2017); Puncreobutr *et al.* (2018); Seddeeq *et al.* (2019); Tayefeh Hashemi *et al.* (2020);Chen and HueE; Gunduz & Maki, (2018); Mary et al., (2018); Derakhshanalavijeh et al., (2016)
F2	Submitting unrealistic financial offers by contractors in competitive bidding conditions	Alsuliman (2019b); Canesi & Marella (2017); Musarat *et al.* (2020); Seddeeq *et al.* (2019); Tayefeh Hashemi *et al.* (2020); Gunduz & Maki, (2018)
F3	The employer's lack of necessary knowledge and experience	Alfakhri *et al. (*2017); Billa *et al.* (2019); Pg *et al.* (2017); Puncreobutr *et al.* (2018); Tayefeh Hashemi *et al.* (2020)
F4	Inability of the selected contractors to implement the project	Alsuliman (2019b); Gebrehiwet & Luo (2017); Perera *et al.* (2020); Pg *et al.* (2017); Tayefeh Hashemi *et al.* (2020)
F5	Lack of attention to the existing financial inflation in the country	Al-Hazim *et al.* (2017); Haslinda *et al.* (2018); Meharie *et al.* (2019); Perera *et al.* (2020); Tayefeh Hashemi *et al.* (2020); [6];Aziz et al.[15]; Gunduz & Maki, (2018); El-Kholy,2015; Susanti, (2020); Derakhshanalavijeh et al., (2016);); Shoar, (2021); Mohammad et al., (2016)
F6	No clear definition of statements and terms in the construction contract	Pg *et al.* (2017); Tayefeh Hashemi *et al.* (2020)
F7	Not considering measures to resolve potential disputes when concluding the contract	Perera *et al.* (2020); Pg *et al.* (2017); Tayefeh Hashemi *et al.* (2020); Waziri *et al.* (2017)
F8	Lack of commitment of the Ministry of Housing and Urban Development as the senior supervisor to holding the tender properly	Al-Hazim *et al.* (2017); Aljohani (2017); Alsuliman (2019b); Tayefeh Hashemi *et al.* (2020); El-kholy (2015); Perera et al., (2020)
F9	Non-compliance of plans with urban development criteria of the intended area	CAR-PUŠIĆ *et al.* (2020); Haslinda *et al.* (2018); Pg *et al.* (2017); Tayefeh Hashemi *et al.* (2020)
F10	The contractors' poor technical and technological capabilities and ineffective planning	Aljohani (2017); Alsuliman (2019b); CAR-PUŠIĆ *et al.* (2020); Haslinda *et al.* (2018); Niazi & Painting (2017); Perera *et al.* (2020); shah Kapur (2016); Tayefeh Hashemi *et al.* (2020); Waziri *et al.* (2017); [16];[17];El-Khoy(2015)
F11	Lack of attention to the financial capacity of contractors	Aljohani (2017); Alsuliman (2019b); Billa *et al.* (2019); Tayefeh Hashemi *et al.* (2020); [17]; El-Kholy,(2015); Susanti, (2020); Fallahnejad, (2013); Mohammad et al., (2016)
F12	The employer's desire for a particular contractor to win, and the existence of economic rent and corruption in the plan	Puncreobutr *et al.* (2018); Tayefeh Hashemi *et al.* (2020); Niazi and Painting;); Shoar, (2021); Larsen et al.[19]; Kamaruddeen et al., 2020; Mary et al., (2018);); Balali et al.,(2020)
F13	Not considering the economic utility obtained from project implementation along with the contractor's	Aljohani (2017); Tayefeh Hashemi *et al.* (2020); Yaskova (2018)

	expectations	
F14	Not considering proper risks during the tender	Waziri *et al.* (2017); Aljohani (2017); Tayefeh Hashemi *et al.* (2020)
F15	Lack of holding joint meetings between the parties and rereading the contract text	Niazi & Painting (2017); Tayefeh Hashemi *et al.* (2020); Waziri *et al.* (2017)
F16	Disproportionate production of raw materials in the country, and their scarcity problems and increased prices	Al-Hazim *et al.* (2017); Chakraborty *et al.* (2020); Doloi *et al.* (2012); Niazi & Painting (2017); Tayefeh Hashemi *et al.* (2020)
F17	Lack of proper supervision of the project	Alsuliman (2019b); Billa *et al.* (2019); Haslinda *et al.* (2018); Pg *et al.* (2017); Puncreobutr & Mon Khin (2017); shah Kapur (2016); Tayefeh Hashemi *et al.* (2020)
F18	The way by which the project is financed and prepayments are made by the employer	Aljohani (2017); Perera *et al.* (2020); Pg *et al.* (2017); Tayefeh Hashemi *et al.* (2020);El-Kholy,(2015); Niazi and Painting; Susanti, (2020); Dolage and Rathnamali 2013
F19	The employer's insistence on delivering the project before the scheduled time, and consequently, project quality reduction	Billa *et al.* (2019); Tayefeh Hashemi *et al.* (2020), Chen and Hu (2019); Khanal & Ojha, (2020); Balali et al., (2020)
F20	Employer's failure to respond to sudden changes in material and fuel prices and unexpected events	Pg *et al.* (2017); Tayefeh Hashemi *et al.* (2020); [6];[17]; Kamaruddeen et al., (2020); Susanti, (2020); Pham et al., (2020); Fernando et al., (2017); Fallahnejad, (2013)
F21	Occurrence of delay and lack of compliance with the predicted schedule	Haslinda *et al.* (2018); Pg *et al.* (2017); Puncreobutr *et al.* (2018); Tayefeh Hashemi *et al.* (2020); Chen and Hu; Flyvbjerg et al [11]; Huo et al., (2018); Kamaruddeen et al., (2020); Shoar, (2021)
F22	Delayed payment of the contractor's statements	Aljohani (2017); Niazi & Painting (2017); shah Kapur (2016); Tayefeh Hashemi *et al.* (2020)
F23	Delay in obtaining various licenses and approvals from relevant agencies	Doloi *et al.* (2012); Niazi & Painting (2017); Tayefeh Hashemi *et al.* (2020); Chen and Hue [13]; Dolage and Rathnamali (2013); Derakhshanalavijeh et al., (2016);); Shoar, (2021)
F24	Delay in making changes during the project	Al-Hazim *et al.* (2017); Puncreobutr *et al.* (2018); Tayefeh Hashemi *et al.* (2020); Mohammad et al., (2016); Edita et al.;[6]; Chen and Hue; Larsen et al.[19]; Gunduz & Maki, (2018); Kamaruddeen et al., (2020); Susanti, (2020); Mary et al., (2018);); Shoar, (2021); Fallahnejad, (2013); Pourrostam & Ismail, (2012)
F25	The employer's delay in arranging the import of project materials and equipment	Billa *et al.* (2019); Niazi & Painting (2017); Tayefeh Hashemi *et al.* (2020); Mohammad et al., (2016)
F26	Delay in timely equipping of the workshop by the contractor	Billa *et al.* (2019); Niazi & Painting (2017); Tayefeh Hashemi *et al.* (2020)
F27	The contractor's poor management	Al-Hazim *et al.* (2017); Haslinda *et al.* (2018); Niazi & Painting (2017); Pg *et al.* (2017); shah Kapur (2016); Tayefeh Hashemi *et al.* (2020); Aziz et al[15]; Gunduz & Maki, (2018); Pham et al., (2020); Santoso et al., (2003);); Shoar, (2021); Pourrostam & Ismail, (2012)
F28	Incidence of inevitable accidents and loss or shortage of materials on the site	Pg *et al.* (2017); Puncreobutr *et al.* (2018); Tayefeh Hashemi *et al.* (2020); Waziri *et al.* (2017)
F29	Delay in site delivery to the contractor	Alsuliman (2019b); Billa *et al.* (2019); Niazi & Painting (2017); Tayefeh Hashemi *et al.* (2020)
F30	Shape and type of the structure (regular, irregular)	Le & Juszczyk (2018); Meharie *et al.* (2019); Niazi & Painting (2017); Sindaka & Simanjuntak (2018); Tayefeh Hashemi *et al.* (2020); Wu *et al.* (2020)
F31	The contractor's failure to observe HSE	Billa *et al.* (2019); Niazi & Painting (2017); Tayefeh Hashemi *et al.* (2020)
F32	The contractor failing to insure the project and staff	Pg *et al.* (2017); Tayefeh Hashemi *et al.* (2020)
F33	Frequent design errors and changes	Niazi & Painting (2017); Pg *et al.* (2017); Tayefeh Hashemi *et al.* (2020); Balali et al., 2020; [16];[17];[21];[2,20]; Susanti, (2020); Mary et al., (2018); Dolage and Rathnamali(2013); Kaming et al., (1997); Santoso et al., (2003);

		Perera et al., (2020); Derakhshanalavijeh et al., (2016)
F34	Changes in the employer's opinions during the project	Al-Hazim *et al.* (2017); Aljohani (2017); Doloi *et al.* (2012); Meharie *et al.* (2019); Puncreobutr *et al.* (2018); Tayefeh Hashemi *et al.* (2020); Zhao *et al.* (2019)
F35	Exchange rate variations during the project	Haslinda *et al.* (2018); Musarat *et al.* (2020); Niazi & Painting (2017); Puncreobutr *et al.* (2018); Rafiei & Adeli (2018); Tayefeh Hashemi *et al.* (2020)
F36	Size of the project	Badawy (2020); Meharie *et al.* (2019); Rafiei & Adeli (2018); Sindaka & Simanjuntak (2018); Tayefeh Hashemi *et al.* (2020); [17]; Huo et al.,(2018);
F37	Site location (soil conditions, etc.)	Al-Hazim *et al.* (2017); Alsuliman (2019b); Canesi & Marella (2017); Le & Juszczyk (2018); Meharie *et al.* (2019); Niazi & Painting (2017); Sindaka & Simanjuntak (2018); Tayefeh Hashemi *et al.* (2020); Susanti, (2020); [6]; Susanti, (2020);
F38	Inefficient savings in design	CAR-PUŠIĆ *et al.* (2020); Tayefeh Hashemi *et al.* (2020)
F39	Rule changes during project construction	Doloi *et al.* (2012); Niazi & Painting (2017); Pg *et al.* (2017); Tayefeh Hashemi *et al.* (2020); Susanti,(2020);
F40	Local problems and requirements	Gebrehiwet & Luo (2017); Pg *et al.* (2017); Rafiei & Adeli (2018); Tayefeh Hashemi *et al.* (2020)
F41	Bank interest rates during the project period	Haslinda *et al.* (2018); Rafiei & Adeli (2018); Tayefeh Hashemi *et al.* (2020); [6];[17];El-Khoy,(2015); Dolage and Rathnamali (2013); Shoar, (2021);
F42	Project type (residential, commercial, industrial, or organizational)	Badawy (2020); Canesi & Marella (2017); Le & Juszczyk (2018); Meharie *et al.* (2019); Rafiei & Adeli (2018); Tayefeh Hashemi *et al.* (2020); Andrić et al., 2019
F43	The neighborhood's awareness level (sociocultural status)	Canesi & Marella (2017); Niazi & Painting (2017); Tayefeh Hashemi *et al.* (2020);Andrić et al., 2019

APPENDIX C

Table C-1. Component matrix of the initial questionnaire based on PCA

	Components												
	1	2	3	4	5	6	7	8	9	10	11	12	13
F1	0.835												
F2	0.381	0.795											
F3			-0.469	-0.516								0.301	
F4	0.666			-0.316									
F5	0.851												
F6	0.365	0.763	-0.307										
F7		0.598											
F8	0.841												
F9	0.800												
F10		0.550			0.426		-0.335						
F11	0.748			-0.334									
F12			-0.714					0.336					
F13			-0.680					0.304					
F14			0.471				0.471	0.311					
F15			0.435		0.567								0.307
F16		0.360		0.382		-0.323					0.359		
F17					-0.306		0.371						
F18	0.308		0.498		0.305								
F19			0.404						-0.457			0.309	
F20								0.333	-0.511				
F21	0.745		0.310										
F22		0.628		0.436							-0.390		
F23				-0.383	0.411	0.428				0.340			
F24	0.568		0.352				0.377						
F25	0.700												
F26		0.657		0.457									
F27		0.490			-0.371					0.351	0.347		
F28	0.621	-0.386											
F29				0.430		0.574							
F30				0.370	0.403		-0.366		0.444	-0.359			
F31	0.478						0.483						
F32				0.365			0.453						
F33			-0.311	0.591		0.454							
F34			0.340			0.482				-0.301	0.304	-0.333	
F35					0.532								
F36					0.673								-0.306
F37			-0.395	0.378				-0.475					
F38	0.454		0.322										
F39				0.380		-0.630							
F40		-0.483					-0.322			0.550			
F41					0.303				-0.343				0.370
F42						-0.381		0.355					

F43		-0.351			-0.310		-0.320	0.322					