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# Risk factors causing cost overruns in road networks

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ABSTRACT

Cost overrun is a common phenomenon observed in construction projects worldwide. It is one of the biggest challenges experienced in the construction industry that leads to overstretched budgets, and directly affects the country's gross domestic product (GDP). This study aims to identify the factors that significantly contribute to cost overrun for road network projects in Egypt during the implementation phase. A survey was conducted to determine the most critical factors affecting the cost overrun for road network construction projects. Results showed that the main factors causing cost overrun are inaccurate cost estimates, design modifications, quantity changes, variation orders, political interference, inflation, specification changes, and change in the scope of work. This study will help decision-makers identify the factors that may affect the costs of future road projects and provide guidelines to mitigate the adverse effects observed during the implementation stage.


## 1. Introduction

The transportation sector is an essential part of the construction industry, which significantly contributes to a country's gross domestic product [15,53,83]. Road networks include highways, primary inter-city roads, toll roads, and other major roads, including bridges, ducts, and tunnels. These play a vital role in economic and social development, geographical diffusion, urban expansion, and community development [55,79,85]. Road network development significantly affects several areas, such as regional development, an influx of foreign investment, and domestic and foreign tourism [30]. Most risks involved in the cost overruns for any construction project are similar to road construction projects. However, their impact on road projects differ due to their horizontal extension, style, implementation method, and impact on the surrounding facilities during the implementation phase. Due to the high investment, large-scale, long duration, and longitudinal site conditions, road network construction projects are exposed to higher risks than traditional construction projects, thus causing cost overruns. Road networks link all construction projects and country facilities, such as ports, airports, factories, universities, and vital facilities.

Cost overrun is defined as the amount by which actual cost exceeds the estimated cost, with the cost measured in the local currency, constant price, and against a consistent baseline [40,61]. In construction projects, the cost overrun amount is the difference between the original project budget and the cost incurred on its completion. Cost overrun may arise from external factors, such as inflation, taxes, and regulations, or internal factors, such as project size, duration, complexity, location, design, and cost estimation method [52,92,20].

The construction of an integrated road network promotes the sustainable growth of the GDP of any country. Therefore, improving road network construction efficiency using cost-effective solutions would help the country in terms of cost savings [72,92] and vice versa. In Egypt, a unit price contract is the main contract type used in road construction projects. In this type of contract, most risks are shared between the owner (Transportation Department of Egypt) and the contractor [69,77], which negatively affects the GDP [18,66]. Therefore, strong management practices are required to identify and control project risks and satisfy project requirements, such as meeting project deadlines with cost-effective solutions [10,49,74].

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Egypt spent EGP 22.5 billion on the road networks that were completed between 2014 and 2017. These investments included 10 new roads with EGP 12.5 billion as a part of National Road Projects (NRP) and the further development of 2000 km of existent roads with EGP 5.7 billion [90]. The Egyptian government made additional investments in the land transport segment. In early 2020, the Ministry of Transportation allocated a budget of $9.8 billion for future road development. Despite this, Egyptian road network projects face various risks. Cost overrun is considered to be the primary technical risk in this sector and exerts the highest level of financial risk by the owner, which results in the misspending of public money subjected to strict controls and regulations [19,47]. Estimating project costs at early stages and managing these costs throughout the construction phases leads to the success of a project.

Some studies have been conducted in Egypt to predict the cost overrun in construction projects. For example, Musarat et al. (2021) studied the impact of inflation rate on construction budget. Nawar and Hosny [68] estimated the owner time and cost contingency for building construction projects. El-Ahwal et al. [29] identified the significant factors that cause cost overrun in construction projects for both the developed and developing countries. These studies were primarily focused on building projects or construction projects of all types, indicating a clear requirement for the identification of these factors, specifically in the road sector; this has been observed by limited studies. For example, from the contractor's viewpoint, Abu El-Maaty et al. [2] studied the major causes of cost overrun in highway projects in Egypt. Yousry [92] focused on the main factors responsible for causing schedule delay, cost overrun, and deterioration in quality in Egyptian public highway projects. El-Touny et al. [32] estimated the cost contingency of highway construction projects for contractors during the bidding stage.

Therefore, the objectives of this study are as follows:

a) Identify the most critical factors that lead to cost overruns in Egyptian road network projects.
b) Rank and assess the critical factors influencing the cost performance of road network projects.
c) To help owner agencies in particular, and other parties in general, avoid these risks or mitigate their impact in future projects.
d) Consider the case studies of previously implemented projects to support decision-makers in managing the expected risks related to the project budget.

## 2. Literature review

Approximately 90% of the transportation network projects experience high completion costs relative to their original budgets, resulting in cost escalation [35,57]. Many well-known transportation projects worldwide have experienced cost overruns [43,75]. For example, the Central Artery/Tunnel in Boston was the most expensive highway project in the US, known as the "Big Dig." Its construction started in 1991 and finished in 2007 with a total cost overrun of $11 billion, a 275% overrun. Table 1 presents examples of cost overrun percentages for some other transportation projects, ranging from 47% to 275%.

**Table 1**
Cost overrun in road network projects.

| Project | Country | Overruns (%) | Source |
|---|---|---|---|
| Jakarta MRT | Indonesia | 47.57 | [24] |
| The Great Belt link | Denmark | 54 | [71] |
| Underground subway | Thailand | 67 | [39] |
| Øresund link | Sweden &Denmark | 68 | [71] |
| Jubilee Line Extension | UK | 71 | [38] |
| Japanese Bullet Train | Japan | 100 | [39] |
| Channel Tunnel project | UK | 111 | [71] |
| Stuttgart 21 Metro Station | Germany | 115 | [71] |
| The Humber bridge | UK | 175 | [71] |
| Central Artery/ Tunnel | USA | 275 | [38] |

Table 2 shows that certain Asian countries experienced cost underrun in international development (ID) projects. This cost reduction was due to the *depreciation of the local currency, lower than estimated tender price, less use of contingency funds, project scope cut, local taxes, interest rate changes, and international competitive bidding* [3,4].

**Table 2**
Cost underrun in certain Asian countries.

| Country | Planned Cost (Million US $) | Actual Cost (Million US $) | Cost Underrun (%) |
|---|---|---|---|
| Thailand | 305.84 | 229.53 | 24.95 |
| Bangladesh | 126.55 | 115.86 | 8.44 |
| India | 418.29 | 308.92 | 26.14 |
| China | 486.67 | 460.33 | 5.41 |

The previous studies indicated that cost overruns occurred significantly in infrastructure projects, such as Norwegian roadway projects [71], road projects in the USA [31], and transport infrastructure in Australia [84]. Cantarelli et al. [21] studied the topic of cost overrun from several perspectives. Their study on cost overrun included>250 projects in the transportation sector in different countries. Flyvbjerg et al. [40] determined that for any randomly selected project, the probability of actual costs being higher than estimated costs is 86%. As compared to the planned cost, the most significant cost overrun (45%) has been noted in rail projects, whereas 20% for road projects. European projects' cost overruns were lower than North American's [21,42]. Several previous studies have analyzed the project cost performance, commonly for developed countries, but there are very limited studies focused on developing countries. Due to the different nature and policies of countries, the cost overrun findings of projects in USA, Australia, and Europe could not be applied to African countries. Road network construction investment plays a vital role in economic growth due to its significant contribution to the GDP and other sectors.

Flyvbjerg et al. [36] studied the causes of cost escalation in transportation infrastructure projects, by analyzing data of 258 projects with a total value of US $9 billion. They focused on the duration and size of projects. They found that (a) the duration of the implementation stage of the project heavily influences cost overrun, and (b) the average increase in cost overrun is 4.64% for every passing year from deciding to build until beginning operations. They also determined that larger projects have a higher percentage of cost overrun than smaller projects, particularly in bridges and tunnels. Love et al. [58] identified the main factors affecting cost overruns in Australian highway projects. These factors include design changes, tender price changes, increasing quality measures, unforeseen conditions, and replacement of unsuitable materials.

In the Norwegian context, Odeck [71] investigated the statistical relationship between actual and estimated road construction costs from 1992 to 1995. The findings confirmed a discrepancy between estimated and actual costs, with a mean cost overrun of 7.9%. According to Chahrour [22], the most common cost overrun factors affecting road projects in Canada were design changes, latent conditions, permits, and regulations. In the construction industry in China, Mansur et al. [60] found that low productivity of labor, escalation of material prices, high cost of equipment, and poor financial management are possible causes that lead to cost overruns. Mahamid and Bruland [59] investigated cost overruns in road construction projects in the West Bank, based on 169 projects from 2004 to 2008. They applied a regression model and revealed that all the investigated projects experienced a cost deviation. The average deviation between the actual and estimated cost was 14%.

In Afghanistan, Niazi and Painting [70] found that corruption, delay in payments by the owners, difficulties in financing projects by the contractor, security, change orders, and market inflation are the key factors that cause cost overruns in the construction industry. Al-Hazim et al. [6] studied infrastructure projects in Jordan and concluded that terrain and weather conditions are the most significant factors causing cost overruns. Table 3 summarizes critical risk factors affecting cost overrun for road construction projects in some countries.

Most previous studies on road construction projects in Egypt have focused on identifying risk factors affecting costs of projects from the point of view of the contractor.

Currently, no study has investigated the most significant factors causing owner's cost overrun for road network construction projects in Egypt. As most road construction projects in Egypt are unit price contracts, owners are the primary victims of cost overruns and pay for most risks. Consequently, the primary factors that contribute to a cost overrun for the owner should be carefully identified. Several interviews and in-depth discussions were conducted with expert engineers involved in road construction projects to identify risk factors that may affect cost overrun in road network projects in Egypt. These factors were tabulated in the questionnaire form and divided into two sections:

1. Respondent and general project information; and
2. Possible risk factors that cause cost overrun in road network construction projects (external and internal risk factors) [20,65,80].

External risk factors are changeable factors that relate to the regional and national market, or the local construction industry,

**Table 3**
Critical factors affecting cost overrun in some countries.

| Researcher | Country | Critical factors affecting Cost Overrun |
|---|---|---|
| [17] | USA | Contract amount, difference between winning bid and second bid, incorrect estimation, project location, and type. |
| [23] | Australia | Design changes, tender price changes, increasing quality measures, unforeseen conditions, and replacement of unsuitable materials. |
| [67] | UK | Inflation, design changes, stakeholder requirements, and unforeseen works. |
| [7] | KSA | Internal administrative problems, payment delays, poor communication, decision-making delays, and design changes. |
| [32] | Egypt | Project location, duration and size, site conditions, procedures of disputes and claims, estimator's inexperience, delays payment, incomplete designs, inflation rate, and fluctuations. |
| [5] | Jordan | Terrain and weather conditions, Variation orders, availability of labor, design mistakes, and planned construction costs. |
| [88] | Vietnam | Design changes, geological conditions, bidding method, inaccurate tender offer, owners' financial difficulties, and fluctuation. |
| [22] | Canada | Design changes, latent conditions, permits, and regulations. |
| [41] | Brazil | Scope changes, political Interference, change orders, the complexity of project design, mistakes in design documents, and change of taxes. |
| [9] | Nigeria | Inflation, fluctuation, exchange rate, changes in policies, variations, inaccurate cost estimates, and design changes. |

which significantly impact the project, such as political interference, regulations, force major or economic conditions [65]. Vasishta et al. [86] classified internal risks as; project and commercial risks, and activity and technical risks:

- Project risks: These are determined by the nature of the project through the project life cycle, such as the scope of work, tender time, project program, third party liabilities, cost estimate, and design issues [36,78,14].
- Activity risks: These are technical and human issues encountered during the implementation phase, such as complexity, poor site management and supervision, unforeseen soil conditions, productivity, and quality of work [51,34,78]. Fig. 1 shows an example of a risk breakdown structure, including the main risk groups, risk classification, and risk factors. These factors were tabulated into a questionnaire and reviewed by experts in road network projects to develop the factors that may affect cost overrun for this type of project.

## 3. Methodology

### 3.1. Research methodology

The main objective of this study is to identify the risk factors affecting cost overrun for road network construction projects. Further, it ranks these factors based on their impact, and finally provides guidelines for owners to mitigate or remove the adverse effect on the project's cost. This study adopted a mixed approach of both, quantitative and qualitative methods to produce a more comprehensive understanding of the research area, to collect the required data. A questionnaire was used to collect qualitative data and the impact of various factors on cost overrun for the road construction sector in Egypt. A survey of construction professionals representing various stakeholders involved in road network projects in Egypt was conducted.

In this study, the respondents' heterogeneity was maintained by approaching the selected respondents that represent the key industry roles across the road construction sector. The risk factors would further be identified and used to collect quantitative data and determine the critical factors that affect cost overrun. The study also used information gathered from three case studies that were executed in Egypt from 2009 to 2019. The selection criteria of these cases were based on the projects' region, duration, and size to reflect road network projects in Egypt and determine the risk factors affecting cost overrun for road projects based on real data and actual practice for further comparison. Therefore, it plays an important role in advancing the knowledge base in the field to support decision-makers to deal with potential budget risks in future projects. The study also considered stakeholders' experiences, follow-ups, and supervision, to develop a road network database and to compare the obtained information from the questionnaire with real project data. The sequence of methodology stages is shown in Fig. 2.

### 3.2. Preparation of questionnaire

Developing the questionnaire was based on two types of data: first, well-documented and peer-reviewed set of cost overrun factors obtained from previous literature. Second, a significant amount of available data for existing road network projects including detailed information about the root causes of road construction cost overrun. The questionnaire was prepared by incorporating the key cost overrun factors reported in the literature and previous road network projects. To obtain cost overrun factors for road network projects in Egypt, personal interviews with road network experts were also conducted. The final questionnaire was designed

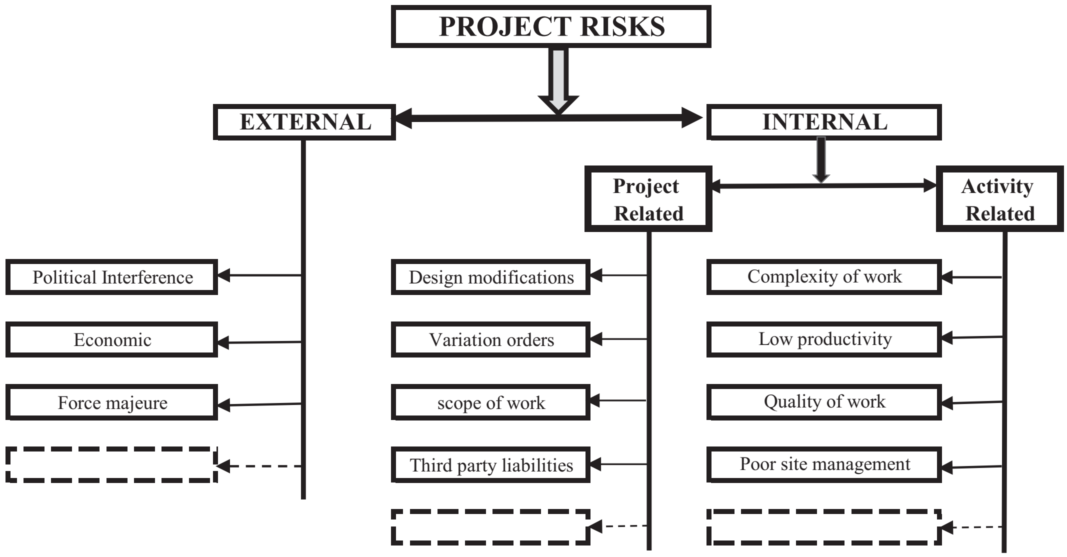


**Fig. 1.** Risk Breakdown Structure.

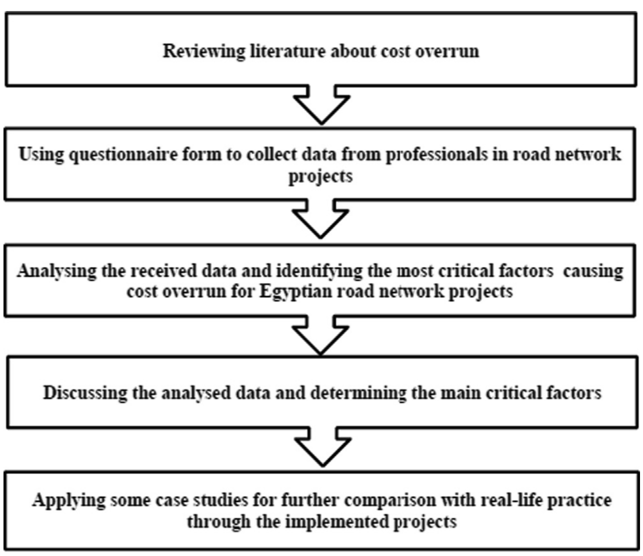


**Fig. 2.** Research methodology stages.

based on these two inputs. A total of 56 cost overrun factors were identified and grouped into three categories, namely, external related, project-related, and activity-related, as shown in Table 5.

A five Likert scale (1 very low, 2 low, 3 moderates, 4 high, and 5 very high) was used in this study to collect data from respondents. Respondents were asked about the probability and impact of each factor on cost overrun based on their previous experience in similar projects. Project threats are represented in a common probability and impact matrix. Descriptive terms such as, VH, H, M, L, and VL were used for probability (P) and impact (I).

The descriptive analysis was further applied to the collected data to rank the 56 risk factors based on their impact, as received by the respondents [45,73]. Descriptive statistics, namely relative importance index (RII) was used to calculate the relative importance of factors perceived by the respondents [8,25]. Various methods such as face-to-face meetings, telephone discussions, and email were used to collect data from experts.

### 3.3. Respondent's profile

Respondents were selected from a wide range of experienced civil engineers engaged in the Egyptian road construction sector (contractors, clients, and engineers). All the respondents verified that they had at least 20 years of experience in road network construction projects. The sample consisted of construction managers, project managers, department managers, and department directors. Table 4 shows a brief description of the respondents' profiles who participated in this study regarding the job description, experience, and affiliation to the project parties. Introductory conversations were conducted to obtain the best possible responses commensurate from the expertise and experience, while each respondent explained and clarified the research objectives.

90 questionnaires were mailed by post and 75 emails were sent, which obtained a response rate of 83%. Though the sample size is relatively small, the quality of the responses was considered reliable for the analysis due to personal level interaction, relevant industry experiences, and clear understanding of the questionnaire among the respondents [36,27]. The respondents consisted of 27

**Table 4**
Respondent's profile.

| Position / Character | Experience (year) | Owner | Consultant | Contractor | Total Per Position | (%) Per Position |
|---|---|---|---|---|---|---|
| Construction Manager | > 20 | 0 | 0 | 6 | 6 | 8 |
| Project Manager | 20–25 | 12 | 8 | 10 | 30 | 40 |
| Projects Manager | 25–30 | 5 | 7 | 5 | 17 | 23 |
| Department Manager | 30–35 | 6 | 5 | 1 | 12 | 16 |
| Department Director | > 35 | 4 | 5 | 1 | 10 | 13 |
| Total Per Character | | 27 | 25 | 23 | 75 | 100 |
| (%) Per Character | | 36 | 33 | 31 | 100 | |

owners (90% participation), 25 consultants (83% participation), and 23 contractors (77% participation), as shown in Table 4.

### 3.4. Data collection

The questionnaire was developed to identify the impact level of the identified factors on cost overrun from the viewpoints of all project parties: owners, contractors, and consultants. Experienced civil engineers were selected to ensure accuracy and reliability and obtain a ranking of the identified 56 risk factors in terms of the degree of severity on construction costs, using an ordinal probability and impact scale. The selected risk factors were used to construct the questionnaire to collect quantitative data and determine the most critical factors affecting cost overrun in Egypt's road network projects.

Every respondent was asked to assign a probability (likelihood) rating and impact on a 1–5 scale for each of the 56 potential drivers. A response of 1 indicates that the factor has a very low (VL) probability of occurrence, 2 indicates low (L) probability, 3 indicates medium (M) probability, 4 indicates high (H) probability, and 5 indicates very high (VH) probability. Similarly, a response of 1 indicates that the factor has VL impact, 2 indicates L impact, 3 indicates M impact, 4 indicates H impact, and 5 indicates VH impact.

### 3.5. Data analysis and ranking

A typical probability and impact matrix has been used to represent external and internal risk factors [1]. Numeric values or descriptive terms, such as VH, H, M, L, and VL can be used to assess the probability (P) and impact (I) for each risk factor. The probability–impact score for each risk was then calculated to calculate the relative priority for each risk factor [76]. Fig. 3 shows an example of a probability and impact matrix with a scoring scheme. The severity is calculated to obtain the score of each risk factor from Eq. (1) [82,28,48].

$$\text{Risk Severity}=(\text{Likelihood})\ \text{Probability}\ (P)^{*}\text{Impact}\ (I) \quad (1)$$

The severity degrees, symbols, and risk scores are presented in the probability–impact matrix as shown in Fig. 3 where;

- Red zone: For critical (C) risks with top priorities, which require special attention to mitigate or remove the negative consequences.
- Yellow zone: For moderate (M) risks that should be controlled as well but have lower priorities than red zone, and
- Green zone: For low (L) risks which can be ignored.

The mean and standard deviation of each factor are not suitable measures for assessment of overall rankings, as they do not reflect a relationship between them. RII is a descriptive statistical technique for extraction of key factors from the complexity of multivariate data. Therefore, RII is the suggested method for sorting the factors [13,50,25].

RII has been calculated for all risk factors under each group and further ranked as per Eq. (2) [16,44,54]. The mean value in Eq. (3) is used for further comparison using RII [26].

$$\text{RII} = \Sigma w/(A * N) \quad (2)$$

$$\text{Mean} = (\Sigma w)/N \quad (3)$$

where

(w) is the weight given by the respondents for each factor, ranging from 1 to 5.
where; 1 = very low impact, 2 = low impact, 3 = moderate impact, 4 = high impact and 5 = major impact;
(A) is the highest weight (5 in this case); and
(N) is the total number of respondents (75 in this case).

## 4. Results and discussion

All the collected data from the respondents were organized into two groups: external and internal. The severity of each factor was calculated using Eq. (1) to determine the risk degree for each factor based on its impact level as identified by participants. RII of each factor was calculated using Eq. (2), to calculate the priority of each risk factor and rank them based on RII.

| Likelihood | | | Risks | | | | |
|---|---|---|---|---|---|---|---|
| 5 | 0.9 | (V.H) | 0.09 (L) | 0.27 (M) | 0.45 (C) | 0.63 (C) | 0.81 (C) |
| 4 | 0.7 | (H) | 0.07 (L) | 0.21 (M) | 0.35 (M) | 0.49 (C) | 0.63 (C) |
| 3 | 0.5 | (M) | 0.05 (L) | 0.15 | 0.25 (M) | 0.35 (M) | 0.45 (C) |
| 2 | 0.3 | (L) | 0.03 (L) | 0.09 | 0.15 | 0.21 (M) | 0.27 (M) |
| 1 | 0.1 | (V.L) | 0.01 (L) | 0.03 (L) | 0.05 (L) | 0.07 (L) | 0.09 (M) |
| | | | (V.L) | (L) | (M) | (H) | (V.H) |
| | | | 0.1 | 0.3 | 0.5 | 0.7 | 0.9 |
| | | | 1 | 2 | 3 | 4 | 5 |
| | | | Impact | | | | |

**Fig. 3.** Example of a probability–impact matrix with a scoring scheme and severity symbols.

### 4.1. External group

In Table 5, there are 12 risk factors considered under the external group. Results indicate that two risk factors are considered as "critical – C," with RII of 0.731 and 0.725, respectively; one risk factor is "moderate – M," and nine risk factors are "low – L."

Table 5 also shows risk severity indices for each factor;

- Severity score, the sum of (P*I) for each risk factor,
- Severity degree, the score of each factor according to the total number of respondents.

Political interference and inflation have the most critical score in the external group and are ranked fifth and sixth, with an RII of 0.731 and 0.725, respectively.

*Political interference* is an external factor linked to the government's plan to determine priorities for project work and the timing of implementation. The interviews and discussions with respondents from all project parties revealed a mostly unanimous opinion that political interference led to fundamental modifications in project horizontal and vertical profiles and most project components. All project parties must consider these modifications. França and Haddad [41] determined that political interference is one of the

**Table 5**
Risk factor groups, ranking, scores, effect, and risk degrees for road network projects in Egypt.

| GROUPS | FACTORS CAUSES COST OVERRUN | Mean | SEVERITY | | | RANKING | |
|---|---|---|---|---|---|---|---|
| | | | Score (ΣW) | Degree (ΣW)/N | Symbol | RII | Rank |
| External | Political Interference | 3.653 | **1043** | **13.91** | **C** | **0.731** | **5** |
| | Price Inflation | 3.627 | **1038** | **13.84** | **C** | **0.725** | **6** |
| | Availability of foreign currency | 2.587 | 582 | 7.76 | M | 0.517 | 27 |
| | Changes in Regulations | 2.133 | 402 | 5.36 | L | 0.427 | 33 |
| | Increase in taxes | 2.093 | 397 | 5.29 | L | 0.419 | 34 |
| | Weather Conditions | 2.040 | 354 | 4.72 | L | 0.408 | 37 |
| | Legal Judgments | 1.667 | 212 | 2.83 | L | 0.333 | 44 |
| | Local Councils Objections | 1.453 | 160 | 2.13 | L | 0.291 | 46 |
| | Conflict of relevant ministries | 1.280 | 120 | 1.60 | L | 0.256 | 48 |
| | Strikes | 1.267 | 129 | 1.72 | L | 0.253 | 49 |
| | Expropriation of land | 1.200 | 118 | 1.57 | L | 0.24 | 50 |
| | Force majeure | 1.013 | 83 | 1.11 | L | 0.203 | 56 |
| Internal | | | | | | | |
| A: Project | Inaccurate Cost Estimate | 4.120 | **1240** | **16.53** | **C** | **0.824** | **1** |
| | Design variations/Modifying | 3.960 | **1189** | **15.85** | **C** | **0.792** | **2** |
| | Quantity Changes | 3.813 | **1126** | **15.01** | **C** | **0.763** | **3** |
| | Variation Orders | 3.693 | **1082** | **14.43** | **C** | **0.739** | **4** |
| | Specification Changes | 3.547 | **1017** | **13.56** | **C** | **0.709** | **7** |
| | Scope of Work | 3.520 | **994** | **13.25** | **C** | **0.704** | **8** |
| | Unforeseen Soil Conditions | 3.493 | **958** | 12.77 | M | 0.699 | 9 |
| | Project Location | 3.493 | **949** | 12.65 | M | 0.699 | 10 |
| | Project Duration/Length | 3.493 | **920** | 12.27 | M | 0.699 | 11 |
| | Schedule Pressure | 3.413 | 889 | 11.85 | M | 0.683 | 12 |
| | Short Tender Time | 3.400 | 900 | 12.00 | M | 0.68 | 13 |
| | Approval Delay (Drawings, Materials, etc.) | 2.947 | 700 | 9.33 | M | 0.589 | 21 |
| | Project Program (Contractor) | 2.907 | 681 | 9.08 | M | 0.518 | 22 |
| | Payment Failure (Owner) | 2.653 | 602 | 8.03 | M | 0.531 | 25 |
| | Delay dispute Resolution | 2.640 | 609 | 8.12 | M | 0.528 | 26 |
| | Improper verification of contract document | 2.493 | 524 | 6.99 | L | 0.499 | 29 |
| | Low Management Competency (Contractor) | 2.320 | 453 | 6.04 | L | 0.464 | 30 |
| | Differing Site Conditions | 2.187 | 348 | 4.64 | L | 0.437 | 32 |
| | Lack of Coordination (Contractor) | 2.067 | 370 | 4.93 | L | 0.413 | 35 |
| | Inadequate Supervision | 2.053 | 380 | 5.07 | L | 0.411 | 36 |
| | Error in Designs | 1.867 | 301 | 4.01 | L | 0.373 | 38 |
| | Lack of Communication (All Parties) | 1.840 | 500 | 6.67 | L | 0.368 | 39 |
| | Lack of funding (Contractor) | 1.827 | 257 | 3.43 | L | 0.365 | 40 |
| | Site Access problems | 1.733 | 232 | 3.09 | L | 0.347 | 42 |
| | Supervisory Violations | 1.040 | 89 | 1.19 | L | 0.216 | 55 |
| B: Activities | Procurement Delay | 3.360 | 871 | 11.61 | M | 0.672 | 14 |
| | Project Complexity | 3.280 | 847 | 11.29 | M | 0.656 | 15 |
| | Availability of Resources | 3.147 | 813 | 10.84 | M | 0.629 | 16 |
| | Unsuitable Construction Planning | 3.133 | 806 | 10.75 | M | 0.627 | 17 |
| | Low Productivity | 3.120 | 799 | 10.65 | M | 0.624 | 18 |
| | Quality of Work | 3.093 | 750 | 10.00 | M | 0.619 | 19 |
| | Wrong Selection of Materials | 3.080 | 790 | 10.53 | M | 0.616 | 20 |
| | Poor Quality Material Supply | 2.813 | 651 | 8.68 | M | 0.563 | 23 |
| | Vendor Delay | 2.760 | 632 | 8.43 | M | 0.552 | 24 |
| | Conversion in Utilities Networks | 2.533 | 521 | 6.95 | L | 0.507 | 28 |
| | Quantity Surveying | 2.187 | 410 | 5.47 | L | 0.437 | 31 |
| | Vendor Defects | 1.787 | 251 | 3.35 | L | 0.357 | 41 |
| | Lack of Previous Experience (Contractor) | 1.707 | 220 | 2.93 | L | 0.341 | 43 |
| | Availability of Equipment | 1.667 | 203 | 2.71 | L | 0.333 | 45 |
| | Skilled Labors | 1.373 | 148 | 1.97 | L | 0.275 | 47 |
| | Third-Party Delay | 1.200 | 112 | 1.49 | L | 0.24 | 51 |
| | Labor Dispute | 1.187 | 100 | 1.33 | L | 0.237 | 52 |
| | Noise and pollution due to const. operations | 1.080 | 92 | 1.23 | L | 0.229 | 54 |
| | Worker Characteristics | 1.147 | 97 | 1.29 | L | 0.208 | 53 |

most important factors causing cost overrun in road construction projects in Brazil.

*Inflation* is an external factor that depends on the economic situation in Egypt, especially after floating the Egyptian pound in November 2016. It has a direct effect on cost overrun for infrastructure projects, particularly road projects. The interviewees (owners and consultants) have concluded that inflation directly affected most aspects of the project. Contractors confirmed that it was responsible for certain risks, such as keeping the price constant regardless of project location, duration, or size due to increased material prices. It is necessary to develop a method to address the effect of inflation on cost overrun that would simplify formulating the budget at the appraisal phase by considering the expected inflation before finalizing the estimation. With the unstable economic situation globally and fluctuations in major currency exchange rates, Egypt, same as other developing countries, suffers from unexpected changes in prices (UN, 2020) [87,56].

Fluctuation in material prices was identified as one of the major reasons for cost overrun in road projects of Pakistan [81]. Inflation was identified as a significant reason for the persistence of road construction cost overrun in Nigeria [9].

### 4.2. Internal group

Table 5 lists all risk factors and their groups, ranks, severity, and degree of risk, affecting cost overrun in road network construction projects in Egypt. The internal group is divided into two risk factor sections:

- Section A has 25 risk factors related to the project; and
- Section B has 19 risk factors related to construction activities.

#### 4.2.1. Section A-Risk factors related to the project

In Table 5, Section A shows that six risk factors are "critical," nine risk factors are "moderate," and 10 risk factors are "low."

The most critical factor in the internal group is *inaccurate cost estimation*, which ranked first with an RII of 0.824. The estimation of quantities and project budgets depends on the efficiency and accuracy of the estimation methods. Most surveyed consultants indicated that the project quantities were often estimated according to the owner's instructions to be within the available budget of the project. The owner's representatives indicated that the project was always awarded a fixed price "bill of quantity," where the prices are fixed regardless of the project location. Therefore, the budget may increase during the implementation phase if the actual quantities exceed the estimation. Hence, most of the risks are shouldered by the owner. Thus, in the appraisal phase, experienced estimators focus on fully understanding the project and its activities, using the detailed final drawings and specifications, and ensuring the availability of a database of bids for the same project. Inaccurate cost estimates may result in risk exposure, financial loss, or loss of reputation and credibility of project stakeholders [33].

Based on the survey results, design modifications, quantity changes, variation orders, specification changes, and scope of work were ranked as second, third, fourth, seventh, and eighth, with an RII of 0.792, 0.763, 0.739, 0.709, and 0.696 from all 56 risk factors, respectively. This implied that the project-related factors have the most significant effect on cost overrun in road network construction projects in Egypt.

Further, based on the professionals' opinions, *design modification* is the main factor affecting variation orders and quantity changes in Egypt. Simultaneously, most contractor representatives added that change in project scope or specifications must be limited. Improper planning, misinterpretation of data, being unaware of future needs are a few of the causes of design changes. Therefore, proper planning, adequate investigation of the site, and accurate design procedure are required to execute the project with high precision. In the scenario of lack of clarity in project scope, the owner's influence in triggering design changes or modifications is greater than that of the other factors. Yet, the role of contractors and consultants in promoting the events causing the changes in design can never be underestimated [11]. [23] determined that project design and scope changes during project development are the major causes of highway project overrun in Australia. Highway agencies are required to focus their efforts on these significant risks. Design modification can be reduced by improving communication and coordination between the various stakeholders of the project.

*Quantity changes are* due to unexpected ground and actual terrain conditions. The actual quantity varies because of improper assessment of ground conditions, nature of soil strata during the preliminary survey, and unexpected sub-surface conditions. Change in ground conditions may lead to several issues in excavation base laying and moving machinery. To avoid these problems, the consultant must provide additional care in preliminary and reconnaissance surveys; otherwise, the project will experience an increase in cost and delay in the schedule.

*Variation orders* can be reduced by engaging the appropriate design consultants who have experience working on similar projects and creating an environment of mutual understanding between key project stakeholders. In addition, the appropriate method statements and a resource-loaded schedule that clearly defines the role and responsibilities of the workforce, equipment, and the projected progress curves of the project can prevent variation orders. Al-Hazim and Abu Salem [5] found that variation orders were the most critical factors affecting cost overrun in Jordan road construction projects.

*Specification changes* rank seventh with an RII of 0.709. All respondents confirmed that specification changes are always based on instructions from consultants. The technical specification is – beside the contract – the most important contractual document that critically details the characteristics of the project during all stages of design and construction, changes in specifications, initiated mostly by consultants and project owners. As some owners have been exposed to poor quality construction, they use more specifications to reduce the risk of nonperformance. However, the owners do not realize that they increase the possibility of nonperformance by issuing more specifications. Specification changes are identified as major project defects, cost overruns, delays, or even project failure [46]. Clear specifications and a consistent understanding of the intent of the specifications by all parties leads to a project of higher quality.

*Scope change* ranks eighth, with an RII of 0.696. All respondents confirmed that scope changes are the sole responsibility of the owner. It is included in lack of clarity of project scope by designer and owner. Many problems may arise with large construction projects due to a lack of clarity in project scope, thus necessitating the coordination of efforts of all project parties, including the owner, designers, contractors, vendors, suppliers, and local authorities [89]. Scope change can be reduced using proper specification, detailed designing and modeling techniques, and accurate quantities before finalizing the scope of work. Clarity in the scope of a project is essential for completion of any project [64]. Change in project scope has been identified as one of the most important reasons for project cost overrun in Australian highway projects [23].

All respondents confirmed that the project's owner is held responsible for controlling project costs and reducing the probability of cost overrun risks.

#### 4.2.2. Section B - risk factors related to construction activities

In Table 5, Section B shows nine risk factors considered as "moderate," 10 risk factors as "low," and no critical risk factors.

Most factors related to the construction activities of road network projects are moderate or low, as they generate fewer risks during the construction phase than specific construction projects such as factories, silos, or power plants.

### 4.3. Main risk factors

Table 5 lists the main risk factors that affect the Egyptian road network construction projects, ranked based on RII. There are eight factors: two from the external group and six from the internal group related to the project; there are no critical factors related to construction activities. In most construction projects, the critical risk factors that affect project cost overrun are similar, regardless of the country; however, they differ in order of ranks, as shown in Table 3.

Table 3 summarizes a comparison between critical risk factors affecting road construction projects. In some countries, design changes, design deficiencies, design delays, detailed drawings, and unavailability of design information are common factors that affect cost overrun for most construction projects. Table 3 further shows a partial agreement between the critical factors in these countries and those in this study.

## 5. Real case studies

Case studies are an important part of developing the field knowledge base [62].Three real-life projects have been conducted as case studies for further comparison. The selection criteria were based on the projects' region, duration, and size to reflect road network projects in Egypt and determine the risk factors affecting cost overrun for road projects based on real data from these projects and actual practice. The results of case studies have been compared to the research findings to verify the extent of the similarity between the theoretical study and the actual reality.

Data was collected from the Authority for Roads and Bridges and Land Transport [12] (GARBLT), Ministry of Housing, Utilities and Urban Communities (MHUC) [63], and real field supervision. All projects were open tenders with unit price contracts except the axis of 30 June, "forced tendering". Data was collected from different sources such as drawings, approved priced bill of quantities (BOQ), supervision data, and field investigation for these projects. The three case studies data analysis will be discussed in details.

### 5.1. Assiut–Sohag Tama axis (2009–2018) case Study-1

This axis was established as a link between the eastern and western roads in Upper Egypt. The entire project consists of three phases: the first phase was completed in 2019, while the second and the third phases are still ongoing. The initial total cost of the project for the three phases was estimated at 1.55 billion LE. The studied case was the first phase, which started in May 2009, with a total length of 6.5 km and an initial cost of 300 million LE, and took 104 months to complete.

Based on project documents and supervision, the actual risk factors associated with drawings, BOQs, and final statements are as follows:

- the design was modified many times;
- quantities of many items were increased due to actual site conditions such as terrain and unexpected ground conditions; and
- some new items were added due to political interference.

The final project statement is as follows:

- phase 1 has been completed with an actual total cost of 412 million LE, with a 37.3% cost overrun; and
- actual completion of phase 1 was in March 2019, with a 15-month delay.

*The results of this case study conform with the survey results on the role of the three critical factors—political interference, design modifications, and quantity changes on project cost overrun and project performance.*

Fig. 4 shows the Egyptian map that includes the location and governorate of the applied case studies.

### 5.2. Zagazig–Sembelawin Road, phase 2 (2013–2019) case Study-2

This case study represents the construction of a dual road of a total length of 17.5 km (Zagazig–Sinbillawain) as a traffic axis between the governorates of *Sharqia* and *Dakahlia*, contributing to resolving the traffic jam between *Zagazig* and *Sinbillawain*. According to the updated BOQ of the project, it experienced a cost overrun through three stages.

- First, the budget increased by 0.19% due to quantity changes.
- Second, the budget increased by 25% due to unforeseen soil conditions, soil report changes, design modifications, and quantity changes.
- Third, the budget increased by 11.11% due to design modifications and quantity changes. Hence, the total cost overrun was 36.30%.

According to these changes, the contractor requested the owner and the consultant to extend the project duration and increase the cost. Therefore, the owner decided to extend the project duration by 14 months.

*The results of this case study conform with the survey results on the role of the two critical factors—design modifications and quantity changes in project cost overrun and project performance.*

### 5.3. Regional Ring road (2015–2018) case Study-3

The Regional Ring Road is an oceanic road in Egypt that surrounds the Middle Ring Road, enclosing the ring road of Greater Cairo. The road is about 400 km long. The project was a collaboration among the Ministry of Transport and Communications, the Ministry of Housing, and the Engineering Authority of the Armed Forces. The project started in 2015 and was launched on September 9, 2018. The route passes through four governorates: *El-Sharqia*, *Qalyubia*, *Menoufia*, and *Giza*, starting from *Belbeis* and ending with the *Cairo–Alexandria* road intersection. This main artery includes 50 bridges and 64 tunnels. The project was scheduled to start in December 2015 and be complete in December 2017, with an initial value of 444 million LE, according to the approved BOQ. By investigating the approved drawings, BOQ, and final invoices, the following risk factors were identified:

- Design modification for the entrance and exit ramps for all bridges;
- Two tunnels were added by political interference.

Due to design modification and additional works, the project was extended by more than six months with a final total cost of 565.5 million LE. Hence, a cost overrun of 27.4% was noted.

*The results of this case study conform with the survey results regarding the three critical factors—political interference, design*

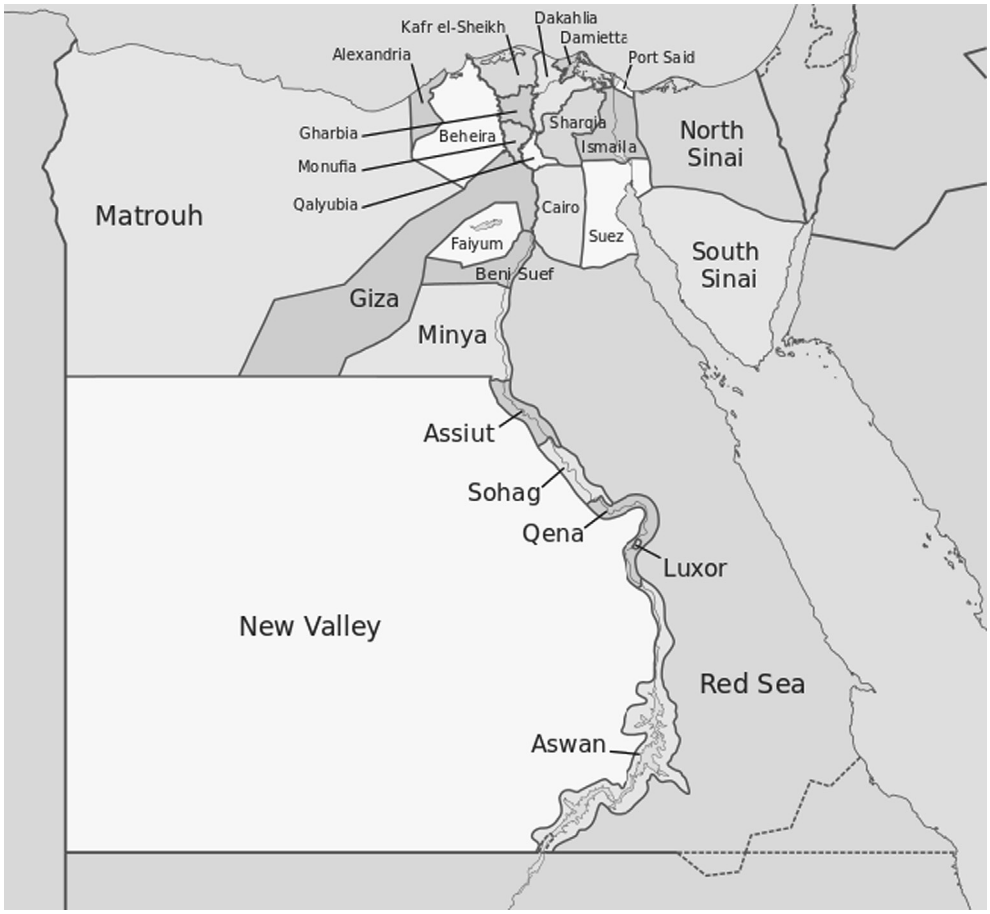


**Fig. 4.** Egyptian governorate, Upper and North Egypt.

**Table 6**
Cost overrun comparison for the studied cases (Source: field investigation).

| Project | TIME (Tender) | TIME (Actual) | BOQ (Price) | Actual Costs | Overruns (%) |
|---|---|---|---|---|---|
| Assiut-Sohag Tama axis | 104 Months | 119 | 300 | 412 | 37.3 |
| Zagazig-Sembelawin Road (Phase 2) | 24 Months | 36 | 168 | 229 | 36.3 |
| Regional Ring Road | 25 Months | 34 | 444 | 565.7 | 27.4 |

**Table 7**
Summary of cost overrun factors for case studies.

| Project | COST OVERRUN FACTORS |
|---|---|
| Assiut-Sohag Tama axis | Design modification, quantity changes, and political interference. |
| Zagazig-Sembelawin Road | Design modification and quantity changes. |
| Regional Ring Road | Political Interference, design modifications, and quantities changes. |

*modifications, and quantities changes—and their impact on project cost overrun and project performance.*

Table 6 shows the comparison between initial and actual costs, tender and actual project duration, and cost overruns for all studied cases.

Table 7 summarizes the actual factors that affected cost overrun for the three case studies.

## 6. Conclusions

The main objective of this study is to identify the critical factors that affect cost overrun in road network construction projects in Egypt to enable owner agencies and other involved parties to mitigate the impact on future projects.

The study adopted a mixed research approach of both quantitative and qualitative methods to obtain the required information. Based on the literature review and expert interviews, 56 risk factors of road construction cost overrun were identified. Further, a structured questionnaire survey was distributed to 75 experienced engineers in road construction and management. The study analyzed and identified the most common factors that cause cost overrun in road network construction projects in Egypt. All identified factors were ranked based on the RII.

Primarily, eight critical factors causing cost overrun were identified based on the survey results. Two are related to external factors, namely *political interference and inflation,* ranking fifth and sixth, respectively. The remaining six factors are related to internal factors, namely *inaccurate cost estimates, design modifications, quantity changes, variation orders, specification changes, and scope of work,* ranking first, second, third fourth, seventh, and eighth, respectively.

Three case studies on real projects have been analyzed to identify the main factors affecting cost overrun in the real construction field to compare and validate the collected data. The results revealed that *design modifications and low estimates for budgets and quantities* are the main factors that affect cost overrun in these projects. The most crucial observation in these case studies is that there is no relationship between project size or duration and cost overrun percentage.

Determining the primary critical factors that cause cost overrun in road network construction projects in Egypt is the most significant contribution of this study. This study also provides guidelines regarding the main causes of cost overruns to help project managers prepare strategies and effective plans to mitigate the potential risks for future projects. The study further contributes to increasing awareness regarding cost overrun factors to enable the preemptive management and mitigation of their effects by owners. Additionally, the findings guide transportation agencies to overcome these obstacles by avoiding or reducing the causes of cost overrun.

Based on the results obtained from the statistical analysis of the data and the studied cases, the following recommendations are suggested to the owners:

1. Select appropriate consultants and designers to develop optimal specifications and design according to the project budget, considering the social and economic needs of the region's residents.
2. Sufficient time is to be given for preparing the tender and formulating the quantities accurately to avoid an increase in quantity in the construction stages.
3. Develop a technique for budget formulation at the appraisal stage by considering the inflation aspect before finalizing the budget estimate.
4. Allow adequate time for consultants and designers to make any required modifications to the design or specifications during the appraisal phase and based on the owner's approval. This should align with the project budget to properly control project costs during the construction stage to avoid any technical causes for cost overrun, such as quantity changes, variation orders, specification changes, and changes in the scope of work.
5. Cost estimation is preferred to be executed by a value estimator to obtain a more accurate budget.
6. Submit a logical and applicable schedule.
7. Consider an appropriate contingency fund during the implementation stage to accommodate any case of cost overrun.

### *6.1. Significance of the research*

Many studies are conducted to identify cost overrun risk factors in road construction projects. This study highlights the primary risk factors affecting cost overrun for road projects with root causes and explanations based on expert interviews and the comparison of its results with that of the previous studies on road projects of different countries. In addition, no previous study has identified and analyzed the risk factors affecting cost overrun for road network projects in Egypt from the perspective of the responsible parties who participated in this study.

### *6.2. Limitations of the study*

First, the sample size of 75 observations is considered to be small for statistical analysis.

Second, this study determined that inadequate project planning, lack of communication, low productivity of labor, escalation of material prices, high cost of equipment, poor financial management, terrain, and weather conditions are not significant factors of cost overrun. Further research could be conducted to examine the impact level of these factors, considering that various studies in road projects [2,60,6] have demonstrated significant effect on cost overrun.

### *6.3. Future scope of the study*

Future studies could identify the cost overrun factors for the road projects of the countries that have not been previously studied; study the relationship between magnitudes and cost overrun factors; and investigate the precise contribution of each cause of cost overrun in a specific one road project, which may contribute toward identifying the exact causes of cost overruns and improving the construction process by taking measures to overcome the cost overruns.

## Declaration of Competing 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.

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