Evaluation of Factors Leading to Time Delays and Cost Overruns in Marine Construction Projects

Aymen Nassar
Department of Civil Engineering, German University in Cairo, Egypt
ayman.hamdy@guc.edu.eg

Ahmed Elbisy
Department of Civil Engineering, German University in Cairo, Egypt
ahmedelbisy98.29@gmail.com (corresponding author)

Received: 13 June 2024 | Revised: 30 June 2024 | Accepted: 3 July 2024

 DOI: https://doi.org/10.48084/etasr.8116

ABSTRACT

Marine construction projects are among the most complex endeavors undertaken, as they are subject to numerous variables and constraints that make them more vulnerable to cost overruns and time delays than other project types. This study investigates the potential factors that influence time delays and cost overruns in marine construction projects. For this purpose, 43 factors that affect marine construction projects in terms of cost overrun and time delay were identified and categorized into nine main groups through a detailed literature review process, as well as interviews with experts from the marine construction industry. The relative importance of these factors and groups was quantified using the Relative Importance Index (RII) method. The ranking of factors and groups was determined according to their level of effect on time delay and cost overrun. Interestingly, the top five factors for both time delay and cost overrun, although ordered differently, were the same: inflation (e.g., material, equipment, and labor prices), fluctuation in cost (e.g., money exchange rate, taxes and burdens, and interest rates charged by bankers on loans), incompetence or inexperience of contractors (lack of experience and/or managerial skills), poor planning and management of contractor's schedule, and difficulties in project financing by the contractor. Contractor-related factors had the highest RII for time delays, followed by external-related factors with a tiny difference. However, for cost overruns, the ranking of these two groups is reversed. The findings of this study could help organizations that plan to carry out successful and sustainable marine construction projects, ultimately contributing to the development of critical maritime infrastructure.

Keywords-time delay; cost overrun; reliability; marine construction projects; relative importance index; Likert scale

I. INTRODUCTION

The construction sector is considered a major contributor to the global economy, representing 13% of the global Gross Domestic Product (GDP), with a promising 85% increase to $15.5 billion globally by 2030, with three leading countries, China, the United States, and India, contributing 57% of its global demand [1]. Furthermore, global infrastructure spending is estimated at $3.4 trillion annually from 2013 to 2030, which is approximately 4% of total GDP. This sector is also considered a major backbone of any country's economy, representing 3% of the total economic output of Nigeria, 4.3% of the total economic output of Germany, 6% of the total economic output of the United Kingdom (UK), and 4.1% and 6.8% of the total economic output of the United States of America (USA) and China, respectively [3, 4].

Completing a project according to the scheduled time and budget is one of the most important aims of project management and is regarded as an essential point in the project's success. However, cost overruns usually occur due to the complexity of construction projects. The World Bank has announced that 30-40% of construction projects worldwide face cost overruns [5-9]. Marine projects are critical economic assets and their failure can have a detrimental impact on a country's economy. They are assets built near the shore and offshore. Common forms of such infrastructure include shore protection structures, jetties, breakwaters, ports, wharves, floating oil and gas platforms, bridges, and underwater pipelines and tunnels. Their construction requires specialized skills and extremely complex technologies to perform tasks under erratic and unpredictable conditions, mostly in remote areas where logistics support is difficult. Their unique attributes distinguish them from other projects, namely complex resources and equipment, dynamic and uncertain work environments, and the interdependency of multiple professional disciplines. In [10], it was argued that the uniqueness of marine projects is defined by weather considerations and sophisticated design principles. These characteristics make them more exposed to overruns than land projects. The adverse impact of overruns on stakeholders can be defined as altering the operation stage and jeopardizing the project's financial viability.

In [11], critical risks were identified in Hong Kong's maritime projects. The results showed that underwater conditions different from bidding assumptions are the most common risk factors in marine projects and that the lack of access to materials, plants, and labor has the greatest impact on risk exposure. The factors that cause schedule delays in offshore projects are delayed payments, changes in specification, material procurement processes, delayed deliveries by contractors, poor site supervision, poor coordination between contractors, technical incompetence, updating technical solutions, construction error, financial processes, and HSE considerations [12, 13]. According to [10], a prominent risk factor that affects marine construction projects is the contradiction between the tender documents and the actual project circumstances. This study identified a variety of design- and construction-related factors, including design errors, estimation errors, inexperience in the design team, construction errors, and the consultant's inability to deal with severe uncertainties. In addition, unreliable geotechnical assumptions are a common cause of overruns in marine projects. This highlights the necessity of pilot studies in the early stages to prevent problems in the construction phase [10]. In [14], 18 critical factors for time delays in marine projects in India were discussed, with the top three factors to be controlled being poor project monitoring, lack of a defined project management plan, and in the third position lack of proper construction methodology and sequence and erroneous quantity survey and estimation.

In [15], the critical risks in marine construction projects in Iran were investigated. The results showed that design variations, lack of skilled labor, improper construction methods, changes in project specifications due to inadequate studies, and unavailability of materials and equipment were the five critical risks of marine construction projects. In [16], a study was carried out in the Iranian natural gas industry to identify the causes of delays in pipeline construction projects. The results showed that the top ten causes of time overruns were imported materials, unrealistic project duration, client-related materials, land expropriation, change orders, contractor selection methods, payments to contractors, obtaining permits, suppliers' cash flow, and contractor's cash flow. In [17], cost overruns were investigated in the Iranian oil and gas industry, showing that the most significant factors were inaccurate cost estimates, improper planning, frequent design changes, inadequate labor/skill availability, inflation of machinery costs, and labor, raw material, and transportation prices.

In [18], the main risk factors for construction projects in Vietnam's oil and gas industry were the bureaucratic government system and long project approval procedures, poor design, incompetence of project teams, inadequate tender practices, and late internal approval processes from the owner. The latter includes delays in land deliveries or site handovers, work approvals, drawing and document approvals, and delivery of test results. The effect of these factors on marine construction projects can be severe. In [19], the causes of delays in the Gulf area for oil and gas projects were poor site management and supervision by contractors, problems with subcontractors, inadequate planning and scheduling of the project by contractors, poor management of contractors' schedules, delay in delivery of materials, lack of effective communication among project stakeholders, and poor interaction with vendors in the engineering and procurement stages. Of these seven major causes, there were significant differences in the perceptions of project stakeholders only for poor management of contractors' schedules. In [20], the main causes of time delay and cost overrun in Saudi Arabian oil and gas construction projects were identified, concluding that the main causes of cost overruns were design changes and scope by the client during construction, poor planning and scheduling of the project, design errors, inadequate comprehension of the scope of work at the bidding stage, underestimating cost and schedules, and overestimating benefits.

In [21-22], risk factors were classified and ranked in terms of their probability and impact on construction projects in the oil and gas sector, to test the relationship between their causes and effects and then develop a risk map to facilitate the planning of risk response strategies. The analysis showed that the most effective risk factors in oil and gas projects were unstable government, corruption accompanying tenders, poor planning and control for scheduling and budgeting, ineffective management, delays in material deliveries, lack of contractor experience, wrong project cost estimate, wrong project schedule estimation, improper project, feasibility study, and lack of effective quality control management. In [23], risks related to the execution of offshore oil and gas projects were identified and analyzed. This study discovered that there are some activities with a very high probability of occurrence and impact, such as bad weather effects on the project, increase in material prices, owner delays in contractor submissions for acceptance or approval of decisions, and high-quality control standards.

The objectives of this study are:

- Investigate the main factors that influence cost overruns and time delays in construction projects,
- Identify and analyze potential factors that influence cost overruns and time delays in marine construction projects,
- Determine the significance of each factor that influences cost overruns and time delays in marine construction projects.

II. METHODOLOGY

Figure 1 shows the methodology adopted to achieve the study's objectives.

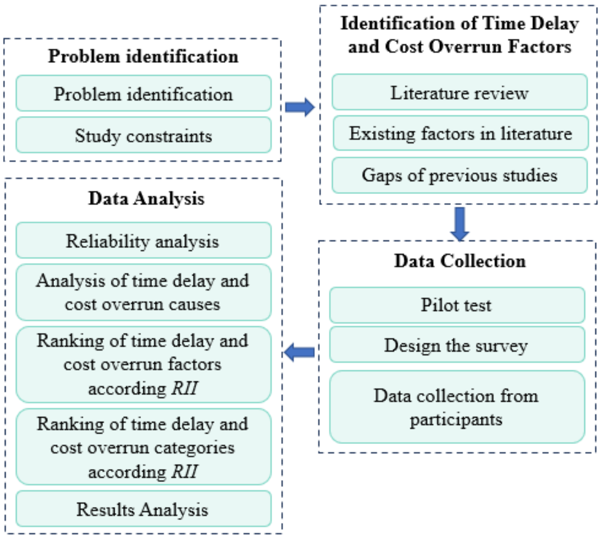

Fig. 1. Methodology process.

III. STUDY CONSTRAINTS

Identifying probable constraints of a study is an essential step, as it provides a clear perception of the current circumstances of the study environment. The constraints of this study are as follows:

- There is a scarcity of marine projects worldwide.
- This study is limited to finding, ranking, and analyzing the causes of time delays and cost overruns in marine construction projects in Egypt, Saudi Arabia, the United Arab Emirates, Kuwait, and Qatar.
- Poor responses to online surveys by participants.

IV. IDENTIFICATION OF TIME DELAY AND COST OVERRUN FACTORS

The primary objectives were to investigate the main factors that influence cost overruns and time delays in construction projects, identify and analyze the potential factors that influence cost overruns and time delays in marine construction projects based on previous studies, and pinpoint existing knowledge gaps within the domain. The literature survey was conducted in three tiers, establishing at the end nine time-delay and cost overrun sources. These sources related to (1) owner, (2) consultant, (3) contractor, (4) designer, (5) all parties, (6) resources (material, labor, and machinery), (7) contract, (8) external, and (9) force majeure.

Inevitably, there were variations in the individual causes of time delay and cost overrun lists identified by previous studies within the different risk source categories. This was attributed to differences within the studies in terms of construction environments, geographical conditions, political situations, construction methods, resource availability, and stakeholder engagements. As such, a first series of meetings was held with ten construction experts to confirm the relevance of the identified causes of time delays and cost overruns to marine construction projects and modify them as necessary. Based on the literature survey and expert meetings, 43 causes of time delays and cost overruns were identified. Table I shows a complete list of these factors within their source categories [24-35].

TABLE I. CAUSES OF TIME DELAYS AND COST OVERRUNS IN MARINE CONSTRUCTION PROJECTS

Category	Identified Factors
1. Owner-related factors	F-1 Owner's financial difficulties. F-2 Delay in settlement of contractor's claims by the owner. F-3 Interference, change orders, scope variance, and slow decisions by the owner. F-4 Delays in site delivery to contractor.
2. Designer-related factors	F-5 Design errors/incomplete or unclear design drawings and design variation. F-6 Weak and insufficient technical studies. F-7 Complexity of design. F-8 Delays in producing design documents.
3. Consultant-related factors	F-9 Poor planning and management of contractor's schedule. F-10 Inadequate quality assurance and control. F-11 Delay in approval of completed work (drawings, equipment, and material samples).
4. Contractor-related factors	F-12 Difficulties in project financing by contractor. F-13 Incompetence or inexperience of contractor (lack of experience and/or managerial skills) F-14 Inadequate site investigation. F-15 HSE considerations. F-16 Inadequate comprehension of the scope of work at the bidding stage. F-17 Incompetent subcontractors deployed by the contractor. F-18 Rework due to non-compliance in quality or poor workmanship. F-19 Inappropriate construction methods and work implementation strategies by the contractor.
5. All parties-related factors	F-20 Lack of effective communication among project stakeholders. F-21 Poor interaction with vendors in the engineering and procurement stages. F-22 Ineffective management, planning, and scheduling of the project. F-23 Legal disputes between project participants.
6. Resource-related factors	F-24 Shortage of skilled labor. F-25 Low productivity of labor. F-26 Improper equipment or lack of high-tech equipment. F-27 Delay in material delivery. F-28 Shortage of construction materials - special building materials not available in the local market.
7. Contract-related factors	F-29 Mistakes or discrepancies in contract documents and incomplete scope definition. F-30 Unrealistic cost and schedules/overestimating benefits. F-31 Unsuitable type of project bidding and award (e.g., negotiation, lowest bidder, etc.). F-32 Ineffective delay penalties. F-33 Poor definition of payment milestones/distribution of cash flow.
8. External-related factors	F-34 Climate and weather conditions. F-35 Sea state (waves, tides, and currents). F-36 Environmental degradation impacts. F-37 Fluctuation in costs. F-38 Inflation (e.g., material, equipment, and labor prices). F-39 The existence of sanctions and the (technical) inability to import essential goods. F-40 Delay in permissions, approvals and statutory compliance from authorities. F-41 Unforeseen geotechnical issues.
9. Force majeure-related factors	F-42 Spreading of diseases, epidemic or pandemic (e.g., COVID-19). F-43 Wars in the region.

V. DATA COLLECTION

To control data collection and facilitate analysis, it was decided to employ a questionnaire with closed-type questions to ensure clarity and completeness and the applicability of the listed causes, which were identified using a literature review. Ten questionnaires were distributed to experts specializing in marine construction to ensure that it comprehensively addressed the majority of factors that may affect marine construction projects in terms of time delays and cost overruns. The experts' advice was considered and incorporated, along with the inclusion of other relevant factors and questions. A 5-point Likert scale was used as shown in Table II. The questionnaire survey was generated using the Google Forms online platform and then distributed to the participants.

A crucial aspect of the data collection process is the determination of the sample size. To ensure the generalizability of the results, it is most useful to utilize a sufficiently large sample. However, the sample size in this study may be relatively small, due to the limited population under investigation. Various criteria, such as population size, minimum acceptable level of precision, and confidence level, determine the sample size. The sample size was set using the commonly employed heuristic "utilize as many participants as possible within budgetary constraints" [37]. Following this regulation, a survey was distributed to a randomly selected subset of 103 individuals from various segments within the marine construction sector. Figures 2, 3, and 4 represent the job description, years of experience, and organization locations in the sample distribution.

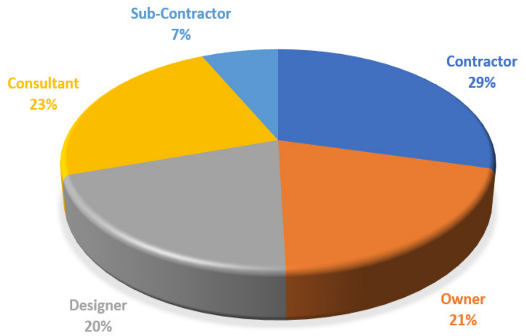

Fig. 2. Respondents' job description.

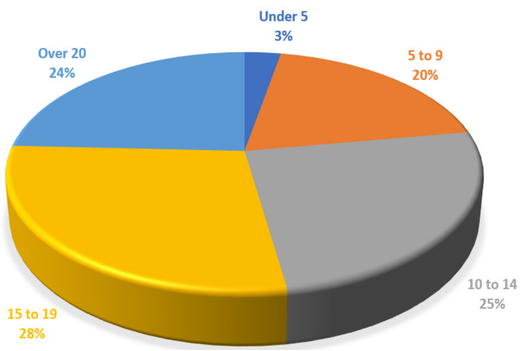

Fig. 3. Respondents' years of experience.

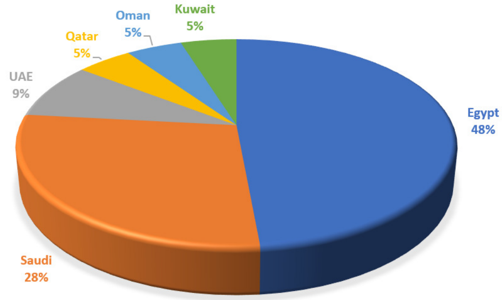

Fig. 4. Respondents' location.

TABLE II. LIKERT SCALE BREAKDOWN

Scale	Probability	Impact
1 (Lowest)	Very Rare	Very Low
2	Rare	Low
3	Possible	Moderate
4	Frequent	High
5 (Highest)	Very Frequent	Very High

VI. ANALYSIS TOOLS

The reliability of the questionnaire was tested using Cronbach's alpha, a coefficient of reliability. Cronbach's alpha is a measure of internal consistency, i.e., measuring how closely related a set of items are as a group. Cronbach's alpha values range from zero to one. A high Cronbach's alpha is often used as evidence that the items measure an underlying construct. Cronbach's alpha (α) is defined as:

$$\alpha = \frac{K}{K-1}\left[1 - \frac{\sum_{i=1}^{k}\sigma_i^2}{\sigma_t^2}\right] \quad (1)$$

where K is the number of questions, σ_i^2 is the variance of scores on each question, and σ_t^2 is the total variance of overall scores. The data was used to rank the factors from highest to lowest according to the Relative Importance Index (RII) method.

$$RII = Probability\ Index\ (PI) * Severity\ Index\ (SI) \quad (2)$$

$$PI = \frac{\sum_{i=1}^{n}(Number\ of\ participants(i) \times Probability\ Scale(i))}{Number\ of\ Respondents} \quad (3)$$

$$SI = \frac{\sum_{i=1}^{n}(Number\ of\ participants(i) \times Severity\ Scale(i))}{Number\ of\ Respondents} \quad (4)$$

VII. RESULTS AND DISCUSSIONS

Cronbach's alpha for the questionnaire was determined using SPSS software, and the coefficient values were 0.963, 0.965, and 0.973 for the severity scales of time delay, cost overrun, and probability scale, respectively. These values were considered acceptable because they exceeded the minimum acceptable level of 0.7 [37]. These Cronbach's alpha values indicate high reliability and internal consistency in each scale [38].

Table III lists the survey results in compact form, showing the 43 identified factors, their RII, and their rank based on RII.

TABLE III. RANKING OF COST OVERRUN AND TIME DELAY FACTORS ACCORDING TO RII.

Factor ID	Category	Time Delay		Cost Overrun	
		RII	Ranking	RII	Ranking
F-1	Owner-related factors	12.917	11	11.762	10
F-2		13.047	9	11.625	13
F-3		12.59	13	11.631	12
F-4		8.831	42	7.966	42
F-5	Designer-related factors	10.984	27	10.678	18
F-6		10.163	35	10.163	26
F-7		7.398	43	6.967	43
F-8		9.988	36	8.123	41
F-9	Consultant-related factors	14.22	3	12.85	4
F-10		10.490	31	10.724	17
F-11		11.03	26	9.09	36
F-12	Contractor-related factors	14.9	1	12.449	5
F-13		13.733	5	13.249	3
F-14		10.835	28	10.631	19
F-15		9.956	37	9.466	33
F-16		11.750	19	12.046	9
F-17		12.498	15	10.823	16
F-18		12.576	14	11.726	11
F-19		11.604	20	10.469	20
F-20	All parties-related factors	13.639	6	11.579	14
F-21		10.28	34	8.861	38
F-22		13.515	7	12.315	6
F-23		9.146	40	8.188	40
F-24	Resources-related factors	11.362	22	9.866	28
F-25		12.183	16	10.395	21
F-26		10.659	30	9.820	29
F-27		11.560	21	9.165	35
F-28		12.869	12	11.20	15
F-29	Contract-related factors	9.172	39	8.857	39
F-30		11.940	17	12.146	8
F-31		9.950	38	9.739	30
F-32		10.817	29	9.688	31
F-33		11.342	23	10.273	24
F-34	External-related factors	11.058	25	9.293	34
F-35		11.905	18	10.357	22
F-36		9.142	41	8.921	37
F-37		13.743	4	14.693	2
F-38		14.313	2	15.441	1
F-39		13.010	10	12.230	7
F-40		13.147	8	10.10	27
F-41		11.076	24	10.316	23
F-42	Force-majeure related factors	10.438	32	9.529	32
F-43		10.309	33	10.238	25

The top ten delay and cost overrun factors are shown in Figures 5 and 6, respectively. The analysis revealed a convergence in the top five factors ranked within each consideration, namely time delay and cost overrun. Although the specific order of these factors differed between the two cases, identical elements occupied the highest levels of the rankings in both cases. These factors were inflation (e.g., material, equipment, and labor prices), fluctuation in cost (e.g., money exchange rate, taxes, burdens, and interest rates charged by bankers on loans), incompetence or inexperience of the contractor (lack of experience, and or managerial skills), poor planning and management of contractor's schedule, and difficulties in project financing by the contractor. Additionally, the RII of each group was calculated, and the groups were ranked from the highest to the lowest. For time delay, the contractor-related factors group had the highest RII, followed by the external-related factors group with an infinitesimal difference, but for cost overrun, the rank of the two groups was reversed. The groups are ranked as shown in Table IV.

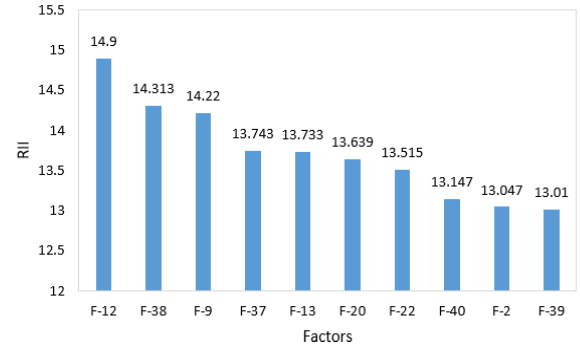

Fig. 5. Top ten factors of time delays in marine construction projects.

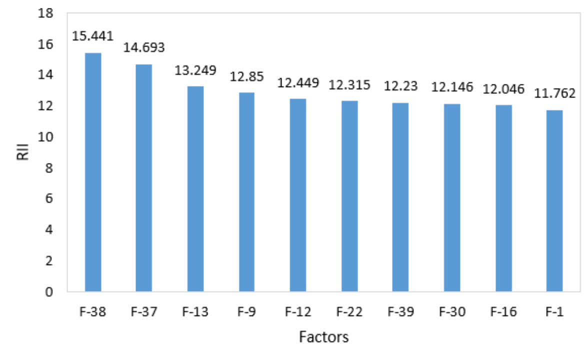

Fig. 6. Top ten factors of cost overruns in marine construction projects.

TABLE IV. RANKING OF TIME DELAY AND COST OVERRUN CATEGORIES ACCORDING TO RII.

No.	Category	Time Delay		Cost Overrun	
		RII	Ranking	RII	Ranking
1	Owner related factors	11.85	4	10.75	4
2	Designer related factors	9.63	9	8.98	9
3	Consultant related factors	11.91	3	10.89	3
4	Contractor related factors	12.23	1	11.36	2
5	All Parties related factors	11.65	6	10.24	5
6	Resources related factors	11.73	5	10.09	7
7	Contract related factors	10.64	7	10.14	6
8	External related factors	12.17	2	11.42	1
9	Force majeure-related factors	10.38	8	9.88	8

A. Owner-Related Factors

In terms of effects on time delay, delay in settlement of the contractor's claim by the owner is the most critical factor within this group, as it scored the highest RII compared to the other owner-related factors. Moreover, it is one of the top ten critical causes of time delay in this study, ranking ninth among the 43 factors. Moreover, the owner's financial difficulties is the tenth factor in the overall ranking of factors causing cost overruns. When the total effect on cost overruns and time delays was evaluated, owner-related factors ranked fourth among the nine categories.

B. Design-Related Factors

Design errors/incomplete or unclear design drawings and design variation scored the highest RII within this category, making it the most effective time delay and cost overrun cause among the designer-related factors. When evaluating the total effect on time delay and cost overrun, the designer-related factors as a group ranked last out of the nine categories based on their RIIs.

C. Consultant-Related Factors

Poor planning and management of the contractor's schedule scored the highest RII in this category, making it the most effective time delay and cost overrun cause among consultant-related factors. Moreover, it was the fifth biggest cause of time delay and cost overrun among the 43 factors considered. Consultant-related factors ranked third out of nine categories affecting time delay or cost overrun, based on their RIIs.

D. Contractor-Related Factors

Difficulties in project financing by the contractor scored the highest RII when studying time delay in the category of contractor-related factors and the entire study, making it the most critical time delay cause in marine construction. It also had the second-highest RII in the category in terms of effects on cost overrun, and the fifth overall. The factor with the highest effect on cost overrun within this category was incompetence or inexperience of contractor (lack of experience, and or managerial skills), which ranked third in the entire study, and fifth overall when studying time delay causes. Inadequate comprehension of the scope of work at the bidding stage came ninth in the entire study in terms of affecting cost overrun. In addition, contractor-related factors came first and second out of the nine categories affecting time delay and cost overrun, respectively, illustrating the criticality of factors in this group.

E. All Parties-Related Factors (Owner-Designer-Consultant-Contractor-…)

In terms of effects on time delay, the lack of effective communication among project stakeholders and ineffective management, planning, and scheduling of the project were ranked sixth and seventh, respectively, in the overall factor ranking according to their corresponding RII. Furthermore, the ineffective management, planning, and scheduling of the project ranked sixth in the overall ranking, making it the most effective cause of cost overrun. The factors related to all parties ranked sixth and fifth affecting time delay and cost overrun, respectively.

F. Resources-Related Factors (Materials-Labor-Machinery)

In terms of RII, the shortage of construction materials-special building materials not available in the local market scored the highest RII in the group, making it the most effective time delay and cost overrun cause amongst this category, followed by low productivity of labor. Among the nine categories, the resources-related factors came fifth and seventh for time delay and cost overrun, respectively.

G. Contract-Related Factors

The unrealistic cost and schedules/overestimating of benefits scored the highest RII values within the contract-related factors category in both cases, making it the most effective time delay and cost overrun cause amongst this category's factors. Moreover, it was the eighth factor in the overall ranking of cost overrun causes. The contract-related factors category came seventh and sixth out of the nine categories for time delay and cost overrun, respectively.

H. External-Related Factors

For time delay causes, inflation had the highest RII within this category, followed by fluctuation in cost, delay in permissions, approvals, and statutory compliance from authorities, and the existence of sanctions, which were second, fourth, eighth, and tenth highest in the entire study, respectively. For cost overrun causes, inflation had the highest RII within this category and the highest throughout the study, making it the most critical cost overrun cause. It was followed by fluctuation in cost and the existence of sanctions and (technical) inability to import essential goods, which were the second and seventh highest in the entire study, respectively. In addition, this category was the first and second highest, affecting cost overrun and time delay, respectively, showing its importance and criticality.

I. Force Majeure-Related Factors

When studying the effects on time delay, spreading of disease, epidemic or pandemic, had a nominal increase in RII compared to wars in the region, but for the cost overrun causes, the rank of the two groups was reversed. The whole category was eighth out of nine for time delay and cost overrun.

VIII. CONCLUSION

Marine construction projects are among the most significant human alterations to the environment. They are a specialized division of the construction sector with a high degree of risk and vast expenditures [39]. In [40, 41], marine projects were classified according to a complex spectrum. Such projects are associated with ambiguity and uncertainty, interdependency, non-linearity, unique local conditions, autonomy, emergent behaviors, and unfixed boundaries [42]. In [43], technological, organizational, goal, environmental, cultural, and information complexities were added to this list.

This study investigated 43 factors that influence time delays and cost overruns of marine construction projects in Egypt, Saudi Arabia, the United Arab Emirates, Kuwait, and Qatar. The probability of occurrence and impact of each factor was determined based on previous studies, expert judgments, and real project cases. In addition, the RII was used to rank the factors. The top five factors for both time delay and cost overrun, although ordered differently, were the same: inflation (e.g., material, equipment, and labor prices), fluctuation in cost (e.g., money exchange rate, taxes and burdens, and interest rates charged by bankers on loans), incompetence or inexperience of contractor (lack of experience, and/or managerial skills), poor planning and management of contractor's schedule, and difficulties in project financing by the contractor. The groups were ranked according to their RII, showing that the contractor-related factors had the highest RII for the time delay, followed by the external-related factors with an infinitesimal difference. However, the two groups' rankings were reversed for cost overruns.

The findings of this study can offer great benefits to various stakeholders operating in marine construction projects, as they offer a ranked list of the main causes of time delays and cost overruns. Therefore, stakeholders can better judge future endeavors in marine construction in a more precise manner, as time and cost can be utilized more effectively and efficiently when the most significant causes of time delay and cost overrun are avoided or taken into account. The outcome of this effort can be reduced project time delays and cost overruns, which in turn will contribute significantly to the economy. Future research can conduct case studies to examine the impact of identified time delays and cost overruns on the quality and life cycle of projects.

REFERENCES

[1] G. Robinson, "Global construction market to grow $8 trillion by 2030: driven by China, US and India," Oxford Economics, London, UK, 2015.

[2] J. Woetzel, N. Garemo, A. Dhabi, J. Mischke, P. Kamra, and R. Palter, "Bridging Infrastructure Gaps - Has the World Made Progress?," McKinsey Global Institute, 2017.

[3] C. N. Egwim, H. Alaka, L. O. Toriola-Coker, H. Balogun, and F. Sunmola, "Applied artificial intelligence for predicting construction projects delay," *Machine Learning with Applications*, vol. 6, Dec. 2021, Art. no. 100166, https://doi.org/10.1016/j.mlwa.2021.100166.

[4] F. de Querol Cumbrera, "U.S. construction industry share of GDP 2000-2023," *Statista*. https://www.statista.com/statistics/192049/value-added-by-us-construction-as-a-percentage-of-gdp-since-2007/.

[5] D. M. Matin, "Identifying The Effective Factors for Cost Overrun and Time Delay in Water Construction Projects," *Engineering, Technology & Applied Science Research*, vol. 6, no. 4, pp. 1062–1066, Aug. 2016, https://doi.org/10.48084/etasr.706.

[6] F. A. Shaikh, "Financial Mismanagement: A Leading Cause of Time and Cost Overrun in Mega Construction Projects in Pakistan," *Engineering, Technology & Applied Science Research*, vol. 10, no. 1, pp. 5247–5250, Feb. 2020, https://doi.org/10.48084/etasr.3271.

[7] S. Sohu, A. H. Abdullah, S. Nagapan, T. A. Rind, and A. A. Jhatial, "Controlling Measures for Cost Overrun Causes in Highway Projects of Sindh Province," *Engineering, Technology & Applied Science Research*, vol. 9, no. 3, pp. 4276–4280, Jun. 2019, https://doi.org/10.48084/etasr.2749.

[8] S. Nawar, O. Hosny, and K. Nassar, "Owner Time and Cost Contingency Estimation for Building Construction Projects in Egypt," pp. 367–377, Mar. 2018, https://doi.org/10.1061/9780784481271.036.

[9] A. H. Nassar, "Causes and Effects of Delay in the Construction Industry in Egypt," *International Journal of Engineering Research*, vol. 5, no. 4.

[10] V. W. Y. Tam and L. Shen, "Risk management for contractors in marine projects," *Organization, Technology and Management in Construction: An International Journal*, pp. 403–410, 2012.

[11] L. Y. Shen and V. W. Y. Tam, "Implementation of environmental management in the Hong Kong construction industry," *International Journal of Project Management*, vol. 20, no. 7, pp. 535–543, Oct. 2002, https://doi.org/10.1016/S0263-7863(01)00054-0.

[12] C. Kaliba, M. Muya, and K. Mumba, "Cost escalation and schedule delays in road construction projects in Zambia," *International Journal of Project Management*, vol. 27, no. 5, pp. 522–531, Jul. 2009, https://doi.org/10.1016/j.ijproman.2008.07.003.

[13] M. Gu and O. T. Gudmestad, "Treatment of Uncertainties, Risks And Opportunities In Cost And Schedule Estimates In the Early Phases of Offshore Projects," presented at The Twenty-second International Offshore and Polar Engineering Conference, Rhodes, Greece, Jun. 2012.

[14] A. Shrivas and H. K. Singla, "Factors Causing Delay in Marine Construction Projects in India," *i-manager's Journal on Civil Engineering,* vol. 8, no. 3, pp. 12–19, 2018, https://doi.org/10.26634/jce.8.3.14035.

[15] A. R. Valyani, N. Feghhi Farahmand, and S. Iranzadeh, "Risk assessment of marine construction projects using Taguchi Loss Function," *International Journal Of Coastal, Offshore And Environmental Engineering*, vol. 4, no. 3, pp. 33–42, Oct. 2019, https://doi.org/10.29252/ijcoe.3.3.33.

[16] M. H. Fallahnejad, "Delay causes in Iran gas pipeline projects," *International Journal of Project Management*, vol. 31, no. 1, pp. 136–146, Jan. 2013, https://doi.org/10.1016/j.ijproman.2012.06.003.

[17] R. Derakhshanalavijeh and J. M. C. Teixeira, "Cost overrun in construction projects in developing countries, Gas-Oil industry of Iran as a case study," *Journal of Civil Engineering and Management*, vol. 23, no. 1, pp. 125–136, Jan. 2017, https://doi.org/10.3846/13923730.2014.992467.

[18] N. V. Thuyet, S. O. Ogunlana, and P. K. Dey, "Risk management in oil and gas construction projects in Vietnam," in *Risk Management in Engineering and Construction*, Routledge, 2019.

[19] M. Ruqaishi and H. A. Bashir, "Causes of Delay in Construction Projects in the Oil and Gas Industry in the Gulf Cooperation Council Countries: A Case Study," *Journal of Management in Engineering*, vol. 31, no. 3, May 2015, Art. no. 05014017, https://doi.org/10.1061/(ASCE)ME.1943-5479.0000248.

[20] A. Bin Seddeeq, S. Assaf, A. Abdallah, and M. A. Hassanain, "Time and Cost Overrun in the Saudi Arabian Oil and Gas Construction Industry," *Buildings*, vol. 9, no. 2, Feb. 2019, Art. no. 41, https://doi.org/10.3390/buildings9020041.

[21] M. A Kassem, M. A. Khoiry, and N. Hamzah, "Assessment of the effect of external risk factors on the success of an oil and gas construction project," *Engineering, Construction and Architectural Management*, vol. 27, no. 9, pp. 2767–2793, Jan. 2020, https://doi.org/10.1108/ECAM-10-2019-0573.

[22] M. A Kassem, M. A. Khoiry, and N. Hamzah, "Theoretical review on critical risk factors in oil and gas construction projects in Yemen," *Engineering, Construction and Architectural Management*, vol. 28, no. 4, pp. 934–968, Apr. 2021, https://doi.org/10.1108/ECAM-03-2019-0123.

[23] M. El Shehaby, M. Abdel-Hamid, and K. El-Dash, "Risk Assessment for Off-Shore Petroleum and Gas Construction Projects in Egypt," *Engineering Research Journal (Shoubra)*, vol. 51, no. 4, pp. 61–74, Oct. 2022, https://doi.org/10.21608/erjsh.2022.147582.1054.

[24] M. A. Ashtari, R. Ansari, E. Hassannayebi, and J. Jeong, "Cost Overrun Risk Assessment and Prediction in Construction Projects: A Bayesian Network Classifier Approach," *Buildings*, vol. 12, no. 10, Oct. 2022, Art. no. 1660, https://doi.org/10.3390/buildings12101660.

[25] A. Balali, R. C. Moehler, and A. Valipour, "Ranking cost overrun factors in the mega hospital construction projects using Delphi-SWARA method: an Iranian case study," *International Journal of Construction Management*, vol. 22, no. 13, pp. 2577–2585, Oct. 2022, https://doi.org/10.1080/15623599.2020.1811465.

[26] M. S. Islam, S. R. Mohandes, A. Mahdiyar, A. Fallahpour, and A. O. Olanipekun, "A Coupled Genetic Programming Monte Carlo Simulation–Based Model for Cost Overrun Prediction of Thermal Power Plant Projects," *Journal of Construction Engineering and Management*, vol. 148, no. 8, Aug. 2022, Art. no. 04022073, https://doi.org/10.1061/(ASCE)CO.1943-7862.0002327.

[27] J. Lerche *et al.*, "Causes of delay in offshore wind turbine construction projects," *Production Planning & Control*, vol. 34, no. 15, pp. 1513–1526, Nov. 2023, https://doi.org/10.1080/09537287.2022.2026673.

[28] A. Gondia, A. Siam, W. El-Dakhakhni, and A. H. Nassar, "Machine Learning Algorithms for Construction Projects Delay Risk Prediction," *Journal of Construction Engineering and Management*, vol. 146, no. 1, Jan. 2020, Art. no. 04019085, https://doi.org/10.1061/(ASCE)CO.1943-7862.0001736.

[29] M. Gebrel, K. A. Assaf, A. Atef, and M. Awad, "Causes of Delay and Cost Overrun for Educational Building Projects in Egypt," *JES Journal of Engineering Sciences*, vol. 49, no. 5, pp. 577–596, Jun. 2021, https://doi.org/10.21608/jesaun.2021.69258.1044.

[30] R. M. Johnson and R. I. I. Babu, "Time and cost overruns in the UAE construction industry: a critical analysis," *International Journal of*

Construction Management, vol. 20, no. 5, pp. 402–411, Sep. 2020, https://doi.org/10.1080/15623599.2018.1484864.

[31] M. Welde and O. J. Klakegg, "Avoiding Cost Overrun Through Stochastic Cost Estimation and External Quality Assurance," *IEEE Transactions on Engineering Management*, vol. 71, pp. 1984–1997, 2024, https://doi.org/10.1109/TEM.2022.3173175.

[32] A. Kamal, M. Abas, D. Khan, and R. W. Azfar, "Risk factors influencing the building projects in Pakistan: from perspective of contractors, clients and consultants," *International Journal of Construction Management*, vol. 22, no. 6, pp. 1141–1157, Apr. 2022, https://doi.org/10.1080/15623599.2019.1683693.

[33] Silvianita, R. B. Sidiq, and C. Utomo, "The analysis of delay factors on the construction of submerged turret production buoy structure," *IOP Conference Series: Earth and Environmental Science*, vol. 1198, no. 1, Mar. 2023, Art. no. 012030, https://doi.org/10.1088/1755-1315/1198/1/012030.

[34] Z. M. Yaseen, Z. H. Ali, S. Q. Salih, and N. Al-Ansari, "Prediction of Risk Delay in Construction Projects Using a Hybrid Artificial Intelligence Model," *Sustainability*, vol. 12, no. 4, Jan. 2020, Art. no. 1514, https://doi.org/10.3390/su12041514.

[35] R. F. Herrera, O. Sánchez, K. Castañeda, and H. Porras, "Cost Overrun Causative Factors in Road Infrastructure Projects: A Frequency and Importance Analysis," *Applied Sciences*, vol. 10, no. 16, Jan. 2020, Art. no. 5506, https://doi.org/10.3390/app10165506.

[36] S. F. Olejnik, "Planning Educational Research: Determining the Necessary Sample Size," *The Journal of Experimental Education*, vol. 53, no. 1, pp. 40–48, Sep. 1984, https://doi.org/10.1080/00220973.1984.10806360.

[37] J. C. Nunnally, *Psychometric theory*. 3rd ed. McGraw-Hill Education, 1994.

[38] J. M. Cortina, "What is coefficient alpha? An examination of theory and applications," *Journal of Applied Psychology*, vol. 78, no. 1, pp. 98–104, 1993, https://doi.org/10.1037/0021-9010.78.1.98.

[39] K. D. Johnson and C. B. Tatum, "Technology in Marine Construction Firms," *Journal of Construction Engineering and Management*, vol. 119, no. 1, pp. 148–162, Mar. 1993, https://doi.org/10.1061/(ASCE)0733-9364(1993)119:1(148).

[40] H. Karami and O. A. Olatunji, "Contractor selection model for marine projects," in *42nd AUBEA Conference 2018: Educating Building Professionals for the Future in the Globalised World*, 2018, pp. 27–37.

[41] H. Karami and O. A. Olatunji, "Key success factors in marine infrastructures, a review," in *42nd AUBEA Conference 2018: Educating Building Professionals for the Future in the Globalised World*, 2018, pp. 121–128.

[42] J. Bakhshi, V. Ireland, and A. Gorod, "Clarifying the project complexity construct: Past, present and future," *International Journal of Project Management*, vol. 34, no. 7, pp. 1199–1213, Oct. 2016, https://doi.org/10.1016/j.ijproman.2016.06.002.

[43] Q. He, L. Luo, Y. Hu, and A. P. C. Chan, "Measuring the complexity of mega construction projects in China-A fuzzy analytic network process analysis," *International Journal of Project Management*, vol. 33, no. 3, pp. 549–563, Apr. 2015, https://doi.org/10.1016/j.ijproman.2014.07.009.