International Journal of Sciences: Basic and Applied Research (IJSBAR)

ISSN 2307-4531
(Print & Online)

http://gssrr.org/index.php?journal=JournalOfBasicAndApplied

Preliminary Study of Risk Factors in Marine Construction Projects in Saudi Arabia

Abdulrahman Alansari[a]*, Tang-Hung Nguyen[b]

[a]*Dept. of Mathematical Sciences, Claremont Graduate University, 150 E. 10th street, Claremont, CA 91711*
[b]*Dept. of Civil Engr. & Construction Engr. Management, CalState Long Beach, 1250 Bellflower Blvd., Long Beach, CA*
[a]*Email: Abdulrahman.alansari@cgu.edu*
[b]*Email: hung.nguyen@csulb.edu*

Abstract

Marine-construction projects are becoming increasingly important for the development of the maritime industry. However, such increases are hampered by various risks that can significantly impact growth. Natural forces, political events, administrative and operational mistakes, equipment failures, external attacks such as arson, and economic events are some of the major risks faced by firms in this industry. Researchers have paid little attention to marine-construction risk assessment, despite the importance of such research. This study sought to investigate risks associated with marine construction projects. A questionnaire survey tool was conducted in this study targeting expertise in Saudi Arabian marine-construction industry resulting in a response rate of 62.5%. Participants were asked to rate the occurrences and impacts on project' safety, schedule, and cost of 37 identified marine construction risk factors. Reliability of gathered data, correlation among the variables, and risk score analyses were performed in this study. The findings of this study indicated that "Unskilled Contractor Labor" had the highest risk scores on marine-construction projects. The study recommends that the marine-construction industry should conduct additional studies to investigate and evaluate risks aspects.

Keywords: Marine construction projects; risk factors; risk assessment.

---

* Corresponding author.

1. Introduction

Marine-construction projects are becoming increasingly important for the development of the maritime industry. However, various risks hamper such increases and significantly impact growth. Natural forces, political events, administrative and operational mistakes, equipment failures, external attacks such as arson, and economic events are some of the main causes of risks that firms face in this industry. In the past, researchers have paid little attention to risk assessment for marine construction projects. This paper presents a preliminary study of risk aspects in the marine construction industry. This study aims to classify, identify, and evaluate risk factors in Saudi Arabian marine construction projects to help managers mitigate project risks and the possibility to develop contingency plans for the tasks that have the highest risk factors.

1.1. Overview of Marine Structures

The marine industry is quite broad; a single research study cannot provide a comprehensive discussion. Marine structures are very important for the development of the maritime industry. All players in this industry rely on ports, harbors, jetties, and other structures to ensure their products move from one location to the other. Marine structures are engineering facilities constructed and installed in coastal zones or open oceans for the exploitation of various marine resources and the maintenance of its continuous operations [1]. Marine structures can be classified according to their functions and characteristics, their installation on the marine environment, or their purposes and uses. Reference [1] grouped marine structures into three types based on their functions and characteristics: coastal, offshore, and deep-ocean structures, shown in Table 1.

Table 1: Marine structures classification according to their functions and characteristics

Coastal structures	Offshore structures	Deep-ocean structures
Breakwater (vertical wall, sloping structure, and composite type)	Fixed structures: jacket platform, tower-type platform (spar platform), and gravity platform	Deep sea manned submersible
Gravity-type piers, pile-foundation piers, and floating piers	Movable structures: jack-up platform, bottom-supported platform, semisubmersible platform, and floating drilling ship	
Seawalls (vertical wall, sloping, and composite)	Complimentary structures: tension-leg platform and guyed-tower platform	
Groins	Mooring system facilities: single-anchor-leg-mooring system and catenary-anchor-leg-mooring system	
Tidal gate	Submarine facilities: subsea pipeline, seabed wellhead template, and submarine tunnel	
Submarine tunnel	Artificial islands: very large floating structures and gravity type artificial islands	

Note. From Environmental and Engineering Geology, Vol. II. Marine Structures and Materials, by Y. Li & L. Li, 2011, Abu Dhabi, United Arab Emirates: Encyclopedia of Life Support Systems, p. 274.

In addition, Reference [1] classified marine structures into fixed, movable (or floating structures), and complimentary structures. Table 2 illustrates the description of these three types of marine structures.

Table 2: Marine structures classification

Marine structures	Description	Example
Fixed structures	Fixed on the seabed on a long-term basis using piles or the gravity of structures	Gravity type (breakwater, pier, groin, seawall, concrete platform), jacket platform, submarine pipeline, submarine tunnel, and various types of artificial islands
Movable structures	Can be operated at different locations by the operation of fixing position, floating, sinking, and removal	Floating type (breakwater, and pier), jack-up drilling platform, bottom-supported platform, semisubmersible platform and various types of specially designed boats.
Complimentary structures	Partially fixed by using guyed cable, tension facilities, and universal joints to limit and control the six degrees of freedom of movement induced by various environmental forces. Complimentary structures are vertically anchored and often oriented using flexible members.	Tension-leg platform, guyed-tower platform, and articulated tower platform.

Note. From Environmental and Engineering Geology, Vol. II. Marine Structures and Materials, by Y. Li & L. Li, 2011, Abu Dhabi, United Arab Emirates: Encyclopedia of Life Support Systems, p. 274.

Moreover, different materials such as concrete, stone, timber, and steel have been used to construct marine structures [1]. Generally, marine structures need to be designed to resist various loads such as service loads, loads from ships, and loads generated by the impact of sea waves. Thus, according to the purpose of the marine structures, they can be classified as berthing facilities, dry-docking facilities, and coastal-protection structures. Table 3 summarizes each type and its purposes with examples.

Table 3: Marine structures classification according to their purposes

Marine structure type	Purposes	Example
Berthing facilities	Provides support for ships, facilitates goods and passenger movements between ships and land transportation. Constructed normal to the shore and parallel to the shore.	Piers (open pier, closed pier, and floating pier), wharves.
Dry-docking facilities	Used to build ships and inspect, maintain, repair, and modify ships	Floating dry dock, graving dry dock, vertical synchronized lifts, and marine railways.
Coastal-protection structures	Provide a barrier between sea waves and structures such as harbors to avoid detrimental effects of sea waves like erosion.	Bulkheads, seawalls, groins, jetties, and breakwaters.

Note. From Environmental and Engineering Geology, Vol. II. Marine Structures and Materials, by Y. Li & L. Li, 2011, Abu Dhabi, United Arab Emirates: Encyclopedia of Life Support Systems, p. 274.

1.2. Significance of the study

About two thirds of the Earth are covered in water. Such a percentage of water opens many opportunities, such as developing travel routes, connecting the world, transporting goods, and trade. But making use of two thirds of earth is a challenging task. Building infrastructure on water is quite different from constructing structures on land. The engineers who attempt to do so not only face the general issues of schedules and budget, but also must tolerate a list of constraints and problems that have to be solved effectively and efficiently. This study presents a risk assessment for marine construction projects that firms can use to manage various risks in marine-construction projects as they emerge. This study also provides policymakers informed decisions when trying to regulate the marine-construction industry. In addition, scholars interested in conducting further studies on risk aspects of the marine-construction industry can benefit from this study significantly.

2. Literature review

Project risk is the potential threat or problem in the completion of a specific task whose occurrence may affect set project goals [2]. These risks are inherent in all projects, and thus, can never be eliminated fully, although they can be managed efficiently to alleviate impacts to the attainment of project goals [2]. Risk management is a systematic approach to manage forces that may negatively impact firms when adverse events occur. Effective risk management in an organization is a vital management tasks that can help in achieving success in major construction projects [3]. Risk management has become a critical aspect of administrative activities in the construction industry. Researchers have proposed various risk-management approaches. Some of the most well-known methods are Project Risk Analysis and Management [4], Risk Analysis and Management for Projects [5], Risk Management Solutions [6], and Project Management Body of Knowledge [7]. An efficient risk-management system should bring various major advantages to organizations [8]. One major benefit is that a risk-management system should facilitate systematic and objective decision-making in an organization when risk occurs. The system should make it possible to compare the robustness of various projects with specific uncertainties. The system should also enable project managers to rank the relative importance of various immediate risks and should offer an improved understanding of specific projects by identifying risks before they can have a devastating impact on an organization. A risk-management system should also be capable of demonstrating a company's responsibilities to customers. Finally, it should enhance the corporate experience and effective communication. The marine-construction industry is unique in numerous ways, but so are the risks, which have the potential to catastrophically affect projects that are being undertaken. It is elementary to discern the high risks associated with marine construction [8]. Usually, handling offshore construction risks requires an additional (and large) amount of funds because considerable delays in time and the quality of the structure may be negatively affected [9]. When off-shore construction is underway, it suffers a greater chance of being exposed to potentially damaging risks, specifically, during the time materials and other necessities are being transported to the offshore construction site and when the equipment is being installed. Most projects in marine construction industry are subjected to numerous risks that may have environmental, financial, health, and many other consequences, if not managed properly. Fire outbreak, explosions, leakages, and accidents that may lead to human injury are common when undertaking such projects. Moreover, risks of delays may result in significant financial consequences. It is difficult to predict some risks and impossible to avoid them completely. For this reason, many firms develop risk management plans. These plans involve identifying risk factors, evaluating predictable consequences on a project's objectives, and creating mitigation plans to overcome the identified risk factors.

3. Research tasks

In this study, there are three tasks. the first one is Risk classification; this task involves classifying risks according to their origins. The second task is Risk identification. In this task risk factors are identified using literature review and the final task is Statistical methods. These tasks are presented in the following sub-sections.

3.1. Risk classification

Through a literature review, numerous marine-construction risk factors were identified. Some of these risks are caused by natural forces such as flooding, cyclones, earthquakes, and massive amounts of rainfall, among other forces which are directly outside human control. Risks may also align with human error. Gross negligence and violation of set safety rules and procedures may result in a major accident in marine-construction projects. Defects in the equipment or failure of the equipment to function as required may also cause accidents when undertaking such projects. Market forces may also impact a project, such as a sudden increase in the international prices of various materials used in the construction [10]. In such cases, price increases may force a project owner to inject more resources into the project to meet the increased costs of operations. Reference [8] found that “underwater conditions are different from tender assumptions”, suggesting that this risk was the most common risk factor associated with marine projects, and the “unavailability of materials, plant and labor” had the most impact to the project if risk was encountered. Inflation is another high-risk factor in major projects, especially when materials need to be imported. A Risk Breakdown Structure was constructed in this research to organize the different categories of project risk as shown in Figure 1. The proposed RBS shows risk groups, risk categories, and risk subcategories at the lowest level. Project risks were categorized based on their source (either internal or external). Internal risks are those generated from project stakeholders and external risks are those risks that come from sources others than the project’s stakeholders. Internal and external risks are then classified according to the party who might be the originator of risk events, such as owner, designer, contractor. A comprehensive review of related literature from textbooks, professional journals, conference proceedings, academic journals, dissertation reports, magazines, newsletters, and Internet materials, was conducted to gain background knowledge about the marine-construction industry and related issues, specifically risk features. In this study, a compilation of all the risks identified by researchers in the past was tabulated in Table 4. This list of 48 risk factors as then used as a reference platform for designing the survey questionnaire in support of this study. The factors are listed in no specific order of importance.

3.2. Risk identification

The comprehensive list of 48 risk factors was combined and reduced to 37 questions presented in Survey Questionnaire (Table 5). The risks were classified into two main categories, internal or external risks, and then divided into eight sub-categories as shown in Table 5. The survey questionnaire technique was selected in this study to collect data due the following reasons: the survey method is inexpensive compared to other techniques, saves researchers and respondents time, provides privacy for participants, provides respondents with readable and understandable context of questions, and removes interviewer expectations from respondents [11]. In addition, questionnaires are an effective tool in constructing a survey to collect data remotely from respondents, and to sample participants' responses in different locations [11]. Generally, researchers design questionnaires to obtain data from participants by choosing a set of answers for each question. **Reference** [12] states that risks can be assessed by their probabilities of occurrence and their consequences. An effective method to assess the significance of a risk is the evaluation of the probability of occurrence and potential impact the risk would have on a marine-construction project. Thus, the questionnaire was structured to determine occurrence frequency and the actual impact of identified risks. The primary data collected from the survey questionnaire helped to understand how practitioners in this industry perceived risk factors. The questionnaire had three parts. The first part was designed to capture participants' information such as a participant's role, level of education, and personal experience.

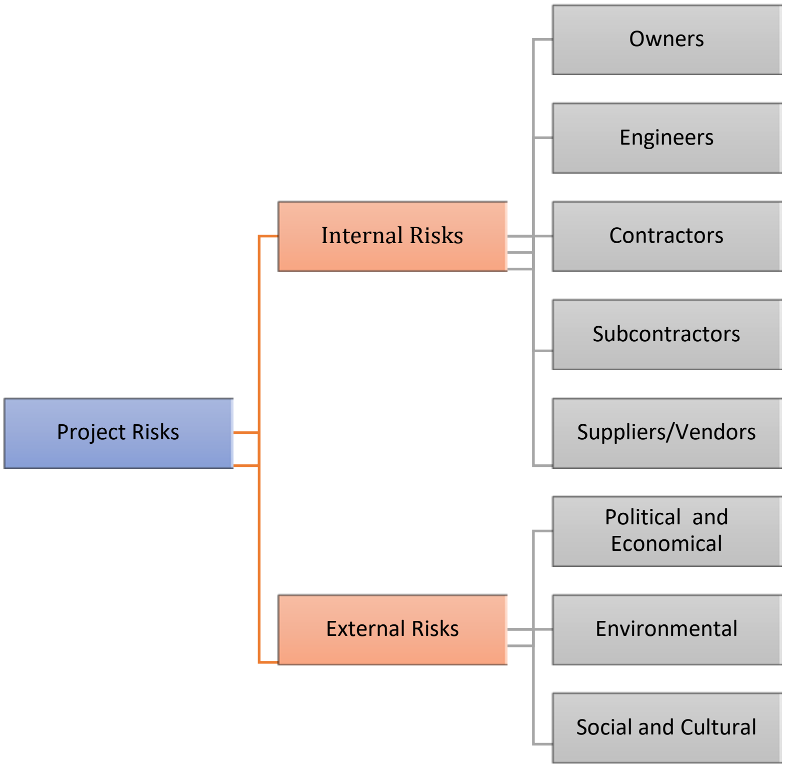


Figure 1: Proposed risk breakdown structure

The second part of the questionnaire gathered data on the risk factors inherent in the execution of marine projects. In the third part of the questionnaire, data on the impacts of the identified risk factors on project cost, time, and safety was sought. A 5-point Likert-type scale was employed as a measurement scale to evaluate the frequency of occurrences and the impacts of identified risk factors. In considering occurrence frequency, respondents judged the likelihood of risk occurrence by selecting one of five proposed levels: 1 (very low), 2 (low), 3 (moderate), 4 (high), and 5 (very high). For severity impacts on project time, cost, and safety, respondents judged the degree of loss if a specific risk occurred by selecting one of five options: 1 (very low), 2 (low), 3 (moderate), 4 (high), and 5 (very high).

3.3. Statistical methods

The collected data was accrued and analyzed using Microsoft Excel and R software to perform the following descriptive and inferential statistics.

3.3.1. Reliability

To ensure the reliable testing of data, the Cronbach's alpha method was used. Cronbach's alpha is the most common measure of internal consistency reliability. It is most commonly used when researchers use multiple Likert-type questions to form a scale and must determine the reliability of the scale [13]. Cronbach's basic equation for alpha [14] follows:

$$\alpha = \frac{n}{n-1}\left(1 - \frac{\Sigma V_i}{V_t}\right) \tag{1}$$

Where,

n = number of questions

V_i = variance of scores on each question

V_t = variance of test scores

3.3.2. Correlation Coefficient

The correlation coefficient measures the strength of association between two variables. The Pearson coefficient method was used in this study to measure the relationship between frequency of risks and the impact of risks. Pearson's *r* is the most widely used statistic when describing the relationship between variables. The correlation coefficient is computed using the following formula [15].

$$r = \frac{\sum_{i=1}^{n}(X_i-\bar{X})(Y_i-\bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i-\bar{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i-\bar{Y})^2}} \tag{2}$$

Where,

r = Pearson's coefficient of correlation,

n = Number of data sets,

X_i = Frequency of occurrence of risks,

Y_i = Impact of risk on project objectives,

$\bar{X}$ and $\bar{Y}$ = Mean of frequency and impact data.

Table 4: Identified marine construction risk factors by researchers in the past

Accidents
Bureaucracy of government
Criminal acts
Delays in documents approval
Ecological damage
Contagious diseases
Poor site management and supervision
Contractor’s financial difficulties
Severe weather condition
Design errors
Social/cultural common policy
Subcontractors interference
Technical problems with vendors/suppliers
Delay in land/water acquisition or site access
Environment pollution
Equipment unavailability
Force majeure events
High/low tide
Improper underwater conditions
Inadequate/unclear definition of project scope
Incompetence of subcontractors
Labor strikes
Low technical standards
Vendors/suppliers lack of quality

Loading/Unloading of material
Low productivity
Contractors’ lack of experience/trained staff
Manpower unavailability
Contractor’s bankruptcy
Poor material selection
Delay in work/labor permits, licenses
Unreliability of construction equipment
Unskilled labor
Construction errors
Breach of agreements between countries
Changes in country laws
Conflicts of government laws
Delay of material supply by vendor/supplier
Fluctuating currencies exchange rates
Frequent change of subcontractors
High waves
Improper construction methods implemented
Inadequate port facilities
Inappropriate vendor list
Inconsistencies in government policies
Inflation in material prices more than estimated
Lack of attention to environmental international laws and regulations
Lack of coordination between project participants

Table 5: Classification of identified risk factors

Risk ID	Risk factor	Source	Category
RF1	Inadequate/unclear definition of project scope	Owner	Internal Risks
RF2	Delay in Work/Labor Permits, Licenses	Owner	Internal Risks
RF3	Delay in Land/Water Acquisition or Site Access	Owner	Internal Risks
RF4	Lack of coordination between project participants	Owner	Internal Risks
RF5	Design errors	Engineer/Designer	Internal Risks
RF6	Delay in Documents Approval	Engineer/Designer	Internal Risks
RF7	Improper Underwater Condition	Engineer/Designer	Internal Risks
RF8	Equipment Unavailability	Contractor	Internal Risks
RF9	Contractors’ Lack of experience/trained staff	Contractor	Internal Risks
RF10	Unskilled Labor	Contractor	Internal Risks
RF11	Manpower Unavailability	Contractor	Internal Risks
RF12	Low Productivity	Contractor	Internal Risks
RF13	Construction errors	Contractor	Internal Risks
RF14	Accidents	Contractor	Internal Risks
RF15	Contractor’s Financial difficulties	Contractor	Internal Risks
RF16	Unreliability of Construction Equipment	Contractor	Internal Risks
RF17	Loading/unloading of material	Contractor	Internal Risks
RF18	Poor site management and supervision	Contractor	Internal Risks
RF19	Frequent change of sub-contractors	Contractor	Internal Risks
RF20	Improper construction methods implemented	Contractor	Internal Risks
RF21	Contractor’s Bankruptcy	Contractor	Internal Risks
RF22	Subcontractors interferences	Sub-Contractors	Internal Risks
RF23	Incompetence of Subcontractors	Sub-Contractors	Internal Risks
RF24	Delay of material Supply by Vendor/supplier	Supplier/Vendor	Internal Risks
RF25	Technical problems with Vendors/suppliers	Supplier/Vendor	Internal Risks
RF26	Poor Material Selection	Supplier/Vendor	Internal Risks
RF27	Laws & Regulations Change	Politics/Economics	External Risks
RF28	Inflation for Material Price more than estimated	Politics/Economics	External Risks
RF29	Fluctuating currencies exchange rates	Politics/Economics	External Risks
RF30	Inconsistencies in government policies	Politics/Economics	External Risks
RF31	Sever weather condition	Environment	External Risks
RF32	Environment Pollution	Environment	External Risks
RF33	Ecological Damage	Environment	External Risks
RF34	Social/Culture Common Policy	Social/Culture	External Risks
RF35	Contagious diseases	Social/Culture	External Risks
RF36	Criminal acts	Social/Culture	External Risks
RF37	Bureaucracy of government	Social/Culture	External Risks

3.3.3. Risk analysis

Data compiled from respondents was analyzed using the multi-attribute analysis method. The multi-attribute analysis method was devised by [16] based on the Multi-Attribute Approach of Chang and Ive (2002), Reference [17]. The Multi-Attribute Analysis was used and adapted by several researchers [18, 19]. The analysis involved computing the mean rating (MR) of respondents' ratings, using the following formula:

$$\mathbf{MR} = \sum_{i=1} \boldsymbol{a_i b_i} \tag{3}$$

Where;

a_i: proportions of the responses associated with a rating point,

b_i: Likert-type rating points from 1 (the lowest scale) to 5 (the highest scale).

Risk score.

Researchers use a mean rating analysis to evaluate respondents' rating on the rating scale used for the frequency of occurrences and impacts of an identified variable. The risk-score formula used in the calculation was adapted by [17] from the qualitative risk-analysis procedure recommended in the Project Management Body of Knowledge [7].

$$\mathrm{RS_i = MR(Freq)_i \times MR(Severity)_i} \tag{4}$$

Where;

$\mathrm{RS_i}$: Risk score for identified risk factor i

$\mathrm{MR(Freq)_i}$: Mean rating of frequency ccurrence for each risk factor i

$\mathrm{MR(Severity)_i}$: Mean rating of severity impact for each risk factor i

Assessing the total severity impacts of identified risk factors:

The decision on total-severity impacts of identified risk factors can be taken based on risk attitude decisions. Three attitudes generaly control the decisions are pessimistic, most likely, or optimistic decisions. In this study, the pessimistic risk attitude was conducted using the following formulas:

$$SI(Pes) = Max[Time\ Impact(TI), Cost\ Impact(CI), Safety\ Impact(SI)] \tag{5}$$

Thus, the mean ratings for severity impact based on pessimistic decisions were computed as:

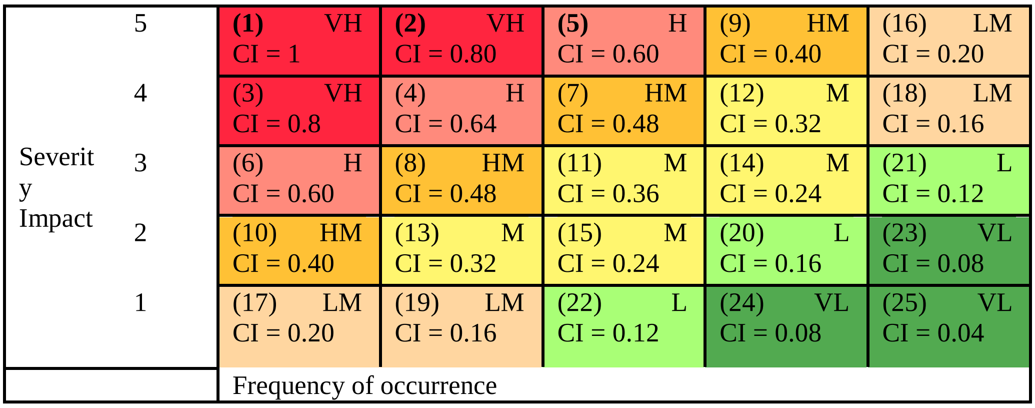
$$\mathrm{MR(Severity) = Max[MR(Schedule\ impact), MR(Cost\ impact), MR(Safety\ impact)]} \tag{6}$$

Risk level:

An impact-frequency (I-F) chart was used in the risk analysis to enable classification of risk factors based on their risk scores, computed from impact and frequency ratings. The (I–F) chart was designed as shown in Figure 2; it is a modification of the probability and impact matrix of the Project Management Book of Knowledge [7], which classifies the risk level of a risk factor as low, moderate, or high. Moreover, [17] extended the three-band set of risk categories to a five-band set to present solid discrimination of the risks based on risk scores. However, the five classes of risk level were extended in this study to seven categories to provide strong clustering of risks based on their risk scores. Figure 2 shows a matrix of 5 X 5 rating scales for each dimension of impact and occurrence frequency giving 25 cells as possible intersections. Thus, the risk level for each risk can be computed as:

$$\mathrm{CI_i} = \frac{\mathrm{RS_i}}{25} \qquad (7)$$

Table 6: provides classification of risk levels based on I-F Figure 2.



Severity Impact	5	**(1)** VH CI = 1	**(2)** VH CI = 0.80	**(5)** H CI = 0.60	(9) HM CI = 0.40	(16) LM CI = 0.20
	4	(3) VH CI = 0.8	(4) H CI = 0.64	(7) HM CI = 0.48	(12) M CI = 0.32	(18) LM CI = 0.16
	3	(6) H CI = 0.60	(8) HM CI = 0.48	(11) M CI = 0.36	(14) M CI = 0.24	(21) L CI = 0.12
	2	(10) HM CI = 0.40	(13) M CI = 0.32	(15) M CI = 0.24	(20) L CI = 0.16	(23) VL CI = 0.08
	1	(17) LM CI = 0.20	(19) LM CI = 0.16	(22) L CI = 0.12	(24) VL CI = 0.08	(25) VL CI = 0.04
		Frequency of occurrence				

Figure 2 impact-frequency (I-F) chart.

VH= very high level, H = High, HM = high medium, M = medium, LM = low medium, L= low, VL = very low; CI = critical index.

Table 6: Classification of criticality index based on the impact-frequency chart

Criticality index	Risk level
0.80–1.00	Very High (VH)
0.60–0.79	High (H)
0.50–0.59	Highly Moderate (HM)
0.31–0.49	Moderate (M)
0.20–0.30	Lowly Moderate (LM)
0.10–0.19	Low (L)
0.00–0.09	Very Low (VL)

4. Research results

Table 7: Respondents profile distribution

Metrics	Frequency	Proportions %
Professional position		
Professor	1	4
Project/field Engineer	7	28
Project Manager	6	24
Project Director	3	12
Senior Engineer	4	16
HSE Manager	2	8
Division Manager	1	4
HSE Supervisor	1	4
Total	25	100
Academic qualification		
Bachelor’s degree	18	72
Master’s degree	6	24
Doctoral’ degree	1	4
Total	25	100
Years of experience in construction industry		
Less than 10 years	10	40
10–19 years	11	44
20–29 years	2	8
30–40 years	2	8
More than 40 years	0	0
Total	25	100
Working number of marine construction projects		
Less than 5 Projects	19	76
5–9 Projects	3	12
10–14 Projects	2	8
15–20 Projects	0	0
More than 20 Projects	1	4
Total	25	100
Contract types mostly used in marine construction projects		
Lump sum	20	80
Unit price	3	12
Cost plus	0	0
Target cost	2	8
Total	25	100

A total of 40 questionnaires was distributed through e-mail and through the professional online questionnaire platform www.docs.google.com. These questionnaires targeted professionals in the Saudi Arabian marine-construction industry. 25 valid responses were received, resulting in a response rate of 62.5%. Reliability and internal consistency checks were carried out using Cronbach’s α on the 37 constructs in the questionnaire to assess their suitability for analysis. α values greater than 0.7 are regarded as sufficient [20].

Table 8: Correlation between occurrence and impacts of risk factors

Risk occurrence	Safety impact	Schedule impact	Cost impact
RF1	-0.086	-0.343	-0.097
RF2	0.279	-0.232	-0.258
RF3	0.311	-0.030	0.037
RF4	0.195	0.055	-0.132
RF5	0.235	0.033	0.045
RF6	**0.542**	-0.104	-0.109
RF7	0.198	0.006	0.037
RF8	0.369	0.136	0.096
RF9	0.275	0.083	0.132
RF10	0.319	-0.056	-0.026
RF11	0.348	0.104	0.050
RF12	0.297	0.133	0.243
RF13	0.297	-0.111	-0.044
RF14	0.276	-0.003	0.271
RF15	**0.414**	**0.446**	**0.428**
RF16	-0.021	0.013	-0.189
RF17	0.248	-0.012	0.148
RF18	0.325	0.360	**0.406**
RF19	-0.086	0.238	-0.049
RF20	**0.422**	0.322	0.271
RF21	0.136	0.024	0.031
RF22	0.341	0.269	0.227
RF23	0.415	0.002	-0.041
RF24	-0.041	0.341	0.252
RF25	0.037	0.381	0.340
RF26	0.207	-0.052	0.103
RF27	0.171	0.349	0.113
RF28	0.284	-0.041	0.233
RF29	**0.520**	**0.538**	0.238
RF30	0.141	0.396	0.201
RF31	0.277	0.222	0.384
RF32	**0.444**	**0.485**	**0.517**
RF33	**0.478**	0.326	0.334
RF34	**0.441**	0.377	**0.417**
RF35	-0.021	0.197	0.098
RF36	0.124	0.207	0.283
RF37	0.211	0.378	0.142

Note. MR = mean rating, Freq. = frequency, TI = schedule impact, CI = cost impact, SI = safety impact, Pes = pessimistic decision, RS = risk score, CI = risk criticality index, RF = risk factor, RL = risk level.

Cronbach's coefficient α was 0.910, which was higher than the 0.7 threshold and thus indicated the reliability of the 5-point measurement scale at the 5% significance level.

Table 7 shows a profile of respondents to the questionnaire survey. A reasonable range of responses emerged across the major professions including 24% responses from project managers, 12% responses from project directors, and 8% from health, safety, and environmental managers.

The results also indicated a diverse set of academic backgrounds among usable responses received, as almost 72% had bachelor's degree whereas 24% had a master's degree.

Moreover, Pearson coefficient of correlations between frequency of occurrences and impacts of the identified risk factors are presented in Table 8.

The coefficient of correlation values indicate that there are positive and negative relationships between the frequency and the impacts on project safety, schedule, and cost of the identified risk factors. To assess the identified risk factors, data were generated from 25 responses and analyzed using R software.

Table 9 below shows risk analysis results including mean ratings for occurrence, schedule, cost and safety impacts provided by respondents, computed severity impacts, risk scores, criticality indexes, and risk levels for the identified risk factors.

According to the risk analysis, the top critical risk factors in marine construction projects in Saudi Arabia are as show in Table 10. The results show that 'unskilled labor', 'lack of experience/trained staff', and 'manpower unavailability' have the highest critical indexes among the other risk factors, and their risk levels have been classified as a highly moderate level.

This means that these risk factors occurred frequently in most of the marine construction projects in SA and they produce moderate/high impacts on project' objectives. Moreover, this result shows that the necessary knowledge and data about marine construction industry is vague to the most of marine construction firms in Saudi Arabia. Moreover, the most frequently occurring risk factors in marine construction projects in Saudi Arabia are tabulated in Table 11.

The top risk factors that have severe impacts on projects' safety, schedule, and cost if they occurred are shown in Tables 12, 13, and 14 respectively.

Table 9: Risk analysis results

Risk ID	**MR (Freq.)**	**MR (T1)**	**MR (CI)**	**MR (SI)**	**SI (Pes)**	**RS**	**CI**	**RL**
RF24	3.00	3.960	3.280	1.880	3.960	11.88	0.4752	M
RF14	2.76	3.480	3.360	3.840	3.840	10.60	0.4239	M
RF11	3.32	3.800	3.320	2.680	3.800	12.62	0.5046	HM
RF9	3.36	3.280	3.200	3.760	3.760	12.63	0.5053	HM
RF12	3.24	3.760	3.560	2.440	3.760	12.18	0.4873	M
RF1	3.04	3.760	3.560	2.800	3.760	11.43	0.4572	M
RF13	3.00	3.720	3.720	2.800	3.720	11.16	0.4464	M
RF19	2.56	3.720	3.480	2.880	3.720	9.52	0.3809	M
RF8	3.04	3.680	3.480	2.480	3.680	11.19	0.4475	M
RF5	2.88	3.680	3.480	2.520	3.680	10.60	0.4239	M
RF6	2.96	3.680	3.000	2.080	3.680	10.89	0.4357	M
RF10	3.48	3.320	3.400	3.640	3.640	12.67	0.5067	HM
RF18	2.76	3.640	3.320	3.320	3.640	10.05	0.4019	M
RF31	2.72	3.400	3.400	3.600	3.600	9.79	0.3917	M
RF21	2.28	3.600	3.560	2.400	3.600	8.21	0.3283	M
RF28	2.44	3.000	3.600	1.640	3.600	9.00	0.3600	M
RF2	3.28	3.560	3.080	2.480	3.560	11.68	0.4671	M
RF4	3.04	3.560	2.920	2.560	3.560	10.82	0.4329	M
RF3	2.92	3.560	3.080	2.440	3.560	10.40	0.4158	M
RF26	2.88	3.360	3.520	3.160	3.520	10.14	0.4055	M
RF23	2.92	3.520	3.040	3.240	3.520	10.28	0.4111	M
RF20	2.88	3.400	3.280	3.240	3.400	9.79	0.3917	M
RF16	2.96	3.200	3.360	3.320	3.360	9.95	0.3978	M
RF25	3.20	3.360	3.080	2.200	3.360	10.75	0.4301	M
RF15	3.08	3.360	3.360	2.040	3.360	10.35	0.4140	M
RF33	2.44	3.000	3.200	3.320	3.320	8.10	0.3240	M
RF27	2.52	3.280	3.120	2.080	3.280	8.27	0.3306	M
RF22	2.52	3.200	3.080	2.640	3.200	8.06	0.3226	M
RF7	3.20	3.160	3.160	3.120	3.160	10.11	0.4045	M
RF36	1.60	2.880	2.800	3.160	3.160	5.06	0.2022	LM
RF35	1.96	2.400	2.400	3.120	3.120	6.12	0.2446	LM
RF32	2.72	2.800	2.960	3.080	3.080	8.38	0.3351	M
RF30	2.44	3.000	2.840	2.040	3.000	7.32	0.2928	LM
RF29	2.32	2.400	3.000	1.440	3.000	6.96	0.2784	LM
RF37	2.84	2.840	2.720	1.880	2.840	7.93	0.3171	M
RF17	2.40	2.640	2.520	2.400	2.640	6.34	0.2534	LM
RF34	2.36	2.440	2.280	2.080	2.440	5.76	0.2303	LM

Table 10: The top critical risk factors

Risk ID	Description	Source	RS	CI	Class	Rank
RF10	Unskilled labor	Contractor	12.667	0.5067	HM	1
RF9	Lack of experience/trained staff	Contractor	12.634	0.5053	HM	2
RF11	Manpower unavailability	Contractor	12.616	0.5046	HM	3
RF12	Low productivity	Contractor	12.182	0.4873	M	4
RF24	Delay of material supply by vendor/supplier	Supplier/Vendor	11.880	0.4752	M	5

Table 11: The most frequent risks in marine-construction projects in SA

	Description	Source
1	Unskilled labor	Contractor
2	Lack of experience/trained staff	Contractor
3	Manpower unavailability	Contractor
4	Delay in work/labor permits, licenses	Owner
5	Low productivity	Contractor

Table 12: The top influential risks on Project' safety

	Description	Source
1	Accidents	Contractor
2	Lack of experience/trained staff	Contractor
3	Unskilled labor	Contractor
4	Poor site management and supervision	Contractor
5	Unreliability of construction equipment	Contractor

Table 13: The top influential risks on project' schedule

	Description	Source
1	Delay of material supply by vendor/supplier	Supplier/Vendor
2	Manpower unavailability	Contractor
3	Inadequate/unclear definition of project scope	Owner
4	Low productivity	Contractor
5	Construction errors	Contractor

Table 14: The most influential risks on Project' cost

	Description	**Source**
1	Construction errors	Contractor
2	Inflation for material price more than estimated	Politics/Economics
3	Contractor’s bankruptcy	Contractor
4	Low productivity	Contractor
5	Inadequate/unclear definition of project scope	Owner

5. Conclusions

Marine construction projects are a very important aspect of infrastructure development, however risks associated with these projects may delay or cease these developments. In the past, researchers have paid little attention to risks assessment for marine construction projects. This study identified, classified, and ranked risk factors associated with marine construction. With a risk-score value assigned to each risk, managers now have a roadmap to mitigate project risks and the possibility to develop contingency plans only for the tasks that have the highest risk levels. The main limitation to this study is the shortage of related previous study on maritime construction industry by scholars. Moreover, the scope of this study is limited to a small number of participants in Saudi Arabia. Future research should replicate the results of the system using a larger sample size, and should focus on developing risk-assessment models for marine-construction projects to explore risky aspects of marine construction industry.

References

[1] Li, Y., & Li, L. (2011). *Environmental and engineering geology, Vol II: Marine structures and materials*. Abu Dhabi, United Arab Emirates: Encyclopedia of Life Support Systems.

[2] Hulett, D. (2012). *Integrated cost-schedule risk analysis*. Aldershot, England: Gower.

[3] Ellis, J. T., Sherman, D. J., & Shroder, J. F. (2015). *Coastal and marine hazards, risks, and disasters*. Amsterdam, The Netherlands: Elsevier.

[4] Chapman, C. B., & Ward, S. C. (1997). *Project risk management: processes, techniques and insights.* Hoboken, NJ: John Wiley & Sons.

[5] Institution of Civil Engineers. (2002). *Risk Analysis and Management for Projects (RAMP).* London, England: Thomas Telford.

[6] Institute of Risk Management. (2002). *A risk management standard.* London, England: Author. Retrieved from https://www.theirm.org/media/886059/ARMS_2002_IRM.pdf

[7] Project Management Institute, 2008. A guide to the project management body of knowledge. Project Management Institute Standards Committee.

[8] Tam, V. W. Y., & Shen, L. Y. (2012). Risk management for contractors in marine projects. *Organization, Technology and Management in Construction: An International Journal, 4,* 403–410. doi:10.5592/otmcj.2012.1.5

[9] Gudmestad, O. T. (2002). Risk assessment tools for use during fabrication of offshore structures and in marine operations projects. *Journal of Offshore Mechanics and Arctic Engineering, 124,* 153–161. doi:10.1115/1.1492825

[10] Bai, Y., & Bai, Q. (2014). *Subsea pipeline integrity and risk management*. Amsterdam, The Netherlands: Elsevier.

[11] Chan, J. H-I. (2011). *Developing a fuzzy risk assessment model for target cost and guaranteed maximum price contracts in the construction industry of Hong Kong* (Unpublished doctoral dissertation). Hong Kong Polytechnic University, Hong Kong, China.

[12] International Organization for Standardization. (2009). *ISO 31000 2009 Risk Management Principles and Guidelines.* Geneva, Switzerland: Author.

[13] Hung, N., Bhagayatulya, G., & Jacobs, F. (2014). Risk assessment: A case study for transportation projects in India. *International Journal of Application or Innovation in Engineering & Management, 3*(9), 1–14. Retrieved from https://www.ijaiem.org/Volume3Issue9/IJAIEM-2014-09-03-2.pdf

[14] Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika, 16*, 297–334. doi:10.1007/bf02310555.

[15] Levine, D. M., Ramsey, P. P., & Smidt, R. K. (2000). *Applied statistics for engineers and scientists: Using Microsoft Excel & Minitab*. London, England: Pearson.

[16] Mbachu, J., & Nkado, R.N. (2006) Conceptual framework for assessment of client needs and satisfaction in the building development process. *Construction Management and Economics, 24*, 31–44. doi:10.1080/01446190500126866

[17] Mbachu, J. (2011). Sources of contractor's payment risks and cash flow problems in the New Zealand construction industry: Project team's perceptions of the risks and mitigation measures. *Construction Management and Economics, 29,* 1027–1041. doi:10.1080 /01446193.2011.623708

[18] Mbachu, J., & Nkado, R.N. (2006) Conceptual framework for assessment of client needs and satisfaction in the building development process. *Construction Management and Economics, 24*, 31–44. doi:10.1080/01446190500126866

[19] Mbachu, J., & Nkado, N. (2007). Factors constraining successful building projects implementation in the South African construction industry. *Construction Management and Economics, 25,* 39–54. doi:10.1080/01446190600601297

[20] Karim, N. A. A, Rahman, I. A., Memmon, A. H., Jamil, N., & Azis, A. A. A. (2013). Significant risk factors in construction projects: Contractor's perception. *2012 IEEE Colloquium on Humanities, Science and Engineering,* 347–350. doi:10.1109/CHUSER.2012.6504337.