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Risk Management Impact for Roadworks in the Kingdom of Saudi Arabia

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Abstract:

This research aimed to identify the most critical risk factors confronting the execution activities of roadway construction projects (RCPs) in Saudi Arabia. A survey instrument containing 39 critical risk factors affecting RCP activities employed and delivered to the participants. The data was analyzed using SPSS software. The probability affected the RCPs' objectives (time, cost, and quality), and the risk severity were determined. Time and cost percentages of each activity weighed. The anticipated rates of time and cost overruns discovered. Results showed that the cut and fill of earthwork had the greatest representation, with 34% for time and 32% for cost. Contrariwise, the road safety and roadway furniture had the least percentage representation among all activities. Results indicated that an overall time overrun of 33% was done in (15-20) % of all executed projects. While the participants indicated that (5-15) % of the projects had an overall cost overrun of 31%.

Keywords: Risk analysis, Execution activities, Time, Cost, and Quality

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1. Introduction:

The Kingdom of Saudi Arabia has seen a complete development renaissance and notable successes in the road sector. Saudi Arabia has extensive road networks encompassing more than 200,000 kilometers, including 66,000 kilometers of highways linking major cities and giving access to trains, ports, and airports. This expanding ground network supported by 5,000 kilometers of bridges, which provide a comprehensive method of transporting people and goods (GOV.SA, 2021). The finest technical standards used to ensure that the roads built with the greatest contemporary materials and equipment that fulfill safety and security requirements. All projects of all types, sizes, and activities face risks, which must managed by identifying, evaluating, and monitoring them to fulfill the project's purpose. Successful organizations understand which risks may tolerated and which must take (Newton, 2015). Risk management is an unavoidable duty for project managers as part of each project. Road construction projects are loaded with risks, and because of their economic impact, they considered important initiatives in many countries around the world.

According to the findings, unknown opportunities and risks represent 27% of the reasons for project failure (PMI, 2019). According to Lavanya and Malarvizhi (2008), the three key restrictions for a given project are time, cost, and the ultimate product's quality. The analysis and management of risks and uncertainties is one of the most important variables affecting project success. Risk analysis and management are critical project management practices to ensure that as few unexpected events as possible occur throughout the course of the project. Numerous risks confront road construction projects (RCPs) throughout the project life cycle, particularly during the implementation phase, owing to the long duration of road projects as well as their high cost, intricate nature, and interaction between implementation activities. Furthermore, RCPs necessitate the availability of wide and diverse resources, such as physical, material, and instrument resources, which makes risks and uncertainty more likely (Mohamed et al., 2015). It is becoming increasingly vital for all stakeholders to use standard risk management practices to meet project objectives on time and within budget (Mahamid, 2013). Risk management is the systematic control of projected risks. It is a step-by-step process that includes duties for hazard detection, classification, risk analysis, and risk response. The risk management process assists project financiers and teams in making educated judgments regarding different approaches to the risks involved. This increases the chance of project success in terms of cost, schedule, and quality (Zayed et al., 2007). Risk identification is the first and most critical step in risk management. It aids in the resolution of difficulties before they have a negative influence on the project. Risks cannot managed, mitigated, or conveyed before they discovered. Unfortunately, it is difficult to eliminate all possible threats as a result.

2. Risk concept:

Risk is defined as the combination of the probability of an event and its impact on the project objectives (ISO, 2009). The PMBOK (Project Management Body of Knowledge) defines a standard process for identifying risks based on an iterative process, as new risks may arise or become known over the life cycle of a project (PMBOK, 2015). Cooper et al. (2015) stated that risk identification identifies what might happen that could affect the project goals. It is important to ensure that as wide a range of risks as possible are identified, as risks that eliminated at this early stage may not analyzed and addressed in later stages. Risk is the situation that occurs because of uncertainty and affects negatively or positively any of the vital project objectives such as project scope, scheduling, cost, or quality. It occurs for several reasons, and its occurrence causes several consequences (Pinto, 2016).

Risk management is a set of activities that the organization must carry out to obtain the best results. The risk management process works to achieve integration between assessing, monitoring, and controlling the risks that the organization faces (Hopkin, 2017). Risk management is an approach that deals with pure risks by predicting potential losses and taking actions that work to reduce the occurrence of losses (Alaghbari et al., 2019). In order to ensure as few surprises as possible during project implementation, risk management is an important part of project management. An uncertain event or circumstance, the occurrence of which will have a positive or negative impact on one or more project objectives referred to as an individual risk (Hillson, 2014). In order to achieve appropriate and justified strategy to minimize and eliminate the negative impact of these risks and optimize the exploitation of opportunities leading to project success, organizations must implement an appropriate project risk management techniques. The contractor is in charge of both the bid and the execution; thus, this strategy should begin at the tender stage. The bid technique used greatly influences the overall business planning of a construction company. Unsuitable bids for a building project have the potential to cause large losses, waste time and resources, or even result in a failing project (Bertalero et al., 2021). Risk management in a construction project is critical to achieving project objectives without cost overruns or delays, as well as achieving good quality based on project design and planning. The risk management system allows project managers to prioritize resource allocation and make reliable decisions that lead to goal achievement and project success (Kassem et al., 2019). Adopting a risk management plan not only results in a high level of awareness of the consequences of risk, but it also focuses on a more organized approach, increased risk data exchange between parties, and more efficient centralized control (Goh & Abdul-Rahman, 2017). The risk management process has several steps, which were addressed in various ways in the sources, but they all agreed on the three basic stages, which are risk identification, risk analysis, and risk response. Risk management is provides an organized and structured way of thinking about risks and how to deal with them according to steps (Caltrans, 2018).

Construction project management is the process of planning, coordinating, and controlling the project from its inception to its completion. To manage a construction project, it is important to understand the project's objectives and the purpose to realized, as well as to determine the resources needed for the project, the time, the cost, and the required quality. Construction project management is the process of combining, monitoring, and regulating all project parts to accomplish the desired outputs, as well as assessing and choosing the best option to meet project objectives (Walker, 2015). The American Society of Civil Engineers (ASCE) adopted the classification of risks in construction projects into major risks, which are as follows: construction risks, physical risks related to nature beneath the earth's surface, legal and contractual risks, performance risks, economic risks, and political risks. These risks, as well as who is liable for them, have been identified (Fisk & Reynolds, 2017).

3. Research Objectives:

The current research aims at analyzing and ranking the risk factors facing the main execution activities associated with global roadway construction projects (RCPs) in the Kingdom of Saudi Arabia and analyzing how these risk factors affect the RCPs activities' timeliness, cost, and pertinent quality.

4. Research Methodology:

This study examines the most important risk factors that the Kingdom of Saudi Arabia's major road construction projects (RCPs) must deal with, as well as how they affect the project's overall quality, timeliness, and cost.

5. Study Population and Sample Size:

The study population for this study includes all consulting companies, engineers, and contractors working on road building projects. Even though a larger sample size yields better results, a sample size of (100) participants was randomly chosen for this study based on budget constraints and time available to perform this research.

6. Data Collection:

In order to analyze the risk factors related to the principal execution activities of global roadway construction projects (RCPs) in the Kingdom of Saudi Arabia, as well as their impact on the project's schedule, cost, and quality, data is gathered from primary and secondary sources. Secondary data collected through published journals, published articles, and different websites. A survey questionnaire that prepared by Issa et al. (2021), shown in table 1, was used to collect primary data; it contained 39 critical risk factors affecting RCPs activity. To assist in data dissemination and collection, the questionnaire produced in two variants. The first format printed in hard copies and delivered to some of the participants as needed, while another electronic version created and disseminated through the internet. The questionnaire divided into three parts. The first part contains the participant's personal information, such as name and email. These are optional entries, but another required field needs to be complete, such as the years of expertise in the area of RCPs and the type of work as an owner's representative, consultant, or contractor. The second part of the tool was devoted to describing risk factors in relation to the relevant implementation of the five main activities.

Table 1: Risk factors affecting RCPs activity, Issa et al. (2021).

Group A - Risks of preliminary preparation before starting the project.
R1 Poor evaluation of design drawings and roadway sections.
R2 Existence of horizontal or vertical obstacles in the roadway route.
R3 No preliminary studies or lack of project data/documentation/details at design stage.
R4 Inaccurate soil investigation.
R5 Existence of problematic soil along the roadway.
R6 Non-conformity between the actual NGL and the NGL mentioned in the drawings of the bidding documents.
R7 There is no water source along the roadway route.
R8 Modify project scope during preparation
R9 Incorrect definition of the main project control points.
Group B- Risks of (cut/fill) Earthwork to achieve the required roadway level.
R10 Lack of experienced surveyors.
R11 Use of old versions of surveying instruments.
R12 Lack of experienced/skilled equipment operators.
R13 Delay of laboratory results for approvals and tests of the materials.

R14 Inexperienced QA/QC team.

R15 Lack of diesel stocks in the site.

R16 Impoverished management between resources and equipment.

R17 Non-compliance with codes.

R18 Poor organization of site preparation, entry, and exit.

R19 Scarcity of water sources on the roadway.

R20 Inexperience of engineer's staff and other personnel.

R21 Bad weather.

R22 Unavailability of the backfill soil sources near roadway.

R23Lack of control by local authorities over local water resources and soil, especially on desert roads.

R24 Poor coordination between stakeholder and with various infrastructure works.

Group C - Risks related to the construction of sub-base and base layers.

R25 Lack of nearby crushed stone source.

R26 Shortage of diesel fuel.

R27 Inexperienced laborers.

R28 Bad grading granular soil.

R29 Delay in the delivery of crushed stone.

R30 Delay in placing next road layer, which causes an erosion of existing layer.

R31 Use of sufficient compaction equipment capacity to achieve the required compaction.

Group D - Factors affecting execution of bituminous layers.

R32 Lack of bitumen and oil products.

R33 Poor batch plant control.

R34 Shortage of skilled workers and technicians.

R35 Use of poor-quality raw materials.

Group E- Risks of road safety and roadway furniture.

R36 Non-compliance with the principles of the code and international traffic sign standards.

R37 Delay in completion and delivery of additional road works such as curbs and barricades.

R38 Lack of coordination with the authorities of the interested parties to obtain the necessary permits to complete the construction of the road network.

R39 Failure to comply with international standards for security measures.

Respondents asked to identify the likelihood of the occurrence of each risk factor and its influence on time, cost, and quality based on their experience implementing RCPs. To standardize participants' perspectives on the percentage of chance of occurrence as well as the weight of the risk effect and its severity, as stated in Table2, pre-specified percentages based on linguistic characteristics that used in comparable research incorporated. The third section of the survey connected the five primary RCP activities in order to calculate the percentage of total time and cost for each activity relative to the project as a whole and assess the relative importance of each activity. In addition, participants asked to specify the anticipated overall project cost and time overruns due to the occurrence of the highlighted items, as well as the percentage of projects that were finished on schedule, within budget, and without going over budget in terms of time or cost. The data source (Alghamdi, 2023) was collected from contractors, consultants, and owners which worked in road projects. Focus was on the central region (Riyadh) and the eastern region (Jeddah) due to the large number of road projects in them as a percentage to the other Kingdom's projects.

Table 2: linguistic variables and relevant percentage range.

Linguistic variables	Very Low	Low	Moderate	High	Very High
Percentage range	0% to 20%	up to 40%	up to 60%	up to 80%	up to 100%
Assigned weight	0.10	0.30	0.50	0.70	0.90

7. Risk factors analysis:

A simple formula used that takes into account the relative importance of risk based on the Risk Probability Index (PI) and Time Impact Index, cost and quality - respectively as IIT, IIC and IIQ referred to (Shen et al., 2001).

$\mathrm{PI} = \sum_{i=1}^{i=5}(\mathrm{pi} * \mathrm{Ni} * \mathrm{EF}) \,/\, Y$, $\mathrm{IIT} = \sum_{i=1}^{i=5}(\mathrm{Iti} * \mathrm{Ni} * \mathrm{EF}) \,/\, \mathrm{Y}$

$\mathrm{IIC} = \sum_{i=1}^{i=5}(\mathrm{Ici} * \mathrm{Ni} * \mathrm{EF}) \,/\, \mathrm{Y}$, $\mathrm{IIQ} = \sum_{i=1}^{i=5}(\mathrm{Iqi} * \mathrm{Ni} * \mathrm{EF}) \,/\, \mathrm{Y}$

Y = (Ni (5-10) * EF1) + (Ni (10-15) * EF2) + (Ni (15-20) * EF3) + (Ni (above20) * EF4)

Were, PI is the index probability for a certain risk factor. Pi is the probability weight that option (i) given based on the five severity levels that have been allocated. Ni is the total number of participants who answered the question (i).

EF is the experience factor: (EF1 = 1 for 5–10 years, EF2 = 1.6 for 10–15 years, EF3 = 2.3 for 15–20 years and EF4 = 3 for more than 20 years).

Y is the total number of respondents when the EF weights are included.

IIT is the impact index for time for a certain risk factor; Iti is the he impact time weight assigned to option (i).

IIC = the impact index for cost for a certain risk factor; Ici = the impact time weight assigned to option (i).

IIQ = the impact index for quality for a certain risk factor; Iqi = the impact quality weight assigned to option (i).

The severity of a particular risk factor affecting project duration, cost and quality can calculated using the following equation (Mossad et al., 2018). Risk factor indicators of time, cost, and quality, namely RFIT, RFIC and RFIQ, respectively indicate the severity of the risk.

RFIT =PI *IIT, Where RFIT = risk index for time.

RFIC= PI * IIC, Where RFIC = risk index for cost.

RFIQ = PI * IIQ, Where RFIQ = risk index for quality.

8. Results:

Table 3 shows the number of respondents according to their job, as well as the distribution of the surveys' response rate. Regarding the years of experience, the results indicated that out of 65 respondents, 50.8% have 15.20 years of experience, 23% have less than 5 years of experience, 15.40 % are above 20 years, and 10.8% have 5-10 years of experience. Fig.1 shows the percentage of each participant category based on workplace.

Table 3: Survey response rate and participation frequency.

Participants	Contractor	Consultant	Owner	Total
Distributed questionnaires	55	25	20	100
Responses received	30	19	16	65
Response rate	55%	76%	80%	65%

Participants	Contractor	Consultant	Owner	Total
Frequency of participation	46.2%	29.2%	24.6%	100%

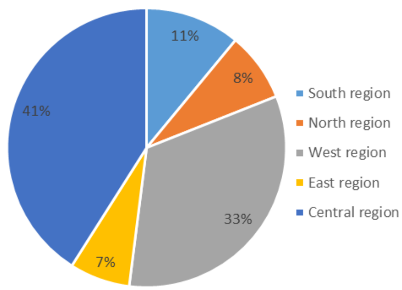


Fig 1: proportion of the sample according to workplace in KSA

Table 4 shows the index probability for a certain risk factor as well as the time, cost, and quality impact index that have the largest and least influence on preliminary project preparations prior to project start-up. The top three risk factors based on PI values are RF5 (PI = 0.84), RF2 (PI = 0.80), and RF4 (PI = 0.74). The least likely risk factor was RF8 (PI = 0.14). According to IIT values, the top three risk variables with the greatest effect on time were RF5 (IIT = 0.86), RF1 (IIT = 0.78), and RF2 (IIT = 0.62). The risk factor that did not significantly affect time was RF6 (IIT = 0.18). The risk factors that had a significant influence on cost were RF1 (IIC = 0.78), RF5 (IIC =0.78), and RF2 (IIC =0.74); the risk factor that did not significantly affect cost was RF8 (IIC = 0.22). While the risk variables that had a significant influence on quality according to IIQ values were RF2 (IIQ = 0.82), RF5 (IIQ =0.82), and RF4 (IIQ =0.66), the risk factors that did not significantly affect quality were RF6 and RF9 = (IIQ = 0.18).

Table4. The risk factors and the impact index according to (PI, IIT, IIC, and IIQ) for preliminary preparation.

N.	Risk factor	PI	IIT	IIC	IIQ
1	Inadequate assessment of roadway segments and design drawings.	0.34	0.78	0.78	0.58
2	Existence of horizontal or vertical obstacles in the roadway route.	0.80	0.62	0.74	0.82
3	No preliminary studies or lack of project data/documentation/details at design stage.	0.26	0.54	0.58	0.46
4	Inaccurate soil investigation.	0.74	0.58	0.62	0.66

5	Existence of problematic soil along the roadway.	0.84	0.86	0.78	0.82
6	Non-conformity between both the real NGL and the NGL indicated in the bidding documents' drawings.	0.21	0.18	0.26	0.18
7	There is no water source along the roadway route.	0.26	0.46	0.34	0.19
8	Modify project scope during preparation	0.14	0.34	0.22	0.20
9	Incorrect definition of the main project control points.	0.19	0.46	0.46	0.18

Fig 2 illustrates that the existence of problematic soil along the roadway is the key risk factor index for time, cost, and quality. In addition, the existence of horizontal or vertical obstacles in the roadway route and inaccurate soil investigation have a great effect.

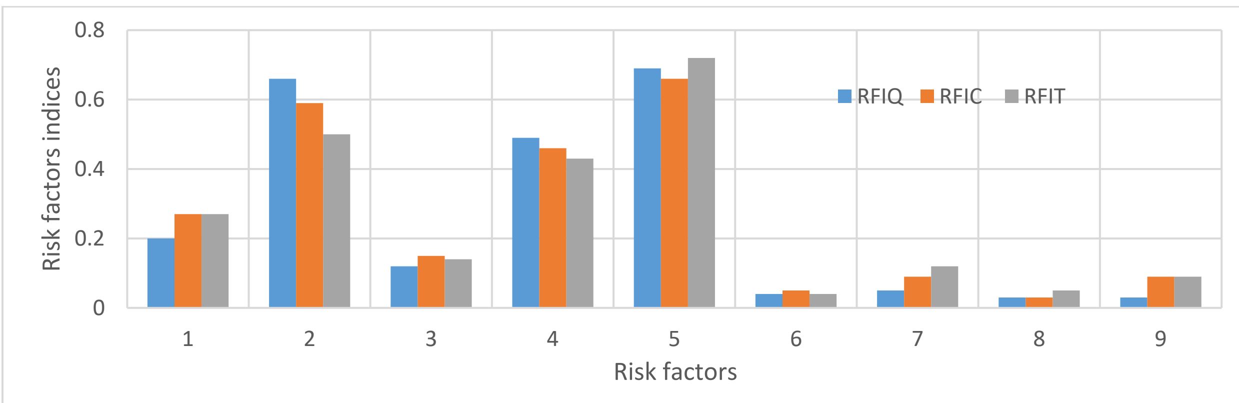


Fig 2: Risk factors indices for time, cost, and quality for preliminary preparation.

Table 5 shows the index probability for a certain risk factor. The time, cost, and quality impact index that have the greatest and least effect on (cut/fill) earthwork to achieve the required roadway level were indicated. It is clear that the risk factors that has significant influence based on PI values are RF14 (PI = 0.78), RF17 (PI = 0.78), and RF20 (PI = 0.74), while the least likely risk factors are RF15,16,18,19,22 (PI = 0.10). The risk factors that have significant influence on time according to IIT values were RF18 (IIT = 0.86), RF22 (IIT = 0.62), and RF19 (IIT = 0.54), while the risk factor that did not significantly affect time was RF15 (IIT = 0.14). The risk factors that had a significant influence on cost were RF17 (IIC = 0.84), RF21 (IIC =0.70), RF20 and 22 (IIC =0.66); the risk factors with the least effect on cost were RF15 and 23 (IIC =0.14). Whereas the risk factors that have significant influence on quality were RF10 (IIQ = 0.82), RF17 (IIQ =0.78), and RF20 (IIQ =0.78), the risk factors that did not significantly affect quality were RF18 and RF 15 and 19 (IIQ = 0.10).

Table5. The risk factor and the impact index according to (PI, IIT, IIC, and IIQ) for Earthworks (cut/fill) to achieve the design levels of the roadway.

N	Risk factor	PI	IIT	IIC	IIQ
10	Lack of experienced surveyors.	0.62	0.46	0.62	0.82
11	Use of old versions of surveying instruments.	0.54	0.42	0.58	0.74
12	Lack of experienced/skilled equipment operators.	0.54	0.50	0.50	0.74
13	Delay of laboratory results for approvals and tests of the materials.	0.14	0.38	0.30	0.18
14	Inexperienced QA/QC team.	0.78	0.38	0.58	0.78
15	Lack of diesel stocks in the site.	0.10	0.14	0.14	0.10
16	Impoverished management between resources and equipment.	0.10	0.50	0.54	0.34
17	Non-compliance with codes.	0.78	0.18	0.84	0.78
18	Poor organization of site preparation, entry, and exit.	0.10	0.38	0.18	0.14
19	Scarcity of water sources on the roadway.	0.10	0.54	0.54	0.10
20	Inexperience of engineer's staff and other personnel.	0.74	0.46	0.66	0.78
21	Bad weather.	0.22	0.86	0.70	0.46
22	Unavailability of the backfill soil sources near roadway.	0.10	0.62	0.66	0.14
23	Lack of control by local authorities over local water resources and soil, especially on desert roads.	0.14	0.22	0.14	0.18
24	Poor coordination between stakeholder and with various infrastructure works.	0.18	0.50	0.42	0.22

As for the risk factors, indices for earthworks (cut/fill) fulfill the road's design levels. Fig. 3 illustrates that the RF20 inexperience of the engineer's staff and other personnel was the most important risk factor for time, cost, and quality. While RF17 non-compliance with codes, an inexperienced QA/QC team, and the inexperience of the engineer's staff and other personnel were the key risk factors for cost and quality.

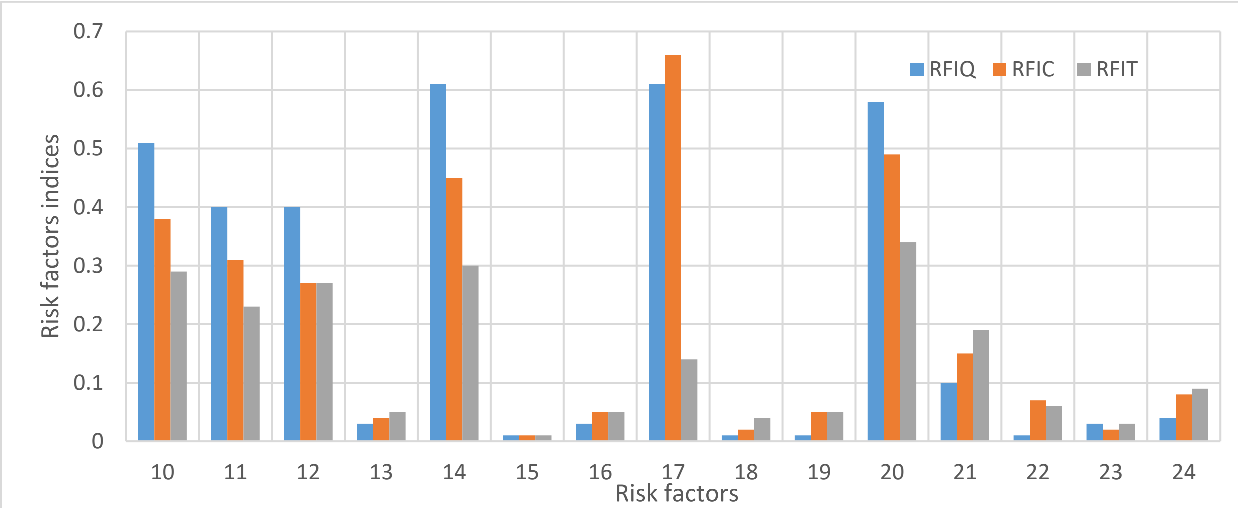


Fig 3: Risk factors indices for time, cost, and quality for Earthworks (cut/fill).

Table 6. Shows the index probability for a certain risk factor, as well as the time, cost, and quality impact index that have the largest and least influence on the execution of sub-base and base layers. The risk factors that have significant impact were RF30 (PI = 0.822), RF29 (PI = 0.80), and RF31 (PI = 0.78), and the risk factor that did not have a significant influence was RF25 (PI = 0.10). According to IIT values, the top risk factors with the greatest effect on time were RF29 (IIT = 0.82), RF28 (IIT = 0.80), and RF30 (IIT = 0.79). The risk factor that did not significantly influence time was RF26 (IIT = 0.30). Whereas the risk factors that have significant impact on cost were RF29 (IIC = 0.78), RF25, and RF30 (IIC = 0.74), the risk factor that did not significantly influence cost was RF26 (IIC =0.40). According to IIQ values, the risk factors that have significant impact on quality were RF29 (IIQ = 0.82), RF31 (IIQ = 0.81), and RF28 (IIQ = 0.74). RF26 = (IIQ = 0.10) was the risk factor that did not significantly influence quality.

Table 6. The risk factor and the impact index according to (PI, IIT, IIC, and IIQ) for the construction of sub-base and base layers.

N.	Risk factor	PI	IIT	IIC	IIQ
25	Lack of nearby crushed stone source.	0.10	0.66	0.74	0.22
26	Shortage of diesel fuel.	0.15	0.30	0.40	0.10
27	Inexperienced laborers.	0.70	0.68	0.54	0.65
28	Bad grading granular soil.	0.73	0.80	0.70	0.74
29	Delay in the delivery of crushed stone.	0.80	0.82	0.78	0.82

30	Delay in placing next road layer, which causes an erosion of existing layer.	0.82	0.79	0.74	0.70
31	Utilizing enough compaction equipment to reach the necessary compaction.	0.78	0.77	0.70	0.81

Fig. 4 illustrates that RF29, 30, and 31 (Delay in each of the delivery of crushed stone, placing next road layer which causes an erosion of existing layer, and utilizing enough compaction equipment to reach the necessary compaction.) were the key risk factors for (time, cost, and quality).

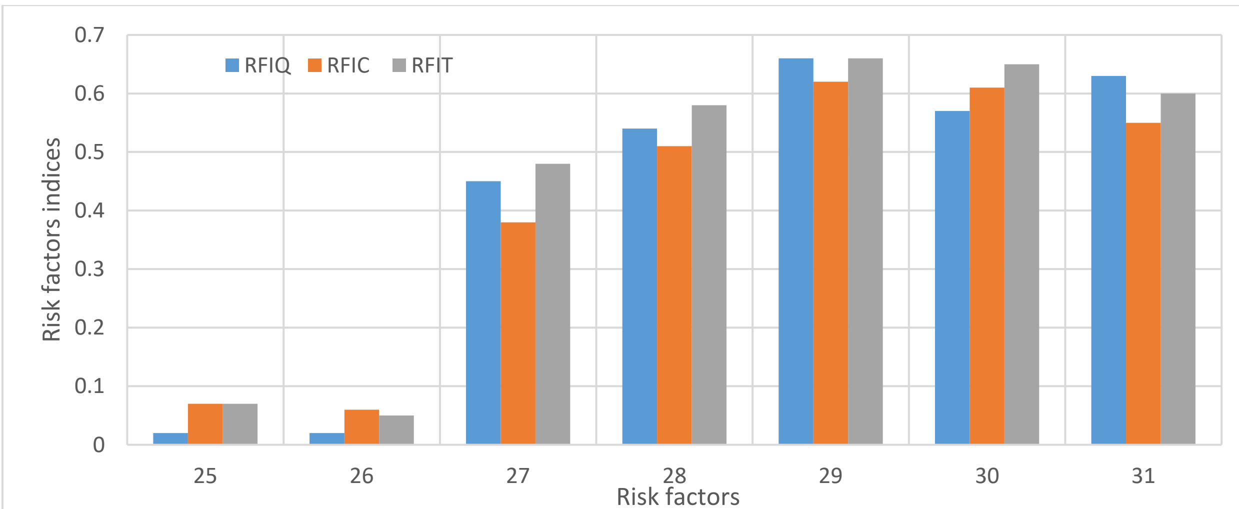


Fig 4: Risk factor indices for time, cost, and quality for the construction of sub-base and base layers

Table 7 shows index probability for a certain risk factor, as well as the time, cost, and quality impact index that have the largest and least influence on the execution of bituminous layers, with the top risk factor being RF35 (PI = 0.73), and RF34 (PI = 0.70), whereas the risk factor with the lowest likelihood was RF32 (PI = 0.10). According to IIT values, RF35 (IIT = 0.80), RF34 (IIT = 0.68), and RF32 (IIT = 0.66) were the most significant. While RF33 (IIT = 0.30) was found to be not significant. RF32 (IIC = 0.74), RF35 (IIC = 0.70), and RF34 (IIC=0.54) had a significant influence on cost. While RF33 (IIC =0.40) did not significantly affect cost. According to IIQ values, RF35 (IIQ = 0.74), and RF34 (IIQ = 0.65) had a significant influence on quality. RF33 = (IIQ = 0.10) was found to be the risk factor that did not significantly affect the quality.

Table 7. The risk factor and the impact index according to (PI, IIT, IIC, and IIQ) for the execution of bituminous layers.

N.	Risk factor	PI	IIT	IIC	IIQ

32	Lack of bitumen and oil products.	0.10	0.66	0.74	0.22
33	Poor batch plant control.	0.15	0.30	0.40	0.10
34	Shortage of skilled workers and technicians.	0.70	0.68	0.54	0.65
35	Use of poor-quality raw materials.	0.73	0.80	0.70	0.74

Fig 5 illustrates that RF33 (Poor batch plant control) and RF 34(Shortage of skilled workers and technicians.) were the key risk factors for (time, and cost). While RF35 (Use of poor-quality raw materials), and RF34 (Shortage of skilled workers and technicians.) were the most important risks of quality.

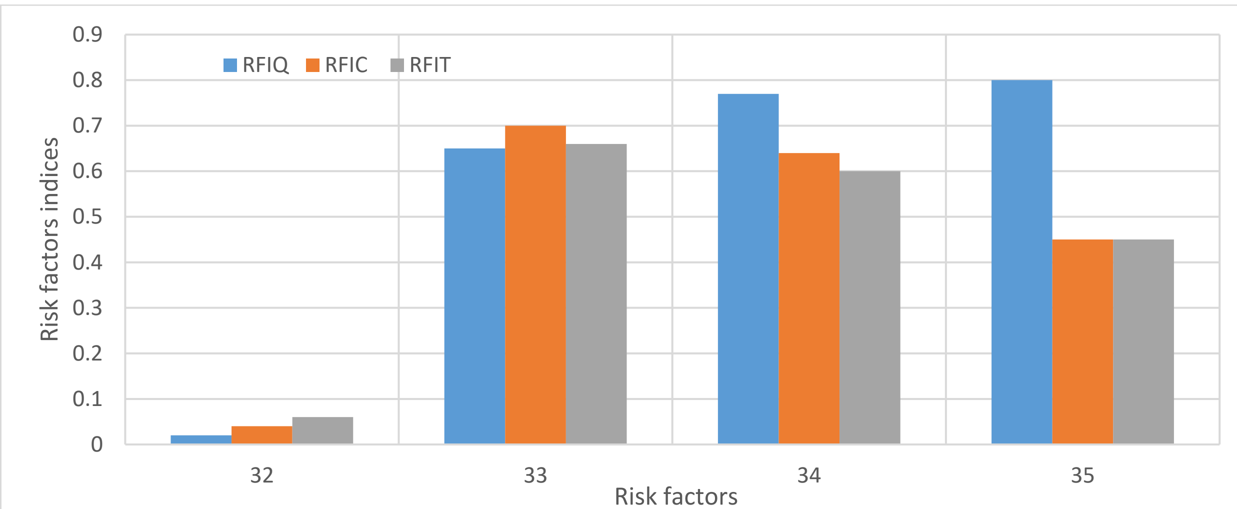


Fig 5: Risk factors indices for time, cost, and quality for the execution of bituminous layers.

As shown in Table 8, RF39 and 38 (PI = 0.73 and 0.70) were the most likely risks to occur, while RF36 (PI = 0.10) was less likely to occur. According to IIT values, the most significant risks were RF39 (IIT = 0.80), RF38 (IIT = 0.68), and RF36 (IIT = 0.66). While RF37 (IIT = 0.30) was found to be the risk factor that did not significantly affect the quality. The results also indicated that RF39 (IIC = 0.70), and RF36 (IIC= 0.74) were the most significant factors affecting cost. While RF37 (IIC =0.40) had less impact. According to IIQ values, RF39 (IIQ = 0.74), and RF38 (IIQ=0.65) were the most important factors affecting quality. While RF37 (IIQ = 0.10) was found to be less significant.

Table 8. The impact index according to (PI, IIT, IIC, and IIQ) for road safety and roadway furniture.

N.	Risk factor	PI	IIT	IIC	IIQ
36	Non-compliance with the principles of the code and international traffic sign standards.	0.10	0.66	0.74	0.22
37	Delay in completion and delivery of additional road works such as curbs and barricades.	0.15	0.30	0.40	0.10
38	Lack of coordination with the authorities of the interested parties to obtain the necessary permits to complete the construction of the road network.	0.70	0.68	0.54	0.65
39	Failure to comply with international standards for security measures	0.73	0.80	0.70	0.74

As for the values of risk factors indices for road safety and roadway furniture through applying the severity equations. Fig 6 illustrated that RF36 and RF39 (Non-compliance with the principles of the code and international traffic sign standards and Failure to comply with international standards for security measures) were the essential risk factor for quality. While the time and cost risk factors have a little effects on all road safety and roadway furniture activities.

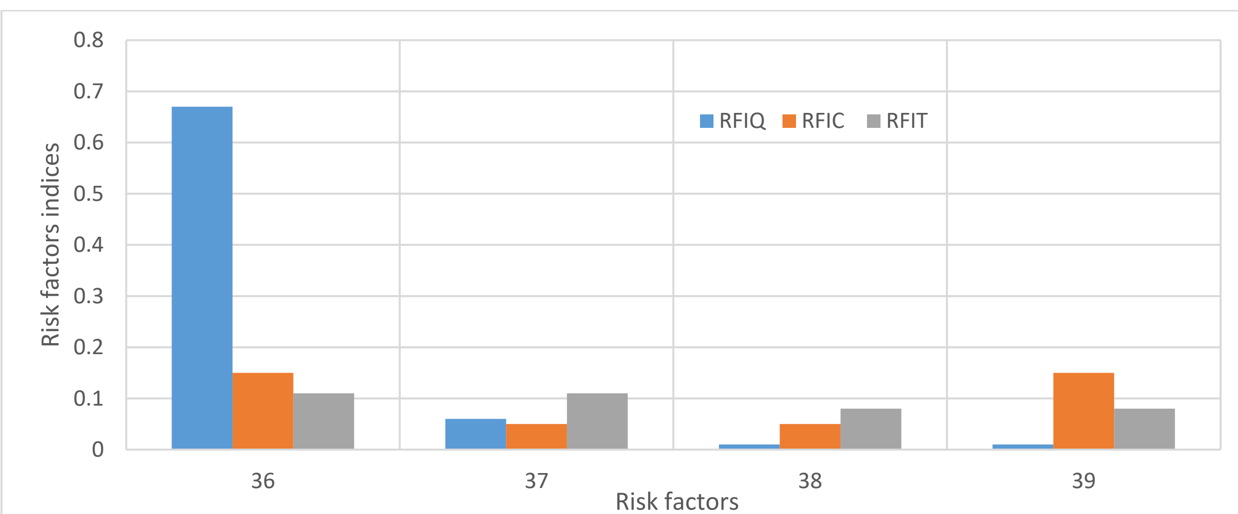


Fig 6. Risk factors indices for time, cost, and quality for road safety and roadway furniture.

8.1 Key risk factors affecting RCPs activities:

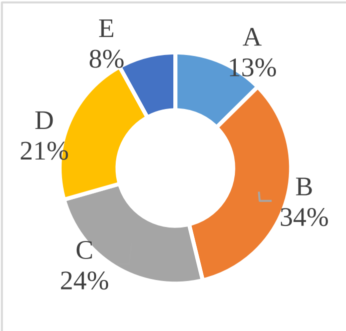
As shown in Table 9. Certain significant risk factors have seen to impact more than one objective. RF5, RF2, RF29, RF31, RF33, and RF34 which are in activity (A), (C), and (D) impact the project's three goals that were deemed significant risk factor for RFIT, RFIC, and RFIQ, with varying rankings within the top ten of the three indices; RF28 and RF30 are deemed critical risk factors for RFIT and RFIC, on the other hand. However, RF17 thought to be a significant risk factor for both RFIC and RFIQ.

Table 9: Top Ten risk factors according to RFIT, RFIC, and RFIQ.

Rank	RFIT	number of Risk	Activity	Rank	RFIC	number of Risk	Activity	Rank	RFIQ	number of Risk	Activity
1	.72	RF5	A	1	.70	RF33	D	1	.80	Rf35	D
2	.66	RF29	C	2	.66	RF5	A	2	.77	RF34	D
3	.66	RF33	D	3	.66	F17	B	3	.69	RF5	A
4	.65	FR30	C	4	.64	RF34	D	4	.67	RF36	E
5	.60	RF31	C	5	.62	RF29	C	5	.66	RF29	C
6	.60	RF34	D	6	.61	RF30	C	6	.66	RF2	A
7	.58	RF28	C	7	.59	RF2	A	7	.65	RF33	D
8	.50	RF2	A	8	.55	RF31	C	8	.63	RF31	C
9	.48	RF27	C	9	.51	RF28	C	9	.61	RF14	B
10	.45	RF35	D	10	.49	RF20	C	10	.61	FR17	B

8.2 Time and cost analysis for the five activities:

Figs 7a and 7b depict the primary five execution activities as well as the corresponding proportion of time and cost throughout the highway project's execution. The findings of activity representation percentages show that activity B (earthworks "cut and fill" to attain highway design levels) had the highest percentage of time and cost across all activities, accounting for 34% of time and 32% of cost. Among all execution activities, activity E (traffic safety and road furniture) had the lowest percentage of time and cost (8% for time and 10% for cost).



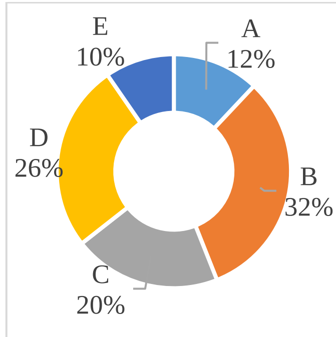


Fig 7, a: Time percentages

Fig 7.b: Cost percentages

Fig 8: Illustrates that an overall time overruns of 33% was done in (15-20) % from all executed projects. While the Participants indicated that (5-15) % from the projects they participated in an overall cost overrun of 31% were more than the plan.

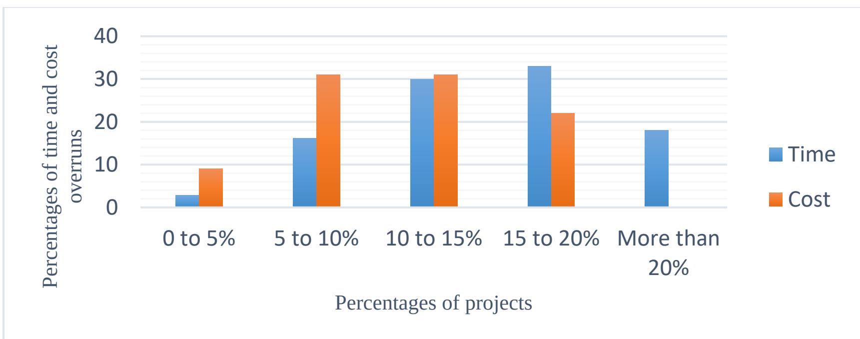


Fig 8: Percentages of expected time and cost overruns.

Fig 9 depicts the experts' assessments on the total impact on the quality of the project, where 57% of the projects ended with a percentage of (0 to 5) % deviation on the overall quality. Moreover, 34% of the projects finished with (5 to 10) % quality deviation.

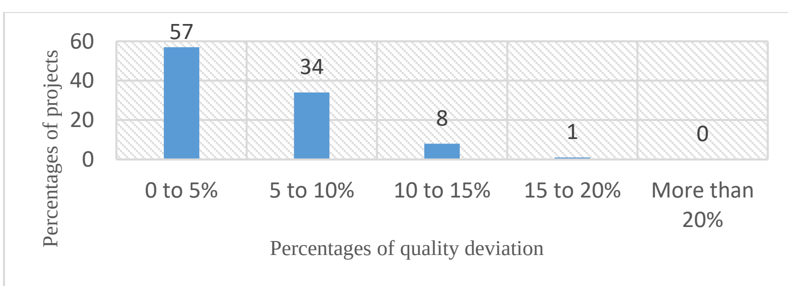


Fig 9: Percentage of overall influence on quality deviation.

9. Conclusion:

This paper aimed at identifying the most critical risk factors confronting the primary execution activities connected with global roadway construction projects (RCPs) in the Kingdom of Saudi Arabia, as well as their impact on the time, cost, and quality of each activity and the project. The results summarized in the following points:

1- As for preliminary preparation before starting the project, the results indicated that the existence of problematic soil along the roadway is the key risk factor index for time, cost, and quality. In addition, the existence of horizontal or vertical obstacles in the roadway route and inaccurate soil investigations have a great effect.

2- As for earthworks (cut/fill) to achieve the design levels of the roadway, the results indicated that the inexperience of the engineer's staff and other personnel was the key risk factor for time. While non-compliance with codes, an inexperienced QA/QC team, and the inexperience of the engineer's staff and other personnel were the key risk factors for cost and quality.

3- As for the construction of sub-base and base layers, the results indicated that delay in each of the delivery of crushed stone and placing the next road layer, which causes erosion of the existing layer and the use of sufficient compaction equipment capacity to achieve the required compaction were the key risk factors for time, cost, and quality.

4- As for the execution of bituminous layers, the results indicated that poor batch plant control and a shortage of skilled workers and technicians were the main risk factors for time and cost. While the use of poor-quality raw materials and the shortage of skilled workers and technicians is the key risks to quality.

5- The agreement between the risk factor indices (RFIT, RFIC, and RFIQ) evaluated, and the relationship between the three indices shown to be significant. The strongest correlation found between (RFIT and RFIC).

6- Each primary activity's time and cost percentages examined and identified. In terms of time and cost, Activity B was the largest ((cut/fill) earthwork to achieve the required roadway level), as it takes 34% of the time and 32% of the cost of all activities. However, activity E (traffic safety and road furniture) had the lowest percentage representation of time and cost among all execution activities, at 8% for time and 10% for cost.

7 -A significant percentage (91%) of the projects finished with a quality deviation (0 to 10) %.

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