Application of Root Causes Analysis Techniques in The Contractor Selection for Highway Projects

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Abstract. Highway projects are one of the most important projects in this decade in Iraq. Highway projects suffer from corruption factors in the contractor selection phase. To succeed in transparency and best value contractor selection for awarding procedure for highway projects, the researcher used root cause analysis techniques to specify the main factors that lead to bad selection for the highway projects in Iraq. Many tools techniques used for the root cause analysis techniques like Fishbone, Pareto chart, and 5-Why. This study conducts the causes of bad contractor selection and analysis by root cause analysis techniques, Pareto chart conducted that internal relationships and administrative corruption are the main causes that covered near than 80% of the problem, and 5-Why conducted that the acceptance of the lowest price is the main cause for bad selection.

Keywords: Highway projects, Contractor selection, Root cause analysis techniques, Fishbone diagram, Pareto diagram, 5-Why analysis.

1. Introduction

Difficult to imagine the awarding procedure for construction projects without problems or restrict or failed during implementation procedure due to poor management and poor monitoring or poor supervision. The highway project is implemented in a complex environment. There is no reliable data and trust information to evaluate project needs. The awarding procedure of highway projects is the start of project success or project failure. There are many problems during the selection procedure for the project criteria and their evaluation with a right way in Iraq:

1) The absence of using modern procedures for the selection of the best contractor.
2) Projects are awarded to poor contractors who have a poor experience and the true ability to implement these projects.
3) Corruption is the main reason for the selection process.
4) Depend on the lowest price.

The main issue during the contract awarding procedure is using traditional methods that not compare with our needs to implements highway projects in this decade. Even the highway projects implemented with traditional methods, we may get many execution problems like does not succeed in project age and high maintenance after project operation. Therefore, RCAT can deal with the awarding issue. In Iraq, the root cause analysis technique culture is absent so, it's useful in project management and with selecting procedure for the best contractor especially. Jimmie [1] investigated the root causes of construction accidents. One source of information on the causes associated with many serious injuries and fatalities is maintained by the Occupational Safety and Health Administration (OSHA). The study presents recommendations on how the OSHA reports could be made more meaningful. First, injuries
had been coded into one of the 20 possible cause categories, rather than the traditional five groups of falls, struck-by, electric shock, caught-in/between, and others. Additional or secondary cause codes also were developed. The results could then be utilized to focus greater attention on those areas for which modifications in the regulations are warranted and it would be more helpful to the construction industry by emphasizing the major causes of serious accidents.

Tariq [2] investigates the root causes of construction accidents. Their study presents an accident root causes tracing model (ARCTM). ARCTM proposes that accidents occur due to three root causes: (1) failing to identify any unsafe condition that existed before an activity was started; (2) deciding to proceed with a work activity after the worker identifies an existing unsafe condition; and (3) deciding to act unsafe regardless of initial conditions of the work environment. Also, ARCTM emphasizes the need to determine how unsafe conditions exist before or develop after an activity is started and proposes that these unsafe conditions are due to four causes: (1) management actions/inactions; (2) unsafe acts of worker or co-worker; (3) non-human-related event(s); (4) an unsafe condition that is a natural part of the initial construction site conditions.

Tommy et al. [3] aimed first, at gathering the perceptions of civil construction practitioners on how significant are the causes of delay; and, second, investigating whether the suggestions as stated in the report of the Construction Industry Review Committee (the committee comprises members with good standing and knowledge in the construction and related fields as well as those from other professions who are responsible for examining the current state of the construction industry in terms of its output quantity, the quality of work, its environmental friendliness, site safety, its workforce and the system of supervision) apply to and effective at mitigating the corresponding delays concerning a ranking order established using the mean score method. The extent of the differences in perception among the different respondent groups on these two issues was also examined using the rank agreement factor (RAF), percentage agreement (PA), and percentage disagreement (PD). This study had been applied on six projects. A strong consensus was found between the client and consultant groups on the significance of the various causes of delay (PA = 74%) and the effectiveness of mitigation measures (PA = 67%) compared with the other pairs of groups.

Yehiel [4] examines cost overruns phenomenon impact on the construction industry as a worldwide problem, identifies its root causes, ranks them (on a local basis), and analyzes them. Firstly, the study had been gathered 146 potential causes from international professional literature as well as from prominent local experts. Finally, they were filtered and merged into merely 15 independent universal root causes. These were further investigated through a cross-sectional survey among 200 local practitioners who ranked the 15 universal root causes according to their conceived local importance and influence on cost overruns. The survey revealed that the three most important causes out of 15 are, cause number 1 premature tender documents; cause number 2 is too many changes in owners’ requirements or definitions, and cause number 3 is tender-winning prices are unrealistically low (suicide tendering). Faq and Reem [5] investigated the cost management status of the highway construction projects in Iraq. The survey included investigating and evaluating the reality of cost planning and control and determine the causes of construction cost deviation. Causes of cost deviation had been investigated and collected by conducting the personal interviews and questionnaires with the site’s engineers and by reviewing the previous literature. Iraqi Road and Bridge Directorate was selected as a sample study. It is worth to mention that the statistical analysis has been conducted by using the SPSS program (version 20). Cost deviation reasons had classified into three groups by the researchers, which are planning reasons, designing reasons, execution reasons. Planning reasons classification had taken relative importance equal to 2.7%, designing reasons classification had taken relative importance equal to 3% and execution reasons classification had taken relative importance equal to 2.45%. The main objective of this paper is to classify and specify the causes that lead to choose poor contractor for the highway projects and give a reliable solution for the awarding procedure applied with project specifications and available needs.

2. Problem Statement
The only important question raised in this study is: "Is the root cause analysis techniques can be applied in highway projects management to control the bad selection for contractors" To answer this question,
we must including the research problem. The research problem is summarized depend on the literature review and some of the interview with the specialist engineers regarding the following:

1) There is a poor check for selection procedure problems for the contractor for highway projects because the available techniques are poor. Besides that, there is a need to use root cause analysis technique, because of its accuracy for construction work and important to ensure good management for our projects.

2) The projects are awarding to contractors who do not have enough experience to implement these projects, despite the big need for these projects in this decade.

3) The importance of highways for Iraq as a developing country, because;
   a) No civilized society can be survived without highways.
   b) Highway has a great cultural value.
   c) Highway has the most important role to play in the defines of the country.
   d) Highway is the symbol of a country’s progress.
   e) Highway development and transport have the highest employment potential of all economic activities.

3. Research Important, Limits and Methodology
Research important summarized as per the following:

- This research highlights the importance of the awarding procedure for highway projects for the best contractor. Because of this type of project have a big important between the other projects.
- It provides a true vision of the difficulties faced by project managers and planners, when applying the methodology of cost management in highway projects, to overcome these obstacles and reduce them.
- Encourage researchers, lecturers and academics to conduct further researchers and integrate with the results of the current study. The motivation of this study is a limited number of researches in the area of awarding contracts about highway projects, and the need for selecting the best contractor in the highway projects.
- The research limited to the following limits:
  - Time limits: gathering data were implemented in 2019.
  - Spatial limits: This study was conducted on highway projects in the Republic of Iraq.
  - A three-step study methodology is conducted, to obtain the objective of the study:
    - Literature review
    - Questionnaire and Personal interviews with engineers of exact specialization in highway engineering or at least experience in highway projects, this step had explained in reference [5].
    - Statistical analysis.

4. Root Cause Analysis Concept
Root cause analysis (RCA) is a useful process for understanding and solving a problem. RCA is a popular and often-used technique that helps people answer the question of why the problem occurred in the first place. It seeks to identify the origin of a problem using a specific set of steps, with associated tools, to find the primary cause of the problem, so that you can:
   a) Determine what happened.
   b) Determine why it happened.

Root cause analysis (RCA) is a valuable management tool that can be readily learned by managers as well as frontline personnel. These techniques can be of enormous value. They capture both the big-picture perspective and the details. They facilitate system evaluation, analysis of the need for corrective action, and tracking and trending. Regarding trending, managers will be able to determine how often a
particular error occurs. This analysis is as useful and perhaps even more efficacious. The technique can be applied not only to engineering but also they apply to other disciplines [6]. It is a method that is used to address a problem or nonconformance to get to “the root cause” of the problem. It is used to eliminate or mitigate the cause and prevent the problem from recurring. RCA is simply the application of a series of well-known common-sense techniques that can produce a systematic, quantified, and documented approach to the identification, understanding, and resolution of underlying causes [3]. Root cause analysis is not merely an arbitrary expression; rather, it is a systematic, formal, well-structured methodology, used as part of the total quality–management approach [5].

5. Root Cause Analysis Techniques

There are several tools of root cause analysis techniques for creative thinking such as Fishbone diagrams, Mind mapping, Pareto analysis, causal tree, brainstorming, nominal group technique, metaphorical thinking, and 5-Why analysis. The researcher will focus on Fishbone diagrams, Pareto diagrams, and 5-Why technique.

5.1. Fishbone Diagrams

Fishbone diagram was devised by Professor Kaoru Ishikawa, a pioneer of quality management, in the 1960s. The technique was then published in his book in 1990, “Introduction to Quality Control.”, the diagrams are known as Ishikawa diagrams, cause and effect analysis, or Fishbone diagram because a completed diagram can look like the skeleton of a fish [6]. This tool is used to come up with new ideas like a brainstorming, but in a more balanced way [7]. A cause and effect diagram offers a structured approach to the search for the possible causes(s) of a problem. This tool helps to organize problem-solving efforts by identifying categories of factors that might be causing problems. Often this tool is used after Pareto or brainstorming sessions to organize the ideas generated [8]. This type of diagram identifies all the potential factors that could contribute to a problem. Once all the desired information had been captured and represented by the fishbone diagram, this can help in finding resolutions [9]. Figure 1 is an example that represents this technique.

5.2. Pareto Diagram

Pareto analysis is a technique for focusing attention on the most important problem areas. The Pareto concept, named after the nineteenth century by Italian economist Vilfredo Pareto, is that relatively few factors generally account for a large percentage of the total causes (e.g., complaints, defects, and problems). The idea is to classify the causes, according to the degree of importance, and focus on resolving the most important, leaving the less important [10]. Pareto analysis is a formal technique for finding the changes that will give the biggest benefits [8].

5.3. 5-Why Technique

It is one of the many brainstorming methodologies of asking “why” five times repeatedly to help in identifying the root cause of a problem. If a problem is repeatedly questioned, each time an alternative solution comes out which is linked to the root cause. However, asking why may be continued till getting an agreeable solution. Five is an arbitrary figure. The theory is that after asking “why” five times one is likely to arrive at the root cause [11].

6. Comparison of Common Root Cause Analysis

Many researchers of root cause analysis techniques state the process is too complicated and we should use several of them for each problem or select them based on problem type. The following table used to compare between root causes analysis techniques.

| Table 1. Comparison of selected RCA methods and tools [12]. |
## Method/Tool

| Method/Tool       | Type          | Define problem | Define all causal relationship | Provide a causal path to root causes | Delineates evidence | Explain how solutions prevent recurrence | Easy to follow report | Score |
|-------------------|---------------|----------------|-------------------------------|--------------------------------------|---------------------|-------------------------------------------|-----------------------|-------|
| Events & Causal Factors | Method        | Yes            | Limited                       | No                                   | No                  | No                                        | No                    | 1.5   |
| Change analysis   | Tool          | Yes            | No                            | No                                   | No                  | No                                        | No                    | 1     |
| Barrier analysis  | Tool          | Yes            | No                            | No                                   | No                  | No                                        | No                    | 1     |
| Tree-Diagram      | Method        | Yes            | No                            | No                                   | No                  | No                                        | No                    | 1     |
| Why-Why chart     | Method        | Yes            | No                            | Yes                                  | No                  | No                                        | No                    | 2     |
| Pareto            | Tool          | Yes            | No                            | No                                   | No                  | No                                        | No                    | 1     |
| Storytelling      | Method        | Limited        | Yes                           | No                                   | No                  | No                                        | No                    | 0.5   |
| Fault Tree        | Method        | Yes            | No                            | Yes                                  | No                  | No                                        | No                    | 4     |
| FMEA              | Tool          | Yes            | Yes                           | Limited                              | No                  | Limited                                   | No                    | 2     |
| Reality Charting  | Method        | Yes            | Yes                           | Yes                                  | Yes                 | Yes                                       | Yes                   | 1.6   |

### 7. Application of Root Cause Analysis Techniques

In this study, the researcher relied on the fishbone diagram to classify the sub-causes and the main reasons leading to the poor selection of the contractor in the highway projects and relying on his practical experience in the highway projects and the work of the contracting management as well as relying on personal interviews.

#### 7.1. Cause and Effect Diagram

The diagram in Fig. 1) is characterized by:

- Four main causes (Client, Contractor, work environment, and Legislations and laws) and 18 secondary causes.
- Absence of any reason leading to choose a bad contractor for project implementation.

![Figure 1. Cause and effect diagram.](image-url)
7.2. Client
The Client is the first beneficiary of the special responsibility after the implementation of the construction work, so the decision of the client is a key decision to choose a good contractor, the employer's foundation must be rehabilitated to face any risk in the selection process, the following are the secondary reasons resulting from the Client:

7.2.1. Administrative and financial corruption. The phenomena of administrative and financial corruption is one of the riskiest events face the countries, where it took necroses in the body of their communities began to security and the subsequent shortage in the construction and economic process development, administrative and financial capacities, then the state's deficit to meet the defies of the age and reconstruction and build the infrastructure needs for growths. These corruptions are met care of many researchers and those who attentive agreed consensus on the need to develop and make an official framework designed to enclose the problem and salted through the serious, real steps in all its forms and manifestations in all areas of life to hurry the process of economic developments [13].

7.2.2. Weak application of standard documents. Due to the shortage of experience of the engineering staff and the lack of training courses necessary to prepare. standard documents need a stable security environment for application ideally and this does not help at the moment to achieve this.

7.2.3. Low engineering efficiency. The engineering staff is not qualified to run the expert work, due to the lack of training courses necessary to develop the experience and keep up with the modern methods, and the lack of sufficient opportunity for the youth to highlight their skills.

7.2.4. It depend on senior contractors and give them preference. The referral committee may play a major role in this regard. Recommendations may be made to the government contractor to evade the Integrity Commission or the reason for relying on the older contractor for financial corruption, leading to loss of the best contractor at the expense of the quality, time, and cost of the project.

7.3. Contractor
The contractor is a company or persons that perform works on a contract basis. the following are the secondary reasons resulting from the contractor:

7.3.1. Inexperience. This leads to improper construction work, such as relying on non-specialized staff and using old equipment to implement the required work, leading to loss of time, poor quality and waste of cost, and may lead to failure of the project and inability to continue to implement it.

7.3.2. Poor-quality for previous projects. Failure to achieve the required quality in previous similar projects is proof of the contractor's inability to carry out the required construction work, such as failure to achieve the project life span, failure to comply with the required specification and failure to deliver the project on time.

7.3.3. Use old equipment to carry out construction work. The use of modern equipment to carry out the construction work leads to faster implementation and minimizing the human resources required in the construction project. The non-use of modern equipment is due to the inability of the contractor to purchase equipment and the lack of operators to use modern equipment.

7.3.4. Low financial efficiency. This is one of the most serious risks of implementing the construction project. The most important problems are the inability to pay the financial dues, such as the wages of workers, machinery, and sub-contractors, which leads to a lack of production and interruption of intermittent work.
7.3.5. **Low engineering efficiency.** The lack of specialized engineers for the contractor leads to a high risk of wrong execution, lack of understanding of the conditions and specifications, in addition to the inability of the contractor to choose a specialized staff to carry out the required construction work.

7.3.6. **Non-compliance with occupational safety plan.** Lack of commitment and lack of attention to occupational safety plan leads to losses in materials and human resources, resulting in loss of time, loss of cost, injury of skilled workers, and disruption of important equipment, resulting in high maintenance costs.

7.4. **Work Environment**

The site where the construction project is carried out, which is an important factor in attracting the best contractors to carry out the work. The following are the secondary reasons resulting from the work environment:

7.4.1. **The environment is not suitable to get a good contractor.** This may be because the natural conditions at the worksite do not help to carry out construction work easily.

7.4.2. **Lack of materials and human resources.** The provision of human resources from a source far from the work site causes an increase in costs, such as housing, transport, and food. In addition to the fact that material resources are not available in the work environment, they will lead to the possibility that they will not reach the worksite.

7.4.3. **Disputes.** Maybe some disputes that prevent implementation, such as tribal conflicts, which prevent the contractor from using their material and human resources, and the use of resources available in the work environment, such as the use of unskilled workers, old equipment, and non-conforming raw materials. Sometimes the client cannot get a contractor from outside the work environment.

7.4.4. **Security Circumstances.** The absence of security in the work environment will lead to a serious risk to the lives of the workers. There is a great risk that the contractor will not be able to complete the work on time or not. The best contractors may not be able to compete on construction work in the environment has no security.

7.5. **Legislation and Laws**

Failure to understand this point leads to considerable disagreement between the contractor and the client directly affecting the quality of the construction work. The following are the secondary reasons resulting from the legislation and laws:

7.5.1. **Banks.** Such as giving a letter of guarantee at a low price, opening an account for the company without updating the company's information, and giving financial efficiency to the contractor without filing the required amounts as required.

7.5.2. **Tax avoidance.** Non-payment of taxes due to the State through the use of illegal methods. The reasons for non-payment of taxes is the imposition of non-strict sanctions, a sense of weakness in the imposition of state law, and administrative corruption. The choice of a tax evasion contractor is a major risk to the construction work.

7.5.3. **Poor law understanding.** Due to the absence of a specialized legal department in the institutions, there is a great challenge in legal problems and not to behave properly. To avoid or minimize bad selection for the best contractors for highway projects, the states must provide periodic trainings for all members, use modern technology for project management, give youth a chance to do their best, and commitment to international standards and specifications for project management.
Results for online questionnaire

| Defects                                      | Frequency | Cumulative, % |
|----------------------------------------------|-----------|---------------|
| Internal relationships                       | 178       | 45.8          |
| Administrative corruption                    | 150       | 84.3          |
| Lack of expertise for the Bid Analysis Committee | 25       | 90.7          |
| Accept the lowest prices                     | 10        | 93.3          |
| There are no correct criteria for choosing a contractor | 8        | 95.4          |
| Recommendations are made out of corruption by the Bid Analysis Committee | 7        | 97.2          |
| Selection of government contractor to evade responsibility | 5        | 98.5          |
| Non-compliance of contractors with quality standards and specifications | 4        | 99.5          |
| Depend on the old contractors and give them the right of preference | 2        | 100.0         |

7.6. Pareto Diagram
The analysis of results using a Pareto diagram is shown in Fig. 2. The result of Pareto chart refers that the cause (internal relationship and administrative corruption) cause 84% of poor selection contractor for highway projects. Solving the causes (internal relationship and administrative corruption), we will correct 80% of the issue.

7.6.1. Internal Relationships. Internal relations are one of the most important factors of corruption that affect the selection of the contractor. This leads to a bias towards one party at the expense of the other, such as revealing the estimated cost of the project and disclosing the required specifications for the work. and accept one of the bidding without seeing competitors.

7.6.2. Administrative Corruption. Non-compliance with work, poor accuracy, and improper management, resulting from administrative corruption. Successful contractor selection is done in proper conditions free of corruption.

7.6.3. Lack of expertise for the Bid Analysis Committee. The analysis of bids requires a team with highly specialized expertise, in addition to training courses to develop skills in this field.

7.6.4. Accept the lowest prices. Acceptance of the lowest bids does not mean choosing the best. Neglecting other factors such as time and quality may negatively affect the implementation and achieve life span and demand maintenance for longer periods.

7.6.5. There are no correct criteria for choosing a contractor. To Choose the best, you must put the correct mechanism commensurate with the work required.

7.6.6. Recommendations are made out of corruption by the Bid Analysis Committee. Incorrect bid evaluation by the Bid Analysis Committee affects the project assignment committee and therefore there is an opportunity to choose a non-qualified contractor to carry out the work.

7.6.7. Selection of government contractors to evade responsibility. Relying on the government contractor and especially the self-financing companies is better than the private contractor even if the price is offered more by a private contractor. The reason for relying on the government contractor may also be to evade the Integrity Commission.

7.6.8. Non-compliance of contractors with quality standards and specifications. Non-compliance with the necessary specifications and quality of work, and consideration by the employer, and acceptance of tender in this cause means there is a risk to implement the construction work.
7.6.9. **Depend on the old contractors and give them the right of preference.** Dependence on the oldest contractor without the decision to choose new contractors is a loss to achieve better results than before, a new decision does not mean failure, but it means looking for the best.

![Pareto chart](image)

**Figure 2.** Pareto chart.

7.7. 5 - **Why Technique**
During the online survey, the most 4 factors affecting on the contractor selection are:

- Internal Relationships
- Administrative Corruption
- Lack of Expertise for The Bid Analysis Committee
- Accept the Lowest Prices

Therefore, the following figure illustrates the root cause factor for the bad selection.
8. Conclusions

Major conclusions can be summarized as follows:

- In this research, root cause identification methodology has been adopted to diagnose the causes of contractor selection in highway projects. Root cause identification for project-related problems is a key and necessary step in the improvement and control of cost deviation. Fishbone diagram (FD), Pareto diagram (PD), and the 5-Why analysis used in this study to diagnose the causes of contractor selection in highway projects in the Republic of Iraq.

- Eighteen causes concentrated mostly in the selection procedure explained by the Fishbone diagram.

- The result of Pareto chart refers that the cause (internal relationship and administrative corruption) cause 84% of poor selection contractor for highway projects, and Solving the causes (internal relationship and administrative corruption), we will correct 80% of the issue.

- Pareto diagram results had been filtered more by applying 5-Why analysis, this analysis concluded that the lowest bid price is a root cause for bad contractor selection for highway projects.

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