



Using cause analysis, decision analysis, and the 5 Whys technique in evaluating engineering construction projects damaged by accidents

*Asmaa Mutar Jaber

Department of Civil Engineering, College of Engineering, Al-Muthanna University, Samawah, Iraq.

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Abstract

The researcher collected the most important documents used to assess accident-damaged projects. These include the original project documents, such as the contract and specifications, approved engineering plans and designs, the original project schedule, the Bill of Quantities (BOQ), and documents proving the occurrence of the accident. The accident report, recorded by the resident engineer or occupational safety officer on site, states the time, location, apparent cause, and initial damage. Photos and videos taken before and after the accident document the extent of the damage. Official reports include a Civil Defense report if it was a fire, a police report if it was a criminal incident, and a soil/concrete testing laboratory report. Technical and financial evaluation documents include the consulting engineer's report, which assesses the extent of the damage technically and determines whether the damaged part is repairable or requires demolition and reconstruction. A damage estimate is also included, detailing the cost of repairs, materials, labor, and equipment. If the project is insured, the resident expert's report, specifying the compensation amount, is also required. Finally, follow-up and management documents include a record of all official correspondence between the contractor, owner, and consultant regarding the accident, as well as stop and resume orders and site orders issued during and after the accident. The incident impact report details how many days the schedule was delayed due to the incident.

Keywords: Project Evaluation, Construction Accidents, Root Cause Analysis, Risk, 5whys techniques Management, Cost and Schedule, Occupational Safety, Case Studies, Iraq.

Introduction

This study used a combination of mixed methods. In particular, a descriptive-analytical study combined with the field survey was adopted. The proposed integrated assessment model was implemented to investigate a particular case study, which relates to a residential project suffering from a partial roof collapse. The assessment model involves root cause analysis through the application of 5 Whys technique, re-evaluation of cost and time variances, and determination of the necessary corrective and preventative measures. Additionally, a set of questionnaires were distributed to a sample of 52 engineers and contractors working in Iraq. The questionnaire aims at evaluating the most critical causes of accidents, as well as their impact on construction project management, from the practitioners' viewpoint. According to the findings, the root causes of accidents are mainly administrative and not technical ones. In particular, time pressures, poor supervision, and low workers' training were revealed as the main reasons for such accidents. Moreover, such accidents have resulted in an increase in costs by an average of 1.5%-4%, as well as project time delays ranging between 10 and 20 days. The implementation of root cause analysis techniques, the update of the Bills of Quantities (BoQs), and activation of the role of the safety engineer can effectively minimize the probability of occurrence of any accident in the future.

Methodology

The evaluation of a project which had an accident will be different compared to regular evaluations since it requires more than finding out about what has been lost. It should include such questions as "how to prevent it, how to restore the project and why it has occurred". Here are the practical steps of evaluating the project:

1. Emergency Evaluation. Stabilizing the process and finding out what losses were made. Safety. There is no threat to the health of the employees and at the construction site. Damage Assessment. Human loss. People who died and got injured;

compensation. Material loss. Broken equipment, building materials and products already produced. Time loss. Work interruption duration; activities disrupted. Documentation. Photos, reports of police/civil defence, statements of witnesses etc. This will be necessary for investigating and filing an insurance claim.

2. Root Cause Analysis (RCA). Not only find out what caused the problem as seen by figure (1) "the crane collapsed". You have to answer "why" five times: The 5 Whys method. Why did it fall? Because the cable broke. Why? It became aged. Why? It was not checked timely. And so forth. The tools which can support RCA can be fishbone diagram and fault tree analysis. Objective. Finding out whether it was due to technical faults, administrative issues, training and education problems or weather conditions.

3. Reviewing the cost and schedule. After the accident happened the old numbers do not hold any relevance. -Direct costs. Payments for repairs, compensation, buying new equipment etc. -Indirect costs. Fines for delay, damage to the reputation, higher insurance rates. -*Schedule*. Changing critical path and identifying new delays. Using software like MS Project or Primavera. Comparison with the initial budget (BoQ) will show the new expenses and whether the project remains economically feasible. Evaluation of the Safety Management System This accident is an indicator of the system performance. Was the plan developed and executed? -Did the workers have enough training? Protective equipment? Poor supervision or did the need to finish on time forced skipping the procedure? Decision-Making as figure (2): Continue, Modify, or Stop Based on the Points Above. Decide: Continue with Modification: If the loss is limited and the cause is addressed. Add preventative measures and amend the Bill of Quantities (BoQ). Restructure: If the problem is administrative, change the contractor or the supervision team. Stop: If the expected cost exceeds the benefit, or the risks are not accounted for. 6. Document Lessons Learned* Record everything in an official log: What happened, why it happened, what corrective action was taken, who is responsible, and when it will be implemented. This log prevents the recurrence of the same incident in future projects. Quick Indicators for Evaluating a Project After an Incident: Indicator (if it exceeds 10%) Meaning: Cost Deviation: The project has become more expensive than anned. Schedule Deviation: The risk of significant and difficult-to-compensate delays. Incident Frequency Rate: The risk of a failing safety system. Areas Damaged: Equipment, Materials, and Completed Work Duration of Downtime: Number of Days and Hours Reporting Entities: Police, Civil Defense, Ministry of Labor. Root Cause Analysis: 5 Whys Question Answer as figure (3).

1. Why did the incident happen?
2. Why did cause number 1 happen?
3. Why did cause number 2 happen?
4. Why did cause number 3 happen?
5. Ultimate Root Cause. Impact on Cost and Schedule Item Before Incident After Incident Difference Total Project Cost Direct Cost of Incident Indirect Cost Planned Completion Date New Expected Completion Date Percentage Delay %
5. *Corrective and Preventive Actions Responsible Action Date Implemented Status
1. Immediate Action Completed/In Progress
2. Root Cause Corrective Action
3. Preventive Action to Prevent Recurrence



Figure (1) Root Cause Analysis (RCA)

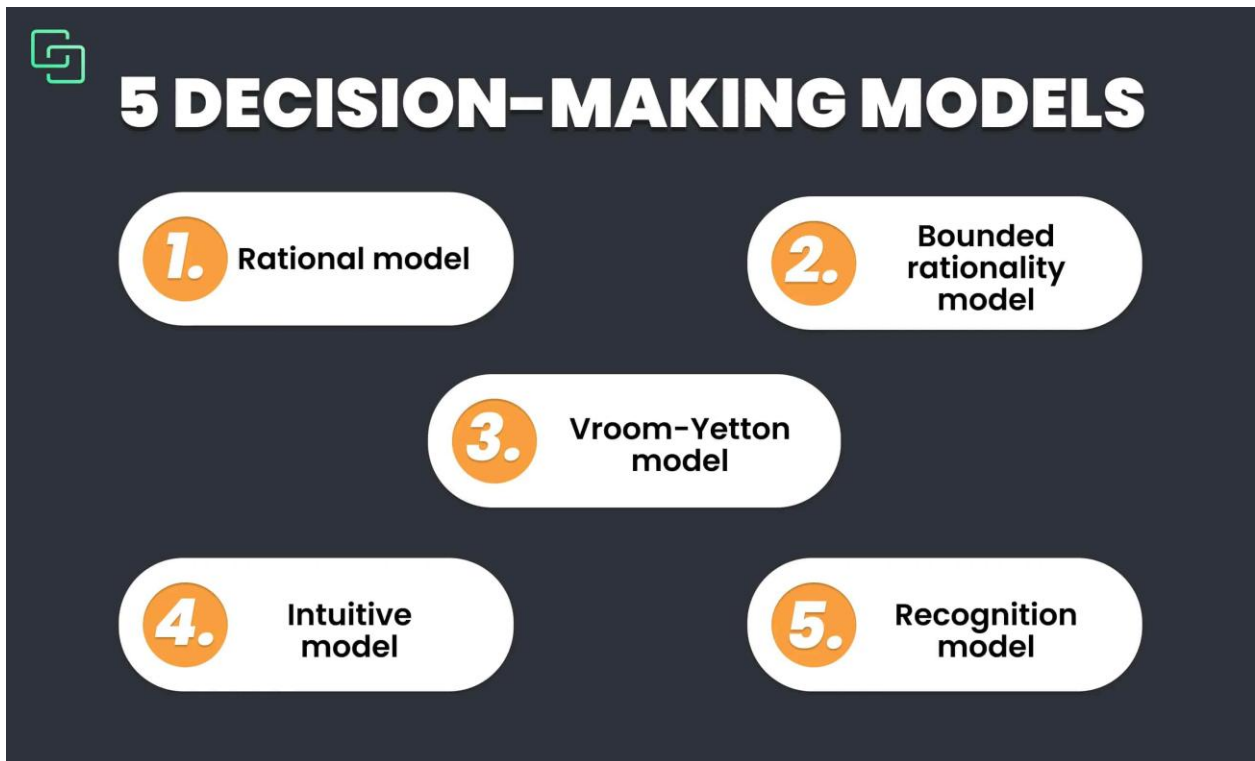


Figure (2) Decision-Making analysis

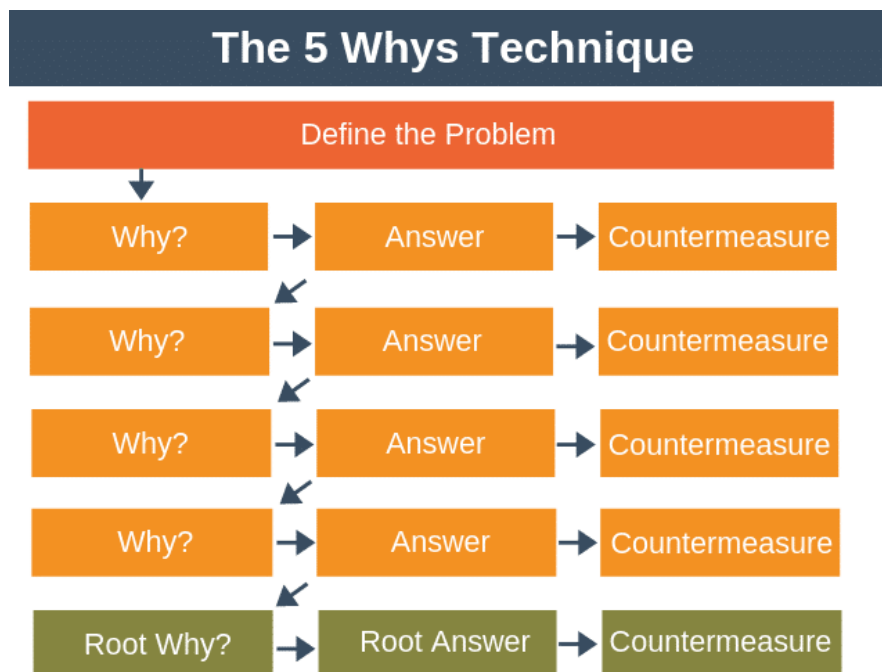


Figure (3) the 5 whys technique

Results and discussion

Evaluating a project that has been exposed to accidents and the conditions for its acceptance:

1. The assessment of any engineering project that has been involved in accidents generally consists of the following: Establishing the private or public ownership status of the building or project, or the plot of land on which the building or project is located, and verifying the validity of the documents submitted by the owner of the building, the apartment located within it, or the project, by referring to municipal documents and the title deed (Tabu), or the approved temporary title deed.

2. Studying the current condition of the building or project, on the ground, and matching the measurements provided by the reconstruction applicant with the documented property measurements.
3. The evaluation of the proposed project must be based on the following necessary steps to assess its current condition and the technical steps required to ensure accurate design and execution:
 - Direct observation of the building and visual inspection on site.
 - Study of the building that has been damaged, following forensic engineering principles, by conducting a structural analysis of the building's elements and identifying the cause of its current condition.
4. Determining the current condition of the building:
 - The building requires only external repairs; specify these repairs in detail.
 - The building has minor internal and external damage and requires some superficial repairs; specify these repairs in detail.
 - The building has extensive damage and requires comprehensive repairs; specify these repairs in detail.
 - The building is completely destroyed and cannot be repaired; it must be completely demolished. Identify what can be salvaged from its rubble, study how to utilize it, and describe how it can be used.
5. A study of the rubble from completely destroyed buildings, and methods for its disposal or utilization, after classifying it into:
 - Concrete rubble that can be reused, after ensuring the absence of unexploded ordnance, mines, or human remains. Then, the reinforcing steel should be separated, transported, and manually repaired, and the remaining concrete ground for use in making new concrete, provided it is not mixed with soil or sewage.
 - Architectural rubble such as doors and windows, sanitary rubble such as bathroom and kitchen fixtures, and electrical rubble such as switches, sockets, outlets, and cables (if found intact), which can be reused in new construction.
 - Mixed rubble that cannot be reused and must be disposed of in public dumps or used to fill craters caused by shelling or wades in non-agricultural areas. We strongly advise against using it to fill in the sea or riverbeds.
6. Studying the identification of private and public properties, various occupations, and the type of project needed to replace those properties, provided that the various municipalities study and examine the documents, and compare what is submitted by the public with the original municipal documents, and ensure that the person submitting the documents is a real person who has the legal and legitimate right to the property.
7. Feasibility study of the project, in public buildings and occupancy. Preliminary study of the project. Study of the project's impact on the environment. Traffic impact study. Preliminary design development studies. Meeting sustainability requirements. Meeting green building requirements. Developing the final designs for the proposed alternative building.
8. Architectural drawings, plans, sections, elevations, architectural details, tables of various openings, finishing tables, 3D models in important projects, special specifications (provided no specific brands are specified), general specifications, source of special specifications, data for soft landscaping and hard landscaping, etc. Structural drawings, based on the soil report, structural study and calculations of the building structure, and a complete description of the materials used, by creating a complete 3D mathematical model on internationally recognized software such as SAP2000, SAFE, ETABS, ROBOT, etc. Study of sections and structural details on internationally recognized software such as PROKON, etc.
9. The foundations upon which the structural design and analysis are based are laid, such as:
 - Specifications for cement (and plain and reinforced concrete) to meet sustainability and durability requirements in a harsh environment, and to withstand natural factors during pouring and throughout the building's service life.
 - Specifications for reinforcing steel (steel bars, FRP bars, stainless steel, etc.).
 - Reinforcement methods (in situ, prestressed, posttensioned).
 - Foundation plans and schedules (spread footings, combined footings, strapped footings, mat foundation).
 - Column plans and schedules.
10. Slab plans and schedules (Slab on Beams & Girders, Flat Slab, Hardy, Waffle Slab, Hollow Core)
 - Retaining wall schedules and elevator shaft schedules (if applicable)
 - Foundation layout for the steel structural design (Hot-rolled Sections, Light Gauge Steel Sections, Pre-engineered) *Establishing fire protection specifications (concrete encasing, intumescent paint, rock wool) and rust protection specifications (galvanization, zinc oxide paint, special paint).
 - Establishing firefighting system drawings and specifications.
 - Establishing the principles upon which composite construction is based.
 - Illustrative sections, especially in precast construction.
 - Clearly stating standard references (codes of practice) where required.
 - Ensuring consistent drawings between the architect and the contractor.

11. Electrical Works Plans.

- Plans and routes of power lines and extensions, the main panel and sub-panels, starting from the main external outlet.
- Routes and specifications of internal connections, horizontal and vertical cables and wires.
- Plans and routes of wires and cables, lighting fixtures, power outlets, and chandeliers.
- Plans of electronic works and their accessories: cameras, doorbells, televisions, computers, and the electronic control system for the building and its contents.
- Plans and specifications of elevators, in buildings that require elevators.
- Plans of fire alarm systems, and their compliance with civil defense requirements.
- Technical specifications for cables and wires, equipment and devices, circuit breakers, sockets and outlets, and lighting switches and fixtures.
- Electrical calculations, including references where required.
- Details of intersections and connections with architectural and structural works.

12. Sanitary Works Drawings.

- Plans, details, parts, and installations for bathrooms and kitchens.
- Drainage plans for bathrooms, kitchens, rooftops, balconies, and outdoor areas and courtyards.
- Plans of internal and external drainage lines and their diameters.
- Plans of internal and external supply lines, their types, and diameters.
- Gully traps and manholes, where required by the drainage system.
- Sewage collection and analysis tanks, and septic tanks, in areas without a public sewer network.
- Underground, aboveground, and rooftop water tanks, and water supply pumps, in areas without a public supply and meters.
- Fire suppression system drawings, with the necessary calculations, according to Civil Defense requirements.
- Technical specifications for supply and drainage pipes, sanitary equipment, fixtures, and pumps.
- Mechanical calculations for supply and drainage systems, including references where required.
- Details of intersections and intrusions with architectural and structural works.

13. Landscaping Plans:

- Hard Landscaping: Sidewalks, walkways, outdoor seating areas (gazebos or pergolas).
- Soft Landscaping: Indoor gardens, shade trees, flower beds, etc.

14. Schedule and Bill of Quantities:

- Proposed schedule from the project provider
- Detailed bill of quantities for materials used in the project, including descriptions, measurement methods, and substitution requirements.

Conclusions and Recommendations

1. Adopt a mandatory standardized assessment form: After each incident, an assessment report must be completed, including a description of the incident, a 5-Whys analysis, the impact on cost and time, and corrective actions.
2. Link payments to safety reports: No payment will be disbursed until a weekly safety report, signed by both the safety engineer and the supervisor, is submitted.
3. Involve safety engineer into working process: The employment of a full-time safety engineer is compulsory for any project which costs more than 500 million dinars.
4. BOQ revision in the event of accident: It is done to clarify the question of extra charges between the owner and the contractor.
5. Creation of common database for accidents: In the ministry of construction or Engineers Syndicate to make use of experiences gained.
6. Compulsory regular trainings: Safety course is provided to each worker and engineer prior to starting work on site and is renewed after six months period.

Proposed future studies

Here are some possible ideas for future research into addressing and fixing project accidents:

1. The use of Artificial Intelligence and Digital Surveying Methods – Investigation of the effectiveness of the use of artificial intelligence, drones, and digital surveying using 3D laser scanning technology that allows for faster and more accurate evaluation than standard methods.
2. Pre-Accident Risk Prediction Models – Studying the creation of such models which would predict the risks to which the project may be exposed.
3. Smart Materials for Rapid Repair. Exploring the use of self-healing building materials such as concrete or thermally bonded polymers to repair cracks and minor damage quickly and at a lower cost.

4. Integrating Insurance with Project Management. Exploring mechanisms to link insurance contracts with the BIM (Building Information Modeling) system to make damage assessment and compensation estimation more automated and transparent.
5. The Psychological and Organizational Impact on the Project Team. This is an often-overlooked topic. A future study on how an incident affects team performance and decision-making, and what procedures can be implemented to minimize the negative impact on the work environment.
6. 6. International Standards for Incident Documentation*: A comparison between the standards used in Iraq and FIDIC and ISO 22301 standards for business continuity management, and a proposal for a unified framework suitable for the local project environment.

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