# A case study of forensic delay analysis in the Construction of a Revamp Power Transmission Project

## Abstract

Project delays are a common feature in the construction of industrial projects. Timely completion of these projects is significantly important for both clients and contractors, though for different reasons. Any delays beyond the stipulated project completion time usually result in substantial commercial losses and often cause litigation among project participants. Therefore, it is critical to understand and analyse major delay events in industrial projects using a method that may have legal acceptance in case of delayed claims and court proceedings. This paper presents a case study of a large-scale power transmission project involving the revamp of 36 substations across eight regions in Saudi Arabia. A forensic delay analysis was performed using a window analysis technique to identify the major causes of delays in the project. The analysis was conducted using a critical path method (CPM)-based simulation model under an Observational Dynamic Logic Contemporaneous framework. The study identified 11 major delay events contributing to delays and work prolongation for 581 calendar days from the baseline mechanical completion of the project. Key findings reveal that the primary contributors to project delays included land and work permit issues, delayed approvals of technical documents, change orders, and procurement challenges. This study draws on a real-world project and actual project data, comparing the contractual baseline schedule with as-built progress to analyse and present research findings. The results offer valuable insights for both academia and industry, enhancing the understanding of delays caused in industrial projects within the context of Saudi Arabia.

## Keywords

Project Delays; Project Management; Window Analysis; Saudi Arabia, Case Study

## 1. Introduction

Infrastructure projects, such as power transmission projects, are high-value industrial installations with substantial impact on a country's economy and business activities. Successful completion of power construction projects includes completion of project activities within the allocated time, budget, and stakeholder satisfaction. "Time is of the essence" is a well-understood and implemented concept in construction contracts, which ensures that a project is completed within a specified timeframe (Lim, 2012). Any delays beyond this time would require the project contractor to spend additional resources, both in terms of direct and indirect costs and be liable for liquidated damages to the client in case of delayed completion. Likewise, the project client may suffer the loss of potential revenue or availability of project services if the project is delayed. So, even though timely completion is critical for all project stakeholders, infrastructure projects often extend beyond the stipulated contractual deadline, which often results in delay claims, cost overruns and litigation among project parties (Iyer et al., 2008).

Power transmission projects in the GCC (Gulf Cooperation Council) regions are often based on EPC (Engineering, Procurement & Construction) Contracts, which allow overlapping of design, procurement and construction activities by the contractor to aim for faster completion of the project. However, EPC contracts are based on a Front-End Engineering Design (FEED) that develops a project concept design and relies on the contractor's design team to develop a detailed design along with the project progress (Sami Ur Rehman & Shafiq, 2022). Within this process, the client requirements may not be clearly elaborated and may warrant several change orders, leading to project delays and contractor claims for disruption and variation orders. Zhang et al., (2018) also pointed out that since designers and suppliers are within the contractor's team in an EPC contract, therefore, delays related to design errors, faults and miscommunication may be reduced in EPC contractors. It can be concluded that EPC contractors are adopted to reduce overall project completion time but are prone to even more delays due to incomplete requirements and expected change orders.

Forensic delay analysis has emerged as a specialized field within construction project management, focusing on the quantification and interpretation of the economic consequences of project delays while incorporating legal and contractual considerations (Grzeszczyk et al., 2024). Forensic delay analysis emphasizes the systematic review of project records to reconstruct timelines and assign liability (Stall, 2022). By integrating quantitative and qualitative assessments, and combining legal, management, and scheduling perspectives, this approach provides a robust framework for resolving disputes and ensuring fair compensation (Grzeszczyk et al., 2024). Previous studies have identified a wide range of factors related to various aspects of project performance and management, which are declared leading causes for project delays. Previous studies have shown that project delay factors are often attributed to legal, financial, technical, organizational, environmental and project-related issues (Doloi et al., 2012; Idress and Shafiq 2021: Sami Ur Rehman et al., 2022). Most delay analysis studies have used survey questionnaires to collect research data from research participants and then apply a mathematical model to rank delay factors according to the questionnaire results. This socio-statistics approach can only present results based on participants' opinion about perceived delay factors and causes which may be spread across a wide range of projects and therefore has limited validity in order to understand actual causes of delays and related delay intensity within a project context. Therefore, a case study approach should be adopted for an in-depth analysis of delay events and underpinning causes of delays using real project data. With the above background, this study has analyzed a large power transmission revamp project using a forensic delay analysis technique to identify various delay events and related impact on project completion.

## 2. Methodology

This study is based on a large power transmission project which included a revamp of 36 substations across 8 areas in the Kingdom of Saudi Arabia (KSA). The split of project work sites is shown in the Table

**Table 1.** Site area of the case study project

| No. | Area Name | Number of sites |
|---|---|---|
| 1 | Ain Dar | 5 |
| 2 | Fazran | 1 |
| 3 | Shedgum | 7 |
| 4 | Abqaiq | 2 |
| 5 | Uthmaniyah | 14 |
| 6 | Hawiyah | 4 |
| 7 | Haradh | 2 |
| 8 | Harmaliyah | 1 |

The project was awarded using an Engineering Procurement Construction (EPC) contract. EPC contracts provide a suitable framework for projects where significant engineering expertise is required especially for large-scale energy and resource developments such as power generation, processing plants, the oil, and gas sector, and mining developments. The project faced substantial delays due to the complexities of such a large-scale revamp project. This study performed a forensic analysis using the window analysis technique to identify major delay events in the project. The window analysis method is a recognized forensic analysis technique by the Association for the Advancement of Cost Engineering International (AACEI) under the 29R-03 recommended code of practice. A core principle of window analysis lies in its dynamic treatment of project changes, advocating for adaptive rather than static approaches to effectively address persistent schedule delays and cost overruns in construction projects (Park and Peña-Mora, 2003). The technique's inherent flexibility facilitates iterative assessments of project timelines, enabling it to accommodate ongoing deviations and modifications, an advantage particularly relevant in complex construction environments characterized by frequent changes (Yang et al., 2011). This study followed an Observational Dynamic Logic Contemporaneous method of delay analysis.

This technique relies on the simulation of a scenario based on a critical path method (CPM) model. The simulation consists of the insertion or addition of activities representing delays or changes into a network analysis model representing a plan to determine the impact of those inserted activities on the network. The stepped insertion

technique was followed to perform what-if analysis/simulations for each of the major delay events, introduced in the previous section, to analyze the impacts of the events and quantification of the culpable delay. In this method, the major events that have significantly contributed to the delay of the project are injected into the baseline schedule and the direct impact is analyzed. The forensic analysis used a mutually agreed baseline plan that showed a project completion date of 26 December. The study has anonymised the project year, client, and contractor details for confidentiality reasons.

## 3. Results and Findings

The project was analysed by dividing it into nine distinct "windows," each representing a period within which specific delay events were examined. This window-based forensic schedule analysis enabled the isolation of critical delay events and their respective impact on the project schedule. Each window incorporated both baseline and revised schedules, as well as As-Built data, allowing for a clear comparison of planned versus actual progress. This approach revealed when delays occurred, how long they lasted, and which parties were responsible.

In the first window (19th October to 30th November), critical path activities at Ain Dar Temporary facilities were delayed by 2 days due to land confirmation and communication issues. This shifted the critical path to Harmaliyah GOSP-1, where delays in ID and work permit processing by the client added another 85 days. During the second window (30th November to 2nd May), delays continued at Harmaliyah GOSP-1, adding another day to the project completion. Land permit issues at Ain Dar Temporary facilities and approval delays for Spot Type Smoke Detectors contributed to a 14-day delay by the end of this window. In the third window (2nd May to 30th May), land permits remained critical, adding 28 days to the project completion. Delays in Dead Tank Circuit Breakers and Gantry Steel Structures added another 29 days, with 28 days concurrent with the land permit delay. The fourth window (30th May to 31st August) saw delays in the approval of NMR 602 for the Gantry Steel Structure, adding 53 days. Dead Tank Circuit Breaker delays added 71 days, with 3 days concurrent with the previous delay, totalling 183 days by the end of this window. In the fifth window (31st August to 19th September), further delays in the approval of NMR 602 for the Dead Tank Circuit Breaker added 13 days. Procurement delays for Spot Type Smoke Detectors and Steel Structure Supports for Electrical Equipment added 17 days, with 16 days concurrent with previous delays. The sixth window (19th September to 31st January) experienced delays in civil works for the Gantry Foundation at Shedgum ACC due to rock excavation issues and work permit problems, adding 26 days. Shutdown activities at Uthmaniya GOSP-4 and other site access delays added another 14 days. In the seventh window (31st January to 2nd April), delays in structural concrete material delivery and approval of the Material Advance Payment Bank Guarantee added 195 days. Design holds, interface management issues, and unidentified ground obstacles contributed to this delay, with site development work at Ain Dar GOSP-2 adding another 16 days. The eighth window (2nd April to 31st July) saw further delays due to Change Order #03, impacting on design, procurement, and construction activities, adding 102 days to the project completion. Finally, in the ninth window (31st July to 27th November), Change Order #03 continued to be critical, adding 119 days, but re-sequencing of work by the contractor limited the impact to 41 days.

In summary (Table 2), the window analysis showed that multiple critical delay events, including issues with land permits, work permits, design approvals, and change orders, cumulatively extended the project completion by several months.

**Table 2.** Summary of Window Analysis

| | Window No. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total delay per |

| Sr No | Delay Events | No of Days of delay | | | | | | | | | delay event |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Delay in the Start of Civil work for Temporary Facilities in the South region – Land permit issues | 2 | | | | | | | | | 2 |
| 2 | Delay in Excavation work in Harmaliyah GOSP-1- No access ID issued | 85 | | | | | | | | | 85 |
| 3 | Delay in Site Preparation work for Temporary Facilities in Ain Dar - Land permit issues | | 1 | | | | | | | | 1 |
| 4 | Delay in Approval of NMR 601 for Spot Type Smoke Detectors | | 6 | | | | | | | | 6 |
| 5 | Delay in providing Land Use Permits | | 7 | | | | | | | | 7 |
| 6 | Delay in the issuance of RFI – Missing technical Information | | | 1 | | | | | | | 1 |
| 7 | Delay in the issuance of RFI - Design revisions | | | 28 | | | | | | | 28 |
| 8 | Delay in Approval of NMR 602 for Gantry Steel Structure | | | | 50 | | | | | | 50 |
| 9 | Delay in Approval of NMR 602 for Dead Tank Circuit Breakers | | | | 3 | | | | | | 3 |
| 10 | Delay in Approval of NMR 602 for Steel Structures Supports for Electrical Equipment | | | | | 1 | | | | | 1 |
| 11 | Delay in Approval of NMR 602 for Spot Type Smoke Detectors | | | | | 16 | | | | | 16 |
| 12 | Delay in Gantry Foundation work - Unforeseen soil conditions discovered + No access ID issued | | | | | | 26 | | | | 26 |
| 13 | Delay in shutdown activities in Uthmaniya GOSP-4 – No access ID issued | | | | | | 2 | | | | 2 |
| 14 | Delay in Foundations work in Shedhum GOSP-3 - No access ID issued | | | | | | 14 | | | | 14 |
| 15 | Delay due to Change Order # 03 | | | | | | 1 | | 102 | 41 | 144 |
| 16 | Delay in Delivery of Structural Concrete | | | | | | | 179 | | | 179 |
| 17 | Delay in Construction work in Aindar GOSP-2 due to Change Order # 03 | | | | | | | 16 | | | 16 |
| | Total Delay in each window | 87 | 14 | 29 | 53 | 17 | 43 | 195 | 102 | 41 | 581 |

As identified in the window analysis, several delays were caused by errors and conflicts in the preliminary design, which led to the reissuing of IFC (Issued for Construction) drawings, rework, and unforeseen ground utilities. The preliminary design failed to identify key utility lines that were impacted by the construction progress and required coordination with relevant government departments to safely execute the work activities. As a result, the project faced several changes in design due to an unfrozen scope and multiple revisions of the primary design by the client.

Another major cause of delay was the suspension of work on 20 out of 32 worksites due to a "hold" imposed by the client. Any hold would lead to demobilisation and remobilisation, further disrupting the planned work progress. Additionally, the scope of work on 12 sites was reduced, preceded by holds on these sites. The contractor-maintained management and logistics infrastructure on these sites due to the uncertainty of holds, which eventually resulted in delays. Interface management with utility supply companies was critical in this project but was poorly managed. Interface management problems resulted in unforeseen ground conditions, work stoppages, reduced access due to shutdown schedules, and holds on several sites. The window analysis noted that several project delays were related to prolonged approvals for IFC drawings, submittals, and requests for information (RFIs). Delays in document reviews impacted the work progress, project cash flow, and delayed payments, causing delays in several procurement activities. To summarise the window analysis, the following delay events are identified.

1. Delay in Design Approvals
2. Delay due to Design changes/revisions
3. Delay in NMR's activities Approval
4. Delay due to Unforeseen underground conditions
5. Delay in Site Preparation and Temporary Facilities Approvals
6. Delay in ID processing
7. Delay due to late issuance of Land Use Permits
8. Delay in the Material Deliveries
9. Delay due to Hold in sites
10. Delay due to the impact of interfacing projects
11. Delay due to late approval of bank guarantee, payments, and disrupted project cash flow

The window analysis was performed and an independent consulting team, therefore the allocation of responsibility for any delays to the client or contractor is not within the scope of this work.

## 5. Conclusions

This study has undertaken a comprehensive examination of project delay events for a large-scale power transmission revamp project in the Kingdom of Saudi Arabia, using the window analysis technique for forensic delay analysis of project schedule. The study has identified 11 major delay events which collectively led to a work prolongation of 581 calendar days beyond the baseline mechanical completion of the project. These delays stemmed primarily from a combination of administrative bottlenecks, such as land and work permit issues, as well as technical and procurement-related setbacks, including late approvals of design modifications, material delays, and complications due to change orders. This case study emphasizes the importance of early stakeholder coordination, timely approvals, and clear communication in complex infrastructure projects. A clear and detailed investigation of project delay events is a steppingstone for client organizations and contractors towards understanding the root causes of project delays and making informed decisions to avoid future project delays. The forensic analysis approach applied here aids in dispute resolution and accountability assignment. The findings of this study are a valuable reference for industry professionals and academics seeking to navigate the causes of project delays, forensic delay analysis and management of industrial projects. This study is limited in scope, and its findings are limited to a single case study. A more comprehensive investigation may include multiple case studies and extend to ranking delay events along with assigned responsibility, which is the scope for future work.

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