Root Cause Analysis of Schedule Variance in the Implementation of a Seawater Desalination Project in the Western African Region

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Abstract

This study investigates the root causes of schedule variance in a seawater desalination EPC project executed by VA Tech Wabag Limited in Western Africa. Using the Critical Path Method, PERT float analysis, Earned Value Management, Fishbone Diagram, and Five Whys technique, the study traces a shift from a peak positive Schedule Variance of US$ 8.47 million to a negative variance of US$ 3.58 million by July 2024. The critical path spans 906 days through ten zero-float activities. Engineering delays (28%) and procurement delays (25%) together account for over half the total schedule variance. Root causes include immature specifications at procurement initiation, absence of engineering-procurement interface gates, inadequate logistical risk planning, and weak client document approval mechanisms. The study recommends formal interface gate checks, contractual review timelines and monthly EVM dashboards with automatic SPI alerts as preventive measures for future EPC projects.

Keywords: Critical Path Method, Earned Value Management, EPC Projects, Root Cause Analysis, Schedule Variance, Seawater Desalination.

Introduction

A Root Cause Analysis (R) refers to a systematic approach for determining the underlying reasons for a particular problem or delay in order to address it effectively. In Project Management, especially EPC Projects, delay or cost overruns usually arise from some deep-seated reasons. RCA helps companies comprehend the underlying causes of problems that led to such issues, hence ensuring that similar problems do not occur again.

Delays within the EPC Project rarely result from a sole reason, but rather from a series of related issues covering areas of engineering, procurement, logistics, civil construction and many others. A structured root cause analysis helps companies disintegrate complex issues and allows project managers to trace the source of deviations.

Schedule Variance (SV) refers to one of the main indicators in Earned Value Management (EVM) which indicates the difference between the planned progress and the actual performance. This is achieved through calculating the difference between EV and PV. An occurrence of a negative value of SV shows that the project is behind schedule while the Schedule Performance Index (SPI) calculated as EV/PV provides a standardized measure.

Desalination of seawater through Reverse Osmosis (RO) has gained prominence as one of the key methods for addressing water shortage issues in various parts of the world. Such projects have technical complexities that require utmost precision. Failure to deliver within the stipulated timeframe in such projects will mean significant repercussions that include liquidated damages, loss of client goodwill, and failing to provide much needed infrastructure at the desired time. The project chosen for study is a desalination project carried out by VA Tech Wabag Limited, which is in West Africa, particularly in Dakar, Senegal.

VA Tech Wabag Limited, headquartered in Chennai, India, is one of the leading firms in providing total solutions in water management. The firm was established in Germany in 1924 and currently works in more than 25 countries around the world, completing over 6,500 projects. The company uses an asset-light strategy that entails the provision of engineering services and technology instead of civil construction projects. This makes procurement very crucial.

The study aims to analyze the schedule performance of the Wabag desalination project in Senegal, identify causes of delays through CPM, PERT, EV, Fishbone Diagram, and Five Whys, and suggest remedial actions for future EPC projects.

Review of Literature

Construction project delays continue to be among the major challenges faced around the globe. According to Karale et al. (2025), an analysis of literature from ten studies conducted between 1987 and 2023 found that common delay factors included changes in designs, communication problems, financial problems, contractors' ability, and supply chain disruption. Improved planning and coordination were proposed as mitigation strategies.

In their study on delay factors in a pipe distribution network project, Kore et al. (2025) reported that the delays experienced in payment from the owners resulted in a domino effect throughout the supply chain. Political influences and shortage of skilled workers were also challenges for the contractors.

The use of Digital Twin has been seen by Al-Nuaimi (2025) to greatly improve the management of construction projects, especially when it comes to the accuracy and consistency of scheduling. Construction projects implementing Digital Twin technology exhibit flexibility in the handling of issues and efficient deliveries.

Delays in construction projects and the use of Primavera P6 software in project scheduling was investigated in journals reviewed by Saiyad and Shinde (2025). These scholars have established that such delays result in time, cost, and quality problems in the projects.

According to Devi and Sindhu (2025), infrastructure construction delays in India have been grouped under four dimensions namely; Resource and Supply Chain, Government and External Factors, Contractor Management, and Design and Planning. The research recommends the use of Building Information Modelling in infrastructure construction projects to mitigate delays.

The impact of water infrastructure development planning in Gondaliya et al. (2025) reveals that several factors including social, economic, political, environmental, and technical factors have significant effects on the decision-making process and outcomes of the project. The study notes the significance of coordinated policies between national and local government authorities in infrastructure project planning.

The evaluation of Widyarso et al. (2025) on the planning and execution of a hospital infrastructure project in Indonesia revealed a cumulative project delay of 29 days with considerable costs overrun. In addition, the study suggests that advanced project management technologies should be embraced in construction projects.

In their study on change orders in Omani construction projects, Al Maamari and Khan (2025) note that changes in specifications and design modifications were the primary causes of variations which in turn resulted in the increase in project cost and the project completion schedule delay.

In their research, Musarat et al. (2025) determined the effects of inflation on budgeting of construction projects and found that inflation is often overlooked when developing cost plans for construction projects because of rising material, labour, and equipment costs annually.

The effect of poor productivity in labour on construction project costs was determined by Abdel-Hamid and Abdelhaleem (2025) using a case of a mega construction project in Egypt, and their results showed a correlation between productivity deviations and cost escalation of construction projects.

Research Gap

While there is substantial literature on the subject matter, most are theories and recommendations that relate to construction projects in general or in sectors like roads, hospitals, and irrigation systems. The current literature does not provide integrated analysis using EVM, CPM, and root cause analysis of EPC-type seawater desalination projects in developing countries.

Objectives of the Study

- To identify the critical path activities that drive the seawater desalination project timeline.
- To assess the magnitude of time overruns by calculating Schedule Variance (SV)
- To analyse the specific root causes of project delay and categorise the contributing factors.

Limitations of the Study

- The analysis (CPM, EVM, Fishbone diagram) depended on the accuracy and thoroughness of progress reports.
- The findings are unique to the project and cannot be generalized to other industries or geographic areas.
- Other external variables that might affect the study include regulations, weather conditions, and international transportation.

Research Methodology

Research Design

The research follows an Explanatory Research methodology that not only describes the scenario but delves into the cause-and-effect relationship between factors. The scope of this study encompasses the Project Management Department of VA Tech Wabag Limited. The data were collected over a period of three months starting from January to April 2026.

Sources of Data

For primary data, unstructured interviews with the project manager and other team members responsible for implementing the Wabag desalination project were conducted. The secondary data were obtained from monthly reports, baseline schedule, work breakdown structure report, and company reports.

Tools for Analysis

Critical Path Method (CPM) was employed to determine the longest sequence of interdependent activities in the project schedule. Project Network Diagram based on Activity-on-Arrow approach was prepared to illustrate all the 23 activities involved in the project starting from awarding till completion and handover.

PERT technique was used to estimate total float, free float, and independent float for each activity.

The EVM method was modified by taking into account the physical accomplishment of activities using the formulas SV = EV – PV, and SPI = EV/PV.

The S curve for the project was drawn to show the difference between planned and actual progress during the period of 24 months of reporting.

Root Cause Analysis was performed using the Fishbone (Ishikawa) Diagram where causes of delays were grouped into six categories, namely Engineering, Procurement, Logistics, Civil Works, Environment, and Client/Consultant. Then, for each category, the technique of Five Whys was used to find the root cause of the delay.

Project Network and Critical Path

The Project Network Diagram mapped all 23 activities across six parallel paths. Path durations were calculated as follows:

Path 2, which takes 906 days, represents the Critical Path of the Project. This path consists of Basic Engineering, Equipment Ordering, Detailed Engineering of Long Lead Items, Manufacturing, Logistics, Electromechanical Installation, Piping, Pre-commissioning, and Commissioning.

Table 1 Project Activity Codes and Descriptions

Activity Code	Description
A	Project Awarded
B	Commencement and Mobilization
C	Basic Engineering
D	Desalination Civil Works
E	Intake Pipeline Works Civil
F	Intake Pipeline Equipments Installation
G	Marine Works Preliminary Study
H	Marine Works Execution
I	Ordering of Equipments
J	Detailed Engineering of Short Lead Items
K	Manufacturing of Short Lead Items
L	Logistics and Customs Clearance From Origin Port to Dakar
M	Detailed Engineering of Long Lead Items
N	Manufacturing of Long Lead Items
O	Logistics and Customs Clearance From Origin Port to Dakar
P	Electromechanical Equipments Installation
Q	Piping and E & I Integration
R	Precommissioning and Wet Testing
S	Commissioning and Handover

Source: Compiled

These processes cannot be delayed as any delay will automatically elongate the project schedule period.

Table 2 Network Path Summary

Path	Duration (Days)
Path 1 (A-B-C-I-J-K-L-Q-R-S)	765
Path 2 – Critical (A-B-C-I-M-N-O-P-Q-R-S)	906
Path 3 (A-B-C-I-M-N-O-F-P-Q-R-S)	896
Path 4 (A-B-E-F-P-Q-R-S)	480
Path 5 (A-B-D-P-Q-R-S)	390
Path 6 (A-B-G-H-R-S)	300

Source: Secondary data

As determined using PERT analysis, there are 10 critical activities (43% of total number of activities) and 13 non-critical activities (57%) for this project. It is worth noting that 100 percentage of the activities have independent float of zero.

Schedule Variance Analysis

Schedule variance was calculated on a monthly basis using Earned Value Management for the total project cost, US$ 45,806,000. The project commenced with high positive SV, with peak value attained at +US$ 8.47 million in January 2023.

Table 3 Schedule Variance Summary

Period	Plan %	Actual %	SV (US $ Millions)
Aug-22	0.00	0.10	+0.04
Dec-22	2.10	16.90	+6.78
Jul-23	37.33	48.10	+4.91
Dec-23	69.31	72.20	+1.34
Jan-24	79.46	75.90	-1.62
Apr-24	98.60	85.50	-5.98
Jul-24	100.00	92.20	-3.58

Source: Compiled

Source: Compiled

Figure 1 Schedule Variance Performance Trend

Schedule delays resulting from Engineering and Procurement together contribute 53 percentage to total schedule variance because of their influence on critical path activities without float time. Client/Consultant contributes 18 percentage to the variance as an exogenous factor within partial control of Wabag through its contracts.

However, since January 2024, the SV became increasingly negative, peaking at -US$ 5.98 million in April 2024. At the projected completion date of July 2024, only 92.2 percentage of physical work was completed. The SPI became less than 1.0 since early 2024 and stabilised at 0.9, showing that there was a reduction in efficiency by 10 percentage in the critical period of construction and commissioning.

Root Cause Analysis

Six groups were identified in the Fishbone diagram as sources of schedule delays. The Five Whys technique was used to find the root causes of each group.

Figure 2 Fishbone Diagram

Weighted Impact Analysis

Engineering (28%): Multiple revisions of FEED and Detailed Engineering documentation due to scope vagueness and a late design freeze led to delayed initiation of the procurement process. The root cause of delays was inadequate cross-functional communications among engineering teams in different time zones.

Procurement (25%): The combination of lengthy delivery terms for unique RO membranes and energy recovery systems, vendor qualification delays, and under-developed technical requirements in RFQ preparation led to overruns of procurement compared to the baseline. The root cause of delays was poor interface planning between engineering and procurement before purchase order placement.

Client/Consultant (18%): Late document approval processes, constant variation orders, and an inability to synchronize the client consultant with Wabag's team on-site were primary causes of the delay. The underlying reason was the lack of a mandatory contractual document review schedule

Civil Works (14%): Unforeseen subsoil conditions necessitating changes in design for the pile foundations, as well as labor shortages in membrane building construction, led to further delay. The underlying reason was insufficient pre-execution geotechnical investigation.

Table 3 Weighted Delay Impact Analysis

Category	Schedule Impact	Weight
Engineering	90–120 days (CP)	28%
Procurement	75–100 days (CP)	25%
Client/Consultant	60–80 days	18%
Civil Works	45–60 days (CP)	14%
Logistics	30–45 days (CP)	10%
Environment	20–30 days	5%

Source: Compiled

Logistics (10%): Increased port congestion in Dakar, slow customs clearance processes, and disruptions in the logistics chain, especially concerning the Red Sea route bottleneck in 2024, caused long lead times. The underlying reason was a lack of contingency planning in logistical risk management.

Environment (5%): Problems getting marine discharge permits and environmental clearance from the Senegalese authorities along with weather-related seasonality issues caused near-critical path delays. The primary reason behind the problem was inadequate risk assessment before execution.

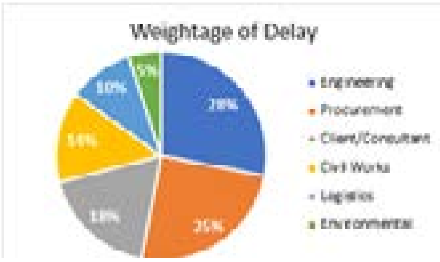

Figure 3 Weightage of Delay Factors

Findings

- From a maximum performance variation of +$8.47M (Dec '23) to - $5.98M (Apr '24); SPI reduced to 0.9 owing to a decrease in efficiency by 10 percentage.
- Since there are ten activities critical to the project having 906 days and zero independent float, the schedule lacks the flexibility for accommodating any delay.
- The reasons for any delay included Engineering, (28%); Procurement, (25%); and Client Coordination, (18%), mainly because of scope change and lengthy approval process.
- Even though 57 percentage of the activities are non-critical, the sensitivity of the network is extremely high as 83 percentage of activities have no Free Float and 100 percentage have no Independent Float.
- Variance in the schedule was caused by weaknesses that existed before execution, including inadequate technical specifications, logistical feasibility analysis, and an absence of a common approval process.

Suggestions

- Apply Document Submission and Review Schedule, with the aim of ensuring 90 percent engineering completeness before any submission to ensure that there will be no delay in revision.
- Apply EVM dashboard, with the alarm set when the SPI is below 0.95 to enable quick corrective measures.
- Implement logistical risk registers and geotechnical checklists before execution.
- Implement Variation Order Management Procedures with tight deadlines for evaluation and compulsory updating of baseline schedules for impacts of more than 5 percentage of the overall duration of the project.
- Conduct Lessons Learned Workshops after project completion to ensure that valuable lessons learned from the execution manual of the EPC Project are captured, preventing similar mistakes in the future.

Conclusion

This research performed Root Cause Analysis of Schedule Variance in a seawater desalination EPC project executed by VA Tech Wabag Limited in Western Africa. Based on CPM, PERT, EVM, Fishbone Analysis, and Five Whys, it was revealed that the key reasons for Schedule Variance in the 906 days long critical path of the project included delays in engineering documentation and immature procurement planning.

Although the project started well ahead of time, it lagged behind at only 92.2 percentage completion by its deadline in July 2024, exhibiting an unfavourable Schedule Variance of US$ 3.58 million. This was evident from a SPI value of 0.9 and persistent schedule inefficiency of 10 percentage throughout the construction process.

It is important to highlight that the identified root causes did not involve any technical problems, rather planning problems, namely procurement without mature specifications, no mechanism for approval under contract terms, poor risk assessment logistics-wise, and incomplete geotechnical surveys.

For prevention purposes, Wabag is advised to incorporate Engineering-Procurement Interface gates before releasing the Request for Quotation, establish binding document reviewing timelines, incorporate geological and logistics risk buffer provisions within future project baselines, implement monthly Earned Value Management (EVM) dashboard tools with automatic Schedule Performance Index (SPI) notifications, and institutionalize best practices through an established EPC Project Execution Manual.

This research is focused on the case study at hand and cannot be generalized to other EPC settings. Nevertheless, the methods and results provide a viable approach that can be replicated by similar projects in the desalination industry sector in developing countries.

References

1. Abdel-Hamid, M., & Abdelhaleem, H. M. (2025). Impact of poor labor productivity on construction project cost. International Journal of Construction Management.
2. Al Maamari, A. S. M., & Khan, F. R. (2025). Evaluating the causes and impacts of change orders on construction projects performance in Oman. International Journal of Project Management.
3. Al-Nuaimi, A. (2025). Assessing the effectiveness of digital twins in construction project monitoring. Automation in Construction.
4. Chopra, S., & Meindl, P. (2015). Supply chain management: Strategy, planning, and operation (6th ed.). Pearson.
5. Devi, L. P., & Sindhu (2025). Delay analysis of infrastructure construction projects in India. Indian Journal of Civil Engineering.
6. Fleming, Q. W., & Koppelman, J. M. (2010). Earned value project management (4th ed.). Project Management Institute.
7. Goetsch, D. L., & Davis, S. (2014). Quality management for organizational excellence: Introduction to total quality (8th ed.). Pearson.
8. Gondaliya, C., Chokshi, R., & Shah, D. (2025). Factors affecting the planning of water infrastructure projects: A comprehensive analysis. Water Resources Management.
9. Heizer, J., Render, B., & Munson, C. (2020). Operations management: Sustainability and supply chain management (13th ed.). Pearson.
10. Karale, Y. A., et al. (2025). Delays in construction projects: Causes, effects, and mitigation – A thematic literature review. Journal of Construction Engineering and Management.
11. Kerzner, H. (2022). Project management: A systems approach to planning, scheduling, and controlling (13th ed.). John Wiley & Sons.

12. Kore, S. A., et al. (2025). Analysing causes and effects of delay in pipe distribution network – A case study of Mhaishal Lift Irrigation. International Journal of Civil Engineering.
13. Musarat, M. A., Alaloul, W. S., & Liew, M. S. (2025). Impact of inflation rate on construction projects budget: A review. Engineering, Construction and Architectural Management.
14. Okes, D. (2019). Root cause analysis: The core of problem solving and corrective action (2nd ed.). Quality Press.
15. Project Management Institute. (2021). A guide to the project management body of knowledge (PMBOK guide) (7th ed.). Project Management Institute.
16. Saiyad, F. M., & Shinde, J. M. (2025). Delay analysis in construction and project planning and scheduling using Primavera P6: A review. Journal of Project Management.
17. Stratton, R. W. (2006). The earned value management maturity model (1st ed.). Management Concepts.
18. Widyarso, R., Witjaksana, B., & Purnama, J. (2025). Analysis of cost and time variance in construction projects using CV and SV parameters: A case study of the Jember Lung Hospital Building. International Journal of Engineering and Technology.