Assessing the Schedule Impact of Design and Scope Changes in Saudi Construction Projects.

Abstract

Design and scope changes affect construction schedules through revised information, additional work, procurement disruption and altered access. Their effect on completion depends on the status of the project and the dependencies controlling the relevant milestone when the change occurs. This paper develops a framework for assessing those effects in Saudi construction projects. A structured narrative review informs a method that combines verified progress, documented change scope, a transparent schedule fragment and explicit comparison of response scenarios. A synthetic network demonstrates how a fourteen day change sequence can produce nine days of completion movement, and how targeted mitigation can reduce the forecast movement to five days. Sensitivity analysis shows that later technical release can consume available float and move the controlling path. The framework connects analytical results to decisions, records and subsequent verification. It provides a practical basis for live project assessment and a research design for validation using archived schedules and change records.

Keywords

Design changes, scope control, schedule impact analysis, critical path, construction planning, Saudi Arabia.

UNDER PEER REVIEW IN IJAR

1. Introduction

1.1 Changes and completion forecasts

A revised equipment selection reaches a construction team after procurement has begun. The revised item needs updated drawings, a different support detail and confirmation of installation clearance. The supplier can deliver the original order on time, but the new item has a different production slot. The site team can continue some work while awaiting technical release and must suspend another area. The change therefore creates several timing effects. A planner needs to establish how those effects connect to the work remaining and to the milestone management has promised.

The duration of the changed work does not by itself establish the movement in completion. Some activities may fit within available float, some may run in parallel and some may affect a successor already held by another package. A revised completion forecast requires an analysis of dependencies and progress at an identified point in time. The project team also needs to understand when a response remains practical. A procurement instruction issued after a factory reservation expires can have a different consequence from the same instruction issued while the original slot remains available.

1.2 Saudi construction setting

Saudi construction projects span industrial facilities, urban developments and buildings with varied ownership and delivery arrangements. Studies of delays in the Kingdom have identified planning, decisions, finance, resources and design among recurring concerns. Those findings provide prompts for a project review, while the timing and consequences of a particular change require project evidence. A programme associated with Saudi Vision 2030 may contain several contracts contributing to one handover, making it important to examine how a design revision affects adjacent packages and operational readiness.

This paper focuses on the planner’s assessment and the management decisions that assessment can support. The proposed process identifies the change, establishes the programme used for comparison, models the remaining work and tests response options. Contract administration should apply the actual agreement and the relevant requirements to each case. The analytical output supplies a reasoned forecast and an account of its assumptions, evidence and limits.

2. Research design

2.1 Purpose and questions

The study asks how a construction team can establish a credible prechange forecast, represent the activities introduced or altered by a change and evaluate whether a mitigation option protects completion. It also asks which records enable a later reviewer to understand why the assessment was made. The unit of analysis is a defined change event assessed against a current schedule at a stated status date. The focus covers engineering, procurement, construction and acceptance activities that can transmit its effect to a milestone.

The paper uses a structured narrative review and a deterministic worked example. Search concepts included construction design changes, scope changes, change timing, productivity,

UNDER PEER REVIEW | IJAR

prospective time impact analysis, schedule updates and change management. Sources were selected from research articles, professional planning guidance and official programme information. General studies support mechanisms such as rework and disruption. Guidance on schedule assessment and time impact analysis informs the controls used to prepare and explain an assessment.

2.2 Synthesis and boundaries

The review was organised around evidence, modelling, decisions and verification. Evidence establishes what changed and what progress had occurred. Modelling connects the revised work to existing activities. Decisions concern practical alternatives and their timing. Verification compares the subsequent result with the assumptions used. The synthetic example isolates those steps using one calendar and a small network. It is intended to make the calculation reproducible and to show where a conclusion depends on an assumption.

The review draws on studies from different countries and contract settings. Findings about the frequency or ranking of change causes should be interpreted within their original samples. The framework uses them to identify issues worth checking, including repeated design development, interrupted work and late information. Its application to Saudi projects requires the actual schedule, instructions and progress evidence. The proposed validation design addresses that requirement through comparisons of contemporaneous forecasts and subsequent outcomes.

3. Establishing the change and schedule basis

3.1 Defining the event

The change record should identify the instruction or request, affected drawings, scope, locations and the dates on which information became available. A description such as revised layout is too broad to support modelling. The planner should identify which design outputs change, which purchased items are affected, what installed work requires removal and what new acceptance evidence is needed. The technical lead should confirm the current design basis and the revisions available for use.

An event can evolve through several decisions. A preliminary request may permit evaluation but leave procurement uncertain. A later instruction may release fabrication, and a final drawing may define site installation. Recording these stages helps the analyst identify what could reasonably proceed at each time. It also allows procurement and construction teams to explain the difference between waiting for usable information and carrying out the changed work. Each material stage should have a source record and a person able to confirm its meaning.

3.2 Choosing the reference programme

The preferred reference is a credible schedule update representing the work immediately before the change affected execution, subject to the available records and agreed analysis method. The accepted baseline establishes the original plan, while the current update includes progress and prior changes. Using an outdated baseline alone can assign existing delay to a later change. The

UNDER PEER REVIEW IN IJAR

analyst should identify the programme version, data date, calendars, approved modifications and any repairs needed before inserting the change.

Repairs require explanation. Missing relationships, inaccurate actual dates or unsupported remaining durations can distort the apparent effect. A corrected model should retain a copy of the original file and a change log showing each repair and its basis. Where participants disagree over a remaining duration, the team can test both values and identify whether the dispute affects the milestone result. This makes uncertainty in the model visible before a management decision relies on it.

3.3 Progress and work already performed

Actual starts and finishes should be supported by field reports, inspections, delivery records or other relevant evidence. Remaining durations should reflect the work and access available at the chosen status date. A percentage complete may help describe production but may not identify which portion must be reworked. For a partially completed installation, the analyst should separate retained work, removal, revised work and verification so that completed quantities are represented consistently.

The same attention is needed for procurement. A component may be ordered, manufactured, shipped or installed when a change arrives. Each state creates different feasible responses. A supplier may accept revised dimensions before production but require a replacement order after manufacture. The schedule should identify the point at which the decision affects fabrication and delivery, and the evidence supporting that point. This distinction makes the forecast more useful to the buyer and helps explain why a later response costs time.

3.4 Following a change through related packages

A design review should identify which other packages rely on the affected information. A revised equipment footprint can change foundations, cable routes, access clearance and architectural finishes. The analyst can use a simple dependency matrix to ask each package manager whether the revision affects work already ordered or planned. The purpose is to discover consequences while a response is still feasible. Each confirmed effect should be assigned to a schedule activity, an evidence source and a responsible lead. Items requiring further investigation should retain a due date that reflects the downstream decision window.

A receiving party should confirm what it needs before it can proceed. An updated drawing may answer the technical question but still require a survey, a new inspection plan or a supplier acknowledgement. Recording these requirements helps prevent a change from being marked complete before it can be executed. It also allows the planner to distinguish release for manufacture from release for site installation. These dates can differ substantially and can govern different branches of the same assessment.

4. Modelling the schedule effect

4.1 Building a schedule fragment

A schedule fragment is a set of activities and relationships representing the change. It can include review, redesign, approval, procurement, removal, installation and repeat testing where

UNDER PEER REVIEW IN IJAR

each is needed. It should connect to the existing network at the point where the change affects work and at the successor that receives the revised output. Duration estimates should specify quantities, resources, working hours and the source of lead time assumptions.

The analyst should explain how the fragment treats work already included in the reference programme. If a replacement activity absorbs the original installation scope, leaving the full original activity in sequence can double count work. If only part of an installation changes, the unchanged portion should retain a defensible path. Splitting by zone or component can be appropriate when the field team can identify a usable boundary and independently verify its completion.

4.2 Comparing schedules and paths

The first comparison uses the reference schedule with its existing scope and progress. The second inserts the change while keeping unrelated assumptions constant. The analyst recalculates the relevant milestone and identifies the driving relationships in both versions. The difference is the modelled incremental movement under those assumptions. The team should also inspect intermediate gates, because a change may threaten a delivery or test slot before it becomes visible at overall completion.

After each intervention, the driving path can move. An equipment delay might initially control testing, while accelerating delivery makes utility acceptance the limiting prerequisite. Reporting the final date alone can conceal that transition. The analysis should identify which predecessor governs the next milestone and whether another branch has little remaining flexibility. This helps management decide where to place resources and what evidence to review in the next update.

4.3 Float, constraints and calendars

Float is a property of the model at a particular time. A change can consume float without moving the selected completion milestone. Such consumption can still reduce flexibility and increase exposure to later events. The report should state the affected activity and milestone, the available float and how the change uses it. Decisions about the contractual treatment of float require the actual agreement and appropriate review.

Constraints and calendars need independent checking. A fixed finish can prevent a revised date from moving while producing negative float. A supplier calendar can move delivery differently from a site calendar. Holidays, shift arrangements and inspection availability should follow the verified assumptions for the project. Modelling everything on one calendar may be useful for an illustration, but an actual assessment should account for differences that materially affect the result.

4.4 Productivity and indirect consequences

Additional quantities are usually easier to identify than disruption to surrounding work. A change can require crews to remobilise, share a constrained area or repeat work in an inefficient sequence. The assessment should specify the physical mechanism behind any productivity allowance. Daily reports, quantities installed and records of crew deployment can help test whether the proposed remaining duration is plausible. Published relationships between

UNDER PEER REVIEW IN IJAR

change and productivity can inform a question for investigation, while the actual allowance should be grounded in the circumstances of the affected work.

An assessment should avoid counting the same effect in both an added activity and a reduced productivity assumption. If removal and reinstatement are modelled explicitly, the remaining installation duration should make clear which quantities it covers. If congestion is expected to slow another trade, the analyst should identify that activity and explain the resource or access interaction. A sensitivity test can show whether the uncertainty materially affects completion. Management can then decide whether more evidence is needed before committing to a response.

5. Decisions and supporting records

5.1 Response options

Possible responses include earlier design decisions, alternate products, separate fabrication releases, additional work fronts, supplier acceleration and revised installation sequences. Each requires technical and operational validation. The team should ask who can commit the action, what evidence supports the new duration and when the decision must be made. An acceleration assumption becomes credible when the supplier or field manager can describe the resources and sequence that would deliver it.

The analysis should test effects on adjacent work and acceptance. An alternate product may require a different interface, additional testing or operator training. Parallel installation can require more access and supervision. Shortening construction while leaving the test window unchanged may improve margin without advancing completion. These consequences should be shown in the scenario, with direct cost estimates and assumptions sufficient for management to compare the benefit with the commitment required.

5.2 Records for a live assessment

A useful assessment package contains the change narrative, reference programme, verified status, fragment description, comparison results and proposed response. It should identify instruction dates, drawing revisions, supplier quotations, resource plans and relevant meetings. Each important duration or relationship should be traceable to evidence or clearly identified judgement. A short register of unresolved assumptions allows reviewers to distinguish what is confirmed from what still needs agreement.

The project should preserve the forecast used at the decision date. Later actual progress can improve understanding without changing what was known at the earlier cut. A follow up assessment may revise the effect as information develops. That revision should identify whether the change arose from new scope, better information, an executed mitigation action or an unrelated event. Maintaining those distinctions makes later review more coherent and supports lessons for future changes.

5.3 Overlapping events

Several events may affect a common period or milestone. Their separate modelled effects cannot automatically be added because they can consume the same float or run on parallel

UNDER PEER REVIEW IN IJAR

paths. A sequence of changes should be assessed using a stated order and appropriate programme updates, with sensitivity testing where order matters. The analyst should examine the controlling work over time and show how existing conditions interact with each new event.

A live assessment supports a decision about the likely future effect. A later retrospective review may need different records and methods because actual sequences, mitigation and other events are now known. The purpose, information boundary and selected method should therefore be explicit. Professional guidance can help structure the work, while conclusions about responsibility and entitlement should follow the project facts and applicable contract provisions.

6. Illustrative change assessment

6.1 Reference network

The synthetic example uses remaining working days from a common status date. Branch A contains design completion lasting five days, procurement lasting fifteen days and installation lasting ten days. Branch B is independent building readiness lasting thirty five days. Integrated testing starts when both branches finish and lasts five days. Final acceptance then lasts three days. The reference therefore finishes Branch A on day 30 and Branch B on day 35, with overall completion on day 43.

A design change introduces six days of redesign and approval after the original design completion, followed by eight days of replacement procurement. Both activities precede the existing fifteen day procurement activity. This represents a hypothetical additional release and supply stage for a changed component. The revised installation remains ten days. Branch A now ends on day 44 and completion moves to day 52. The fourteen day inserted sequence consumes five days of available margin and produces nine days of movement at completion.

Table 1. Reference, changed and mitigated schedule comparison

Scenario	Added approval	Added supply	Branch A finish	Branch B finish	Test start	Completion	Movement
Reference	0	0	30	35	35	43	0
Change inserted	6	8	44	35	44	52	9
Mitigated change	6	4	40	35	40	48	5

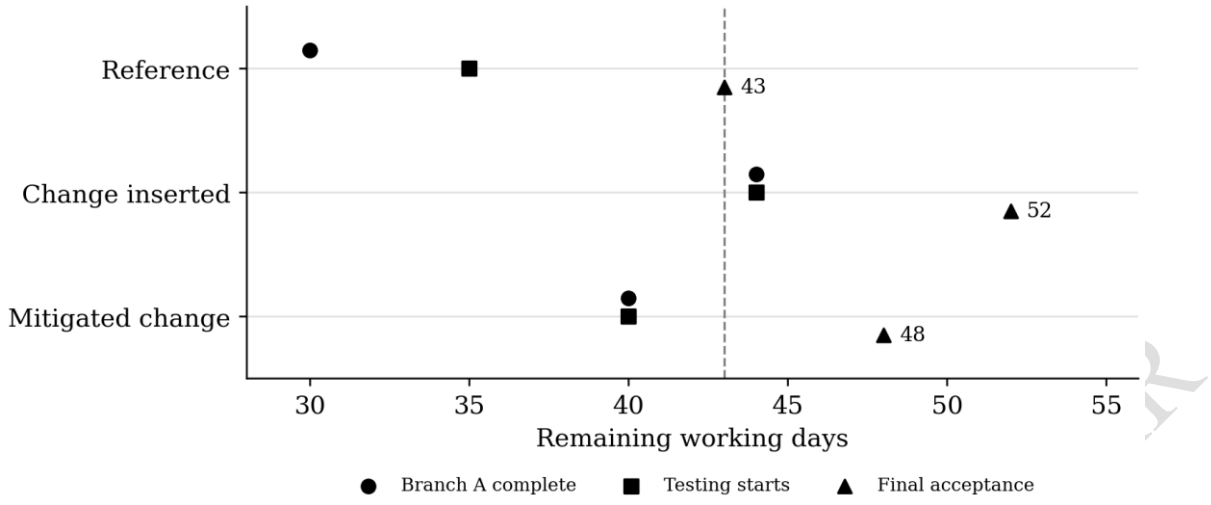
Note: All values are working days. Movement is measured against reference completion on day 43.

6.2 Mitigation and interpretation

In the mitigation scenario, the team obtains a supplier commitment that shortens the added replacement procurement stage from eight days to four. The remaining activities and Branch B stay unchanged. Branch A finishes on day 40, testing begins on day 40 and final acceptance occurs on day 48. The intervention recovers four days relative to the changed forecast and leaves five days of movement relative to the reference. Figure 1 compares the stage completion points.

UNDER PEER REVIEW IN IJAR

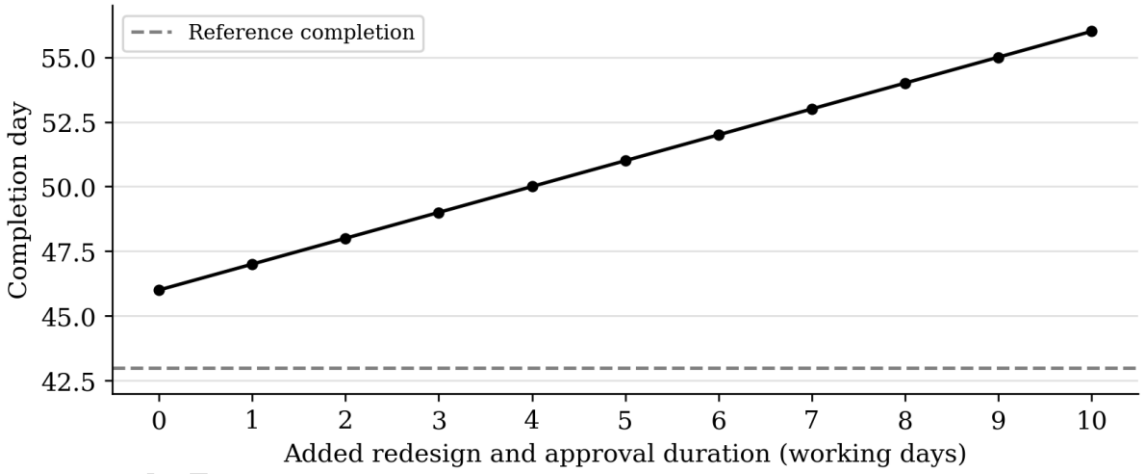
Figure 1. Stage forecasts before and after the change



Source: Synthetic construction network described in Section 6.

The sensitivity in Figure 2 varies the redesign and approval duration from zero to ten days while retaining the eight day added procurement stage. Branch A finishes on day 38 plus the varied duration, and final completion falls on day 46 plus that duration. Even with immediate approval, the added procurement stage produces three days of movement against day 43. Each further day of approval duration moves completion by one day because Branch A already exceeds the thirty five day readiness branch.

Figure 2. Completion sensitivity to added redesign and approval



Source: Synthetic construction network described in Section 6.

The team can also examine the response required to regain the original date. With the six day approval stage retained, the changed Branch A already requires thirty six days before any added replacement procurement time. Removing the entire eight day stage would still leave a one day completion movement. Achieving day 43 would require another verified improvement or a different technical solution. This threshold calculation helps management see why a supplier quotation alone may be insufficient and identifies the need for engineering and site participation.

6.3 Using the example in a workshop

A planner could reproduce the network in scheduling software and ask engineering to confirm the release sequence. Procurement would verify whether the added stage is genuinely sequential and whether the original order can continue during the change. Construction would check whether installation can start by zone. The commissioning lead would confirm that the test and acceptance durations remain valid for the revised scope. A revised technical solution can change the network, so its effect should be calculated before selecting an option.

The example deliberately holds other work constant so that the incremental effect is visible. A project update may reveal that independent building readiness has also moved. The analyst would then need to preserve the reference used for the original decision and evaluate the new condition separately or within an updated assessment. This avoids assuming that every later day of movement was produced by the design change.

7. Implementation and evaluation

7.1 Practical workflow

A project can establish a common review process when a change first becomes sufficiently defined to assess. The technical lead states the scope and usable information dates. The planner verifies status and logic. Procurement and construction confirm durations and alternatives. Commercial staff identify the decision and notice requirements under the project arrangements. The authorised manager selects a response with a clear owner, decision date and next verification point.

The assessment should be scaled to the consequence of the change. A small local revision with clear float may require a short documented check. A change affecting fabrication and a shared test window warrants a detailed fragment and comparison. The project controls lead should set criteria for escalation using milestone consequence, uncertainty and remaining time to act. The same criteria help prevent large volumes of minor items from obscuring changes that need an immediate decision.

7.2 Validation and research needs

A field study could collect archived updates, change logs and acceptance records from several Saudi construction packages. The evaluator would reconstruct the information available at the assessment date and compare the forecast effect with subsequent progress. Measures could include time to complete an assessment, traceability of assumptions, frequency of revised forecasts and error in the milestone date. A separate review should identify whether a proposed mitigation was actually carried out.

Comparisons should account for scope maturity, supplier dependence and the quality of the reference schedule. Complex changes are more likely to receive extensive analysis, so simple comparisons between reviewed and unreviewed items can misrepresent effectiveness. Matched packages or a staged introduction of the procedure could provide a stronger basis for assessing benefits. Interviews with technical and field teams would help explain whether a sound analytical recommendation was practical at the decision date.

UNDER PEER REVIEW IN IJAR

7.3 Learning from successive assessments

A closeout review can compare the predicted sequence with the actual one and identify which assumptions repeatedly failed. Supplier quotations may omit approval time, access forecasts may prove optimistic or repeat tests may be more frequent than expected. The organisation can improve future assessments by retaining the reason for each forecast revision and the evidence that became available. Consistent definitions of technical release, site readiness and accepted completion make comparisons across projects more meaningful.

Review should also examine decision speed. A technically sound option may become unavailable while approval is pending. Tracking the interval between identifying an option, obtaining authority and instructing the work can reveal where the project loses its ability to respond. This evidence can support clearer delegation and earlier escalation on later projects, with the applicable commercial and technical approvals established by the organisation.

8. Limitations and conclusion

8.1 Limitations

The framework combines evidence from several construction settings and a synthetic example. The deterministic network excludes resource competition, variable calendars and uncertainty in test outcomes. Its calculations demonstrate how logic and float affect the result under stated assumptions. They do not estimate typical delay for Saudi projects. Actual applications should test alternative assumptions and retain disagreements that materially influence the forecast.

8.2 Conclusion

A credible schedule impact assessment begins with a defined change and a verified picture of progress immediately before its effect. A transparent fragment then connects redesign, procurement and field work to existing dependencies. Comparing the resulting paths shows how much of the added work consumes flexibility and how much moves a selected milestone. Testing mitigation against the same reference makes the proposed gain and residual exposure visible.

The example demonstrates that fourteen days of added work can move completion by nine days, while targeted procurement mitigation reduces the forecast movement to five days. Further recovery depends on a broader change to the sequence or durations. For Saudi construction teams, the proposed approach connects design decisions with a reproducible forecast and a clear record of what must happen next. Its effectiveness can be tested through project records and the subsequent delivery of the commitments used in each assessment.

UNDER PEER REVIEW IN IJAR

References

1. AACE International. (2017). Forensic schedule analysis (Recommended Practice 29R-03). Source

2. AACE International. (2017). Prospective time impact analysis as applied in construction (Recommended Practice 52R-06). Source

3. AACE International. (2019). Integrated cost and schedule risk analysis using risk drivers and Monte Carlo simulation of a CPM model (Recommended Practice 57R-09). Source

4. Al-Kharashi, A., & Skitmore, M. (2009). Causes of delays in Saudi Arabian public sector construction projects. Construction Management and Economics, 27(1), 3–23. DOI

5. Alajmi, A. M., & Memon, Z. A. (2022). A review on significant factors causing delays in Saudi Arabia construction projects. Smart Cities, 5(4), 1465–1487. DOI

6. Alnuaimi, A. S., Taha, R. A., Al Mohsin, M., & Al-Harthi, A. S. (2010). Causes, effects, benefits, and remedies of change orders on public construction projects in Oman. Journal of Construction Engineering and Management, 136(5), 615–622. DOI

7. AlSehaimi, A., Koskela, L., & Tzortzopoulos, P. (2013). Need for alternative research approaches in construction management: Case of delay studies. Journal of Management in Engineering, 29(4), 407–413. DOI

8. Assaf, S. A., & Al-Hejji, S. (2006). Causes of delay in large construction projects. International Journal of Project Management, 24(4), 349–357. Source

9. Ballard, H. G. (2000). The last planner system of production control [Doctoral dissertation, University of Birmingham]. Source

10. Government Accountability Office. (2015). Schedule assessment guide: Best practices for project schedules (GAO-16-89G). Source

11. Hamzeh, F., Ballard, G., & Tommelein, I. D. (2012). Rethinking lookahead planning to optimize construction workflow. Lean Construction Journal, 15–34. DOI

12. Hamzeh, F., Saab, I., Tommelein, I. D., & Ballard, G. (2015). Understanding the role of tasks anticipated in lookahead planning through simulation. Automation in Construction, 49, 18–26. Source

13. Hanna, A. S., Camlic, R., Peterson, P. A., & Nordheim, E. V. (2002). Quantitative definition of projects impacted by change orders. Journal of Construction Engineering and Management, 128(1), 57–64. DOI

14. Herroelen, W., & Leus, R. (2005). Project scheduling under uncertainty: Survey and research potentials. European Journal of Operational Research, 165(2), 289–306. Source

15. Hulett, D. T. (2009). Practical schedule risk analysis. Gower. Source

16. Ibbs, W. (1997). Quantitative impacts of project change: Size issues. Journal of Construction Engineering and Management, 123(3), 308–311. DOI

17. Ibbs, W. (2005). Impact of change's timing on labor productivity. Journal of Construction Engineering and Management, 131(11), 1219–1223. DOI

18. Kelley, J. E., Jr., & Walker, M. R. (1959). Critical-path planning and scheduling. Proceedings of the Eastern Joint IRE-AIEE-ACM Computer Conference, 160–173. DOI

UNDER PEER REVIEW IN IJAR

19. Motawa, I. A., Anumba, C. J., Lee, S., & Peña-Mora, F. (2007). An integrated system for change management in construction. Automation in Construction, 16(3), 368–377. DOI

20. NASA. (n.d.). Schedule management overview. Source

21. Ramanathan, C., Narayanan, S. P., & Idrus, A. B. (2012). Construction delays causing risks on time and cost: A critical review. Construction Economics and Building, 12(1). DOI

22. Saudi Vision 2030. (2025). Saudi Vision 2030 annual report 2024. Source

23. Society of Construction Law. (2017). Delay and disruption protocol (2nd ed.). Source

24. Sun, M., & Meng, X. (2009). Taxonomy for change causes and effects in construction projects. International Journal of Project Management, 27(6), 560–572. DOI

25. Van de Vonder, S., Demeulemeester, E., Herroelen, W., & Leus, R. (2005). The use of buffers in project management: The trade-off between stability and makespan. International Journal of Production Economics, 97(2), 227–240. Source

UNDER PEER REVIEW IN IJAR