Rework in Engineering and Construction Projects[1]

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This paper is focused on engineering and construction projects which will experience increased emphasis as nations increase their focus on economic stimulus[2,3,4] and climate change. It deals narrowly with the inevitable rework these projects often experience and which contributes to the cost and schedule growth we all too often witness. The objective of this paper is to:

- Categorize rework factors into four broad categories – project, human, organizational and complexity
- Identify rework impacts not just on cost and schedule but importantly morale and trust.
- Recognize that strategies exist to reduce the potential for required rework
- Suggest four dozen control points.

Each item identified lends itself to separate treatment and separate papers that will benefit these projects and the project management profession. The impacts of design and construction rework have been well-researched and documented over the years. Despite this, rework remains a systemic industry challenge[5] contributing measurably to the cost overruns the industry experiences.

This paper builds on my paper[6] of the same title published in Project Management Review (China) in December 2020, further organizing my recommendations and providing extensive references related to numerous elements covered in the paper.

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[1] How to cite this paper: Prieto, R. (2021). Rework in Engineering and Construction Projects, *PM World Journal*, Vol. X, Issue IV, April.
[2] B. Prieto; The Challenge of Infrastructure and Long Term Investment; PM World Journal; Vol. III, Issue XII – December 2014; https://pmworldlibrary.net/wp-content/uploads/2014/12/pmwj29-Dec2014-Prieto-Challenge-of-Infrastructure-and-Long-Term-Investment-featured-paper.pdf
[3] B. Prieto; Classes of Factors to be Considered in Infrastructure Investment Prioritization; PM World Journal; Vol. III, Issue X – October 2014; https://pmworldlibrary.net/wp-content/uploads/2014/10/pmwj27-oct2014-Prieto-classes-of-factors-infrastructure-investment-Featured-Paper.pdf
[4] B. Prieto; Meeting Tomorrow's Infrastructure Needs; Vol. IV, Issue IX – September 2015; https://pmworldlibrary.net/wp-content/uploads/2015/09/pmwj38-Sep2015-Prieto-meeting-tomorrows-infrastructure-needs-featured-paper.pdf
[5] B. Prieto; Candidate Strategies to Reduce Risks in Large Engineering & Construction Programs; Vol. I, Issue II – September 2012; https://pmworldlibrary.net/wp-content/uploads/2013/02/PMWJ2-Sep2012-FeaturedPaper-PRIETO-CandidateStrategiesToReduceRisks.pdf
[6] Rework in Engineering and Construction Projects; Project Management Review (China); December 2020

Factors that lead to rework

There are many potential ways to categorize the factors that lead to rework. One possible segregation of these factors groups them broadly into four categories:

- **Project** – modified (including changed requirements, codes, standards), incomplete or unclear scope[7] (changes); incomplete, unclear or poor-quality design and design documentation (RFIs); site and location issues (improper survey/layout; geotechnical or other underground factors; unrecognized environmental factors).

- **Human** – Incomplete or lack of appropriate knowledge or skills (experience) including poor workmanship; lack of diversity of thinking and effectiveness of reviews[8,9].

- **Organizational** – communication deficiencies; inadequate management and coordination including reviews; poor supervision; weak quality systems[10,11] (including quality oversight of subcontractors) and culture; unrecognized coupling[12,13] of activities and constraints; poor safety culture and commitment.

[7] Prieto, R. (2019). The Primacy of the Scope Baseline in Engineering & Construction Projects; PM World Journal, Vol. VIII, Issue IX, October; https://pmworldlibrary.net/wp-content/uploads/2019/10/pmwj86-Oct2019-Prieto-primacy-of-scope-baseline.pdf
[8] B. Prieto; Effective Project Review Meetings; National Academy of Construction Executive Insights; https://www.researchgate.net/publication/340949649_Effective_Project_Review_Meetings_Key_Points
[9] B. Prieto; Design Review; National Academy of Construction Executive Insights; https://www.researchgate.net/publication/342448233_Design_Review_Key_Points
[10] B. Prieto; Redefining Quality; National Academy of Construction Executive Insights; https://www.researchgate.net/publication/344597803_Redefining_Quality_Key_Points
[11] B. Prieto; Quality Transformation; National Academy of Construction Executive Insights; https://www.researchgate.net/publication/344597803_Redefining_Quality_Key_Points
[12] Prieto, R. (2020). The Impact of Correlation on Risks in Programs and Projects; PM World Journal, Vol. IX, Issue XII, December; https://pmworldlibrary.net/wp-content/uploads/2020/12/pmwj100-Dec2020-Prieto-impact-of-correlation-on-risks-in-programs-and-projects.pdf
[13] B. Prieto; Coupling in Large Complex Projects; National Academy of Construction Executive Insights; https://www.researchgate.net/publication/342452306_Large_Complex_Projects_Coupling_in_Large_Complex_Projects_Key_Points

- **Complexity**[14,15,16,17] – technical, human, execution and informational complexity; unagreed to or emergent objectives.

Impacts of Rework

Rework's impacts on project performance are expansive and corrosive. Impacts on cost and time are to be expected but the human and relationship impacts cannot be ignored. Select impacts include:

- Delay[18]
- Productivity loss with attendant cost and schedule impacts
- Labor force availability impacts especially when skilled trades involved
- Increased material and wastage costs
- Negative impacts on workforce morale and psychology
- Stakeholder (owner, contractor, engineer, other 3rd party stakeholders) conflict and trust

Two Examples of Rework Challenges and How They Are Addressed		
	Challenge	**Response**
Scaffolding	Modifications and relocation/ reconfiguration required due to failure to recognize future needs, obstructions and complications	Scaffolding and other temporary works reflected in 3D/4D models allowing assessment of evolving conditions as construction progresses.

[14] Prieto, R. (2021). Large Complex Project Success: Have we institutionalized the wrong lessons? PM World Journal, Vol. X, Issue I, January; https://pmworldlibrary.net/wp-content/uploads/2021/01/pmwj101-Jan2021-Prieto-Large-Complex-Project-Success.pdf
[15] Prieto, R. (2020). Systems Nature of Large Complex Programs; PM World Journal, Vol IX, Issue VIII, August; https://pmworldlibrary.net/wp-content/uploads/2020/07/pmwj96-Aug2020-Prieto-Systems-Nature-of-Large-Complex-Programs.pdf
[16] B. Prieto; Complexity in Large Engineering & Construction Programs; PM World Journal, Vol. VI, Issue XI – November 2017; https://pmworldlibrary.net/wp-content/uploads/2017/11/pmwj64-Nov2017-Prieto-complexity-in-large-engineering-construction-programs.pdf
[17] Stephen R. Thomas; Modeling and Mitigating Project Complexity; National Academy of Construction Executive Insights; https://www.naocon.org/wp-content/uploads/Thomas-Modeling-and-Mitigating-Project-Complexity-02.08.19.pdf
[18] B. Prieto; Perspective on the Cost of Delayed Decision Making in Large Project Execution; PM World Journal, Vol. III, Issue II – February 2014; https://pmworldlibrary.net/wp-content/uploads/2014/02/pmwj19-feb2014-Prieto-perspective-on-cost-of-delay-FeaturedPaper.docx_.pdf

Two Examples of Rework Challenges and How They Are Addressed		
HDPE piping	Material and weld testing were inconsistent often requiring replacement and rework in field	Develop and gain approval of new international testing standard

Control of Rework

This paper is primarily focused on identifying ways to control rework in engineering and construction projects. Control strategies and tactics are available throughout the project execution lifecycle. Forty-eight control points have been identified and are recommended:

Strengthened Project Foundations[19]

- Scope completeness reviews including using emerging AI[20] tools (preventive)
- Scope change control (corrective) – reconfirmation of project objectives; root cause analysis (assure full impact and cause of change understood); modifications to project plan, budget and schedule detailed; configuration management verified; impact on project risks assessed; formal approval of change (include determination of need for change); update baselines and project management plan (ask one last question – when is the change most efficiently made?)
- Adequate site investigations
- Early value management studies and workshops (act to limit client directed changes)
- Ensure plot plan and layout allows for late delivery of major equipment
- Owner understanding of their role[21] (governance vs micro-management)
- Robust baseline

[19] Prieto, R. (2008). Foundations, Frameworks & Lessons Learned in Program Management , Second Edition, PM World Journal, Vol. IX, Issue XI, November. Originally published in PM World Today, May 2008; https://pmworldlibrary.net/wp-content/uploads/2020/11/pmwj99-Nov2020-Prieto-foundations-frameworks-lessons-learned-in-program-management-2008.pdf
[20] Prieto, B. (2019). Impacts of Artificial Intelligence on Management of Large Complex Projects. PM World Journal, Vol. VIII, Issue V, June; https://www.researchgate.net/publication/334162272_Impacts_of_Artificial_Intelligence_on_Management_of_Large_Complex_Projects
[21] B. Prieto; Owner Readiness; National Academy of Construction Executive Insights; https://www.researchgate.net/publication/342452390_Owner_Readiness_Key_Points

Increased Focus on Project "Flows"[22,23]

- Comprehensive design planning reflecting procurement and construction requirements[24]
- Adequate design staffing and design timeframes
- Comprehensive design procedures that are being utilized
- Smooth flow of design information from suppliers
- Agreed to design freeze
- Strong, rigorously implemented quality system including effective, timely reviews and strong quality audit system
- Up to date documents/BIM. Version control is essential.
- Complete tender packages and contract documentation[25]
- Effective workface planning and scheduling of required resources
- Translate lessons observed into lessons learned by communicating broadly in a timely manner

Strengthened Stakeholder Engagement

- Early contractor and other key stakeholder engagement (expanded basis of design)
- Early O&M involvement reduces rework during startup and commissioning phase

Technical Robustness

- Utilize AI based design checking tools
- Confirm adequate support, flexibility and expansion provisions for piping systems.
- Check equipment flange bolt holes for correct orientation/straddle of centerline. Check equipment at suppliers before shipment.
- Reduce number of field welds required
- Establish a Zero Rework target. Benchmark rework. Identify rework risk areas along critical path.
- Minimization and timely resolution of Requests for Information (RFI)

[22] Gregory Howell; Improving Work Flow Reliability on Projects; National Academy of Construction Executive Insights; https://www.naocon.org/wp-content/uploads/Improving-Work-Flow-Reliability-on-Projects.pdf
[23] B. Prieto; "Flows" in Large Complex Projects; National Academy of Construction Executive Insights; https://www.researchgate.net/publication/344306324_Flows_on_Large_Complex_Projects#fullTextFileContent
[24] B. Prieto; Business Basis of Design; National Academy of Construction Executive Insights; https://www.researchgate.net/publication/340949572_Business_Basis_of_Design_Key_Points
[25] B. Prieto; Procurement Management in Large Complex Programs; National Academy of Construction Executive Insights; https://www.researchgate.net/publication/342449248_Procurement_Management_in_Large_Complex_Programs_Key_Points

- Early RFI trends monitored to identify potential areas of design challenges
- Strong, systematic documentation to support change requests and resolve latent issues (avoidance of similarly caused rework)
- Effective use of BIM to identify potential conflicts, challenges and incomplete design or vendor changes
- Appropriate but only necessary notes on drawings for intended purpose
- Strong interface management and configuration control processes
- Supplier to supplier connections must be carefully checked for compatibility (example: Buss duct to switch gear).
- Safety through design practices employed (hazard avoidance)[26,27,28]

Construction Execution Readiness

- Workforce, subcontract and supplier quality and availability
- Effective use of information technology
- Rigorous material quality testing
- All specialized equipment should be shop inspected prior to shipment to the field.
- Real time inspection of the works (task completion focused)
- Prudent use of hold and control points
- Periodic 3D scanning of installed works as part of progress monitoring and configuration control.
- Effective materials management to ensure correct materials and equipment used and minimize relocations of materials at site to reduce damage
- Improved access to real time information utilizing wearable technologies
- Effective visibility in multi-layered subcontracting
- Supply chain quality visibility and inspection rights
- Pre-shipment inspection of prefabricated items
- Use of appropriate construction means and methods and fit for purpose processes and tools.
- Adequate protection of completed works. Sequence of construction to consider potential damage to completed works.
- Track and assess rework items and ripple effects using an established taxonomy
- Incentivize/disincentivize rework

[26] B. Prieto; Safety Through Design; National Academy of Construction Executive Insights; https://www.researchgate.net/publication/340949703_Safety_Through_Design_Key_Points
[27] B. Prieto; Safety by Design Suggestions; National Academy of Construction Executive Insights; https://www.researchgate.net/publication/340949699_Safety_by_Design_Suggestions_Key_Points
[28] Jim Porter; Safety Leadership–Invest in Business Sustainability: Here's Your Roadmap to Zero Incidents; National Academy of Construction Executive Insights; https://www.naocon.org/wp-content/uploads/Invest-in-Business-Sustainability-Here%E2%80%99s-Your-Roadmap-to-Zero-Incidents.pdf

Summary

Engineering and construction rework remains a challenge today but strategies to improve outcomes exist and many have been identified in this paper. Rework control really begins at the point of project conception and newer technologies (BIM, AI, laser scanning) provide new weapons in our arsenal to battle this performance enemy throughout the project execution lifecycle.

About the Author

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Bob Prieto is a senior executive effective in shaping and executing business strategy and a recognized leader within the infrastructure, engineering and construction industries. Currently Bob heads his own management consulting practice, Strategic Program Management LLC. He previously served as a senior vice president of Fluor, one of the largest engineering and construction companies in the world. He focuses on the development and delivery of large, complex projects worldwide and consults with owners across all market sectors in the development of programmatic delivery strategies. He is author of nine books including “Strategic Program Management”, “The Giga Factor: Program Management in the Engineering and Construction Industry”, “Application of Life Cycle Analysis in the Capital Assets Industry”, “Capital Efficiency: Pull All the Levers” and, most recently, “Theory of Management of Large Complex Projects” published by the Construction Management Association of America (CMAA) as well as over 700 other papers and presentations.

Bob is an Independent Member of the Shareholder Committee of Mott MacDonald. He is a member of the ASCE Industry Leaders Council, National Academy of Construction, a Fellow of the Construction Management Association of America and member of several university departmental and campus advisory boards. Bob served until 2006 as a U.S. presidential appointee to the Asia Pacific Economic Cooperation (APEC) Business Advisory Council (ABAC), working with U.S. and Asia-Pacific business leaders to shape

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