Resource Allocation Optimization for Transmission Line Projects

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Abstract

This project developed a resource allocation framework, a companion planning tool, and supporting case study evidence to address the absence of audited labor baselines in Owner's Engineer transmission line work. The framework was structured around four sequential phases covering historical labor audit, workload mapping, work order extension response, and constraint management. It was tested on a single high-voltage corridor in the United States where a contractual work order extension transferred senior review and quality control scope from the transmission utility onto the consultant team

Introduction

High-voltage greenfield transmission line corridors in the United States are typically delivered under an Owner's Engineer model, where an engineering consultancy oversees design quality, contractor performance, and field verification on behalf of the transmission utility. The technical scope is anchored on two deliverables: digital twin representations developed in PLS-CADD and Excel-based Planning Data Sheets used by field crews for walkdown verification. Midway through execution of the case study corridor, the utility issued a contractual work order extension that transferred senior review and quality control scope onto the consultant team, creating the conditions to study how a consultant absorbs externally induced review demand without breaching its own labor budget.

Background

Effective resource allocation in linear infrastructure requires moving beyond traditional scheduling. Resource leveling within Primavera P6 frequently struggles with the linear constraints of transmission line construction, where activities must follow a strict spatial sequence along the corridor. Memetic algorithms provide a mathematical foundation for configuring complex leveling priorities and stabilizing demand for specialized crews. Hybrid approaches using graph theory and Line of Balance scheduling enforce strict adjacency constraints in repetitive linear corridors. At the execution level, baseline schedules informed by historical field data and real-time subcontractor reporting reduce schedule variance, and integration of P6 with simulation tools supports more accurate cycle-time estimates.

Problem

No audited baseline exists for consultant labor consumption when a transmission utility issues a contractual work order extension and transfers senior review and quality control scope onto the Owner's Engineer team. Scope negotiations and forward labor projections therefore depend on theoretical estimates rather than verified operational data. The objective of this project was to develop a scalable resource allocation framework that documents the labor consumption pattern of an Owner's Engineer team operating under a work order extension and translates that pattern into a repeatable planning tool for upcoming high-volume engineering programs, including transmission line clearance infraction remediation initiatives covering thousands of infractions across the affected region.

Methodology

The framework was executed through four sequential phases, each producing deliverables that fed directly into the next.

PHASE 1

Baseline and Data Audit

Historical labor charges audited across the corridor. Verified hours for PLS-CADD digital twin review and Planning Data Sheet cycles established as the factual foundation.

PHASE 2

Labor and Workload Mapping

Workload map constructed across digital twin QA/QC, walkdown attestation, design review, and client coordination. Overallocation peaks identified.

PHASE 3

Work Order Extension Response

Additional senior review scope absorbed into the workload map. Weekly labor reports verified original deliverables were not displaced. Sequencing adjusted to prioritize the active front.

PHASE 4

Constraint Management and Deliverables

Labor utilization report consolidated from actual project data. Framework documented for absorbing future scope expansions. Senior reviewer availability identified as the governing constraint.

Results and Discussion

The labor audit produced findings that established the empirical baseline for the framework. First, the Owner's Engineer team absorbed $82,836.36 in estimate-to-complete labor across 754.75 job-to-date hours under the work order extension, confirming that client-driven scope expansions translate into measurable consultant labor commitments. Second, QA/QC activity accounted for $72,431.27 of the absorbed labor, approximately 91% of the remaining commitment, identifying senior-level review of digital twin representations as the dominant labor driver. Project lead supervision and project management functions consumed 9% and 4% respectively. Third, the binding constraint of the framework is not aggregate consultant headcount, but the limited subset of engineers qualified to perform senior-level quality control review.

The companion planning tool applies four inputs (infraction count, per-infraction review rate, QA/QC overhead ratio, and reviewer-tier assignment rule) through a deterministic calculation chain. The tool outputs a projected reviewer-hour budget, FTE commitment, recommended reviewer tier, and reserve allocation flag for work categories that cannot be deterministically estimated at the planning stage.

Applied to the active clearance mitigation program of approximately 2,000 infractions, the tool projects 935 reviewer-hours and approximately 0.52 FTE-years of junior reviewer demand for the distribution and right-of-way tier (1,700 infractions at 0.5 hours each plus 10% QA/QC overhead). The transmission line redesign tier (300 infractions) is flagged as a reserve requiring case-by-case engineering scoping. The tool prevents misallocation of approximately 7,565 senior reviewer-hours that would otherwise result from assigning senior staff to compliance documentation at the observed senior pace.

Table 1. Owner's Engineer Team Audited Labor Budget Under Work Order Extension.

Task	Contract ($)	JTD (Hr.)	ETC Labor ($)
Project Mgmt	3,384.72	4.25	2,785.33
Project Lead	11,271.20	24.25	7,619.76
QA/QC	163,481.60	726.25	72,431.27
Total	**178,137.52**	**754.75**	**82,836.36**

Note: JTD = job-to-date charged labor hours; ETC = estimate-to-complete remaining labor commitment in U.S. dollars.

Table 2. Planning Tool Projection for the Transmission Line Clearance Mitigation Program.

Scope Input	Distribution / ROW Tier	T-Line Redesign Tier
Infraction count (planning estimate)	1,700	300
Work type	Compliance documentation	Engineering redesign
Per-infraction review rate	0.5 reviewer-hours	Reserve allocation
Pure review hours	850	Reserve allocation
QA/QC overhead (10%, junior reviewer)	85	Reserve allocation
Projected reviewer-hours	**935**	**Reserve allocation**
Recommended reviewer tier	**Junior (E2/E3)**	**Senior (E5+)**
Projected FTE-years	**~0.52**	**Determined per project**

Note: FTE = full-time equivalent, calculated against 1,800 productive hours per year.

Conclusions

Client-driven scope expansions are absorbed not by aggregate consultant capacity but by the narrow subset of senior reviewers qualified to attest digital models. The framework converts that observation into a structured response by replacing theoretical labor estimates with auditable historical baselines, mapping workload against the actual constrained resource rather than against headcount, and treating work order extensions as a forecastable category of demand rather than as exceptional disruption. The methodology transfers directly to the planning of upcoming high-volume engineering programs. Consultant firms operating under the Owner's Engineer model should treat senior review capacity as their governing constraint when negotiating contractual scope adjustments.

Future Work

Subsequent extensions of the framework should integrate high-precision GPS field telematics and simulation-informed cycle estimates documented in the literature to close the gap between algorithmic scheduling logic and empirical execution data. The framework will be applied to the active transmission line clearance mitigation program to validate its forward-projection logic under actual program conditions and to calibrate the per-infraction review rate and QA/QC overhead ratio from observed performance.

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