

Productivity in Multi-Trade Construction Workflows

Report 2 in Volume 1 of the *Multiskilling in the U.S. Construction Industry* research series



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Productivity in Multi-Trade Construction Workflows

Report 2 of 6 in Volume 1

Multiskilling in the U.S. Construction Industry

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About the Series

This report is one of six reports in Volume 1 of *Multiskilling in the U.S. Construction Industry*. The series examines multiskilling through distinct research questions, evidence sources, and analytical methods. Volume 1 includes the largest field-collected dataset assembled to date on multiskilling as practiced in active U.S. construction projects and operations. It also includes controlled field trials, project records, evidence on employer workforce capability systems, a comprehensive review of peer-reviewed literature, and contractor safety context.

The research was conducted by the Simplar Foundation in collaboration with researchers affiliated with the University of Kansas, the University of North Carolina at Charlotte, and Arizona State University. Each report is designed to be read independently while contributing to the combined evidence base.

All published reports and related resources are available at the Simplar Foundation's Multiskilling Knowledge Hub (simplarfoundation.org/multiskilling).

Reports in Volume 1: Evidence on Project Performance

01	Work-Time Utilization and Staffing Level Impacts in Construction Crews	
02	Productivity in Multi-Trade Construction Workflows	THIS REPORT
03	Schedule Duration and Labor-Curve Outcomes	
04	How Construction Employers Develop, Verify, and Sustain Workforce Capability	
05	A Comprehensive Review of Prior Evidence	
06	Contractor Safety Context	

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Table of Contents

Study at a Glance	1
Executive Summary	2
Section 1 • Introduction	4
Evidence, Assumptions, and Scope of Applicability for this Study	5
Section 2 • Literature Review	7
How Work Sequencing Affects Productivity	7
Prior Studies on Handoffs and Trade Transitions	7
Why Multiskilling Matters on Highly Interactive Work Scopes	8
Section 3 • Research Objective	9
Gaps in the Existing Literature	9
Research Objective	9
Key Terms and Reported Metrics	10
Section 4 • Research Methodology	12
How to Interpret the Methodology	12
Design and Setup of the Controlled Trials	14
Modeling of Handoff Effects in Multi-Trade Work Scopes	19
Section 5 • Results	25
How to Read the Results	25
Metrics Used to Report the Results	25
Summary of Modeled Results	26
Derivation of the Headline Result	27
Section 6 • Discussion	32
Section 7 • Practical Applications	35
Section 8 • Limitations & Recommendations for Future Research	40
Summary	41
References	42
Appendix A • Examples of Where Owners Should Look for High-Handoff Work Scopes	43
Appendix B • Monte Carlo Simulation Results	46
Appendix C • Terms, Abbreviations and Definitions	48

Productivity in Multi-Trade Construction Workflows

Report 2 of 6 in Volume 1 of the *Multiskilling in the U.S. Construction Industry* research series

30%

faster completion time with fewer handoffs

43%

more installed work in the same production time

2

controlled field trials of the same work sequence

120,000

Monte Carlo simulation runs across 12 modeled scenarios

KEY FINDINGS

- 1 For closely sequenced work with frequent handoffs, reducing those handoffs cut completion time by about 30%.** Across all 12 scenarios and 120,000 simulation runs, reducing repeated handoffs shortened the time required for the defined work scope.
- 2 The reduced-handoff workflow could complete about 43% more installed work in the same amount of production time.** The workers were not assumed to perform individual tasks faster. The result came from reducing waiting, setup, reorientation, coordination, and restart between crews.
- 3 Multiskilling created the most value when frequent handoffs were concentrated within a closely sequenced work scope.** The size of the benefit ranged from almost none to very large, depending on how frequent and disruptive the handoffs were. Individual modeled scenarios ranged from 2% to 92% less elapsed time.
- 4 Two multiskilled workers completed a scope spanning seven trade functions without repeatedly handing the work to separate crews.** The one-trade workflow used 12 workers across the same sequence and transferred the work from one trade to another 10 times.

Two controlled field trials conducted for the same work sequence.

11

construction activities observed

10

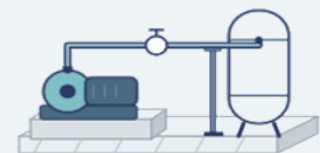
trade-to-trade handoffs

7

trade functions represented

221

minutes productive-work duration



Common pump assembly used in controlled trial

PRACTICAL APPLICATIONS

Plan for handoffs

Consider handoff exposure in production-planning

Flag high-handoff scopes

Identify tight, shared, handoff-heavy work packages early

Use where qualified

When multi-craft workers can safely do adjacent tasks

Check contractor capability

Owners can evaluate the ability to deploy multiskilled crews

Targeted strategy

Use selectively, not as a replacement for specialization.



Executive Summary

Construction projects often include scopes that require sequential handoffs between multiple trades working in the same work area.

Handoffs between trades can create waiting, setup, reorientation, and restart time between productive work activities, which can increase the total elapsed time required to complete the scope. In such cases, field productivity can be directly impacted by how efficiently the work moves from one trade to the next.

This study examined the elapsed-time reduction and equivalent production-rate gain of a reduced-handoff multitasked workflow compared with a conventional single-trade handoff workflow. The analysis was based on controlled field trials of a common construction scope which requires multiple handoffs between trades, followed by statistical scenario modeling of different handoff conditions.

Study Summary

What was tested	Crew-level elapsed production time for a multi-trade work sequence
Analysis basis	Controlled field trials with handoff scenario modeling
Observed workflow in controlled trial	11 activities with 10 trade-to-trade handoffs
Observed productive-work duration	Two controlled field trials of a half-day sequence of work (221 minute productive-work duration)
Modeled productive-work duration	Half-day, one week, and two weeks of productive-work duration were analyzed with different handoff conditions
Main outcome measure	Modeled elapsed-time reduction (%) and equivalent production-rate gain (%) associated with a reduced-handoff multitasked workflow.

Headline Findings

In construction scopes which require multiple trades to be closely coordinated in sequence, the study found a reduced-handoff multiskilled workflow achieved an ***approximate 30% reduction in crew-level elapsed production time*** relative to a conventional single-trade handoff workflow.

- In productivity terms, the reduced-handoff workflow with a multiskilled crew completed 43% more installed work during the same production time compared with the conventional single-trade workflow.

MAIN TAKEAWAY

A reduced-handoff multiskilled workflow may have significant productivity benefits for construction scopes and assemblies that require frequent trade-to-trade handoffs.

NOTE: *These results are crew-level estimates of specific work sequences; therefore, they should not be interpreted as universal productivity factors or whole-project performance estimates.*

DATA AT A GLANCE

30%

approximate reduction in crew-level elapsed production time with a reduced-handoff multiskilled workflow

43%

more installed work during the same production time

10

trade-to-trade handoffs in the observed 11-activity workflow

221

minute productive-work duration observed in two controlled field trials



SECTION 1

Introduction

Construction work involving multiple trades is often planned around the time required to complete each individual task. However, on highly interactive work scopes which depend upon multiple trades working in sequence, production is also affected by what happens between tasks performed by different trades. When work transfers from one trade crew to another, time may be added for coordination, waiting, tool staging, work-area preparation, or reorientation activities.

These handoff-added durations may seem small individually, but they can accumulate across tightly sequenced work. In those conditions, productivity depends not only on task execution, but also on how continuously the work can flow from one activity to the next.

This report focuses on multi-trade scopes which require multiple specialized crafts to complete interdependent activities in sequence or close coordination within the same work area. The findings are most applicable for scopes, assemblies, and projects which have frequent handoffs, shared workface access, and limited tolerance for waiting or restart time.

Qualified multiskilled crews may enable a reduced-handoff workflow by completing sequential tasks without repeatedly transferring work responsibility to separate single-trade crews. A multiskilled approach may be most useful where multiple trade specialties must work in rapid sequence.

This study examined how a reduced-handoff multiskilled workflow can affect trade-to-trade handoff exposure, crew-level elapsed production time, and the equivalent production-rate for multi-trade scopes. The results should be read as crew-level estimates for defined high-handoff work scopes, not as whole-project performance estimates.

Qualified multiskilled crews may enable a reduced-handoff workflow by completing sequential tasks without repeatedly transferring work responsibility to separate single-trade crews.

Examples of Where Handoffs Can Affect Multi-Trade Work

PROJECT SCOPE	WHY HANDOFFS MATTER
Phased school renovation	Work is often limited to nights, weekends, breaks, or summer windows. Repeated handoffs among demolition, structural systems (formwork, reinforcing steel, concrete, masonry), MEP, finishes, inspections, and turnover activities can affect reopening dates.
Transit station or airport terminal renovation	Work occurs around public access, security, operations, inspections, and phased turnover. Trade-to-trade delays can disrupt passenger-facing areas and downstream activities.
Bridge or roadway closure work	Multiple trades and crews must complete work within limited closure windows. Handoff delays can affect lane reopening, public access, and traffic impacts.
Water or wastewater treatment plants	Equipment installation, rigging, setting, piping, electrical, controls, insulation, flushing, testing, and startup must often be sequenced tightly to enable plant operations.

Note: These examples are illustrative. Additional examples are provided in [Appendix A](#). The study findings are most relevant wherever work involves frequent trade-to-trade handoffs, tight sequencing, shared workspace access, and limited tolerance for waiting or restart time.

Evidence, Assumptions, and Scope of Applicability for this Study

This study combined controlled field trials with statistical scenario modeling. The controlled trials were used to document the work sequence, activity structure, crew arrangements, transition points, and handoff opportunities for a specific high-interaction multi-trade work sequence. The Monte Carlo model then used the observed sequence to estimate how different handoff-duration conditions would affect crew-level elapsed production time and equivalent production-rate gain. See [Figure 1](#) for a summary of the evidence chain which underpins this study.

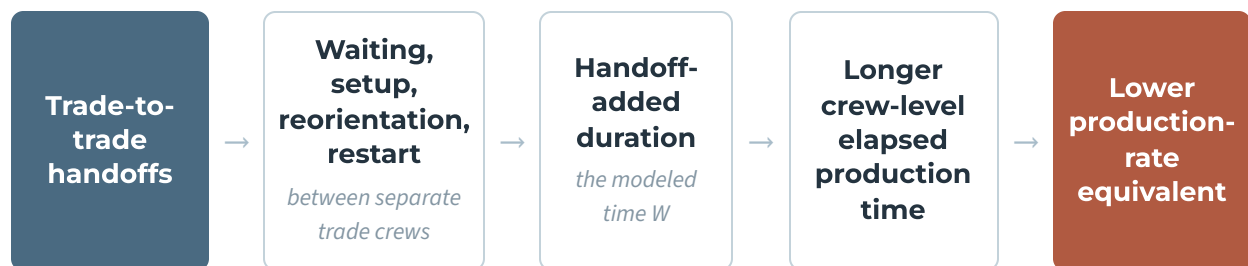
Evidence chain



Figure 1: Evidence Chain used in this Study

The study was designed to isolate the total handoff-added duration when work responsibility transfers between separate trade crews. As shown in **Figure 2**, these trade-to-trade handoffs can add time through waiting, setup, reorientation, and restart activities. When these delays occur across a tightly sequenced scope, they increase the total elapsed time to complete the scope. Because the same amount of work is completed over a longer period, the effective production rate decreases.

Hypothesized causal chain for how trade-to-trade handoffs reduce productivity



Each trade-to-trade handoff can add waiting, setup, reorientation, and restart time. Across a tightly sequenced scope, that added duration lengthens elapsed time and lowers the effective production rate.

Figure 2: Hypothesized Causal Chain for how Handoffs Reduce Productivity

The study did not assume that multiskilled workers perform each individual task faster. Instead, it evaluated how much crew-level elapsed production time could be reduced when repeated trade-to-trade handoff exposure is reduced via a multiskilled labor approach. Because the model isolated this mechanism, the findings should be interpreted as conditional crew-level estimates rather than whole-project performance estimates.





SECTION 2

Literature Review

This section reviews prior research relevant to the study in three areas: 1) how workflow continuity between tasks affects productivity, 2) how productivity losses occur at handoffs between crews and trades, and 3) how multitasking has been used to improve labor flexibility and continuity. Reviewing these areas together also helped frame the specific gap this study addressed.

How Work Sequencing Affects Productivity

Prior research shows that construction productivity is shaped not only by how efficiently individual tasks are performed, but also by how smoothly work can flow between tasks.

- From a lean construction perspective, Kalsaas (2010) linked workflow fragmentation to time losses associated with movement, setup, reorientation, tool and material handling, and restarting work.
- Bashford et al. (2002) similarly emphasized that production performance depends on how work moves from one activity to the next, not only on the duration of each individual task.

Together, these studies support treating workflow continuity as a production issue, not merely a coordination detail. For multi-trade work scopes, this means that time lost between activities can affect crew-level elapsed production time even when the individual trade tasks themselves are performed efficiently.

Prior Studies on Handoffs and Trade Transitions

Although prior research has not directly quantified the productivity impact of trade handoffs using the approach that was applied in this study, several studies have examined productivity losses that occur at boundaries between crews, trades, or shifts.

- Yaw et al. (2020) used simulation methods to show that increasing the number of separate trades in a work sequence can increase handoffs, nonproductive time, mobilization and demobilization, and communication-related errors.
- Rathnayake et al. (2024) measured activity-level productivity in sequential trade work and reported productivity losses associated with crew handoffs and work discontinuities.
- Hanna et al. (2008) examined work transfer across shifts and showed that productivity effects depend on how the transfer is organized. Walsh et al. (2003) also identified repeated trade turnover as a contributor to cycle-time waste.

These studies support the premise that productivity can be affected by what happens between activities, not only by the activities themselves. They also show that the handoff problem can appear in several forms, including elapsed handoff delay, restart time, loss of work continuity, communication errors, or added cycle time when responsibility changes hands.

Why Multiskilling Matters on Highly Interactive Work Scopes

Prior research has also examined multiskilling as a labor-flexibility strategy. Burleson et al. (1998), Haas et al. (2001), and Wang et al. (2009) linked multiskilling to broader task coverage, reduced crew or workforce requirements under some conditions, and improved continuity of work. The prior literature is summarized in Table 1.

For highly interactive multi-trade scopes, these findings are important because a reduced-handoff multiskilled workflow can reduce the number of times work transfers between separate single-trade crews. Where multiple trade specialties must work in rapid sequence within the same work area, qualified multiskilled crews may be able to preserve workflow continuity by completing adjacent tasks with fewer trade-to-trade handoffs.

Where multiple trade specialties must work in rapid sequence within the same work area, qualified multiskilled crews may be able to preserve workflow continuity by completing adjacent tasks with fewer trade-to-trade handoffs.

Table 1: Prior Research Basis for This Study's Handoff and Productivity Analysis

Topic	Study	Why It Matters for This Analysis
Production flow	Bashford et al. (2002)	Productivity depends not only on individual task performance, but also on how work moves from one activity to the next.
Crew and shift changeovers	Hanna et al. (2008)	Productivity can improve or decline when work transfers from one crew or shift to another, depending on how the transition is managed.
Workflow fragmentation	Kalsaas (2010)	Fragmented work can add time for movement, setup, reorientation, tool and material handling, and restarting work.
Sequential trade handoffs	Yaw et al. (2020)	Using more separate trades in a sequence can increase handoffs, nonproductive time, mobilization / demobilization, and communication-related errors.
Measured handoff productivity loss	Rathnayake et al. (2024)	Crew handoffs and work discontinuities were associated with productivity losses ranging from 26% to 48% in sequential trade work.



SECTION 3

Research Objective

This section summarizes the research objectives of this study, which are intended to address gaps in the prior research.

Gaps in the Existing Literature

A gap in the existing research literature is the specific relationship between handoff exposure, crew-level elapsed production time, and equivalent production-rate gain on highly interactive multi-trade work scopes. Prior studies show that workflow fragmentation and handoffs can reduce productivity, and that multitasking can improve labor flexibility and continuity. Less directly established is how much crew-level elapsed production time may be affected when a defined high-handoff work sequence is organized to reduce repeated trade-to-trade transfers.

This study addressed that specific gap by combining controlled field observations with Monte Carlo modeling of handoff-added duration. The purpose was not to establish a universal productivity factor for all construction work, but to estimate how reducing handoff exposure affects the crew-level elapsed production time required to complete a defined high-handoff multi-trade work sequence.

Research Objective

To address the gaps in the existing literature, the objective of this study was to estimate how reducing trade-to-trade handoff exposure affects the crew-level elapsed production time for a defined, high-handoff multi-trade construction work sequence.

To do this, the study used controlled field observations to establish the activity sequence, trade arrangements, and handoff points between trades. The observed work sequence was a common setup of a pump system which would be applicable to both public and private project types, such as construction of facilities related to water, wastewater, industrial, and manufacturing uses.

Monte Carlo scenario modeling was then applied to estimate how different handoff-added duration profiles affect total crew-level elapsed production time across the observed 221-minute productive-work duration. The modeling was also scaled for one-week and two-week productive-work durations to test how the modeled effect changes when the same handoff exposure was spread across longer time periods. These scaled scenarios helped evaluate sensitivity to the frequency with which handoffs may occur across different productive-work durations; in turn, the study results may be applicable to a wider range of work sequences, durations, and project types.

The results support production-planning and policy discussion for highly interactive work scopes, not to establish a universal productivity factor. They are most relevant to work packages with frequent trade-to-trade handoffs, tight sequencing, shared workspace access, and limited tolerance for waiting or restart time.

Key Terms and Reported Metrics

Table 2 provides a comprehensive list of relevant terms used in the study design and analysis.

Table 2: Key Terms Used in the Study

Term	Definition
TERMS USED TO DESCRIBE THE WORKFLOWS OBSERVED IN THE CONTROLLED FIELD TRIALS	
Handoff	A trade-to-trade transfer of work responsibility, which can add time for setup, reorientation, coordination, waiting, restart, tool staging, or work-area preparation before productive work resumes.
Handoff profile	A three-point duration profile used to model uncertainty in handoff-added duration. Each profile includes optimistic, most likely, and pessimistic values.
Handoff density	The number of handoffs relative to the productive-work duration. Handoff density is higher when many handoffs occur within a short work sequence.
Transition	A within-crew movement from one activity to the next, especially in the multitasked trial, where work responsibility does not transfer to a separate trade crew.
Worker-level nonproductive time	Time when a worker is present but not performing direct or supportive work. This is a worker-level concept and is not the primary modeled outcome.
Elapsed handoff delay	Elapsed time associated with a handoff that delays the start or continuation of the next activity. This is an elapsed-duration concept and is distinct from worker-level nonproductive time.
Handoff-added duration	Modeled time added at trade-to-trade handoffs, including waiting, setup, reorientation, coordination, restart, and related work-continuity losses.
Elapsed-time reduction	The modeled reduction in total crew-level elapsed production time when handoff-added duration is removed or reduced.

Term	Definition
TERMS USED TO MEASURE THE IMPACT OF A REDUCED-HANDOFF MULTISKILLED WORKFLOW	
Crew-level elapsed production time	The total elapsed time required for the crew/work sequence to complete the modeled scope, including productive-work duration and modeled handoff-added duration.
Equivalent production-rate gain (%)	The calculated percentage increase in installed work per unit of crew-level elapsed production time when handoff-added duration is removed or reduced. In this study, it was calculated as $G = W / B$, where W is modeled total handoff-added duration and B is productive-work duration.
Production-rate equivalent	A conceptual framing of the increase in installed work per unit of crew-level elapsed production time when the same modeled work sequence is completed in less elapsed time. In this report, the reported percentage version of this concept is equivalent production-rate gain (%).
Productive-work duration	The baseline duration required to complete the active work sequence before modeled handoff-added duration is added. In this study, the productive-work durations are 221 minutes, 2,400 minutes, and 4,800 minutes. This term replaces “work-in-place / WIP duration.”
TERMS USED TO DESCRIBE THE CONDITIONS USED IN STATISTICAL MODELLING	
Favorable handoff condition	A low-disruption handoff profile representing well-coordinated transition conditions. In tables, this condition is labeled “Favorable” for brevity.
Routine handoff condition	A moderate handoff profile representing routine coordination delays. In tables, this condition is labeled “Routine” for brevity.
Severe handoff condition	A high-disruption handoff profile representing substantial workflow breakdowns, such as one-hour, half-day, or full-day interruptions. In tables, this condition is labeled “Severe” for brevity.
Composite handoff condition	A mixed-condition scenario in which different handoff profiles are assigned to different handoffs in the same work sequence.

PRODUCTIVE-WORK DURATIONS MODELED IN THIS STUDY

221 min

observed half-day duration

2,400 min

scaled modeled 1-week duration

4,800 min

scaled modeled 2-week duration



SECTION 4

Research Methodology

The methodology consisted of three parts (**Table 3**). First, the study documented a controlled construction assembly completed under two crew arrangements: a reduced-handoff multiskilled workflow and a conventional single-trade handoff workflow. Second, it recorded and compared workflow observations from the two trials, with particular attention to trade-to-trade handoff points. Third, it used the observed workflow as the basis for modeling how broader handoff conditions could affect crew-level elapsed production time and equivalent production-rate gain.

Table 3: Summary of Study Design

Step	What Was Done	Purpose
1. Controlled field trials	A multi-trade construction assembly was completed under two crew arrangements.	Compare how the same work sequence progressed under a reduced-handoff multiskilled workflow and a conventional single-trade handoff workflow.
2. Workflow tracking	Activity durations, handoff points, and pauses between activities were recorded.	Identify where handoffs occurred between trades and how workflow continuity changed between the two crew arrangements.
3. Handoff scenario modeling	Handoff-added durations were modeled under Favorable, Routine, Severe, and Composite conditions.	Estimate how different handoff conditions could affect handoff-added duration, crew-level elapsed production time, elapsed-time reduction, and equivalent production-rate gain.

How to Interpret the Methodology

This subsection explains how to read the study methodology and the resulting findings. The controlled field trials documented the observed work sequence, crew arrangements, transition points, and handoff opportunities. The Monte Carlo model then used that observed sequence to test how different handoff-added duration assumptions would affect crew-level elapsed production time and equivalent production-rate gain.

Table 4 clarifies what was observed, assumed, simulated, and held constant, while also identifying what should not be inferred from the study. This framing helps ensure the results are used appropriately: as crew-level decision-support estimates for a defined high-handoff work sequence, not as universal productivity factors or whole-project outcome estimates.

Table 4: How to Interpret the Methodology

What was observed?	A specific multi-trade construction assembly, the activity sequence, two crew arrangements, transitions between activities, handoff points, and favorable handoff conditions in the controlled trials.
What was assumed?	The same modeled work scope was completed within each scenario; productive-work duration was held constant within each scenario; handoff-added duration was additive to crew-level elapsed production time; and the number of handoffs was held constant at 10.
What was simulated?	Handoff-added duration under Favorable, Routine, Severe, and Composite handoff profiles across three productive-work durations: 221 minutes, 2,400 minutes, and 4,800 minutes.
What was held constant?	Work sequence, number of handoffs, productive-work duration within each scenario, and productive task durations.
What should not be inferred?	The results should not be interpreted as universal productivity gains or whole-project performance estimates. They do not directly estimate cost, schedule, labor-hour productivity, safety, quality, or workforce outcomes.
What did the study support?	The study supported the conclusion that, for the high-handoff work sequence modeled, reducing handoff exposure reduced crew-level elapsed production time and produced an equivalent production-rate gain, with the effect depending on handoff severity and handoff density.

This report used productivity in the context of a specific multi-trade work sequence. The modeled work scope was held constant within each scenario while the elapsed production time required to complete that scope changed depending on modeled handoff-added duration. Because the installed scope was held constant within each scenario, a reduction in elapsed production time corresponded to an increase in the rate at which the sequence is completed. This derived rate was reported as the production-rate equivalent, expressed as installed work per unit of crew-level elapsed production time. The percentage version of this rate comparison is reported as equivalent production-rate gain (%).

Design and Setup of the Controlled Trials

This section describes the construction assembly used in the controlled trials, the two crew arrangements under which it was performed, and the methods used to track activity timing, handoffs, and workflow continuity across both conditions.

Work Scope

The study examined a controlled assembly involving construction of a concrete pump pad followed by installation of a pump and associated piping connection system (Figure 3). The sequence would typically involve multiple trades on a construction project, making it suitable for examining workflow under closely interdependent trade-to-trade interaction.



Figure 3: Photo of the completed pump assembly from the controlled trials.

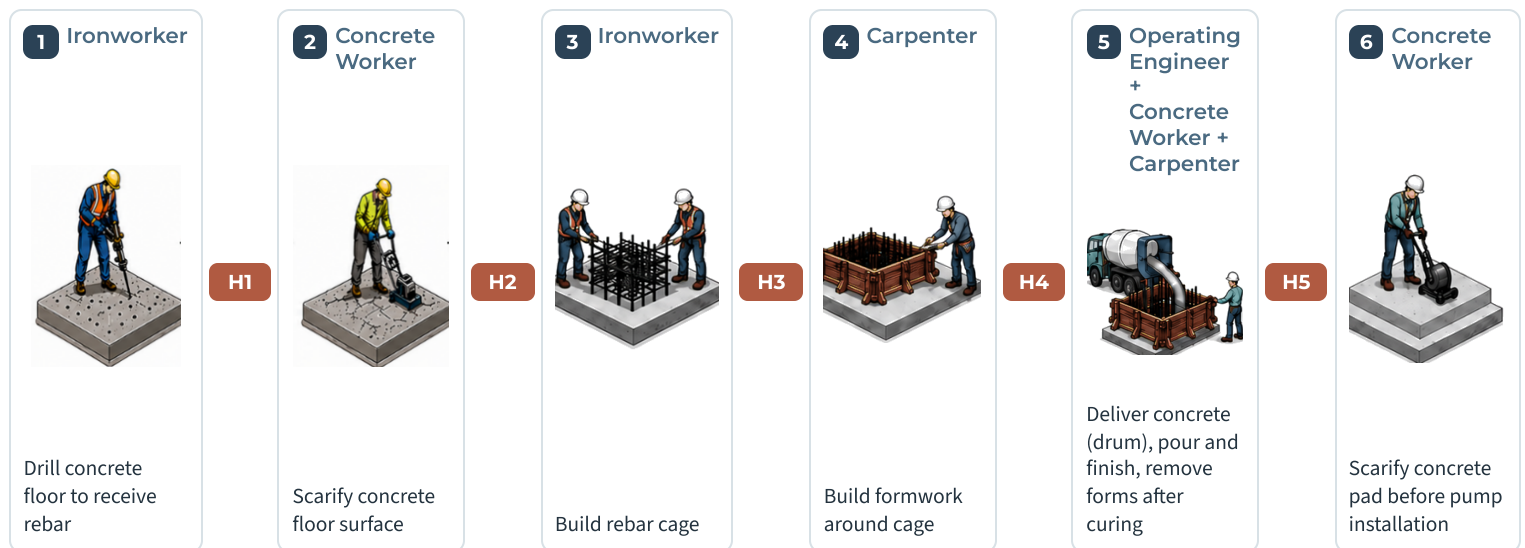
The work was organized into two phases:

- **Phase 1** included worksite layout, rebar placement, formwork installation, concrete pouring and finishing, and formwork removal.
- **Phase 2** included pump delivery and placement, pipe installation, and welding of required supports.

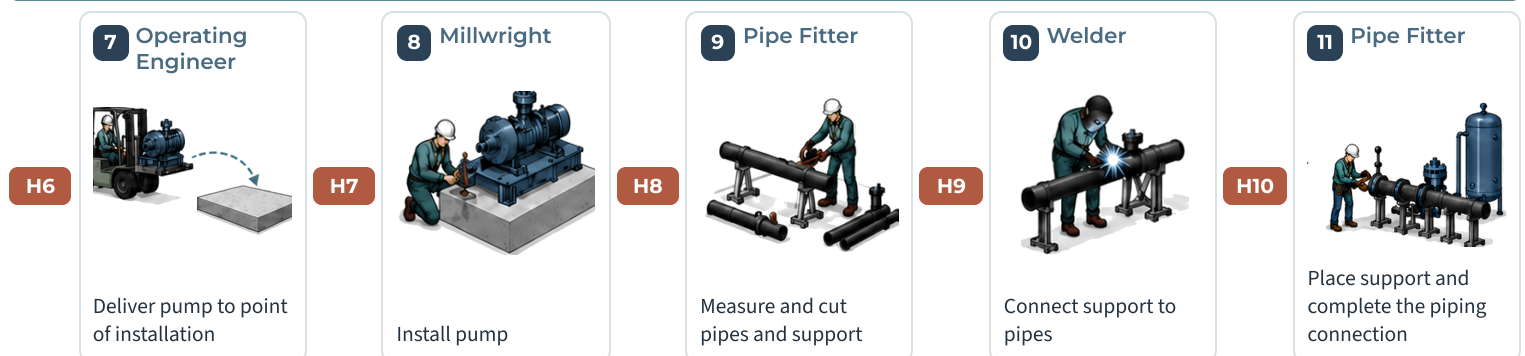
Figure 4 provides a graphical illustration of the tasks performed in each phase, the trades involved in each task, and the ten handoff points between trades. In this report, the construction assembly refers to the physical pump-pad and pump/piping installation; the work sequence refers to the 11 observed activities and 10 handoff points used in the model.

Observed work sequence in the controlled trials

PHASE 1 — CONCRETE PAD / FOUNDATION PREPARATION



PHASE 2 — PUMP AND PIPING INSTALLATION



LEGEND # Activity (step number) H# Handoff (trade transition)

NOTE Handoff (H1–H10) denotes the point where work responsibility transfers from one trade to the next.

Figure 4: Illustration of the Observed Work Sequence in the Controlled Trials

Crew Composition

The same work sequence was performed under two trial conditions that differed in how labor was organized. Participating workers held National Center for Construction Education and Research (NCCER) credentials in their respective trades, and the workers involved across both trials averaged 17 years of construction experience. The represented trades included reinforcing ironwork, carpentry, concrete finishing, millwright work, pipefitting, welding, and equipment operation. The two controlled trials are described below and illustrated in Figure 5.

Worker and trade combinations in controlled trials

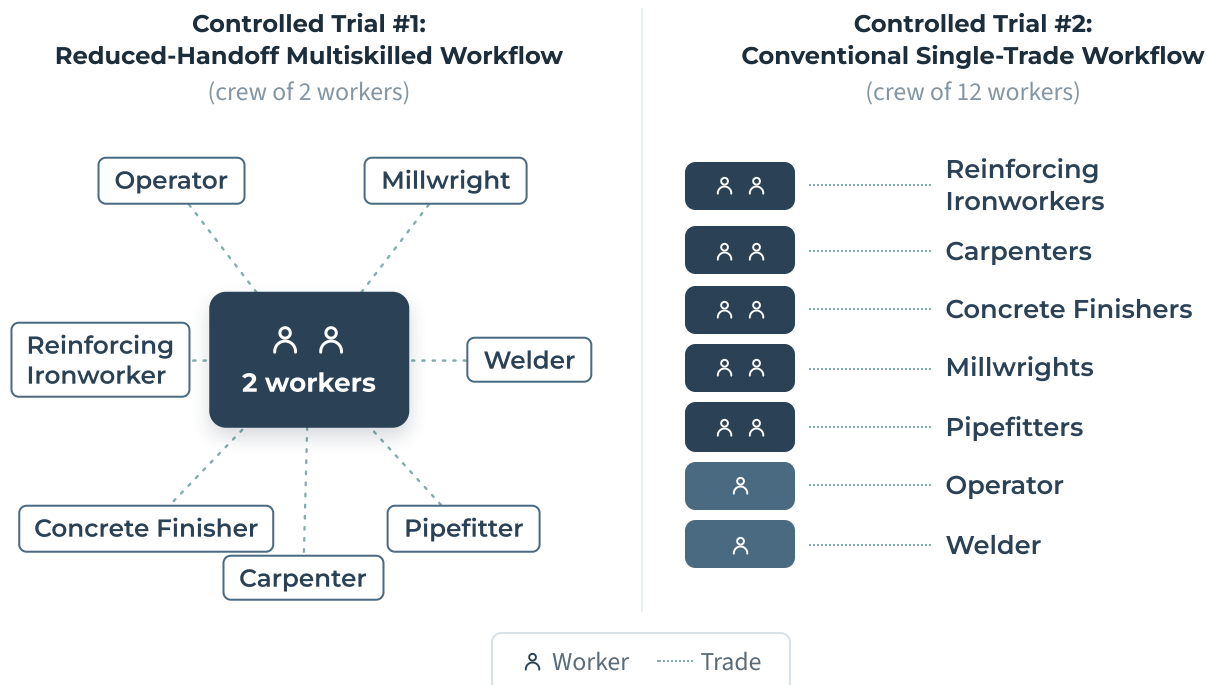


Figure 5: Worker and Trade Combinations in Controlled Trials

Workflow Tracking

During both trials, the timing and sequence of work activities were recorded to examine how work progressed through the assembly. The following information was recorded:

- activity description; start and finish time for each activity;
- transition points or handoff points between activities; and
- any pauses where work stopped while waiting for the next task or trade to begin.

In the conventional single-trade workflow, pauses occurred at handoff points between workers or trades, making it possible to examine not only individual task durations but also how repeated trade-to-trade transfers affected workflow continuity and the overall pace of the sequence.

Workflows observed in the controlled trials

Figure 6 illustrates the two workflows observed in the controlled trials.

Trial 1: Reduced-handoff multitasked workflow.

The work was completed by a two-person crew. This allowed the crew to move from one activity to the next without waiting for additional trade crews to be brought in.

Trial 2: Conventional single-trade handoff workflow.

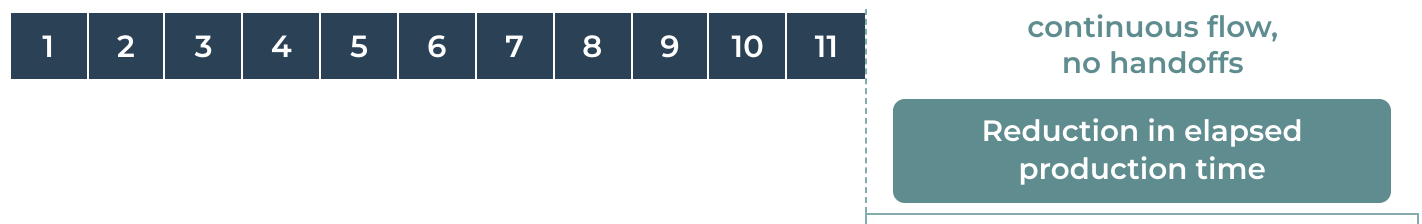
The work was completed using a conventional single-trade workflow in which workers were assigned to distinct activities based on trade specialization.

Two trials observed in the controlled study

■ Productive work activities ■ Handoff-added time

Trial 1: Reduced-handoff multitasked workflow

11 activities · 2-person crew · within-crew transitions



Trial 2: Conventional single-trade workflow

11 activities · 12 workers · 10 trade-to-trade handoffs



Phase 1 · concrete pad / foundation preparation

- 1 Drill concrete floor (Ironworker)
- 2 Scarify floor surface (Concrete Worker)
- 3 Build rebar cage (Ironworker)
- 4 Build formwork (Carpenter)
- 5 Pour, finish, strip forms (Op. Eng., Concrete, Carpenter)
- 6 Scarify pad for pump (Concrete Worker)

Phase 2 · pump and piping installation

- 7 Deliver pump to location (Operating Engineer)
- 8 Install pump (Millwright)
- 9 Measure & cut pipes (Pipe Fitter)
- 10 Connect support to pipes (Welder)
- 11 Complete piping connection (Pipe Fitter)

Figure 6: Two Trials Observed in the Controlled Study

Workflow Observations

The observed workflow consisted of 11 activities and 10 handoff points between successive workers or trades, with an observed productive-work duration of 221 minutes, or approximately half of an eight-hour workday. Table 5 summarizes the outcomes of the trials.

- In the reduced-handoff multiskilled workflow trial (Trial 1), the crew moved through the sequence with relatively little interruption. Because both workers had overlapping skills, they were able to transition directly from one activity to the next without waiting for another trade to mobilize. The crew also prepared for upcoming tasks before the current one had fully ended by staging tools, preparing materials, and setting up equipment in advance. This maintained continuity across the workflow.
- In the single-trade trial (Trial 2), the use of separate trade assignments established clear handoff points in the workflow. As responsibility shifted from one trade to the next, incoming workers typically needed time to orient themselves to the work area, identify where the previous crew had left off, and prepare tools or equipment before productive work could resume. Activities such as locating tools, staging equipment, cleaning the work area, and confirming measurements added coordination time at each handoff. Elapsed handoff delay was also observed around several transitions, with incoming workers waiting while the previous task was still being completed, suggesting that some delay began before the formal handoff itself.

Because both workers had overlapping skills, they were able to transition directly from one activity to the next without waiting for another trade to mobilize.

Both trials were recorded under controlled conditions in which workers and crews were already favorably positioned within the immediate work area (summarized in Table 5). As a result, travel, re-entry, and crew mobilization or demobilization were limited as compared to how field conditions may be reflected on an active construction site. The observed handoff durations were therefore treated as favorable relative to standard practice and used as a lower reference point in the simulation analysis.

Table 5: Observed Trial Summary

Metric	Reduced-Handoff Multiskilled Trial (Trial 1)	Conventional Single-Trade Handoff Trial (Trial 2)
Workers assigned to observed sequence	2	12
Activities	11	11
Crew-to-crew handoffs	Eliminated; primarily within-crew transitions	10
Observed handoff/transition notes	Single crew moved directly between adjacent tasks and often prepared tools and materials before the next activity began.	Separate crews for each trade function created repeated handoff points requiring orientation, staging, coordination, and waiting before productive work resumed.

Modeling of Handoff Effects in Multi-Trade Work Scopes

The modeling component estimated how handoff-added duration could affect crew-level elapsed production time and equivalent production-rate gain in a conventional single-trade handoff workflow. The model isolated the effect of handoff-added duration on a defined work sequence. Productive-work duration, work sequence, and number of handoffs were held constant within each scenario so that the effect of handoff conditions could be examined separately.

Handoff Duration Benchmarks

The controlled trials reflected well-coordinated handoff conditions and likely did not represent the full range of delays that can occur in practice. Benchmark values were therefore drawn from both the controlled trials and prior construction research to represent a broader range of handoff conditions that may occur in a conventional single-trade workflow. **Table 6** summarizes the benchmark handoff-duration values used in the analysis.

Table 6: Basis for Handoff-Duration Values Used in the Simulation

Duration of Handoff	Source	Basis for Use
5 min	Controlled trial	Based on the most favorable handoff points observed in the controlled trial, with the next crew already present and ready to begin work with the necessary tools, materials, and safety preparation.
8 min	Rathnayake et al. (2024)	Derived from the lower productivity-loss condition reported in prior research and translated into an equivalent handoff-duration benchmark for the observed workflow.
13 min	Rathnayake et al. (2024)	Derived from the average productivity-loss condition reported in prior research and translated into an equivalent handoff-duration benchmark for the observed workflow. The 13-minute value is a conservative approximation of the average-condition conversion.
20 min	Rathnayake et al. (2024)	Derived from the higher productivity-loss condition reported in prior research and translated into an equivalent handoff-duration benchmark for the observed workflow.
60 min	Hanna et al. (2008)	Used to represent a one-hour handoff condition informed by research on work transfer, shift changes, and loss of work continuity.
240 min (half-workday)	Study-selected value informed by Hanna et al. (2008) and Walsh et al. (2003)	Used as a half-workday disruption condition between the one-hour and full-workday cases.
480 min (full workday)	Walsh et al. (2003)	Used as a full-workday disruption condition representing an extreme handoff delay.

Conversion of Rathnayake et al. Productivity-Loss Values

The Rathnayake *et al.* (2024) productivity-loss values shown in **Table 6** were converted into equivalent per-handoff duration benchmarks using the observed 221-minute productive-work duration and 10 modeled handoffs (see section 4.3.5).

For a given productivity-loss value **L**, the equivalent total handoff-added duration was calculated via Equation 1.

$$W = \frac{L}{1 - L} \times B$$

Equation 1: Equivalent total handoff-added duration

where:

- **W** = equivalent total handoff-added duration
- **L** = prior reported productivity-loss value from Rathnayake et al. (2024)
- **B** = productive-work duration for the modeled scenario

The equivalent per-handoff duration was then calculated according to Equation 2:

$$h = \frac{W}{n} = \frac{\left[\frac{L}{1 - L} \right] \times B}{n}$$

Equation 2: Equivalent per-handoff duration

where:

- **h** = equivalent per-handoff duration
- **n** = number of modeled handoffs

Applying this conversion produced approximate benchmark values of 8, 13, and 20 minutes for the lower, average, and higher loss conditions. The 13-minute benchmark was a conservative approximation of the average-condition conversion.

PERT-Based Handoff Duration Profiles

Program Evaluation and Review Technique (PERT)-based three-point estimates were used to represent uncertainty in handoff duration through optimistic, most likely, and pessimistic values rather than a single fixed duration. This approach was consistent with industry-standard risk analysis practices; for example, the schedule risk analysis approach described in the U.S. Government Accountability Office (GAO) Schedule Assessment Guide 16-89G (GAO, 2015) recommends three-point estimating when activity durations are uncertain.

For each simulated handoff, durations were sampled from a beta-PERT distribution defined by the optimistic, most likely, and pessimistic values assigned to that handoff profile. The expected handoff duration was calculated using the standard PERT technique supported by the GAO as shown in Equation 3.

$$E[h] = \frac{O + 4M + P}{6}$$

Equation 3: PERT expected handoff duration

where:

- **O** = optimistic handoff duration
- **M** = most likely handoff duration
- **P** = pessimistic handoff duration

Three PERT-based handoff profiles were defined for the simulation: Favorable, Routine, and Severe (see [Table 7](#)). For each profile, the three values represent optimistic, most likely, and pessimistic handoff durations, respectively.

Table 7: PERT-Based Handoff Duration Profiles

Handoff Profile	Optimistic	Most Likely	Pessimistic	Expected Handoff Duration
Favorable	5 min	8 min	13 min	8.3 min
Routine	13 min	20 min	60 min	25.5 min
Severe	60 min	240 min	480 min	250.0 min

The favorable profile reflects well-coordinated transition conditions. The routine profile reflects moderate coordination delays. The severe profile reflects substantial workflow breakdowns that may occur when handoff delays escalate into one-hour, half-day, or full-day interruptions.

Monte Carlo Simulation Design

Monte Carlo simulation was used to examine how the handoff duration profiles could affect total handoff-added duration, crew-level elapsed production time, and equivalent production-rate in the conventional single-trade handoff workflow. Two analyses were performed as shown in Figure 7 and outcomes summarized in Table 8:

1. The first applied a consistent handoff condition across all 10 modeled handoffs. Three consistent handoff conditions were evaluated: Favorable, Routine, and Severe. Each profile was tested at three productive-work durations: the observed 221-minute duration from the controlled trial, a scaled modeled 1-week duration of 2,400 minutes, and a scaled modeled 2-week duration of 4,800 minutes. Each profile-duration combination was simulated using 10,000 model runs, resulting in 90,000 runs (10,000 model runs x 3 handoff conditions x 3 productive-work durations) for the consistent-profile analysis.
2. The second analysis applied a Composite varying-condition profile across the same 10 handoffs. In this case, favorable conditions were assigned to handoffs 1 through 3, routine conditions to handoffs 4 through 6 and 10, and severe conditions to handoffs 7 through 9. The Composite profile was evaluated at the same three productive-work durations, with 10,000 model runs at each duration. This resulted in 30,000 runs for the composite-profile analysis and 120,000 runs across both analyses.

The composite scenario was included as an illustrative mixed-condition case to represent a sequence in which some handoffs remained well coordinated, some experienced routine coordination delay, and several experienced severe disruptions.

Handoff conditions used in Monte Carlo simulations

Condition assigned to each of the 10 handoffs · applied at the half-day, 1-week, and 2-week productive-work durations

	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10
Favorable consistent	5/8/13	5/8/13	5/8/13	5/8/13	5/8/13	5/8/13	5/8/13	5/8/13	5/8/13	5/8/13
Routine consistent	13/20/60	13/20/60	13/20/60	13/20/60	13/20/60	13/20/60	13/20/60	13/20/60	13/20/60	13/20/60
Severe consistent	60/240/480	60/240/480	60/240/480	60/240/480	60/240/480	60/240/480	60/240/480	60/240/480	60/240/480	60/240/480
Composite varies by handoff	5/8/13	5/8/13	5/8/13	13/20/60	13/20/60	13/20/60	60/240/480	60/240/480	60/240/480	13/20/60

□ Favorable · 5/8/13 min □ Routine · 13/20/60 min □ Severe · 60/240/480 min

Values are PERT optimistic / most likely / pessimistic handoff durations, in minutes

Figure 7: Handoff Conditions Used in Monte Carlo Simulations for the Half-Day, 1-Week, and 2-Week Productive-Work Durations

The 1-week and 2-week scenarios were scaled modeled productive-work durations based on the same observed sequence of trade functions and the same 10 handoff points documented in the 221-minute controlled trials. These scaled durations were used to test how the percentage impact of the same handoff exposure changed when the productive-work duration became longer. The number of handoffs was held constant so the analysis could isolate the effect of handoff density on crew-level elapsed production time and equivalent production-rate gain.

Table 8: Monte Carlo Simulation Setup Summary

Model Component	Values
Handoffs and Trades	10 handoffs among seven trade functions represented in the observed work sequence
Productive-work durations tested	Observed half-day duration: 221 min scaled modeled 1-week duration: 2,400 min scaled modeled 2-week duration: 4,800 min
Simulation Type 1: Consistent handoff conditions	Favorable: 5 / 8 / 13 min (per Controlled Trial and Rathnayake et al.) Routine: 13 / 20 / 60 min (per Rathnayake et al. and Hanna et al.) Severe: 60 / 240 / 480 min. (per Hanna et al. and Walsh et al.) Each profile was tested at all three productive-work durations.
Simulation Type 2: Composite handoff conditions	H1–H3: Favorable H4–H6 and H10: Routine H7–H9: Severe Composite handoff condition tested at all three productive-work durations.
Scenarios tested	12 total: 9 consistent-profile conditions + 3 Composite-profile conditions
Simulation runs	10,000 per scenario; 120,000 total
Probability distribution used	Beta-PERT distribution defined by optimistic, most likely, and pessimistic values

Each handoff duration was sampled from the probability distribution assigned to its handoff profile. For consistent-profile scenarios, the same handoff profile was applied to all 10 modeled handoffs. For the Composite scenario, different profiles were assigned to different handoffs in the same work sequence.

Model Assumptions in Monte Carlo Simulations

The model used the following assumptions:

- The same modeled work scope was completed within each scenario.
- Productive task durations were held constant within each scenario.
- The number of handoffs was held constant at 10.
- Modeled handoff-added durations were additive to crew-level elapsed production time.

- Each handoff duration was treated as a separate uncertain event drawn from its assigned handoff profile. The model did not assume that a delay at one handoff was linked to the duration of other handoffs.
- The 1-week and 2-week scenarios were scaled modeled productive-work durations based on the same observed sequence of trade functions and the same 10 handoff points documented in the 221-minute controlled trial.
- Project-level effects such as parallel work, critical-path float, labor reassignment, procurement, inspection timing, rework, safety, quality, and cost were outside the model scope.

These assumptions allowed the analysis to isolate the effect of handoff-added duration on a defined work sequence. They also limited how broadly the findings should be applied. The results are most applicable to high-handoff, tightly sequenced multi-trade work scopes where multiple trade activities occur in close sequence within the same work area.

The analysis did not assume that individual tasks are performed faster. Instead, the modeled effect comes from reducing handoff-added duration, including waiting, setup, reorientation, coordination, and restart time between separate trade crews. A summary of the model runs in the simulation design is shown in **Figure 8**.

Summary of Monte Carlo model runs

	3 productive-work durations	4 handoff conditions	12 modeled scenarios	10,000 runs per scenario	120,000 runs in total
	Favorable Routine Severe Composite				
Half-day 221 min	10,000 runs				10,000 runs
1 week 2,400 min	10,000 runs				10,000 runs
2 weeks 4,800 min	10,000 runs				10,000 runs

Each scenario pairs one productive-work duration with one handoff condition · 12 scenarios × 10,000 runs = 120,000 runs

Figure 8: Summary of Monte Carlo Model Runs





SECTION 5

Results

The simulation results showed that the reduced-handoff multiskilled workflow was modeled to reduce crew-level elapsed production time by 27% to 33%, corresponding to an equivalent production-rate gain of 37% to 50% for the modeled high-handoff work sequence.

How to Read the Results

The controlled trials established the observed work sequence and activities, crew arrangements, and 10 handoff opportunities for the high-handoff work sequence studied. Monte Carlo models estimated the elapsed-time effect of avoiding those handoff-added durations across the modeled scenarios by using the reduced-handoff multiskilled workflow. This allowed the analysis to isolate how handoff density affects the modeled result.

The results should therefore be interpreted as modeled effects of reducing handoff exposure for this specific type of high-handoff work sequence. The equivalent production-rate gain was reported as installed work per unit of crew-level elapsed production time.

Metrics Used to Report the Results

The Results section reports two related but different percentage measures:

- **Elapsed-time reduction** (Equation 4) represented the percentage reduction in crew-level elapsed production time when handoff-added duration was removed or reduced by the multiskilled workflow

$$R = \frac{W}{B + W}$$

Equation 4: Elapsed Time Reduction (%)

- **Equivalent production-rate gain** (Equation 5) represented the implied increase in installed work per unit of crew-level elapsed production time when handoff-added duration was removed or reduced by a multitasked workflow.

$$G = \frac{W}{B}$$

Equation 5: Equivalent Production-Rate Gain (%)

Where

- **B** = baseline productive-work duration
- **W** = modeled total handoff-added duration
- **G** = equivalent production-rate gain (%)
- **R** = elapsed-time reduction (%)

These two metrics are related but not numerically identical. This relationship explains why a 27% elapsed-time reduction is equivalent to roughly 37% more installed work per unit of crew-level elapsed production time, and why a 33% elapsed-time reduction is equivalent to roughly 50% more installed work per unit of crew-level elapsed production time.

Summary of Modeled Results

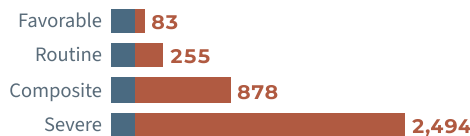
The full modeled results are illustrated in **Figure 9** and for the average elapsed-time reductions accomplished via the reduced-handoff multitasked workflow. The handoff-added durations were modelled for each handoff condition (Favorable, Routine, Composite, Severe) and then applied to the three productive-work durations that were investigated, which were durations of a Half-Day (221-min), 1-Week (2,400-min), and 2-Weeks (4,800-min).

All durations and conditions

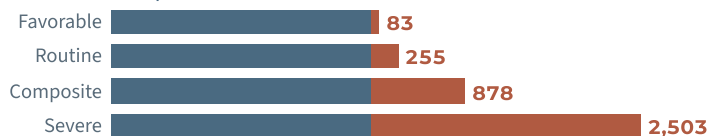
Common scale across all 12 scenarios (minutes)

■ Baseline productive work duration (B) ■ Modeled total handoff-added duration (W)

HALF-DAY • B = 221 MIN



1 WEEK • B = 2,400 MIN



2 WEEKS • B = 4,800 MIN



Note: productive work is held constant within each scenario; handoff-added time varies by condition.

Figure 9: Modeled Results for all 12 Scenarios

Table 9 provides additional details for the results across the 12 modeled scenarios.

- The key pattern is that the reduced-handoff multiskilled workflow produced meaningful elapsed-time reduction by reducing handoff-added duration.
- The reduced-handoff multiskilled workflow also produced an equivalent production-rate gain in all modeled scenarios.
- As the productive-work duration increased, the percentage effect declined because the same number of handoffs was spread over a longer baseline.

Table 9: Monte Carlo Results by Productive-Work Duration and Handoff Condition

Productive-work duration	Handoff condition	Mean total handoff-added duration (min)	Mean conventional single-trade crew-level elapsed production duration (min)	Equivalent production-rate gain (%)	Mean elapsed-time reduction from reducing handoff-added duration (%)
Observed 221-min duration (half-day)	Favorable	83	304	38	 27
	Routine	255	476	115	 53
	Severe	2,494	2,715	1,128	 92
	Composite	878	1,099	397	 80
Scaled modeled 2,400 min duration (1-week)	Favorable	83	2,483	3	 3
	Routine	255	2,655	11	 10
	Severe	2,503	4,903	104	 51
	Composite	878	3,278	37	 27
Scaled modeled 4,800 min duration (2-week)	Favorable	83	4,883	2	 2
	Routine	255	5,055	5	 5
	Severe	2,499	7,299	52	 34
	Composite	875	5,675	18	 15

Appendix B provides more information, where detailed Monte Carlo percentile results with P10, P50, and P90 values are provided in **Table 11** for the handoff-added durations and **Table 12** for the elapsed-time reduction and equivalent production-rate gain.

Derivation of the Headline Result

The following subsections summarize the key results of the reduced-handoff multiskilled workflow for policy and industry readers.

Elapsed-Time Reduction

Figure 10 provides a matrix of results for only the elapsed-time percentage reductions. This format is useful because it shows the overall pattern more clearly by focusing only on the elapsed time reduction associated with the multiskilled labor strategy across the 12 modeled scenarios. The median elapsed-time reduction was found to be 27% and the unweighted average was 33%.

This 27% to 33% range was used as an overall scenario summary for high-handoff construction scopes that require sequential coordination of multiple trades. Because these high-handoff scopes typically occur as portions of larger projects, the 27% to 33% range should be interpreted as a crew-level scenario summary, not as a whole-project productivity factor. Individual modeled scenarios ranged from 2% to 92%, depending on the productive-work duration and the severity of handoff conditions.

For policy and industry audiences, the plain-language statement that reduced handoff exposure was modeled to reduce crew-level elapsed production time by “about 30%” is a rounded summary of these two central values, not a confidence interval, universal productivity factor, or prediction for any individual project

ELAPSED-TIME REDUCTION

27%

median elapsed-time reduction across the 12 modeled scenarios

33%

unweighted average elapsed-time reduction

2–92%

range of individual modeled scenarios, by productive-work duration and handoff severity

Heatmap of elapsed-time percentage reduction

Mean elapsed-time reduction (%)

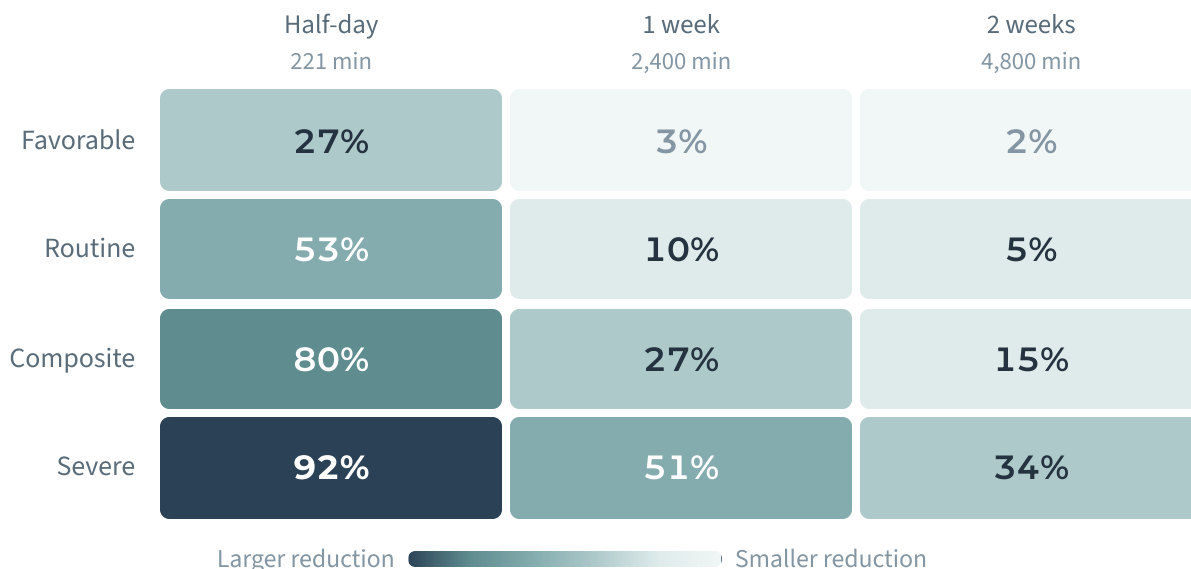


Figure 10: Heatmap of Elapsed-Time Percentage Reduction Results

Equivalent Production-Rate Gain

Figure 11 presents the heatmap for equivalent production-rate gain for the modeled scenarios. The median equivalent production-rate gain was 38% and the unweighted average was 159%. The large average reflects the skewed nature of the modeled results, especially the severe scenarios where handoff-added duration exceeds the productive-work duration.

The unweighted average is reported for transparency but should not be interpreted as a typical expected production-rate gain.

To provide a more conservative headline, the study used Equations 4 and 5 to convert the elapsed-time reduction headline results to the equivalent production-rate gain values of 37% to 50%.

Heatmap of equivalent production-rate gain

Mean equivalent production-rate gain (%)

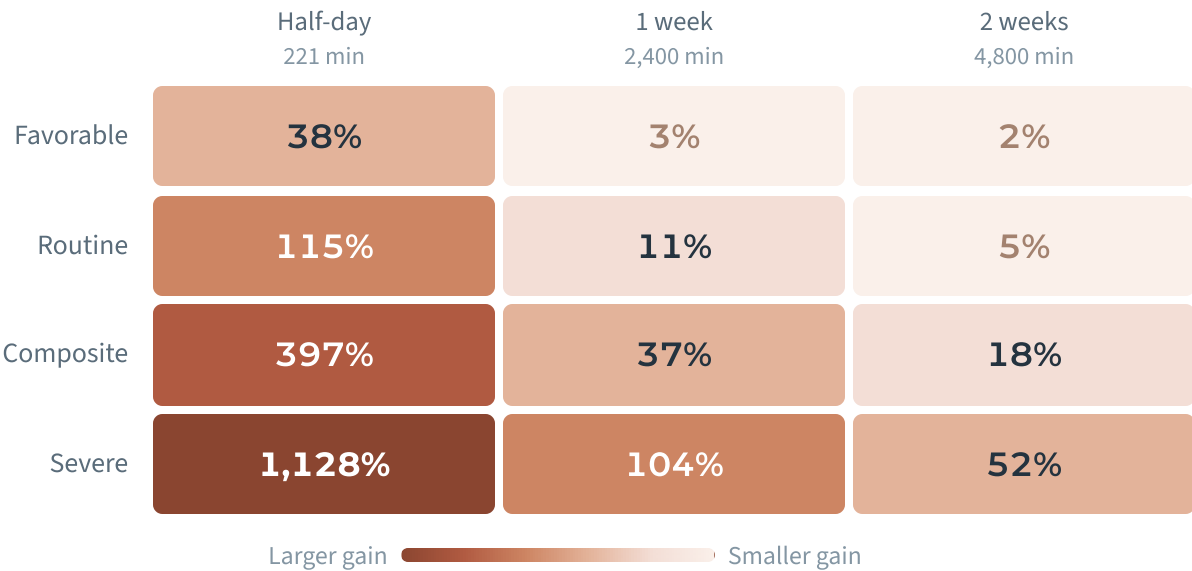


Figure 11: Heatmap of Equivalent Production-Rate Gain Results

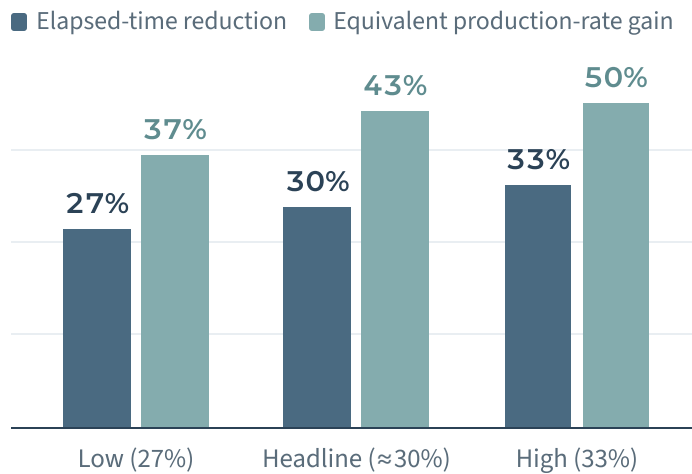
A 27% elapsed-time reduction is equivalent to roughly 37% more installed work per unit of crew-level elapsed production time, and a 33% elapsed-time reduction is equivalent to roughly 50% more installed work per unit of crew-level elapsed production time.

Why a Time Reduction Implies a Larger Rate Gain

Figure 12 illustrates the relationship between the Elapsed-Time Reduction and the Equivalent Production-Rate Gain. As described in the analogy provided in the figure, a reduction in the elapsed-production time to complete the observed scope in the controlled trials corresponds to a greater amount of work produced in a given period of time. Therefore, a reduction in the elapsed-time to perform the assembly can be expressed as an equivalent gain in the crew's production rate.

Why a time reduction implies a larger rate gain

Elapsed-time reduction and its equivalent production-rate gain



Same effect, two units

Rate is the inverse of time, so a given percentage of time saved always converts to a larger percentage of output gained.

ANALOGY

A 60-minute drive completed in 45 minutes is **25% less time**, and equivalent to **33% more distance per hour**.

Figure 12: Elapsed-Time Reduction and its Equivalent Production-Rate Gain

Crew-Level Personnel Requirement Observed in the Controlled Trials

In the controlled trials, the reduced-handoff multitasked workflow was executed by two workers with overlapping skill sets. The conventional single-trade handoff workflow trial involved twelve workers assigned to distinct trade activities in the observed sequence.

This comparison indicates a lower crew-level personnel requirement for executing this specific work sequence under the trial conditions. This should not be interpreted as a total project workforce reduction, because project-level staffing depends on simultaneous workfaces, schedule requirements, crew availability, labor agreements, and parallel work.

A potential benefit of a reduced-handoff multitasked workflow is that a qualified crew can safely complete a wider range of tightly sequenced tasks without repeated crew changes. This benefit is most relevant on highly integrated work scopes where multiple trade specialties must work in rapid sequence within the same work area. When those adjacent specialties can be performed by a qualified crew, multitasking can reduce handoff exposure, improve continuity, and lower the number of separate workers needed to execute that specific sequence.

Results Highlights

- The reduced-handoff **multiskilled workflow was modeled to reduce crew-level elapsed production time by about 30%** for the high-handoff work sequence studied.
- Across the 12 modeled scenarios, the **median** elapsed-time reduction was **27%**, and the **unweighted mean** was approximately **33%**.
- The full modeled range of crew-level elapsed-production time was decreased between **2% to 92%**, depending on productive-work duration and handoff severity.
- Expressed as equivalent production-rate gain, the elapsed-time reduction corresponds to roughly **37% to 50% more installed work per unit of crew-level elapsed production time**.
- In the controlled trial, the multiskilled crew was able to safely and competently perform seven unique trade functions required to complete the observed work sequence.
- The modeled results are conditional crew-level estimates for the high-handoff work sequence studied, not universal productivity factors.

RESULTS AT A GLANCE

30%

less crew-level elapsed
production time, about

37–50%

more installed work per unit of
crew-level elapsed production
time

7

unique trade functions performed
by the multiskilled crew





SECTION 6

Discussion

The main production benefit of the reduced-handoff multiskilled workflow was improved workflow continuity.

The model held productive-work duration constant within each scenario and added handoff-related duration to the conventional single-trade workflow. The modeled elapsed-time reduction therefore resulted from reducing waiting, setup, reorientation, coordination, and restart time between separate trade assignments through the reduced-handoff multiskilled workflow.

The results were strongest where handoff density is high.

The modeled effect was largest when many trade-to-trade handoffs occur within a short or highly constrained productive-work duration (see [Figure 13](#)). At the observed 221-minute productive-work duration, the 10 handoffs represented a large share of total crew-level elapsed production time. At the scaled one-week and two-week productive-work durations, the same 10 handoffs were spread across a longer baseline, so the percentage effect became smaller. This showed that a reduced-handoff multiskilled workflow is most likely to produce measurable production benefits where handoffs are frequent, sequencing is tight, and workface access is shared. [Figure 14](#) provides several examples for where owners should look for high-handoff scopes, which is when a reduced-handoff multiskilled workflow is most likely to achieve productivity benefits.

Severe disruption scenarios should be interpreted as a source of risk to productivity.

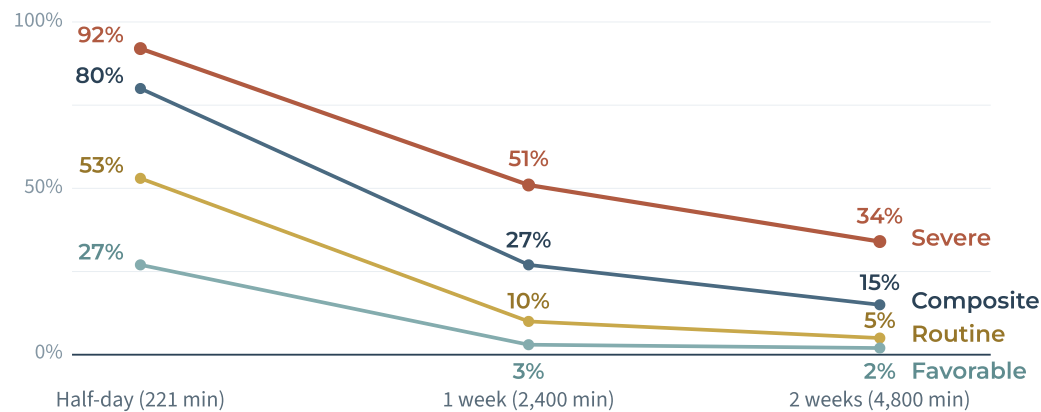
The severe-disruption scenarios showed the potential risk exposure when handoff delays escalate into one-hour, half-day, or full-day interruptions (see [Figure 15](#)). These values were scenario assumptions informed by prior literature and were selected to represent more severe workflow breakdowns which can occur in the field. These cases are useful because they illustrate how repeated trade-to-trade dependencies can create substantial productivity risk; however they should not be interpreted typical outcomes. Rather, they represent severe disruption conditions that projects should seek to prevent or avoid.

The reduced-handoff multiskilled crew completed the observed work sequence with fewer workers and fewer crew changes.

The controlled trials showed that the multiskilled crew could execute the observed sequence with fewer workers assigned to the observed scope sequence. This is a crew-level finding, not a project-level workforce estimate. The implication is that qualified multiskilled crews may be able to complete a broader range of tightly sequenced activities with fewer crew changes, especially where multiple trade specialties must work in rapid succession within the same work area.

Handoff density: the same 10 handoffs across longer durations

Mean elapsed-time reduction (%) falls as productive-work duration grows



The same 10 handoffs across longer productive-work durations

Figure 13: Illustration of Handoff Density

Where to look for high-handoff scopes

Categories where reducing trade-to-trade handoffs is most likely to help, grouped from Appendix A

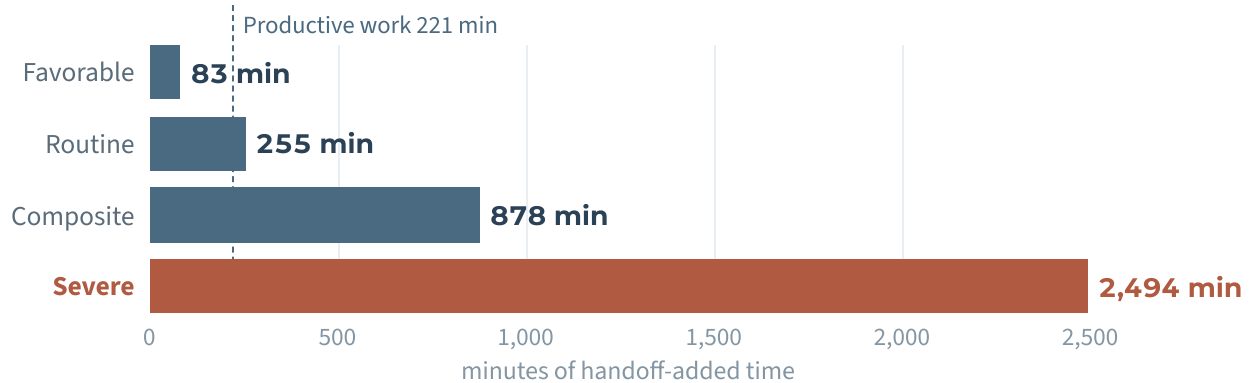
Infrastructure shutdowns & closures	Occupied & phased renovations	MEP-intensive systems	Equipment & process tie-ins	Commissioning-heavy work
- Bridge / roadway closures - Site utility tie-ins - Central plant equipment swaps	- School / summer work - Transit & airport terminals - Occupied public buildings	- MEP / service corridors - Pipe racks & utility corridors - Healthcare build-outs - Restroom & bathroom cores	- Process piping tie-ins - Manufacturing line installs - Rooftop equipment - Modular / prefab tie-ins	- Commissioning-intensive systems - Fire & life-safety completion - Labs & cleanrooms

Figure 14: Scope Types Where Reducing Trade-to-Trade Handoffs is Most Likely to Help

A reduced-handoff multitasked workflow is most likely to produce measurable production benefits where handoffs are frequent, sequencing is tight, and workforce access is shared.

Severe handoffs as risk exposure

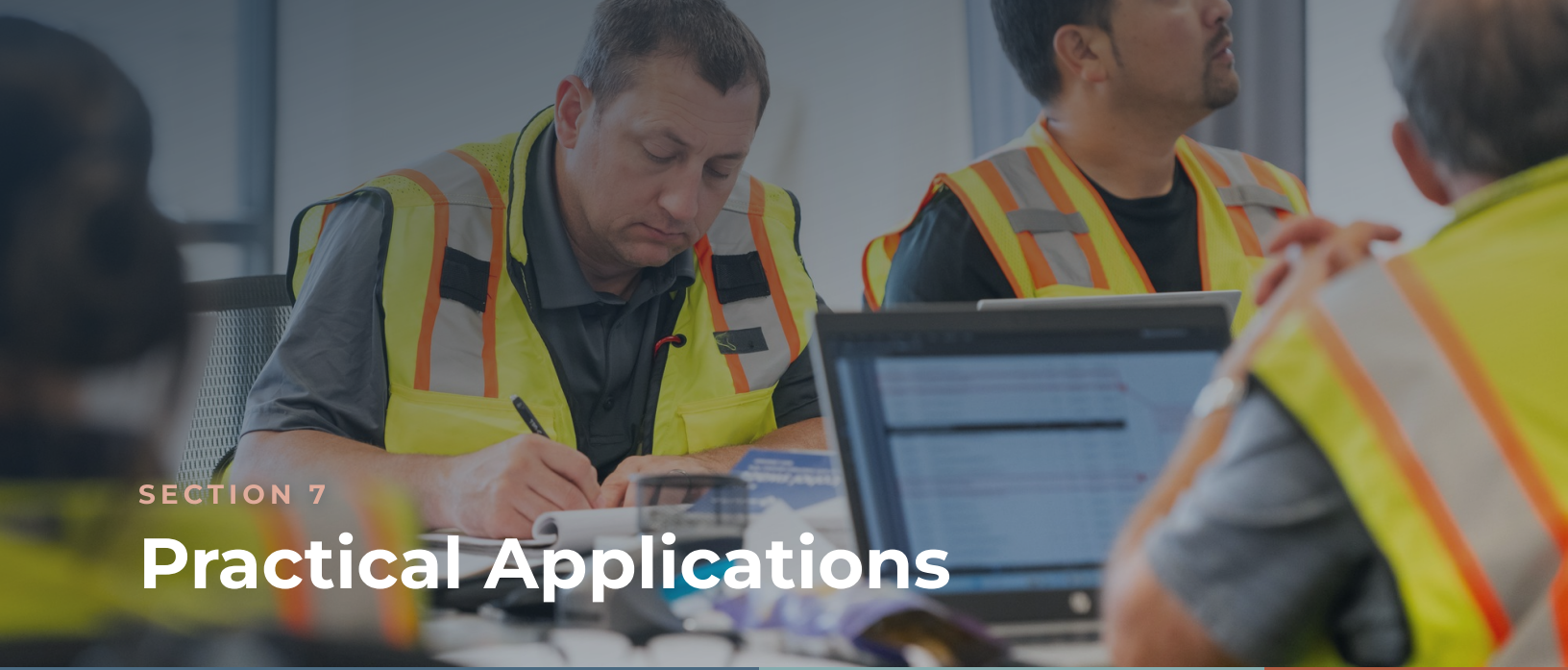
Handoff-added duration at the half-day baseline



RISK EXPOSURE

Severe scenarios represent potential risk exposure from repeated trade-to-trade dependency. Each severe handoff can add 1 hour to a full workday of delay (60 to 480 min); projects should seek to avoid them.

Figure 15: Severe Handoff Scenarios as Risk Exposure

A photograph of three construction workers wearing high-visibility yellow safety vests. One worker in the foreground is focused on writing in a notebook, while another worker behind him looks at a laptop screen. A third worker is partially visible on the right. The scene is set in a professional or office-like environment.

SECTION 7

Practical Applications

The practical opportunity identified by this study is to complete selected multi-trade work sequences with fewer avoidable interruptions between activities. The modeled benefit came from reducing handoff-added duration, including waiting, setup, reorientation, coordination, and restart time. It did not depend on assuming that workers performed each individual task faster. For industry and policy audiences, the central question is therefore where qualified multiskilled workers can maintain continuity across adjacent activities that would otherwise require repeated crew changes. The recommendations below apply this finding to five stakeholder groups.

The practical opportunity identified by this study is to complete selected multi-trade work sequences with fewer avoidable interruptions between activities.

Target Specific Assemblies and Work Packages

The starting point should be a defined assembly or work sequence within a project. The controlled trials examined a concrete pump-pad and pump/piping installation involving adjacent reinforcing, formwork, concrete, equipment-setting, piping, and support-welding activities. This provides a direct reference for examining similar interfaces within water, wastewater, industrial, manufacturing, and central utility projects.

Other candidate work packages can be identified within the project contexts described in [Appendix A](#). The examples in the following table illustrate how to narrow that review to the work packages and possible trade-to-trade handoffs.

Project context	Illustrative work package to evaluate	Handoff opportunity to examine
Water, wastewater, industrial, or central utility facilities	A defined equipment-base, pump-placement, piping, and support package	Repeated transfers between the workers preparing the base, setting equipment, and completing selected piping and support activities.
Service corridors and utility pipe racks	One corridor segment, overhead services area, or rack bay	Short, interdependent activities and repeated crew changes within the same work area.
Restroom cores and commercial kitchens	One restroom sequence or equipment group and its connections	Adjacent installation and finishing activities that repeatedly wait for another qualified trade.
Modular and prefabricated construction	Selected field connections for a placed module, rack, skid, or pod	Tightly sequenced connection activities after placement.
Phased renovations and equipment replacements	A defined work zone or replacement package within a school, public building, transportation facility, or plant	Crew changes and restarts within a constrained access, shutdown, or turnover period.

These are screening examples, not additional tested assemblies or a ranking of proven benefits. A short shutdown or reopening window makes an interruption consequential, but does not by itself establish high handoff density. Teams should examine how frequently work transfers between crews relative to the productive-work duration, how much time those transfers add, and which transfers qualified workers could avoid.

The objective is to reduce unnecessary transfers of work responsibility, not to remove necessary project functions. Required inspections, tests, certifications, authorizations, supervision, and independent oversight must remain where applicable. Specialized crews should continue to perform work that requires their expertise. Multiskilling should expand the ways qualified workers contribute without weakening the standards governing the work.



Individual Workers: Connect Broader Capability to Work, Earnings, and Career Choice

Use complementary capabilities to expand real work opportunities. For workers, the practical value of multitasking is the opportunity to contribute through more of a work sequence and qualify for additional assignments. The companion worker-benefits research describes opportunities for more annual hours, longer project assignments, access to more projects and phases, and greater earning potential. Where suitable local assignments are available, broader capability may also reduce the need to travel to find the next job. These opportunities depend on available work and on employers connecting demonstrated capability to actual assignments.

Choose additional capabilities with a clear purpose. Workers and employers should discuss which capabilities complement the worker's primary craft, appear regularly in the company's upcoming work, and fit the worker's interests. A useful addition might address a recurring adjacent task, an equipment need, or a transition between activities. The goal is not for every worker to perform every trade. Workers should be able to deepen their primary craft, add selected capabilities, or pursue another development path with a clear understanding of the preparation and opportunities involved.

Build understanding of the completed assembly and a career beyond the immediate task. In the multitasked trial, workers prepared tools, materials, and equipment for upcoming activities while progressing through the sequence. This observation points to the practical value of understanding what the next activity requires, not only where the current assignment ends. The companion worker handout also describes pride in broader contribution, continuity with the same crew, and opportunities to become a coach, assessor, instructor, or field leader. These pathways allow workers to shape careers that evolve with their interests and experience while helping transfer craft knowledge to others.

Polymakers: Enable Qualified Flexibility While Preserving Specialization

Support the appropriate use of verified complementary capabilities. The policy implication is to allow qualified workers and contractors to use multitasking where it fits the work, while retaining deep specialist expertise. This study did not evaluate particular laws, regulations, or workforce policies. Its findings provide a basis for considering how policy can accommodate appropriate workforce approaches rather than prescribing one labor arrangement for every project.

Review barriers and support broad qualified participation. Polymakers should consider whether workforce programs, procurement provisions, or other requirements unintentionally prevent qualified workers from completing appropriate adjacent tasks. That review should preserve applicable licensing, credentialing, safety, quality, supervision, and other required controls. Public programs should also support fair participation by qualified contractors of different sizes and types, allowing suitable workforce approaches to emerge from the organizations performing the work.

Link development support to demonstrated capability and useful outcomes. Competency-based pathways can combine primary-trade development with selected additional capabilities, practical demonstration, and current documentation. Employer participation should connect that preparation to actual assignments. Program evaluation should consider whether workers gain usable capabilities and career opportunities, whether contractors can deploy qualified capacity where needed, and whether selected projects achieve the intended outcomes. Training participation alone should not be treated as evidence that these outcomes occurred.

Taxpayers, Communities, and End Users

Expect public owners to examine avoidable interruptions in consequential work. For the public, the relevant opportunity is not an abstract productivity percentage. It is the possibility of less avoidable interruption within work packages that affect access to school renovations, roadway closures, occupied public buildings, and utility upgrades. The public interest is not simply whether an individual task is completed quickly, but whether the construction team has considered avoidable interruptions that could affect access, operations, or service availability. Public owners should ask whether selected reduced-handoff workflows can help address those interruptions.

Connect workforce investment to meaningful outcomes. The public should also expect workforce investment to create meaningful worker opportunity. The benefits to evaluate include both useful worker development and the performance of the selected work package. This study did not demonstrate lower taxes, a project-cost reduction, or earlier reopening of an entire facility.

Contractors and Construction Companies: Build Workforce Capability Around their Work

Select skill combinations that solve a recurring workflow problem. Contractors should begin with their backlog and the assemblies their crews regularly perform. Map the activities, identify where work responsibility changes hands, and examine the waiting, setup, and restart time associated with those changes. Then determine whether selected complementary capabilities would allow qualified workers to continue into adjacent activities. The objective is not to maximize the number of skills each worker holds, but to develop combinations that are useful to the work and to the worker's development.

Prepare the actual crew and sequence before deployment. Define the tasks each worker will perform, the required technical and productive-performance standards, the safety and quality expectations, and the conditions of authorization and supervision. Connect instruction to coached practice, demonstration, assessment, and documented readiness. For critical or unfamiliar work, use a mock-up, test assembly, equipment practice, or actual-team rehearsal to review the sequence, tools, materials, work-area access, and communication. A worker's additional capability becomes useful when both the worker and the work package are ready.

Plan the transitions that remain. Fewer trade-to-trade handoffs do not eliminate every changeover between activities. Crews still need appropriate tools, materials, equipment, access, and preparation for the next task. The trial observations suggest that advance preparation for upcoming activities is an important consideration in maintaining continuity. Plans should distinguish the crew changes being avoided from the necessary preparation and controls that remain, and should identify where dedicated specialists are still needed.

Measure the selected work package and feed the lessons back into development. Track the completed scope, crew-level elapsed production time, and the number and duration of handoffs. Review quality, rework, safety observations, and worker and supervisor feedback alongside those production measures. Where improved worker opportunity is an objective, also examine assignments, hours, earnings progression, and advancement. Use the results to adjust training, assessment, crew selection, and preparation for the next deployment. Claims about labor-hour productivity, cost, or whole-project schedule performance require separate measurement rather than inference from elapsed-time reduction alone.

Owners and Buyers: Ask for a Scope-Specific Plan and Evidence of Readiness

Identify opportunities early and ask contractors to explain their approach. During capital planning, procurement, and preconstruction, owners should identify packages with frequent handoffs, several short interdependent activities, shared work areas, or limited tolerance for interruption. Ask bidding or proposing contractors where they would use qualified multiskilled workers, which capabilities would be combined, which handoffs they expect to reduce, who would perform the work, what result they expect to improve, and how that result would be measured.

Evaluate demonstrated readiness, not the multiskilling label alone.

Owners should ask how the contractor knows that the proposed workers can perform the defined work. Relevant evidence includes practical assessments, current qualifications and authorizations, applicable supervision, relevant experience, and project-specific preparation. The proposed workforce approach should be considered alongside technical qualifications, safety performance, quality systems, cost, schedule, and prior project experience. A credible reduced-handoff plan is more useful than a general claim that the contractor employs multiskilled workers.

Create the conditions for preparation and appropriate deployment.

Give contractors early visibility into upcoming scopes, specialized systems, operating constraints, shutdowns, and turnover requirements. Include workforce strategy in work-package, schedule, logistics, safety, and quality planning. Review whether contract provisions or owner practices unnecessarily prevent qualified workers from performing suitable adjacent tasks, while retaining applicable requirements. Provide time for focused refreshers or rehearsals where the work warrants them.

Measure value where the strategy was used. Compare the planned and actual performance of the selected package, including elapsed production time, waiting between trades, handoffs, quality, rework, and worker feedback. Examine separately whether any improvement affects a project milestone or operational outcome. The report's headline percentages should not become an automatic project-wide schedule reduction, cost discount, or staffing requirement. At closeout, identify which scopes benefited, which capabilities were useful, which handoffs remained difficult, and what should be prepared earlier next time.





SECTION 8

Limitations & Recommendations for Future Research

This study had several limitations. First, the analysis was conducted at the crew/work-sequence level and should not be extrapolated directly to whole-project productivity, cost, schedule, profit margin, or bottom-line performance. The model estimated crew-level elapsed production effects for a specific high-handoff work sequence. Project-level outcomes would depend on additional factors, including crew availability, parallel work, trade stacking, procurement, inspection timing, quality, rework, safety requirements, labor agreements, float, and whether the affected work sequence lies on the project critical path.

Second, the controlled trial involved a specific construction assembly and a limited set of participants, which limited generalizability. The selected work assembly was highly relevant to a range of public and private sector projects, such as water treatment, water distribution, wastewater treatment, industrial, and manufacturing projects. This was intended to make the study relevant to a range of common public and private project types; however, it does not eliminate the recommendation for replication across other assemblies and site conditions.

Third, the model isolated handoff-related waiting by holding productive task durations and the number of handoffs constant within each scenario. Fourth, the modeled handoff-duration profiles were scenario assumptions informed by trial observations and prior research, not direct measurements across a broad sample of projects. Fifth, the simulation did not account for task-duration uncertainty, correlated handoff delays, crew reassignment, labor-hour costs, quality outcomes, safety outcomes, inspection constraints, or rework.

Future research should replicate the study across additional work scopes, project types, crew configurations, and site conditions. Additional field studies should measure both elapsed handoff delay and worker-level nonproductive time over full production periods. Future models should incorporate task-duration uncertainty, correlated handoff delays, crew availability, parallel work, critical-path effects, labor-hour costs, quality outcomes, safety outcomes, and rework. These extensions would allow the crew-level findings reported here to be connected more directly to project-level performance.



Summary

This study examined how reducing trade-to-trade handoff exposure affects crew-level elapsed production time and equivalent production-rate gain on highly interactive multi-trade work. Based on the controlled field trials and follow-on Monte Carlo modeling, the results showed that the primary benefit of the reduced-handoff multiskilled workflow is improved continuity across the work sequence. The model did not assume that individual tasks are completed faster. Instead, the modeled benefit came from reducing waiting, setup, reorientation, coordination, and restart time between separate trade assignments.

The main takeaway was that handoff exposure should be treated as an important production factor on high-handoff work scopes. Across the modeled scenarios, reducing handoff exposure produced a central modeled result of about 30% less crew-level elapsed production time for the high-handoff work sequence studied, which was equivalent to approximately 43% more installed work per unit of production time at the crew level.

The effect was largest where handoff density was high and where handoff conditions became more disruptive. This means the findings were most relevant to work scopes where several trades must complete interdependent activities in close sequence within the same work area.

For owners, contractors, policy makers, and project teams, the practical implication is that multiskilling should be considered as a targeted production-planning strategy where repeated handoffs are likely to create measurable delay. A qualified multiskilled crew can enable a reduced-handoff workflow that reduces unnecessary crew changes, improves workflow continuity, and makes production more predictable on the right type of work scope. These results should be used as crew-level decision-support estimates for high-handoff work scopes, not as universal productivity factors or whole-project performance estimates.

A qualified multiskilled crew can enable a reduced-handoff workflow that reduces unnecessary crew changes, improves workflow continuity, and makes production more predictable on the right type of work scope.

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Examples of Where Owners Should Look for High-Handoff Work Scopes

Table 10: Examples of High-Handoff Work Scopes Where Reducing Trade-to-Trade Handoffs May Improve Production Flow

Work scope	Typical project context	Typical trade-to-trade handoff conditions
School renovation or summer work	Public school renovation, modernization, or capital improvement programs	Handoffs occur among demolition, abatement if applicable, MEP rough-in, framing, finishes, inspections, furniture/equipment, cleaning, and turnover teams. Work is often tied to summer, break, or reopening deadlines.
Bridge or roadway closure work	New infrastructure, reconstruction, or major public works projects	Handoffs occur among traffic control, demolition, structural repair, utilities, concrete placement, lighting, striping, inspections, and reopening crews. Work is often organized around limited closure windows.
Water or wastewater treatment facilities	New construction, expansion, or operating facility modernization	Handoffs occur among civil, mechanical, electrical, controls, process piping, equipment setting, testing, startup, and operations teams. Work often must be sequenced around active treatment operations.
Transit station or airport terminal work	New construction, expansion, or phased renovation in active transportation facilities	Handoffs occur among structural, MEP, communications, security, signage, finishes, inspections, commissioning, and operations teams. Work is often constrained by public access, security, and phased turnover.
Central utility plant construction	New campus, healthcare, university, industrial, municipal, or public-sector facilities	Handoffs occur among equipment setting, mechanical piping, electrical, controls, insulation, flushing, testing, balancing, and commissioning teams. Work is often sequenced around bringing major systems online.
Central plant equipment replacement or upgrade	Public-sector, campus, healthcare, school, or municipal modernization	Handoffs occur during demolition, isolation, equipment removal, rigging, setting, reconnection, testing, and restart. Work is often constrained by active building operations or limited shutdown windows.
Occupied public building renovation	Courthouses, municipal buildings, libraries, public safety facilities, and agency buildings	Handoffs occur among demolition, temporary protection, MEP, security systems, finishes, inspections, and occupant coordination teams. Work is often phased around public access and ongoing operations.
Laboratory or cleanroom construction	New research, life sciences, healthcare, or university facilities	Handoffs occur among specialty HVAC, process piping, plumbing, electrical, controls, casework, finishes, testing, balancing, certification, and turnover teams. Work is often sequenced around testing and certification requirements.

Work scope	Typical project context	Typical trade-to-trade handoff conditions
Healthcare clinical space build-out	New hospital, outpatient, medical office, or clinical facility construction	Handoffs commonly occur among framing, medical gas, HVAC, plumbing, electrical, communications, nurse call, fire protection, finishes, testing, and inspections. Many trades share wall and ceiling zones.
Mechanical/electrical/service corridor build-out	New institutional, industrial, healthcare, laboratory, airport, or campus projects	Multiple systems compete for the same overhead or corridor space. Handoffs often occur among hangers, ductwork, piping, conduit, cable tray, fire protection, insulation, controls, and inspections.
Manufacturing line installation	New manufacturing or advanced manufacturing projects	Handoffs occur among equipment setting, structural supports, utilities, controls, guarding, testing, validation, and production-start teams. The work is often tied to a defined startup or production-readiness milestone.
Commissioning-intensive systems work	New buildings with complex mechanical, electrical, controls, life-safety, or security systems	Handoffs occur among installers, controls technicians, testing and balancing teams, fire alarm/security teams, commissioning agents, inspectors, and owner operations staff. Troubleshooting may require repeated handbacks between trades.
Utility corridor or pipe rack installation	New industrial, campus, utility, or infrastructure projects	Multiple trades work along the same linear workforce, including supports, piping, conduit, cable tray, insulation, fireproofing, and access coordination. Handoffs often occur as each system layer is installed or cleared.
Commercial kitchen build-out	New schools, universities, hospitals, hotels, restaurants, or public facilities	Handoffs occur among plumbing, gas piping, electrical, ventilation, fire suppression, equipment setting, controls, inspections, and startup teams. Equipment turnover often requires multiple systems to be ready at the same time.
Bathroom group or restroom core construction	New schools, offices, hotels, dormitories, healthcare, or public buildings	Handoffs occur among framing, rough plumbing, electrical, blocking, drywall, waterproofing, tile, fixtures, accessories, final connections, and inspections. The sequence is often repetitive across multiple rooms.
Vertical transportation core work	New multi-story commercial, residential, institutional, transit, or public buildings	Handoffs occur among structural, electrical, controls, fire alarm, mechanical, cab installation, testing, inspection, and certification teams. Access to shafts and machine rooms is often controlled.

Work scope	Typical project context	Typical trade-to-trade handoff conditions
Building-envelope and facade systems	New commercial, institutional, airport, healthcare, or public buildings	Handoffs occur among structural attachments, framing, waterproofing, glazing, sealants, insulation, exterior panels, access equipment, and inspections. Sequencing often depends on shared lifts, scaffolds, or exterior work zones.
Modular or prefabricated assembly tie-ins	New construction using prefabricated modules, racks, skids, panels, pods, or assemblies	Handoffs occur after module placement when structural, piping, electrical, fire protection, controls, testing, and inspection teams complete field connections. Tie-ins are often tightly sequenced.
Rooftop equipment installation	New commercial, institutional, healthcare, school, or industrial projects	Handoffs occur among crane/rigging crews, structural review, curb installation, roofing, ductwork, piping, electrical, controls, startup, and testing teams. Work may be constrained by weather, access, or crane availability.
Fire protection and life-safety system completion	New buildings with complex inspection and occupancy requirements	Handoffs occur among sprinkler, fire alarm, smoke control, electrical, controls, doors, firestopping, testing, and authority inspection teams. Final occupancy may depend on coordinated completion of several systems.
Process piping and equipment tie-ins	New industrial, water, wastewater, or process-heavy construction	Handoffs commonly occur among pipefitters, welders, inspectors, insulators, controls, testing personnel, and startup teams. Work often depends on pressure testing, inspection release, and system turnover.
Site utility tie-ins	New campus, infrastructure, municipal, school, healthcare, or industrial projects	Handoffs occur among excavation, shoring, utility installation, conduit, piping, inspections, testing, backfill, paving, and system activation teams. Work may also require coordination with utility providers or public agencies.
Electrical room or substation build-out	New commercial, institutional, industrial, utility, or infrastructure	Handoffs occur among pad preparation, equipment setting, conduit installation, grounding, cable pulling, terminations, controls, firestopping, testing, inspections. Energization often depends on sequential completion.

APPENDIX B

Monte Carlo Simulation Results

This appendix provides the results from Monte Carlo simulation for the full distribution of handoff-added durations (Table 11) and the two primary outcomes of elapsed-time reduction and equivalent production-rate gain (Table 12).

Table 11: Monte Carlo Results: Distribution of Handoff-Added Duration

Productive-work duration	Handoff condition	Simulation runs	Mean total handoff-added duration, W	P10 W	P50 W	P90 W
Observed 221-min duration	Favorable	10,000	83	77	83	90
Observed 221-min duration	Routine	10,000	255	223	254	288
Observed 221-min duration	Severe	10,000	2,494	2,175	2,493	2,818
Observed 221-min duration	Composite	10,000	878	699	876	1,058
Scaled modeled 1-week (2,400 min)	Favorable	10,000	83	77	83	89
Scaled modeled 1-week (2,400 min)	Routine	10,000	255	224	254	288
Scaled modeled 1-week (2,400 min)	Severe	10,000	2,503	2,190	2,498	2,828
Scaled modeled 1-week (2,400 min)	Composite	10,000	878	701	876	1,057
Scaled modeled 2-week (4,800 min)	Favorable	10,000	83	77	83	90
Scaled modeled 2-week (4,800 min)	Routine	10,000	255	224	254	288
Scaled modeled 2-week (4,800 min)	Severe	10,000	2,499	2,179	2,500	2,818
Scaled modeled 2-week (4,800 min)	Composite	10,000	875	697	875	1,052

Note: **W** = total handoff-added duration. P10, P50, and P90 are simulation percentiles. For example, P90 means that 90% of simulated outcomes were at or below that value

Table 12: Monte Carlo Results: Distribution of Elapsed-Time Reduction and Equivalent Production-Rate Gain

Productive-work duration	Handoff condition	Mean elapsed-time reduction (%), R	P10 R	P50 R	P90 R	Mean equivalent production-rate gain (%), G	P10 G	P50 G	P90 G
Observed Half-day (221-min)	Favorable	27%	26%	27%	29%	38%	34%	38%	41%
Observed Half-day (221-min)	Routine	53%	50%	53%	57%	115%	101%	115%	130%
Observed Half-day (221-min)	Severe	92%	91%	92%	93%	1,128%	984%	1,128%	1,275%
Observed Half-day (221-min)	Composite	80%	76%	80%	83%	397%	316%	396%	479%
Scaled modeled 1-week (2,400 min)	Favorable	3%	3%	3%	4%	3%	3%	3%	4%
Scaled modeled 1-week (2,400 min)	Routine	10%	9%	10%	11%	11%	9%	11%	12%
Scaled modeled 1-week (2,400 min)	Severe	51%	48%	51%	54%	104%	91%	104%	118%
Scaled modeled 1-week (2,400 min)	Composite	27%	23%	27%	31%	37%	29%	37%	44%
Scaled modeled 2-week (4,800 min)	Favorable	2%	2%	2%	2%	2%	2%	2%	2%
Scaled modeled 2-week (4,800 min)	Routine	5%	4%	5%	6%	5%	5%	5%	6%
Scaled modeled 2-week (4,800 min)	Severe	34%	31%	34%	37%	52%	45%	52%	59%
Scaled modeled 2-week (4,800 min)	Composite	15%	13%	15%	18%	18%	15%	18%	22%

Note: **R** = elapsed-time reduction from reducing handoff-added duration. **G** = equivalent production-rate gain, or the implied increase in installed work per unit of crew-level elapsed production time. These metrics are related but not numerically identical because they use different denominators.

Terms, Abbreviations and Definitions

The following explains the statistical, modeling, and methodological concepts referenced throughout this report, along with the abbreviations used.

ESTIMATING THE DURATION OF A SINGLE HANDOFF

Three-Point Estimate: Instead of guessing a single number for how long something takes, a three-point estimate uses three numbers: an optimistic value (if things go well), a most likely value (the typical case), and a pessimistic value (if things go badly). This captures the reality that a handoff between trades might take 5 minutes on a good day but much longer if a crew has to wait or re-stage tools. Using a range instead of one fixed number is standard practice in schedule risk analysis, and the report follows the approach recommended in the U.S. Government Accountability Office (GAO) Schedule Assessment Guide.

Expected Value: In the equations, the notation $E[h]$ means "the expected value of h." The expected value is the long-run average you would get if you repeated a random process many times, with each possible result weighted by how likely it is. In the PERT formula, it is the single representative duration the model settles on for a handoff after accounting for the optimistic, most likely, and pessimistic possibilities. The square brackets are just standard notation for "the expected value of whatever is inside."

PERT (Program Evaluation and Review Technique): PERT is a method for turning a three-point estimate into a single "expected" duration, while giving the most likely value the most weight. The formula is $(\text{Optimistic} + 4 \times \text{Most Likely} + \text{Pessimistic}) \div 6$. The most likely value is multiplied by four because it should count more heavily than the two extremes, which are less common. For example, a favorable handoff with values of 5, 8, and 13 minutes produces an expected duration of about 8.3 minutes. PERT was originally developed for large scheduling projects and is widely used wherever task durations are uncertain.

Beta-PERT Distribution: A distribution describes how likely each possible value is across a range. The Beta-PERT distribution takes the same three points (optimistic, most likely, pessimistic) and forms a smooth, bell-like curve that peaks at the most likely value and tapers off toward the two extremes. This means that when the model picks a handoff duration, values near the most likely one come up often, while values near the optimistic or pessimistic ends come up rarely, mirroring how delays actually behave in the field. It is the probability curve that the simulation draws from for each handoff.

THE MONTE CARLO SIMULATION

Monte Carlo Simulation: A Monte Carlo simulation runs the same scenario thousands of times, each time drawing slightly different values from the distributions described above, to see the full range of outcomes rather than just one. Rather than calculate a single answer, the computer "rolls the dice" for each of the 10 handoffs on every run, adds up the results, and records the total. Doing this 10,000 times per scenario produces a realistic spread of possible outcomes that accounts for uncertainty. The report ran 12 scenarios at 10,000 runs each, for 120,000 simulation runs in total. The name comes from the Monte Carlo casino, a nod to the role of chance.

Simulation Run: A single pass through the model, in which the computer draws one value for each handoff, totals them, and records the result. One run is one possible version of how the work sequence could play out. The patterns only become meaningful across many runs.

KEY ASSUMPTIONS BUILT INTO THE MODEL

Additive Assumption: The model assumes handoff-added time simply adds on top of the productive-work time rather than overlapping with it or being absorbed. Each delay extends the total by its full amount. This keeps the model straightforward and is reasonable for tightly sequenced work where one crew genuinely waits for another, but it is part of why the results apply best to high-handoff, closely coupled sequences.

Independent Events (Independence Assumption): Two events are independent when the outcome of one has no effect on the outcome of the other. The model treats each of the 10 handoffs as independent: a long delay at one handoff makes a long delay at the next neither more nor less likely. This is a simplifying assumption. The report is explicit that it did not link the duration of one handoff to another, and it flags this as a limitation, because in real projects delays can sometimes cascade.

Correlation (and Correlated Delays): Correlation describes the degree to which two things tend to move together. Positively correlated delays would mean that when one handoff runs long, others tend to as well (for example, one disruptive crew or a bad weather day affecting everything). The model assumes no correlation between handoffs, treating each as independent. The report lists "correlated handoff delays" as something future models should incorporate, since real delays are not always independent.

READING AND SUMMARIZING THE RESULTS

Percentiles (P10, P50, P90): A percentile tells you what share of the simulated outcomes fell at or below a given value. P90 means 90% of the runs came in at or below that number, so only 10% were higher. P10 is the low end (only 10% were lower) and P50 is the middle. Reporting P10, P50, and P90 shows not just a single answer but how wide the range of outcomes was, which signals how much uncertainty surrounds each scenario.

Median (P50): The median is the middle value when all results are lined up from smallest to largest: half are above it and half below. It is the same thing as the P50 percentile. The median is useful because it is not distorted by a few unusually large values.

Unweighted Mean (Average): The mean is the ordinary average: add up all the values and divide by how many there are. "Unweighted" means each scenario counts equally, regardless of how likely it is. The report notes that the mean and median can differ substantially. In the severe-disruption scenarios, a handful of very large delay values pull the average upward, so the mean is higher than the median. This is why the report leans on the median as the more representative central figure and flags the average as something that should not be read as a typical expected result.

Skewed Results: Data is "skewed" when it is lopsided rather than symmetric, with a long tail stretching toward one end. Here, most scenarios produce moderate gains, but a few severe ones produce very large gains, creating a long tail on the high side. Skew is the reason the average sits well above the median, and why the median is the safer summary number.

CONVERSIONS AND RELATIONSHIPS BETWEEN THE NUMBERS

Productivity-Loss Conversion: Equation 1 converts a productivity-loss percentage from prior research into an equivalent amount of added time, using $W = [L (1 - L)] \times B$. The $L (1 - L)$ form is needed because a productivity loss is expressed as a share of total time, not as a simple add-on. For example, a 20% productivity loss does not mean 20% more time; it means the lost time equals one-quarter (0.20 0.80) of the productive time. This let the study translate findings reported in other research into handoff durations it could plug into its own model.

Reciprocal Relationship Between Time Saved and Output Gained: A reduction in elapsed time and an increase in production rate are related but not equal, which is why a 27% time reduction corresponds to roughly 37% more work, and a 33% reduction to roughly 50%. The reason is that the two figures are measured against different baselines. Cutting the time to finish a task by a given percentage always produces a larger percentage increase in how much you can complete in a fixed period, because rate is the inverse of time. As an everyday illustration: if a drive that took 60 minutes now takes 45, that is a 25% time saving, but you are now covering 33% more ground per hour.

HOW THE EFFECT CHANGES WITH HANDOFF DENSITY

Handoff Density: The number of handoffs relative to the length of the work period. Many handoffs packed into a short sequence is high density; the same handoffs spread across a long sequence is low density. This concept explains why the modeled benefit is largest on the short 221-minute sequence and smaller on the one-week and two-week durations.

Sensitivity Analysis: Testing how much the results change when one input is varied while everything else is held constant. The report does this by spreading the same 10 handoffs across three different productive-work durations (half-day, one week, two weeks). Because the number of handoffs stays fixed while the baseline duration grows, this isolates the effect of handoff density and shows how the percentage impact shrinks as the work period lengthens.

STUDY DESIGN AND SCOPE OF THE FINDINGS

Controlled Trial (Controlled Conditions): A controlled trial is an experiment run under deliberately managed conditions so the effect of one factor can be observed without interference from others. Here, the same work sequence was performed twice, changing only how the labor was organized (a multitasked crew versus separate single-trade crews) while keeping the task, work area, and other conditions as consistent as possible. The goal is a fair comparison in which any difference in workflow can be attributed to the crew arrangement rather than outside factors. The report also notes the trials ran under favorable conditions, which is why the observed handoff times were treated as a low reference point.

Generalizability: The extent to which findings from one specific study apply to other settings, projects, or conditions. The report repeatedly cautions that its results have limited generalizability: they come from one work assembly with a small number of participants, so they should be treated as illustrative of high-handoff sequences rather than proven for all projects. This is why it recommends replication across other scopes and site conditions.

Extrapolation: Extending findings beyond the range actually studied. The report warns against extrapolating its crew-level results to whole-project outcomes such as total cost, schedule, or profit, because project-level performance depends on many factors the model does not include. The findings describe a specific work sequence, not an entire project.

Conditional Estimate: An estimate that holds true only under stated assumptions. The report calls its results "conditional crew-level estimates," meaning they apply given the specific conditions modeled (a defined high-handoff sequence, a fixed number of handoffs, the stated handoff profiles, and so on). Change those conditions and the numbers would change. It signals that the results are valid within a defined boundary, not universal truths.

ABBREVIATIONS AND ACRONYMS

GAO = U.S. Government Accountability Office

NCCER = National Center for Construction Education and Research

PERT = Program Evaluation and Review Technique (defined above under “Estimating the Duration of a Single Handoff”)



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