Schedule Duration and Labor-Curve Outcomes

Report 3 in Volume 1 of the *Multiskilling in the U.S. Construction Industry* research series



SIMPLAR FOUNDATION

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AUTHORS

Brian Lines, Ph.D., P.E. — Principal Investigator
Associate Professor
Civil, Environmental & Architectural Engineering Department
University of Kansas
brianlines@ku.edu

Ibilola Ogundare
Ph.D. Student
Civil, Environmental & Architectural Engineering Department
University of Kansas
Ibilola_Ogundare@ku.edu

Rebecca Kassa, Ph.D.
Senior Researcher
Simplar Foundation
Rebecca.Kassa@simplarfoundation.org

Jake Smithwick, Ph.D., M.P.A.
Associate Professor
Albert School of Construction
University of North Carolina at Charlotte
Jake.Smithwick@charlotte.edu

Kenneth Sullivan, Ph.D., M.B.A.
Professor
Del E. Webb School of Construction
Arizona State University
Kenneth.Sullivan@asu.edu

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Schedule Duration and Labor-Curve Outcomes

Report 3 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 Center (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	
03	**Schedule Duration and Labor-Curve Outcomes**	THIS REPORT
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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STUDY AT A GLANCE

Schedule Duration and Labor-Curve Outcomes

Report 3 of 6 in Volume 1 of the *Multiskilling in the U.S. Construction Industry* research series

1 THE PROJECT RECORDS

Contractors provided day-by-day labor records from recent projects built with a multiskilled labor strategy.

18 project records from **11 contractors**

14 project types in **9 states and DC**

183 workers

10,194 worker days

89,620 labor hours

8 of 18 prevailing wage projects

2 THE EXTENT OF MULTISKILLING OBSERVED

Workers recorded hours outside their primary trade on every project.

17.3%
of labor hours were multiskilling hours
(5% to 50% by record)

18 of 18
records had multiskilling hours

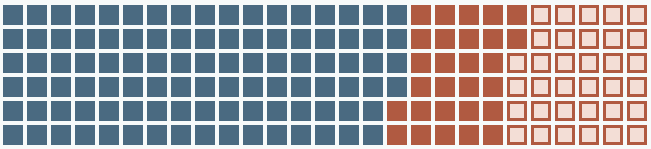
80
trade combinations
across 18 trades

3 IF EACH WORKER WERE LIMITED TO ONE TRADE

Estimated effects from schedule and labor-curve analysis:

SCHEDULE

Workdays to finish the same work



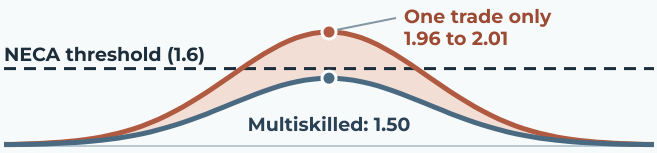
Multiskilled: 100 workdays One trade only: 28 to 62 more

28% to 62%
more workdays to finish the same work (central schedule assumption)

73%
of workdays with a trade gap

LABOR CURVE

Peak-to-average ratio



Multiskilled, as recorded One trade only, estimated

9 to 12
added workers per 100 workers on an average day

31 to 34
added workers per 100 workers on the peak-demand day

4 PRACTICAL TAKEAWAYS

Plan by trade and workday
Compare the hours each trade needs with the qualified workers available each day, not total headcount alone.

Plan for peak-demand days
Added staffing needs on the peak-demand day were about three times the average-day need.

Build targeted skills
Add skills that cover the trade gaps that keep recurring.

Use where qualified
Broader assignments must keep specialization, verified qualifications, safety, and quality in place.

Modeled, not measured
The results are estimates built from labor records, not measured delays or productivity gains.

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Executive Summary

The 18 construction projects in this report were built by contractors using a multiskilled labor strategy, in which qualified workers moved between trades as the work progressed. This report uses their labor records to estimate what would have happened if each worker had been limited to one trade: how much longer the same work would have taken with the same crew, or how many workers would have had to be added to keep the same schedule.

The records came from 11 contractors and covered 14 project types, including bridges, hospitals, manufacturing facilities, and a wastewater treatment plant. The analysis focused on each project's core crew, the workers who did most of the work: 183 workers who recorded 10,194 core-worker days and about 89,620 hours. Every project used multiskilling, and multiskilling hours made up about 17% of the core crews' hours. Each result below is a range. The low end assigns each worker to their theoretically optimal trade, chosen with hindsight to keep the overall impact smallest. The high end keeps each worker in their primary trade, the trade they worked most.

Limiting workers to one trade would have required 28% to 62% more workdays to finish the same work. This is under the central schedule assumption, the middle of three assumptions about how strictly the work must stay in sequence. Put the other way, the multiskilled crews finished in about 22% to 38% fewer workdays than the same crews limited to one trade would need. Every project showed an increase. Keeping the recorded schedule instead would have required about 9 to 12 added workers for every 100 core workers on an average day. That rose to 17 to 22 on a high-demand day (a level exceeded on one workday in ten) and 31 to 34 on each project's peak-demand day. Peak staffing would have reached about twice the average, a level prior research associates with productivity losses of about 15% to 20%. At least one trade would have had a trade gap, more work than its workers could cover, on about 73% of recorded workdays: nearly three days in four. The findings held even when only half of the multiskilling hours were treated as necessary.

DATA AT A GLANCE

18
project records from 11 contractors

14
project types in 9 states and DC

183
workers

10,194
worker days

89,620
labor hours

8 of 18
prevailing wage projects

THE FINDINGS IN BRIEF

28% to 62%
more workdays to finish the same work

9 to 12
added workers per 100 core workers on an average day (31 to 34 on the peak-demand day)

About 73%
of workdays with a trade gap

1.50 to about 2.0
peak-to-average ratio, as recorded and with each worker limited to one trade

For contractors, the practical lesson is to plan by trade and by workday and to plan for peak staffing, not just the average. Added skills should target the trade gaps that keep recurring. Owners can ask how a proposed workforce will cover each trade's needs as the work progresses, and workforce-development organizations can tie training to the work projects actually need. Broader assignments must keep specialization, verified qualifications, safety, and quality in place. The findings are modeled estimates from labor records, not measured delays or productivity gains.

Across these 18 projects, qualified workers who could move between trades let the crews finish the same work in fewer workdays, or with fewer workers, than the same crews would have needed if limited to one trade.





SECTION 1

Introduction

1.1 Problem Statement

Construction projects need different trades at different stages of the work. As the work progresses from one scope to the next, contractors must keep matching the workers they have to the trades the work requires. A project can have enough workers overall and still be short in one trade on a given day. That can leave one trade with spare hours while another has more work than its workers can handle.

Figure 1.1 illustrates this common labor challenge, which is the focus of this report. If each worker can work in only one trade, those spare hours cannot move to the trade that is short, even when the workers are qualified to do that work. The contractor then has two practical choices: keep the crew and take longer, or keep the schedule and add workers.

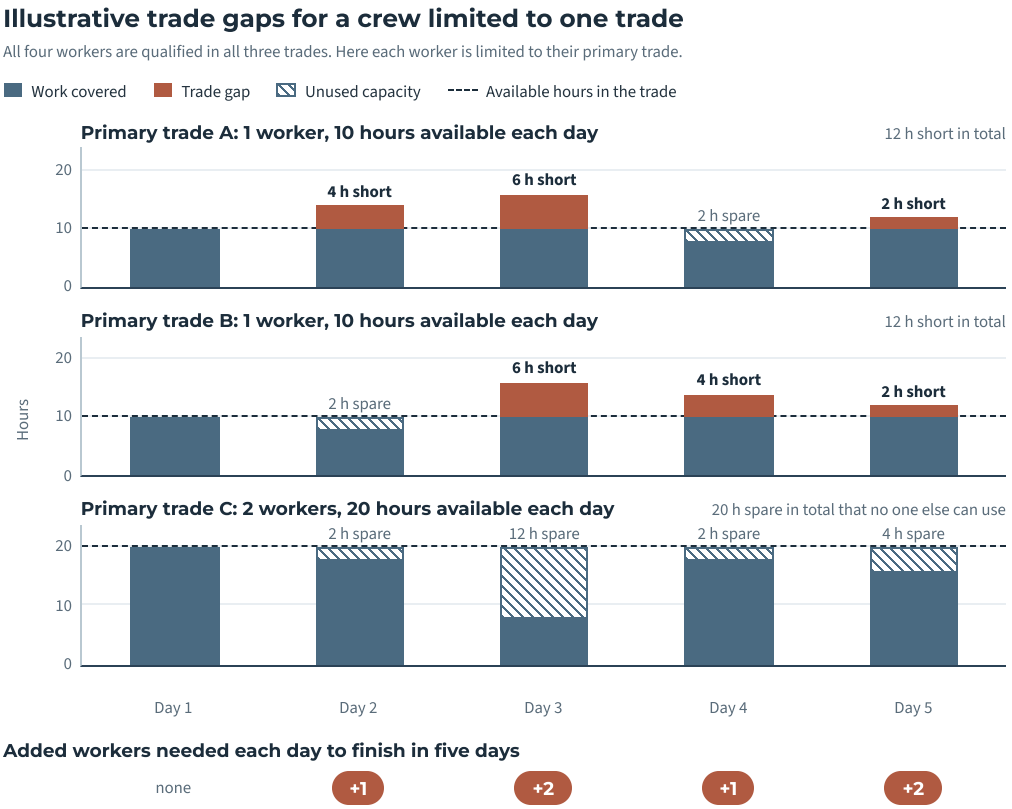


Figure 1.1. Illustrative trade gaps for a crew limited to one trade. All four workers are qualified to work safely and competently in Trades A, B, and C, and each has one primary trade (the trade they work most): one worker in Trade A, one in Trade B, and two in Trade C. Each day the crew has 40 hours of work and 40 hours available. Limited to their primary trades, the crew is 24 hours short over five days (12 in Trade A and 12 in Trade B), while Trade C has 20 spare hours it cannot share. Keeping the same crew, the work takes about 7 workdays instead of 5; keeping the five-day schedule, the crew needs one or two added workers on four of the five days. Values are illustrative, not study results.

Multiskilling is one way to close that gap. It means selected workers are qualified to work in more than one trade. Workers keep their primary trade and add related skills they can use when the work calls for them, and that work must still meet the usual safety, quality, supervision, licensing, and employment requirements. Earlier studies, mostly computer models, suggest multiskilling can shorten schedules and smooth the labor curve, the number of workers a project needs day to day (Section 2). None of those studies used data from U.S. construction projects (Report 5 in this series). This report asks: on projects that used multiskilling, how would schedule and staffing have changed if each worker had been limited to one trade?

1.2 Purpose and Objectives

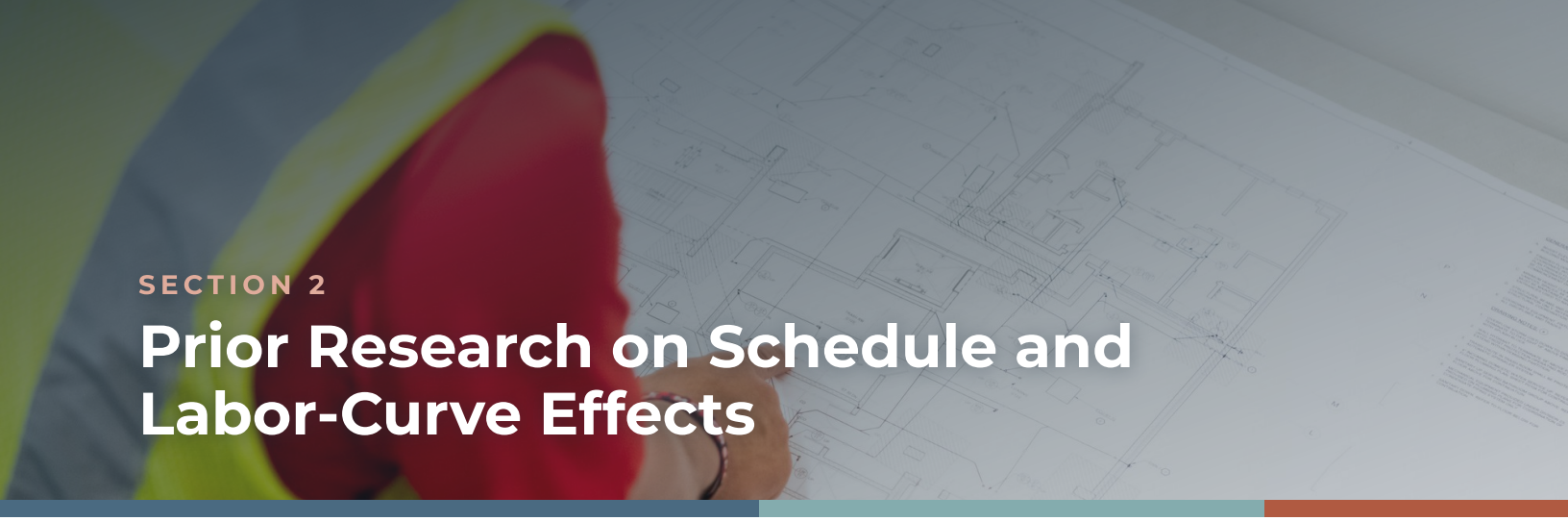
The 18 projects in this report were built by contractors using a multiskilled labor strategy. This report uses their labor records, which show the hours each worker recorded in each trade on each workday, to estimate what would have happened to schedule and staffing if each worker had been limited to a single trade. The analysis looked at two scenarios:

Schedule analysis (same crew): keep the same crew and the same hours, but limit each worker to a single trade. What happens to the schedule?

Staffing analysis (same schedule): keep the same work on the same workdays, but limit each worker to a single trade. Would workers need to be added to finish each day's work, and how many?

Section 4 explains how each worker's single trade was assigned, and Appendix B defines key terms. The report has three objectives:

1. **Describe the recorded multiskilling:** review projects delivered with a multiskilled labor strategy and describe the share of hours workers spent outside their primary trade (multiskilling hours) and the trade combinations they used (Section 3).
2. **Estimate the effect on schedule:** how many more workdays the same work would take with the same crew (Section 5.1).
3. **Estimate the effect on staffing and the labor curve:** how many workers would have to be added on an average day, a high-demand day, and a peak-demand day, and how much higher peak staffing would be (Section 5.2).



SECTION 2

Prior Research on Schedule and Labor-Curve Effects

Earlier research points to two ways multiskilling can help a project: shorter schedules and a smoother labor curve. This section explains how each works and, briefly, how large the effects were in earlier studies (Figures 2.1 and 2.2).

2.1 Multiskilling and Schedule Performance

Multiskilling does not mean training every worker in every trade. It usually means adding selected skills in adjacent trades and related work, so a crew can cover closely connected tasks as the work progresses. Earlier modeling found that this kind of partial multiskilling captured most of the benefit. The benefit leveled off once workers could cover two or three trades (Gomar et al., 2002). In off-site production, training workers to cover just the next workstation captured much of the benefit of broader skills (Nasirian et al., 2019a).

Earlier studies describe three ways multiskilling can shorten a schedule (Figure 2.1):

Spare hours follow the work: When one trade has more work than its workers can cover that day, qualified workers from other trades can step in to keep the work moving (Hegazy et al., 2000; Lill, 2009; Wongwai & Malaikrisanachalee, 2011).

Bottlenecks clear faster: A sequence of work moves only as fast as the trade with the most work left to complete. Moving multiskilled workers to that trade speeds up the whole sequence (Nasirian et al., 2019a, 2022).

Fewer handoffs and less waiting time: When one crew can carry work across trade lines, the next step does not wait for another trade to arrive, and less idle capacity is needed between trades (de Miranda Filho et al., 2007).

Most of these results come from scheduling and optimization models, not measured field results. Across the 16 prior studies that reported schedule effects, reductions ranged from about 2% to 58%, and most fell between about 15% and 40%. Examples include about 20% for a simulated construction firm (Lill, 2009), 27% for a residential building when crew makeup (the mix of trades on the crew) was also optimized (Ahmadian Fard Fini et al., 2016), and 30% to 33% for an off-site factory (Nasirian et al., 2022).

How multiskilling can shorten schedules, as described in earlier research, with the range of effects that modeling studies estimated



Figure 2.1. How multiskilling can shorten schedules, as described in earlier research, with the range of effects that modeling studies estimated.

2.2 Multiskilling and the Labor Curve

A labor curve shows how many workers a project needs over time. The average sets the overall size of the workforce. The peaks set how many workers must be hired, oriented, supervised, and fit on site during the busiest stretches, often for a short time.

Earlier studies describe three ways multiskilling can change the labor curve (Figure 2.2):

Fewer workers on average: A one-trade workforce must cover each trade's work separately. Multiskilled workers can cover the combined work. In a model industrial plant, multiskilling cut the required workforce by 18% to 35% (Burleson et al., 1998). Combining two trades into one crew roughly halved the crew size needed on a repetitive housing project (Pandey & Maheswari, 2015). On a pipeline project, multitasking crews cut the number of crews needed from 14 to 9 (Gouda et al., 2017).

Lower peaks and smaller swings: Each trade's workload rises and falls at different times. A one-trade workforce has to hire and release workers in each trade as that happens, which creates sharper peaks and more turnover. Multiskilled workers can shift between trades instead. In one modeled construction program, a one-trade workforce had swings in staffing up to about one-third larger, and more layoffs, than a multiskilled one (Florez et al., 2013). Firms with multiskilled teams moved workers between tasks to absorb swings in demand instead of keeping extra workers on hand (de Miranda Filho et al., 2007).

Smaller shortfalls when demand spikes: When work bunches up in a few trades, a one-trade workforce comes up short in exactly those trades. In a simulation of a disrupted labor supply, making 20% of the workforce multiskilled cut the worker shortfall for critical work roughly in half (Araya, 2022).

A smoother labor curve can also help workers. Models found that workers stayed employed longer on a project when they could follow the work across trades (Burleson et al., 1998; Pandey & Maheswari, 2015).

Most of this evidence came from models, simulations, and factories rather than labor records from active construction projects. This report looks at both outcomes, schedule length and the labor curve, using day-by-day labor records from active U.S. projects.

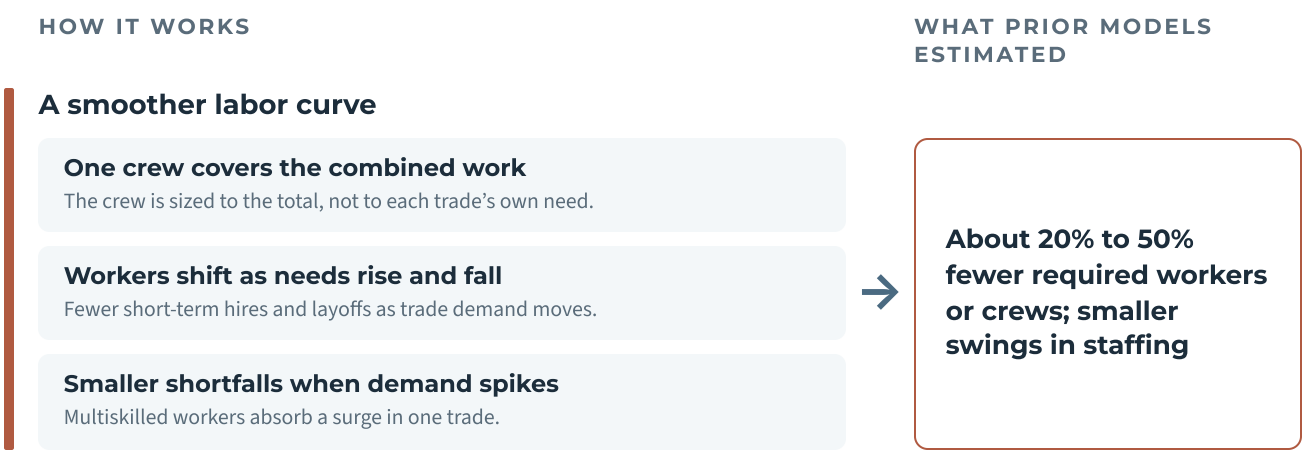


Figure 2.2. How multiskilling can smooth the labor curve, as described in earlier research, with the range of effects that modeling studies estimated.



SECTION 3

Data Collection and Dataset Characteristics

This report uses 18 project records from 11 contractors, covering 14 project types in nine states and Washington, DC. A project record is the labor record for one project, or for one subcontractor's scope within a project, over the period the contractor supplied.

3.1 Data Collection and Record Structure

Participating contractors provided labor records for recent projects. For each worker, the records showed a worker ID, the work dates, and the hours worked by trade and activity. That let the analysis follow the work day by day and see when workers worked outside their primary trade. Eight records came from prevailing wage projects, which require certified payrolls.

Before analysis, entries that were not craft work on site were removed, such as supervisory and salaried staff time, leave, travel, and payroll adjustments. The hours that remain are the record's craft hours, and a workday is a day with recorded craft hours.

The research team looked for projects where multiskilling was used, so the 18 records are detailed cases from varied settings, not a random sample of U.S. construction.

Researchers personally visited 14 of the 18 projects during construction to add firsthand context and observations of the projects in the dataset.

3.2 Dataset Overview and Project Scope

The analysis focused on each record's core crew: the smallest group of workers who together recorded at least 80% of the record's craft hours (Section 4.2). This kept the focus on the workers who did most of the work, not those who helped briefly. Across the 18 records, the core crews had 183 workers, who recorded 10,194 core-worker days (one core worker on one

workday) and about 89,620 core hours, 81% of all craft hours in the records. Figure 3.1 summarizes the dataset.

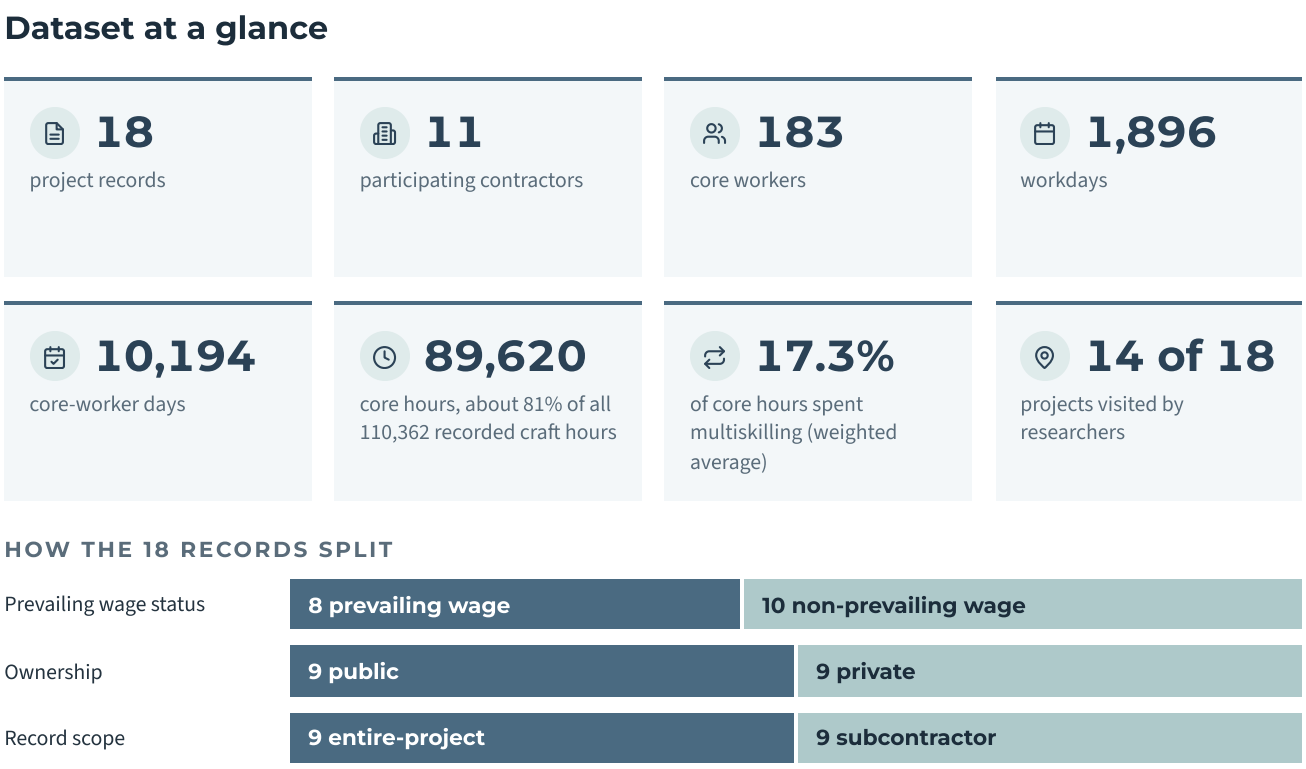


Figure 3.1. Dataset at a glance.

Records varied in size, from 48 to 2,169 core-worker days, and the five largest made up about 62% of the total. Results were weighted by core-worker days, so larger records counted more (Section 4.5).

Nine are entire-project records, in which the contractor performed the whole project with its own workforce. Nine are subcontractor records, covering one subcontractor's scope within a larger project. An entire-project record covers the full scope of work, but not always the full project schedule. In both cases, the analysis covered only the work and period in the record.

3.3 Project Types and Locations

The records spanned 14 project types: seven infrastructure and utility projects, three hospitals, three manufacturing facilities, and five other buildings (Table 3.1). They came from nine states and Washington, DC, with five records in Washington State (Figure 3.2).

Table 3.1. Project types

Group	Project types (records)
Infrastructure and utilities (7)	Bridge, heavy civil, road, wastewater treatment plant, fuel site, EV charging station, substation (1 each)
Hospitals (3)	Hospital (3)
Manufacturing (3)	Manufacturing facility (3)
Other buildings (5)	Amusement park, library, military facility, multifamily residential, sports facility (1 each)

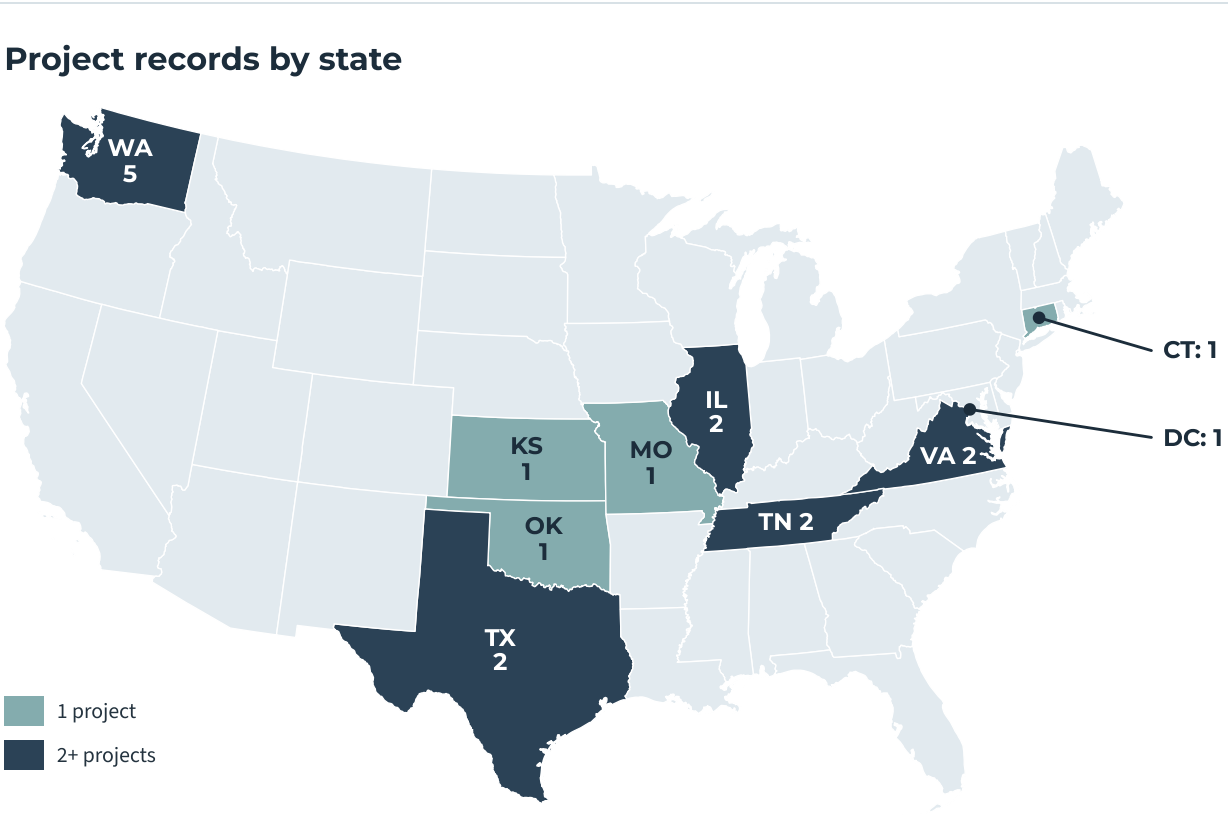


Figure 3.2. Project records by state. Individual jobsites are not shown.

3.4 Recorded Multiskilling Hours

Multiskilling hours are the hours a core worker recorded outside their primary trade. A worker's primary trade is the trade in which they recorded the most hours. Where the company also listed a primary trade for the worker, the two usually matched. Because each worker's primary trade is their most-worked trade, this definition gives the lowest share of multiskilling the records can support, a conservative choice.

Every one of the 18 records had multiskilling hours, from about 5% to 50% of core hours, with a weighted average of 17.3% (Figure 3.3). Counting each record equally gives 24.5%; the weighted figure is lower because the largest records had less multiskilling.

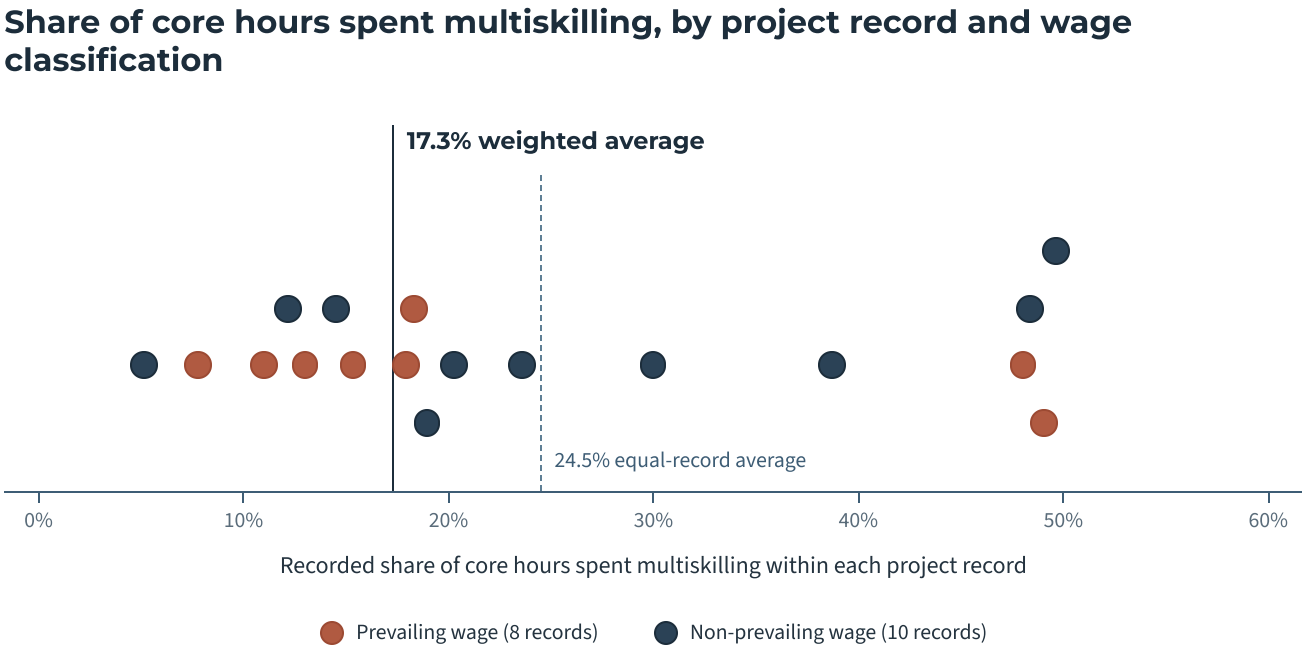


Figure 3.3. Share of core hours spent multiskilling, by project record and wage classification. Each dot represents one project record; vertical offsets separate nearby values. The solid line marks the weighted average (17.3%) and the dashed line the equal-record average (24.5%).

Every prevailing wage record had multiskilling hours (8% to 49% of core hours). Weighted, prevailing wage records averaged 14.4% and non-prevailing wage records 20.2% (Table 3.2). All eight prevailing wage records were public projects and seven were entire-project records, so this comparison describes these records, not an effect of prevailing wage rules.

Table 3.2. Share of core hours spent multiskilling, by wage classification

Records	Count	Weighted average	Range across records
Prevailing wage	8	14.4%	8% to 49%
Non-prevailing wage	10	20.2%	5% to 50%
All records	**18**	**17.3%**	**5% to 50%**

3.5 Recorded Trade Combinations

Multiskilled workers each recorded hours in 2 to 7 trades over the period of their record. The set of trades one worker recorded hours in, not necessarily on the same day, is that worker's trade combination. The records showed 80 different trade combinations across 18 trades: carpenter, concrete finisher, crane operator, drywall hanger, electrician, glazier, HVAC technician, insulator, ironworker, laborer, operator, painter, pile driver, pipefitter, plumber, roofer/waterproofer, scaffold builder, and sheet metal worker. The 80 combinations averaged 3.2 trades each. Table 3.3 shows selected examples. Of the 183 core workers, 139 recorded hours in more than one trade, and Figure 3.4 shows how many of them recorded each pair of trades.

Table 3.3. Examples of recorded trade combinations

Primary trade	Additional recorded trades	Total trades
HVAC technician	Plumber	2
Crane operator	Laborer	2
Carpenter	Ironworker, laborer	3
Insulator	Scaffold builder, electrician	3
Ironworker	Carpenter, laborer	3
Pile driver	Carpenter, ironworker	3
Drywall hanger	Painter, laborer, carpenter	4
Laborer	Operator, ironworker, carpenter, concrete finisher	5
Operator	Laborer, pipefitter, concrete finisher, carpenter, ironworker	6
Carpenter	Laborer, ironworker, sheet metal worker, concrete finisher, plumber, insulator	7

Trades recorded together by the same worker

Number of core workers (of 183) who recorded hours in both trades over the period of their record.

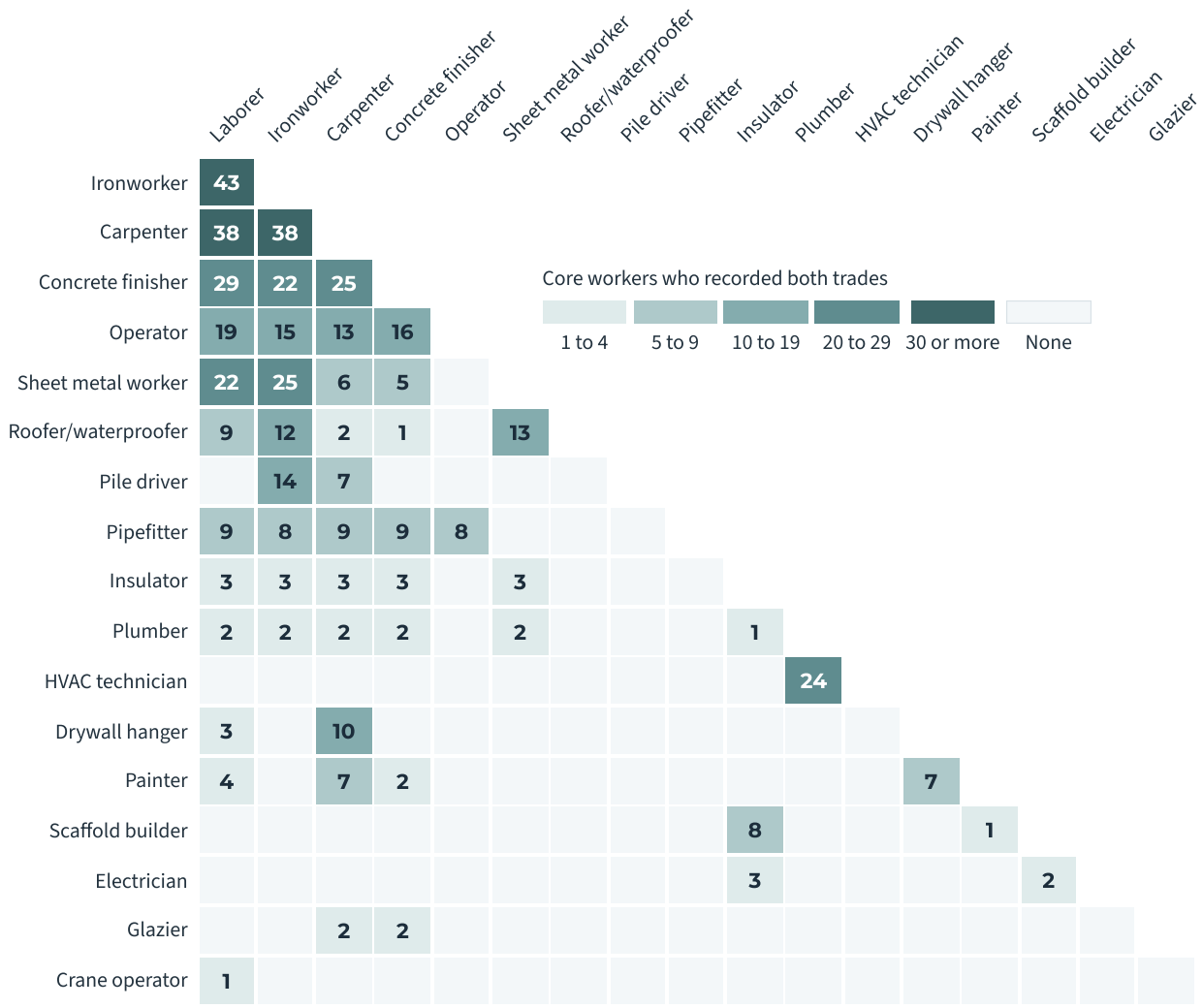


Figure 3.4. Trades recorded together by the same worker. Each cell shows how many of the 183 core workers recorded hours in both trades over the period of their record; darker cells mean more workers. Blank cells are pairs no core worker recorded.



SECTION 4

Research Methodology

This section explains how the 18 project records were used. Section 4.1 gives the big picture; Sections 4.2 to 4.5 cover each step.

4.1 How the Analysis Was Set Up

On these projects, qualified workers moved between trades as the work required. The analysis compared the work as recorded with the same work done by the same core workers, each limited to one trade. The work, the workers, and the hours worked all stayed as recorded; only the trade restriction changed.

Limited to one trade, some trades would come up short on some days. The analysis looked at two scenarios (Figure 4.1):

Schedule analysis (same crew): keep the crew and see what happens to the schedule. The same core workers, with the same hours, finish the recorded work. When a trade cannot finish its work on a given day, the rest carries into later days. The result is the percentage of additional workdays (Section 5.1).

Staffing analysis (same schedule): keep the schedule and see whether workers must be added. The same work has to be done on the same days it was recorded. When a trade cannot finish its work on a given day, workers are added to that trade. The result is the number of added workers on an average day, a high-demand day, and a peak-demand day, and the effect on peak staffing (Section 5.2).

Both analyses were run for the observed and theoretically optimal workforces (Section 4.2), both built from the same crew. Results for the 18 records were then combined, with larger records counting more. Each result is therefore a range: the theoretically optimal workforce gives the low end and the observed workforce the high end.

4.2 Preparing the Records and the One-Trade Workforces

Preparing the Project Records

Each record was checked for worker identifiers, work dates, repeated entries, hours, and trade classifications. Trade and pay classifications were grouped into the 18 trades listed in Section 3.5, and totals were checked after the exclusions described in Section 3. Each analysis covered only the work and period in that record. The hours each core worker recorded in each trade on each workday were the work to be covered.

Steps in the analysis

Both analyses impose the same single change, limiting each worker to one trade, and then let one thing give: the schedule analysis lets the work take longer; the staffing analysis adds workers.

1 Prepare the project records

18 project records from 11 contractors. Non-craft entries removed; trades grouped into 18 trades.

2 Select the core crew and primary trades

Core crew: the workers who together recorded at least 80% of hours (183 workers, 10,194 core-worker days). Primary trade: the trade each worker recorded the most hours in.

3 Make sure every trade has someone assigned

Where a trade had no assigned worker, a core worker's role was reassigned or a trade-coverage role was added (19 roles in 6 records). Base core workforce: 202 (183 core workers plus 19 trade-coverage roles).

4 Impose one change: limit each worker to one trade, two ways

Observed workforce
Each worker keeps the trade they worked most.

Theoretically optimal workforce
Workers reassigned to their best single trades.

both versions go through both analyses

5 Schedule analysis (Section 5.1)

Holds fixed	the same core workers and their recorded hours
If a trade is short	its unfinished work carries into later days
Result	percent more workdays under lower bound, central, and upper bound schedule assumptions

6 Staffing and labor curve (Section 5.2)

Holds fixed	the recorded workdays: the same work on the same days
If a trade is short	workers are added to that trade to finish the day's work
Result	added workers on average, high-demand, and peak-demand days; the peak-to-average ratio

7 Combine the 18 records

Weighted by core-worker days. Each result is a range: theoretically optimal (low) to observed (high).

Figure 4.1. Steps in the analysis. Both analyses limited each worker to one trade. The schedule analysis kept the crew and measured the effect on the schedule; the staffing analysis kept the schedule and measured how many workers would have to be added.

Core Crew and Primary Trades

The analysis focused on each record's core crew (Section 3.2). Workers were ranked by their total hours and added, in order, until the group covered at least 80% of the record's craft hours.

Each core worker's primary trade is the trade they recorded the most hours in (Section 3.4).

Making Sure Every Trade Had Someone Assigned

To limit each worker to one trade, every trade with recorded work needs at least one worker assigned to it. That was not always the case: a worker may have done some work in a trade that was no one's primary trade. Table 4.1 shows how this was handled.

Table 4.1. Making sure every trade had someone assigned

Situation	What was done	Records
Every trade with recorded work already had someone assigned	Kept each worker in their primary trade	5
A trade had no one assigned, but the crew had enough workers to cover every trade	Moved one core worker's assignment to the trade with no one assigned	7
The crew had fewer workers than trades	Added the fewest trade-coverage roles needed (19 in all), moving assignments where also needed	6
Total		**18**

The base core workforce is the recorded core crew plus any trade-coverage roles: 183 recorded workers and 19 roles, or 202 in total across the 18 records. Trade-coverage roles are not real workers. They were added only so every trade had someone assigned, and they added no recorded hours or multiskilling; each role could cover up to 10 hours a day in its trade, the same as an added worker.

Both one-trade workforces started from the same base, and the roles were not counted again when workers were added. Including them in the base makes the staffing percentages smaller, not larger.

Work and Available Hours

On each workday, a worker could provide exactly the hours they recorded, with no daily limit, so the one-trade workforce had the same people working the same hours as the multiskilled crew; only the trade restriction changed. With each worker limited to one trade, those hours could be used only in the one trade that worker was assigned. Spare hours in one trade could not cover work in another.

Observed and Theoretically Optimal Workforces

Both analyses used the same two workforces for each crew, with each worker limited to one trade. They started from the same workers and the same hours; only the trade each worker was assigned to differed.

Observed workforce: the recorded crew, with each worker limited to their primary trade (the trade they worked most), except where a worker had to be moved so every trade had someone assigned (Table 4.1).

Theoretically optimal workforce: the same workers, each assigned to one trade so that, taken together, the assignments kept the one-trade impact as small as possible: the fewest workdays in the schedule analysis (found separately for each schedule assumption) and the fewest trade-gap hours in the staffing analysis (Section 4.4). This is each worker's theoretically optimal trade.

The theoretically optimal workforce is a best case built with hindsight. It was chosen after looking at all the work each project actually did, something no contractor knows when putting a crew together.

4.3 Schedule Analysis

The schedule analysis kept the same core workers, hours, and work for each project, but limited each multiskilled worker to one trade: their primary trade in the observed workforce, or their theoretically optimal trade in the theoretically optimal workforce (Section 4.2). It then measured how many more workdays the same crew would need, with any work a trade could not finish carrying into later days.

Three Schedule Assumptions

The schedule impact of limiting workers to one trade depends on how strictly the work must stay in order. The analysis used three schedule assumptions, labeled lower bound, central, and upper bound, as defined in Table 4.2. Figure 4.2 shows how the three assumptions work for a simple two-worker crew.

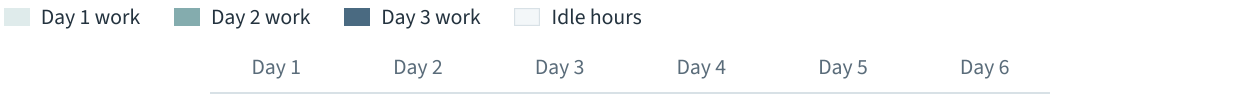
Table 4.2. Schedule assumptions

Schedule assumption	Technical model name	How work progresses
Lower bound	**Trade Parallel**	Each trade works at its own pace; no trade waits on another. Work a trade cannot finish carries forward within that trade.
Central	**Global Day Package, with Carryover**	Work moves through the recorded days in order. Each day's work must be finished in every trade before the next day's work starts; once it is, spare hours that same day can start the next day's work.
Upper bound	**Global Day Package, no Carryover**	Same order as central, but the next day's work cannot start until the following workday, even if some trades have spare hours.

The central assumption is used in the headline results because it is closest to how crews usually work: they finish the work in front of them before moving on, but they don't stand idle once it is done. The lower bound and upper bound assumptions bracket it.

Illustrative example of the three schedule assumptions

Illustrative example. Two workers, 10 hours each a day. Each day has 20 hours of work (Trade A: 16, 16 and 6 hours; Trade B: 4, 4 and 14) and 20 hours available. As recorded, the workers moved between trades and finished in 3 days. Limited to one trade each (Worker 1 in Trade A, Worker 2 in Trade B), the same work takes 4 to 6 days.



As recorded (crew can work across trades)

Either worker can take the work waiting in either trade.

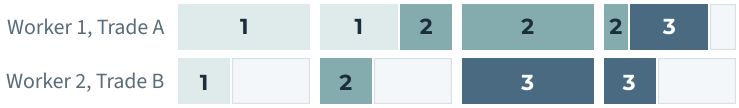


3 days
as recorded

Each day's work is finished that day: the workers split their hours between Trades A and B (letters show the trade).

Lower Bound

Each trade works at its own pace; no trade waits on another (Trade Parallel)

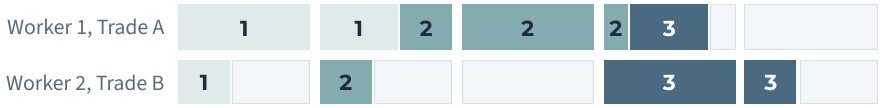


4 days
+1 day (+33%)

A trade that falls behind works off its own backlog; the other trade never waits for it.

Central (used in the headline results)

Days in order; spare capacity can start the next day's work (Global Day Package, with carryover)

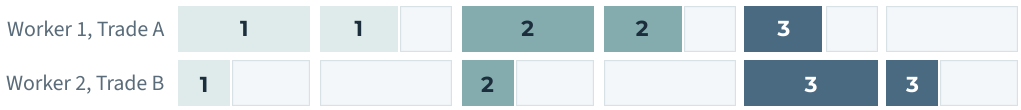


5 days
+2 days (+67%)

A day's work must be finished in both trades before the next day's can start; hours left over that day can start it.

Upper Bound

Days in order; no head start on the next day (Global Day Package, no carryover)



6 days
+3 days (+100%)

Same order, but hours left over after a day's work is finished go unused; the next day's work waits for a new day.

Figure 4.2. Illustrative example of the three schedule assumptions. Two workers finish three days of work in 3 days by working in each other's trade (top row). Limited to one trade each, the same work takes 4, 5, or 6 days, depending on the assumption.

Estimating Additional Workdays

Each one-trade workforce worked through the recorded work, day by day, under each assumption. Once the recorded days ran out, each trade kept working at its average daily pace, and no workers were added. The result for each record was the percentage of additional workdays, and the records were then combined (Section 4.5).

4.4 Staffing and Labor-Curve Analysis

The staffing analysis flipped the question. It kept the recorded schedule, the same work on the same days, and asked how many workers would have to be added, and in which trades, to get each day's work done with each worker limited to one trade. Tracking those additions day by day shows how the labor curve would change.

Trade Gaps and Added Workers

For each trade on each workday, the analysis compared the hours of work with the hours the workers assigned to that trade could provide. Any shortfall is a trade gap. Spare hours in another trade could not fill it, because every worker was limited to one trade.

Each gap was filled with whole added workers, each able to cover up to ten hours. A 6-hour gap took one added worker; a 14-hour gap took two. An added worker was also limited to one trade, so gaps in two different trades could not share one.

Figure 4.3 shows one day for an illustrative crew of four, each limited to one trade. Trades A and B are each 6 hours short, while Trade C has 12 hours to spare. Because Trade C's workers cannot move, the crew needs one added worker in Trade A and one in Trade B: two workers, even though the gaps total only 12 hours. Section 5 reports these whole-worker counts, and also notes the smaller result from counting gaps as fractions of a worker (12 hours is 1.2 ten-hour workers).

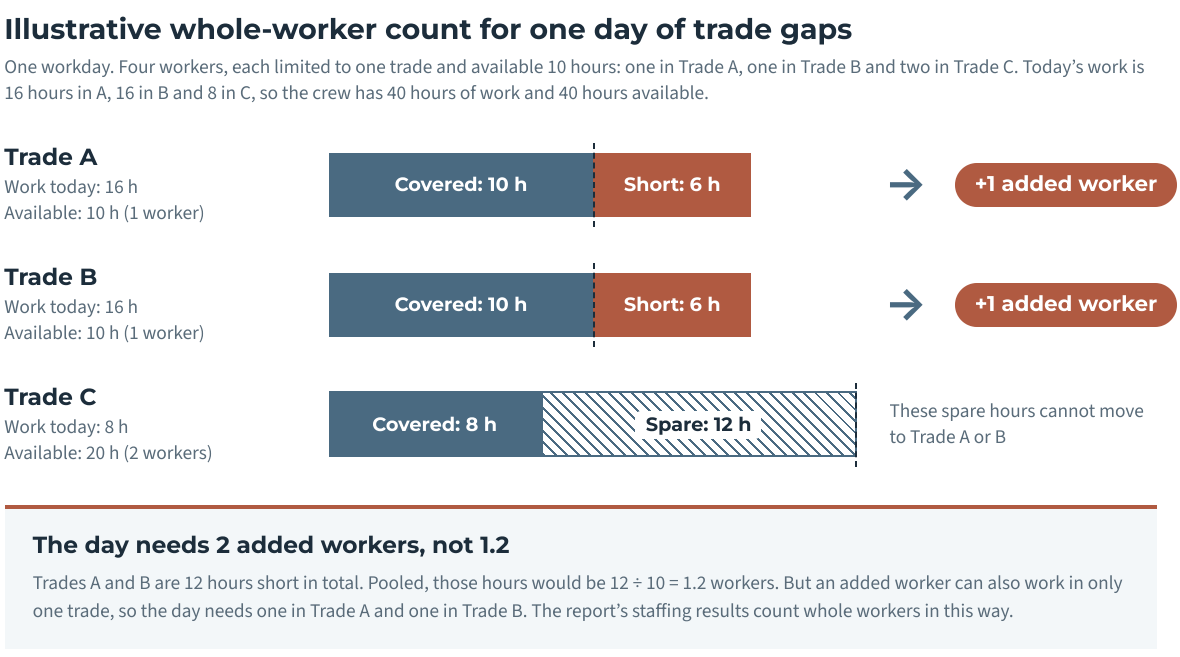


Figure 4.3. Illustrative whole-worker count for one day of trade gaps. On this day, Trades A and B each have a 6-hour trade gap while Trade C has 12 spare hours that cannot move. Because each added worker is also limited to one trade, the day needs two added workers, not 1.2.

Average, High-Demand, and Peak-Demand Days

For each record, added workers were summarized three ways, each as a percentage of the base core workforce:

Average day: the average number of added workers across all recorded workdays, including days that needed none.

High-demand day: the 90th percentile, a number of added workers exceeded on only one workday in ten.

Peak-demand day: the most added workers needed on any single workday.

The analysis also counted how many workdays had at least one trade gap, and the total trade-gap hours: the hours in all trade gaps before any workers were added. Added workers are the people needed on site on those days, not the number of new hires.

Peak-to-Average Ratio

The peak-to-average ratio compares the most core workers on site on any workday with the average number per workday (Equation 4.1). Each core worker counted once per day, however many trades they worked.

$$\text{Recorded peak to average ratio} = \frac{\text{Most core workers on any workday}}{\text{Average core workers per workday over recorded period}}$$

Equation 4.1. Recorded peak-to-average ratio

To show how a one-trade workforce would change this ratio, each record's recorded peak was raised by the percentage of added workers on its peak-demand day and divided by the same recorded average.

For example: a project that averaged 10 core workers a day and peaked at 15 has a ratio of 1.5. If a one-trade workforce would need 34% more workers on its peak-demand day, the peak rises to about 20.1 workers (15 × 1.34), and the ratio to about 2.0 (20.1 ÷ 10). This one-trade ratio was calculated for each record and then combined.

4.5 Combining and Checking the Results

Combining Records

Each result was calculated for each record, then combined as a weighted average in which each record counted in proportion to its core-worker days. A core-worker day is one core worker working on one day, so larger records counted more. Core-worker days measure how much core work each record contains, combining crew size and length. Weighting by them lets the combined results reflect where most of the work happened, rather than letting a short record with a small crew count as much as a long record with a large crew. Section 5.1 also reports the median record, which does not depend on weighting.

The total weight across the 18 records was 10,194 core-worker days. The same weights were used for both one-trade workforces and for every reported measure.

In all 18 records, the theoretically optimal workforce did at least as well as the observed workforce on the measure it was chosen for.

Supplemental Sensitivity Analysis

The main analysis uses the work exactly as recorded. A supplemental sensitivity analysis repeated both analyses with only part of the multiskilling hours treated as necessary on the day they were recorded (90%, 75%, two-thirds, and half). Appendix A gives the method and results.





SECTION 5

Results

This section compares the work recorded in the 18 project records with the same work assigned to a workforce in which each worker is limited to one trade. Each result is a range. The lower number reassigns workers to the trades that, taken together, keep the impact smallest (the theoretically optimal workforce). The higher number keeps each worker in the trade they worked most (the observed workforce).

5.1 Schedule Duration

Limiting workers to one trade would require an estimated 28% to 62% more workdays to complete the same recorded work.

For example, the same work that took 100 workdays as recorded would take an estimated 128 to 162 workdays if each worker were limited to one trade.

Put the other way, the multiskilled crews finished their work in about 22% to 38% fewer workdays than a one-trade workforce would need: work that would take a one-trade workforce 100 workdays took the multiskilled crews about 62 to 78.

Under the central assumption, every one of the 18 records showed an increase for both workforces, and the median project result (26% to 66%) was close to the weighted average. The increase held for both entire-project records (27% to 73%) and

subcontractor records (29% to 51%). Figure 5.1 shows how the result changed under two alternative schedule assumptions; across all six estimates (three schedule assumptions for each of the observed and theoretically optimal workforces), the increase ranged from 12% to 130%.

Estimated increase in workdays if each worker were limited to one trade, under three schedule assumptions

Schedule assumption Potential schedule impact of moving from a multiskilled to a one-trade workforce	Each worker limited to one trade	
	Theoretically optimal workforce (each worker assigned to their theoretically optimal trade)	**Observed workforce** (each worker kept in their primary trade)
Lower Bound Each trade works at its own pace; no trade waits on another (Trade Parallel)	+12% more workdays	+37% more workdays
Central (used in the headline results) Days in order; spare capacity can start the next day's work (Global Day Package, with carryover)	+28% more workdays	+62% more workdays
Upper Bound Days in order; no head start on the next day (Global Day Package, no carryover)	+93% more workdays	+130% more workdays

Percent more modeled workdays than the recorded schedule; core-worker day weighted average of the 18 project records. All six cells: 12% to 130%.

The rows are modeling assumptions about how work can be sequenced, not forecasts or probabilities.

Figure 5.1. Estimated increase in workdays if each worker were limited to one trade, under three schedule assumptions. The outlined central row supplies the headline result.

5.2 Staffing Needs and the Labor Curve

On an average day, limiting workers to one trade would require added workers equal to about 9% to 12% of the base core workforce.

The added need was larger on busier days: about 17% to 22% on a high-demand day (the 90th percentile, a level of need exceeded on only one workday in ten) and 31% to 34% on each project's peak-demand day (Figure 5.2). Put simply, for every 100 core workers, a one-trade workforce would need about 9 to 12 more on an average day, 17 to 22 more on a high-demand day, and 31 to 34 more on the peak-demand day.

Every record needed added workers under both one-trade workforces. The theoretically optimal workforce needed fewer added workers but still needed some.

Estimated added workers per day if each worker were limited to one trade, as a percentage of the base core workforce

Labor-curve measure Potential staffing impact of moving from a multiskilled to a one-trade workforce	Each worker limited to one trade: Theoretically optimal workforce (each worker assigned to their theoretically optimal trade)	Each worker limited to one trade: Observed workforce (each worker kept in their primary trade)
Average day Added workers on an average workday (average whole-worker addition)	+9% added workers	+12% added workers
High-demand day Added workers on the top 10% of workdays by labor need (90th-percentile addition)	+17% added workers	+22% added workers
Peak-demand day Added workers on the day of greatest modeled labor need (peak daily addition)	+31% added workers	+34% added workers

Added workers as a percent of the base core workforce; core-worker day weighted average of the 18 project records.
All six cells: 9% to 34%. The rows are different days of the same projects, not scenarios or probabilities.

Figure 5.2. Estimated added workers per day if each worker were limited to one trade, as a percentage of the base core workforce (Section 4.2). Measured as fractional capacity rather than whole workers, the average-day result was 6% to 8%.

Days with Trade Gaps

On about 73% of recorded workdays, at least one trade would have had a trade gap: more work than its assigned workers could cover that day.

Trade gaps remained common even in the theoretically optimal workforce. They appeared in both prevailing wage records (about 72% to 78% of workdays) and non-prevailing wage records (about 69% to 73%). Across the 18 records, trade-gap hours totaled about 12,200 to 15,900, roughly 14% to 18% of all core hours (Table 5.1). These are hours of recorded work that no worker in the needed trade could cover that day, before workers were added; they are not measured lost production.

Table 5.1. Trade gaps for the observed and theoretically optimal workforces

Measure	Theoretically optimal workforce	Observed workforce
Workdays with at least one trade gap (weighted average)	73%	73%
Trade-gap hours (total, 18 records)	About 12,200	About 15,900
Trade-gap hours as a share of all core hours	14%	18%

Peak Staffing and Productivity Risk

A one-trade workforce would also have higher peak staffing, pushing the labor curve into the range that prior research associates with productivity losses of about 15% to 20%.

The peak-to-average ratio compares the most core workers on site on any workday with the average (Section 4.4). As recorded, the multiskilled crews had a weighted ratio of 1.50, below the 1.6 level above which research by the National Electrical Contractors Association (NECA) and ELECTRI International reports negative project performance impacts. Raising each record's recorded peak by the added workers on its peak-demand day (31% to 34% weighted) lifts the ratio to about 2.0



(1.96 to 2.01, calculated record by record): peak staffing would be about twice the recorded average. Figure 5.3 shows four of the records. In each, the number of added workers varied from day to day, so peak staffing rose proportionally more than average staffing.

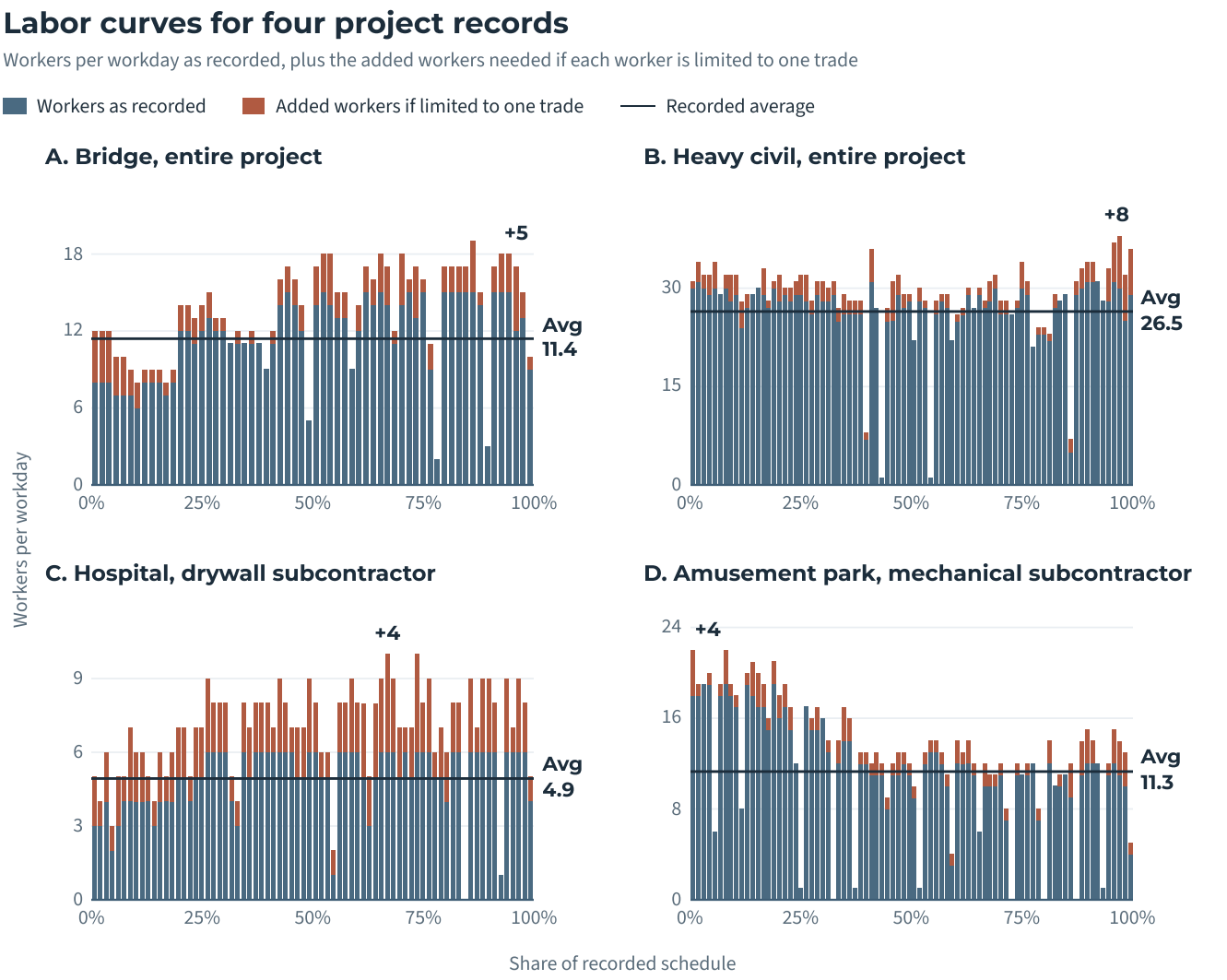
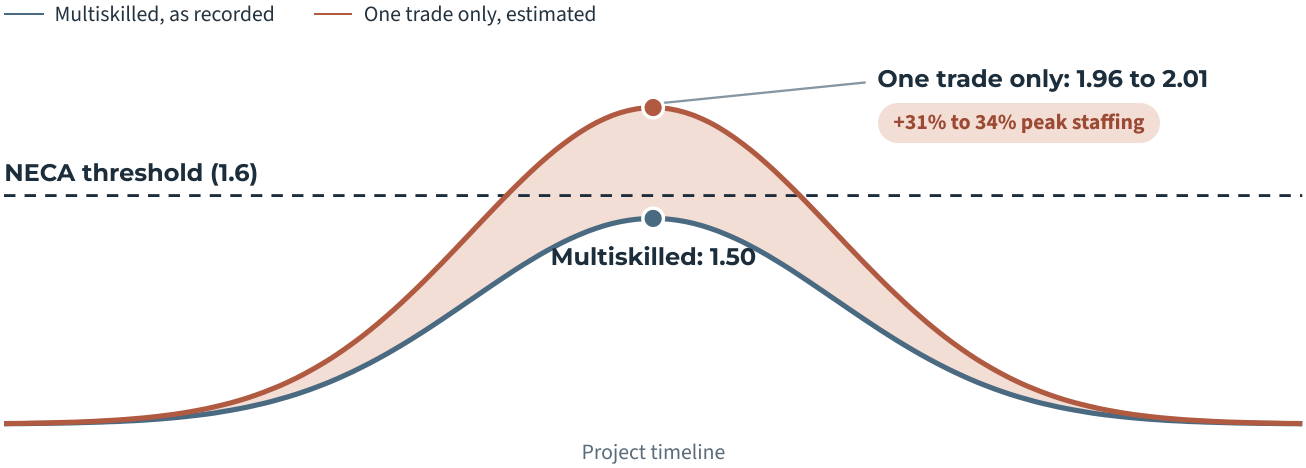


Figure 5.3. Labor curves for four project records: two entire-project records (A, B) and two subcontractor records (C, D). Bars show workers per workday as recorded (core crew) and the added workers needed if each worker were limited to their primary trade. Labels show each record's recorded average and largest one-trade addition; each panel has its own vertical scale.

NECA research associates ratios between 1.6 and 3.0 with a typical productivity loss of about 15%, and ratios near 2.0 with a loss of roughly 20% (Figure 5.4; ELECTRI International & NECA, 2018, Table 2.1, p. 11; ELECTRI International & NECA, 2007, Figure 2, p. 9). Research on overmanning, adding workers beyond the crew size the work needs, has found productivity losses of 0% to 41% in mechanical and sheet metal work (Hanna et al., 2007). Productivity was not measured in the project records; these are benchmarks from prior research.

Peak-to-average ratio of the multiskilled crews as recorded and of the same work with each worker limited to one trade, compared with industry benchmark ranges

Daily staffing ÷ recorded project average. Curve shapes are illustrative; peak values are from the 18 project records.



INDUSTRY PRODUCTIVITY BENCHMARKS FOR THE PEAK-TO-AVERAGE RATIO

Above 1.6
Negative performance impacts typically occur

1.6 to 3.0
Typical productivity loss about 15%

Near 2.0
Loss of roughly 20%

Figure 5.4. Peak-to-average ratio of the multiskilled crews as recorded and of the same work with each worker limited to one trade, compared with industry benchmark ranges.

Note: Ratios are core-worker day weighted across the 18 project records; the one-trade range runs from the theoretically optimal workforce (1.96, +31%) to the observed workforce (2.01, +34%). Benchmark values come from prior research and were not measured in the project records: above 1.6 and 1.6 to 3.0 (ELECTRI International & NECA, 2018, Table 2.1, p. 11); near 2.0 (ELECTRI International & NECA, 2007, Figure 2, p. 9).



SECTION 6

Discussion

This section discusses what the results mean in four areas: how often multiskilling was needed (Section 6.1), how crew makeup compares with multiskilling (Section 6.2), the schedule implications (Section 6.3), and the labor curve implications (Section 6.4).

6.1 How Often Multiskilling Was Needed

The labor records showed that trade gaps were common. With each worker limited to one trade, at least one trade would have come up short on about 73% of recorded workdays, nearly three days in four. These gaps were not limited to peak-demand days; added workers were needed across most of each project. Day after day, the trade the work needed was not the trade that had spare hours, and adding workers to trades that already had enough would not have helped.

The share of hours a crew spent multiskilling did not predict how much limiting it to one trade would lengthen the schedule. On a heavy civil record, only 8% of core hours were multiskilling hours, yet a one-trade workforce would have needed 17% to 44% more workdays. On a wastewater plant record, 24% of core hours were multiskilling hours, yet a one-trade workforce would have needed only 2% to 9% more. Across the 18 records, records with more multiskilling hours did not consistently show larger schedule increases (Figure 6.1). The schedule effect depended on when and in which trades those hours were used: a few hours in the trade that was short on a given day kept the work moving.

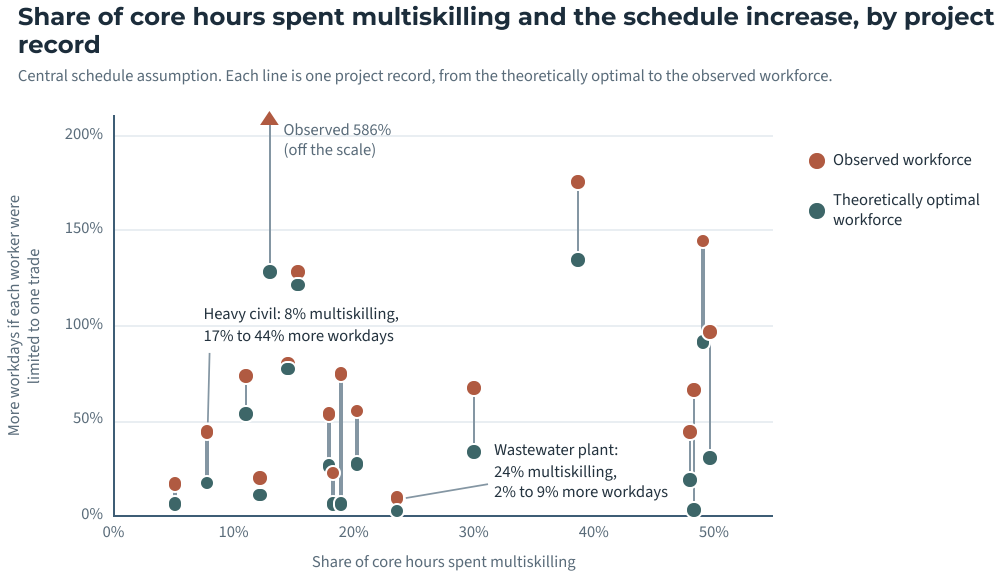


Figure 6.1. Share of core hours spent multiskilling and the schedule increase, by project record. Central schedule assumption. Each line runs from the theoretically optimal workforce (lower dot) to the observed workforce (upper dot). One observed value, 586% for a military facility record, is off the scale.

The value of multiskilling appears to lie in covering the trades and days where work would otherwise wait, not in how often workers switch trades. The combinations that showed up most in the records (laborer, ironworker, carpenter, and concrete finisher work) are closely related trades in the same sequence of work, the kind of adjacent skills that let a crew handle the work in front of it.

6.2 Crew Makeup Versus Multiskilling

Assigning the same workers to their theoretically optimal trades reduced every effect without adding anyone, so crew makeup matters. But the improvement was uneven (Figure 6.2). The theoretically optimal workforce removed more than half of the schedule effect, from 62% to 28% more workdays, but barely changed peak staffing: added workers on the peak-demand day fell only from 34% to 31%, and the share of workdays with a trade gap stayed at 73%.

The reason is timing. Under the central schedule assumption, work that fell behind could be made up on later days, so the theoretically optimal mix of trades shortened the schedule. In the staffing analysis, each day's work had to be done that day. A fixed crew cannot keep up with day-to-day shifts in which trades are needed; workers who can move between trades can. The upper bound schedule assumption shows the same pattern. There, each day's work must be finished before the next day's work can start, and the theoretically optimal workforce still needed 93% more workdays, compared with 130% for the observed workforce. Its better mix of trades removed less than a third of that effect, compared with more than half under the central assumption.

This comparison was generous to the one-trade workforce. The theoretically optimal workforce was chosen with hindsight, after seeing all the work each project actually did, something no contractor can do when putting a crew together. Even so, no fixed assignment of the same workers to single trades matched what multiskilling achieved.

The practical lesson is to develop selected skills that complement specialization, not to have everyone do everything. That matches earlier modeling, which found that most of the benefit came from multiskilling part of the workforce and from workers with two or three trades (Gomar et al., 2002). It also depends on workers being trained, current, and authorized for the added work.



How much of each one-trade effect the theoretically optimal workforce removed

Assigning the same workers to their theoretically optimal trades (chosen with hindsight) compared with keeping each worker in their primary trade. Weighted across the 18 project records.

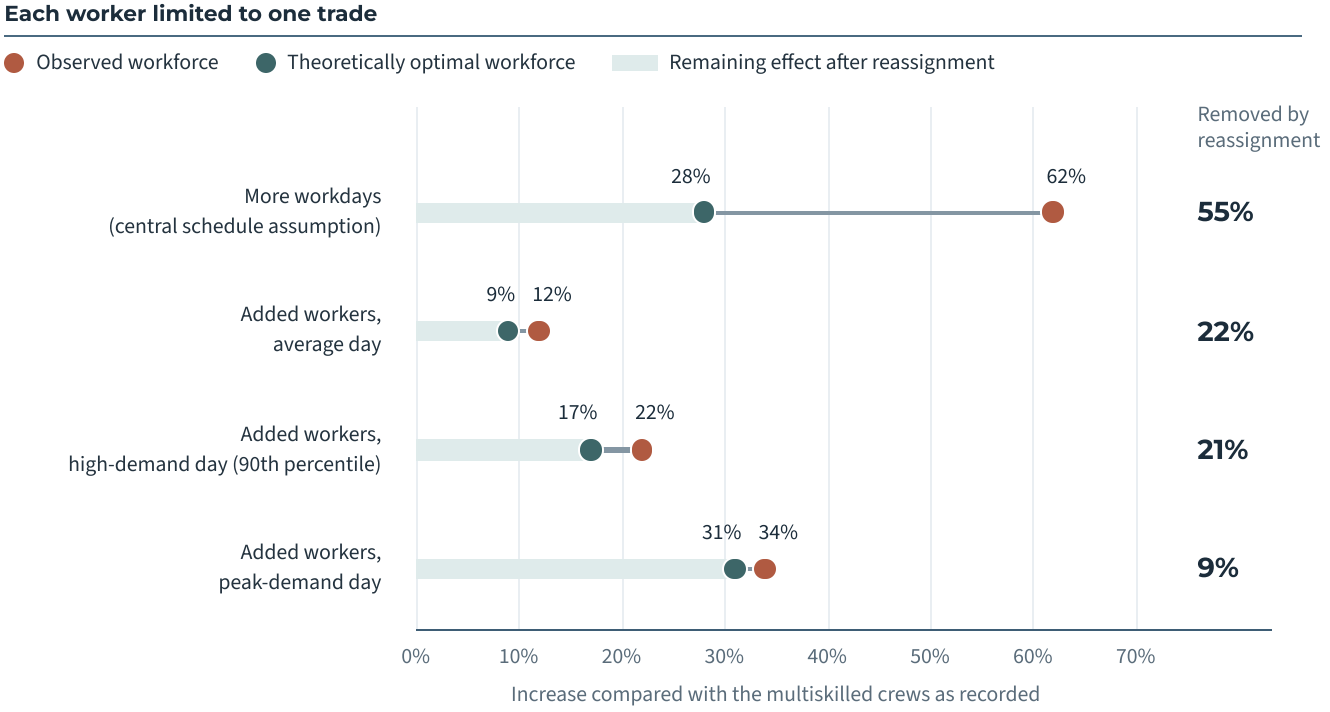


Figure 6.2. How much of each one-trade effect the theoretically optimal workforce removed. Weighted results for the observed and theoretically optimal workforces across the 18 project records.

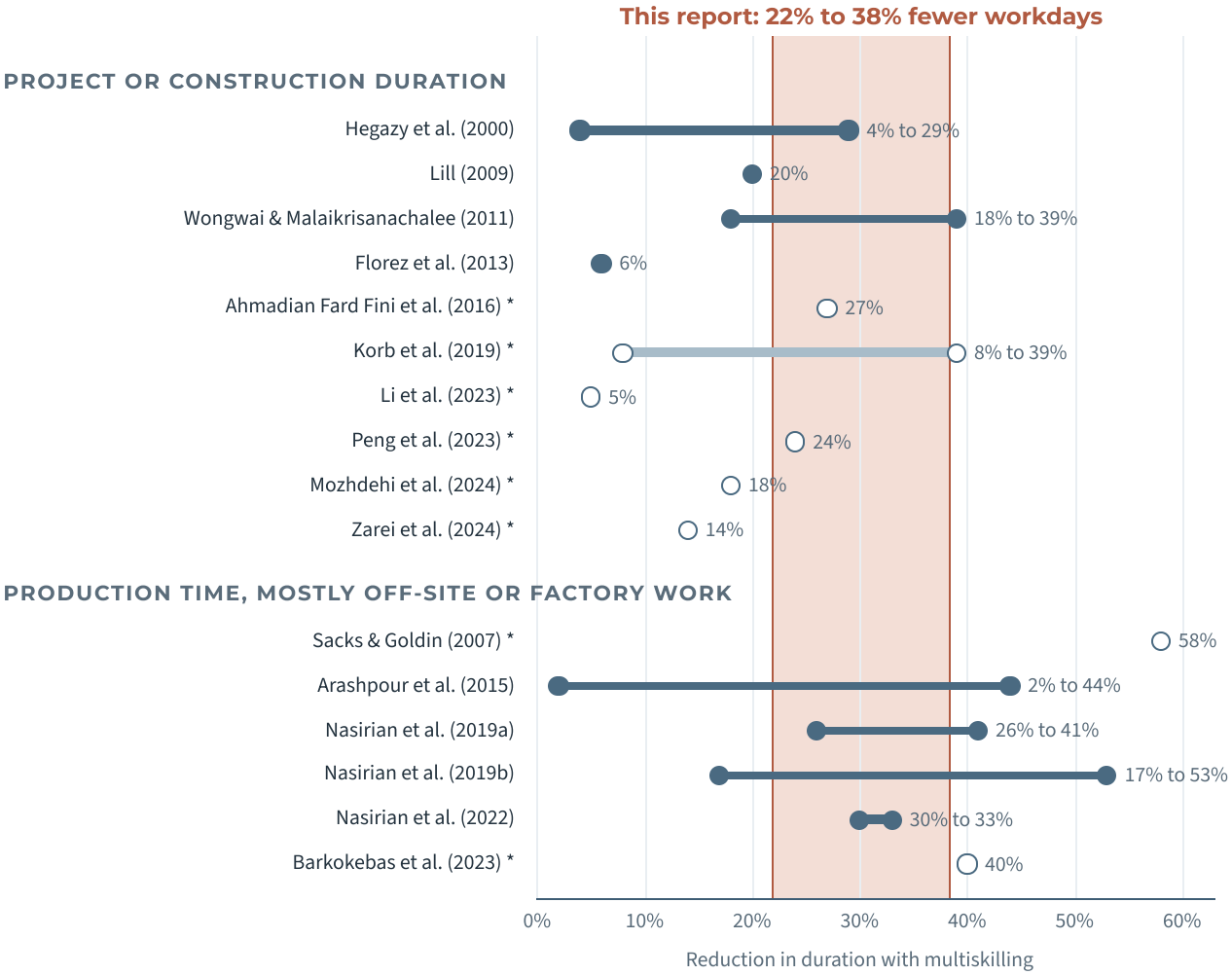
6.3 Schedule Implications

The schedule results depended on how tightly the work was sequenced. The increase was smallest under the lower bound assumption, where each trade works at its own pace, and largest under the upper bound assumption, where each day's work must be finished before the next can start: from 12% to 130% across all six estimates. The tighter the sequence, the more a one-trade workforce loses, because work in one trade waits on work in another. Multiskilling is likely to help most where work is tightly sequenced and trades depend on each other.

These results line up with earlier modeling. The multiskilled crews finished their work in 22% to 38% fewer workdays than one-trade workforces would need. That is within the range earlier scheduling and optimization models estimated (Figure 6.3), but these results are built from labor records on active U.S. projects rather than from hypothetical projects.

Schedule reductions in earlier studies and in this report

Each row is one earlier study: bars show a reported range, dots a single value.



* Open markers: multiskilling was combined with another change, such as crew makeup, batch size, or learning effects.

Figure 6.3. Schedule reductions in earlier studies and in this report. Each row is one earlier study; bars show a reported range and dots a single value. Open markers show studies in which multiskilling was combined with another change, such as crew makeup, batch size, or learning effects. The shaded band is this report's result: the multiskilled crews finished in about 22% to 38% fewer workdays than one-trade workforces would need (central schedule assumption).

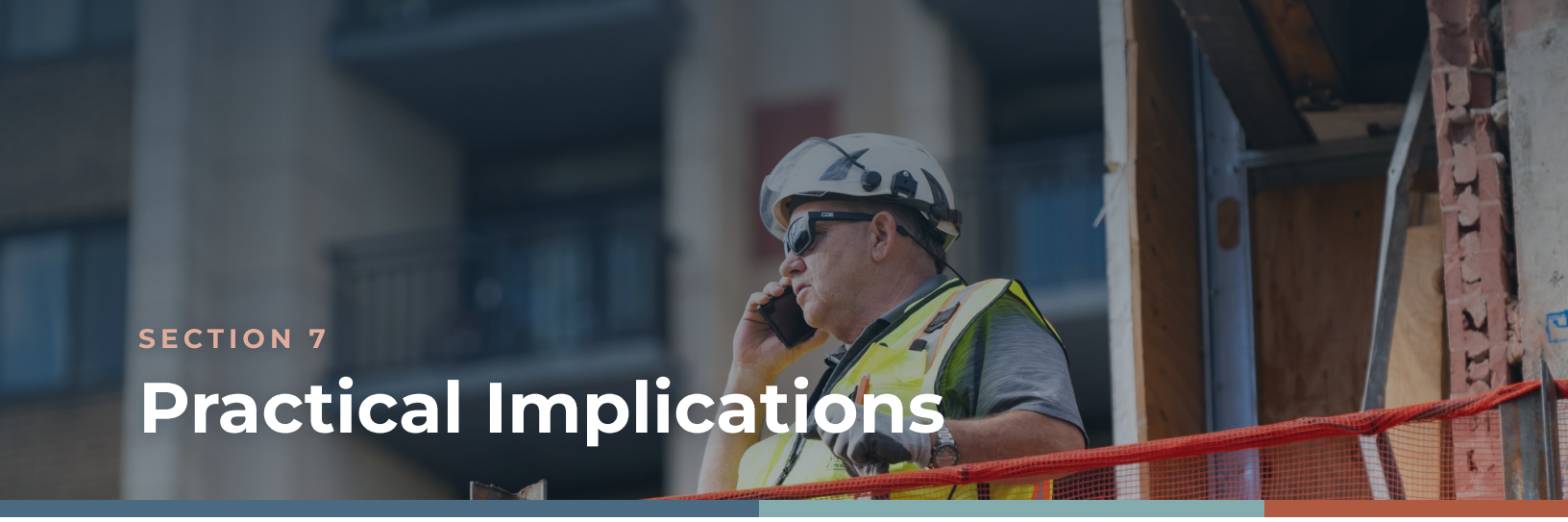
6.4 Labor Curve Implications

The difference between average and peak staffing is one of the most important findings of this report. A one-trade workforce would need 9% to 12% more workers on an average day, but 31% to 34% more on its peak-demand day. On the peak-demand days, several trades tend to need help at once, and each short trade needs its own added worker, even when no single gap fills a full day. A crew sized for an average day would come up short when it matters most.

That changes the shape of the labor curve. As recorded, the multiskilled crews stayed below the 1.6 peak-to-average level that NECA research links to negative project performance. A one-trade workforce would reach about 2.0, a level that research associates with productivity losses of roughly 15% to 20%. The reasons are practical: more workers on site at the peak means more congestion, more competition for tools, materials, and work space, and thinner supervision (ELECTRI International & NECA, 2007, 2018; Hanna et al., 2007).

The planning lesson is to look at when, and in which trades, added workers would be needed, not just at the average. Added workers help only if they can be found, brought up to speed, and fit in where the work is. The right crew size, a good mix of trades, and qualified multiskilling work together, and none of them can be judged from total headcount alone.





SECTION 7

Practical Implications

The findings of this report point to a practical priority: match qualified workers to the trades needed as the work progresses. The implications below are organized by audience.

7.1 Contractors and Construction Companies

1 **Plan by trade and workday, not total headcount alone.**

Use upcoming work plans to compare the hours each trade needs with the qualified workers available on those days. Find the trade gaps and spare hours by trade before deciding the project simply needs more people. Repeat the check as the work progresses.

2 **Improve crew makeup and plan for shifting assignments.**

Check whether the starting crew has the right balance of trades, then find where workers with verified added skills can cover trade needs from day to day. A good crew makeup is a starting point, not a substitute for day-to-day flexibility. The theoretically optimal workforce in this report is a benchmark built with hindsight, not a roster to copy into the field.

3 **Decide in advance how to respond to trade gaps.**

Where the finish date is fixed, identify which trades will need added qualified workers and when. Where those workers cannot be found, decide whether resequencing the work, adding time, or a mix of both is the better response.

4 **Plan for high-demand and peak-demand days.**

Look at staffing needs on high-demand and peak-demand days, not just the average. Identify which trades need added workers at the same time, for how long, and whether work areas, equipment, materials, and supervision can handle them. Use the peak-to-average ratio as a warning sign of staffing pressure, not as an automatic productivity-loss factor.

5 **Use project records to improve the next workforce plan.**

Keep secure records of workers, dates, trades, and hours, and compare planned trade coverage with actual staffing and progress. Review recurring trade gaps and peak periods with field leaders and workers, and use the lessons to set the next crew makeup and training priorities.

7.2 Individual Workers

1 Choose added skills based on the work that needs covering.

Workers, employers, and training providers should review upcoming work together and find the trade gaps that keep recurring. Choose added skills that fit the worker's primary trade and interests and that the worker will actually get to use.

2 Verify readiness before broadening assignments.

Define the work, provide supervised practice and assessment, and document each worker's qualifications and authorizations. Make those records available to supervisors when assignments shift. Hours charged to a trade do not, by themselves, show that a worker is qualified for every task in that trade.

3 Connect training to planned assignments.

Agree in advance on the assignments, the chances to practice, and how added skills and responsibility will be recognized. Schedule training before the skill is needed, then check whether it helped cover the planned work.

7.3 Owners and Buyers of Construction Services

1 Ask for a workforce plan by trade.

During procurement and preconstruction, ask contractors how the proposed crew will cover each trade's needs as the work progresses, which workers can work across trades, and how their qualifications will be verified. Ask for a plan for high-demand periods and the limits of that flexibility, not just a total headcount.

2 Share schedule and operating constraints early.

Give contractors milestone dates, access limits, shutdown or turnover windows, and expected changes in the work early enough to prepare the workforce. Review schedule commitments alongside trade availability and peak staffing. Adding workers does not solve every schedule problem.

3 Know where qualified workers may work across trades.

Review project requirements, work-assignment provisions, and contract terms to see where qualified workers may work across trades. Where clarifications or adjustments are needed, follow the required contract and regulatory processes. Keep licensing, wage, safety, quality, specialist, and supervision requirements in place.

4 Measure the result where the strategy is used.

Agree with the contractor on how to track milestone progress, staffing by trade, peak staffing, safety, and quality on selected scopes, and judge the approach on that project evidence.

7.4 Policymakers

1 **Consider how rules affect qualified workers covering more than one trade.**

When reviewing workforce or public-project rules, ask whether they keep necessary controls in place while still letting qualified workers cover each trade's needs as the work progresses. This report modeled a one-trade restriction. It did not evaluate specific laws or measure the effects of prevailing wage policy.

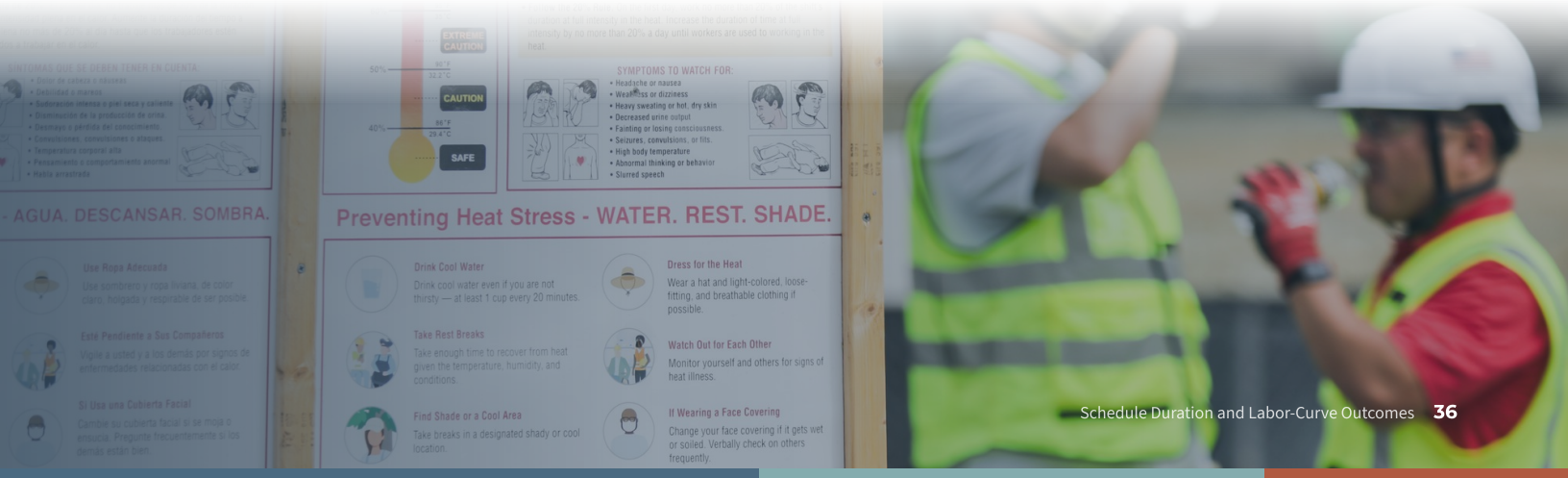
2 **Support development tied to project needs.**

Work with employers and workforce-development organizations to find recurring trade gaps and prepare workers to cover them. Tie support to skills workers can demonstrate and will use, while keeping primary-trade training and required qualifications in place.

7.5 Taxpayers, Communities, and End Users

1 **Ask how the workforce plan supports reliable delivery.**

For public projects, ask how the planned workforce will cover the work, including the busiest periods, and how agencies will report progress against promised milestones. Qualified multiskilling is an option to evaluate, not a guarantee of faster completion or lower public cost. Safety, quality, and worker protections should remain in place.





SECTION 8

Limitations and Recommendations for Future Research

8.1 Limitations

- The schedule and staffing results are estimates built from the labor records, not measured delays, actual hiring, or observed changes in productivity. Productivity and crowding were not measured.
- Recorded hours were used as the measure of work to be covered, not as a measure of installed quantities or productivity.
- Each analysis covered only the work and period in the supplied record.
- The records did not include full project schedules or the order in which activities depend on each other. The three schedule assumptions bracket how work could progress; they do not recreate the actual schedule or every way a contractor could organize the work or respond to trade gaps.
- The theoretically optimal workforce was found by a computer search knowing all of the recorded work in hindsight, which a contractor planning a new project would not have.
- The research team sought projects where multiskilling was used, so the 18 records are detailed cases rather than a representative sample of U.S. construction.

8.2 Recommendations for Future Research

- Test mixed responses, in which a contractor adds some workers and some time, rather than one or the other.
- Measure productivity, crowding, and supervision directly on high-demand days to test the peak-staffing benchmarks on multiskilled and one-trade workforces.
- Link labor records to activity schedules so dependencies and float can be modeled directly.
- Extend the dataset to more contractors, regions, and project types, including projects where multiskilling is rare.



SECTION 9

Conclusion

This report estimated how limiting construction workers to one trade would change schedule duration and staffing. Using labor records from 18 U.S. construction projects, it compared the multiskilled crews as recorded with the same workers limited to one trade, assigned two ways: to their primary trades, and to their theoretically optimal trades, chosen with hindsight. The results show that the value of multiskilling comes from having qualified workers who can cover the trades the work needs each day. Having enough workers or hours overall is not enough.

Under the central schedule assumption, limiting workers to one trade would have required about 28% to 62% more workdays to finish the same work. Keeping the recorded schedule instead would have required added workers equal to about 9% to 12% of the base core workforce on an average day, 17% to 22% on a high-demand day, and 31% to 34% on the peak-demand day, with peak staffing reaching about twice the recorded average. At least one trade would have had a trade gap on about 73% of recorded workdays, nearly three days in four, so the problem would have been a daily one, not limited to occasional peaks.

Assigning the same workers to their theoretically optimal trades reduced these effects but did not remove them. A good crew makeup helps, but it is not the same as having workers who can move to the trade that is short. The value of multiskilling also depended on when and in which trades workers used their added skills, not on how often they worked across trades. These findings held even when only half of the multiskilling hours were treated as necessary (Appendix A).

For contractors, owners, and workforce-development organizations, the practical lesson is to treat multiskilling as a targeted planning tool. Plan labor by trade and by workday, build added skills where they cover recurring trade gaps, and plan for peak staffing as well as the average. These are modeled estimates from recorded craft hours. They are not guaranteed schedule or staffing savings or measured productivity gains, and using them must keep qualifications, specialization, safety, quality, and other required controls in place.

Multiskilling lets qualified workers follow the work from trade to trade. On these 18 projects, that let crews finish the work in fewer workdays, or with fewer workers, than the same crews would have needed if limited to one trade. The largest difference came on the days of highest demand.

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Appendix A · Supplemental Sensitivity Analysis

The main analysis uses the work exactly as it was recorded: every multiskilling hour counts as work that had to be done on the day it was done. This supplemental analysis asks how much the findings would change if only part of that work had to be done that day. It repeats the schedule and staffing analyses with 100%, 90%, 75%, 66.7% (two-thirds), and 50% of multiskilling hours treated as necessary.

The percentages apply only to multiskilling hours. Hours in each worker's primary trade stay in full, and the hours removed are dropped rather than moved to later days.

At each level, the workers, their trade assignments from the main analysis, their available hours, the schedule assumptions, and the weights stayed the same; only the multiskilling hours to be covered were reduced. The schedule results cover all three schedule assumptions. The staffing results cover how often trade gaps occurred and how many added workers were needed on an average day, a high-demand day, and a peak-demand day.

The 100% level matches the main results, which use the work as it was recorded. Lower levels show how the findings change if some multiskilling hours did not have to be done on the day they were recorded; the 50% level is the most conservative.

A.1. Schedule Results

Even if only half of the recorded multiskilling hours were necessary, limiting workers to one trade would still require 19% to 44% more workdays under the central assumption.

Table A1. Estimated additional workdays if each worker were limited to one trade, at different levels of multiskilling hours treated as necessary.

Multiskilling hours treated as necessary	Lower Bound	Central	Upper Bound
100% (main results)	12% to 37%	28% to 62%	93% to 130%
90%	11% to 35%	27% to 58%	92% to 126%
75%	10% to 32%	24% to 53%	89% to 120%
66.7% (two-thirds)	10% to 31%	22% to 49%	87% to 116%
50%	10% to 28%	19% to 44%	83% to 110%

The schedule estimates decreased as fewer multiskilling hours were treated as necessary, but the reductions were much smaller than the amount of work removed. Under the central assumption, the estimated increase fell from 28% to 62% when all recorded multiskilling was included to 19% to 44% when only half was included. In other words, removing half of the multiskilling hours reduced the central schedule effect by about 30%, not 50%.

The central assumption showed the largest relative drop, and the lower bound assumption changed the least in percentage points. The upper bound assumption still gave the largest increases because of its stricter sequencing. Under all three assumptions, substantial additional workdays remained even at the 50% level.

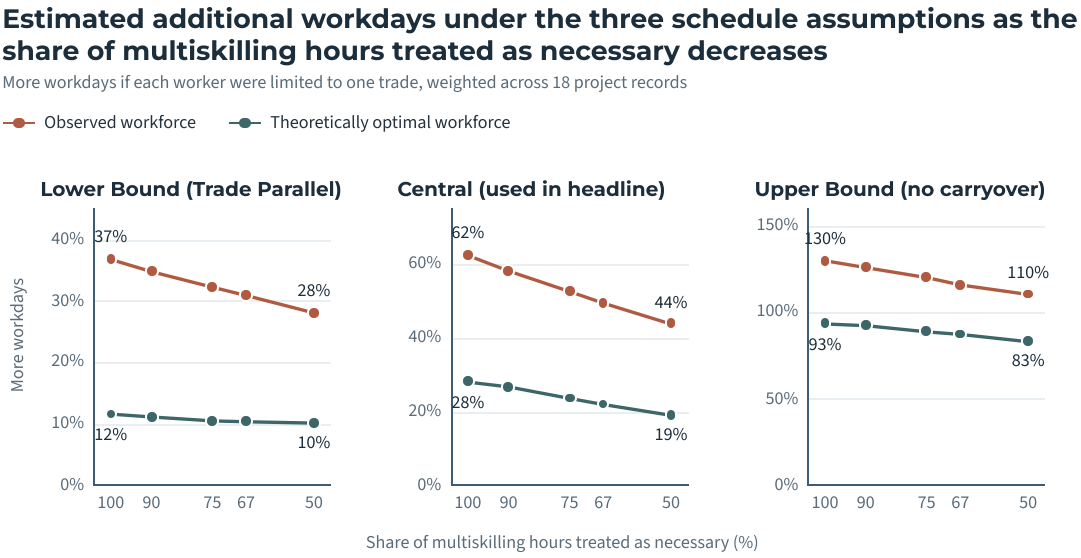


Figure A1. Estimated additional workdays under the three schedule assumptions as the share of multiskilling hours treated as necessary decreases. Results are weighted across the 18 project records.

A.2. Staffing Results

Trade gaps remained common even when only half of the recorded multiskilling hours were treated as necessary.

Table A2. Estimated workdays with trade gaps and added workers needed to keep the recorded schedule, at different levels of multiskilling hours treated as necessary

Multiskilling hours treated as necessary	Workdays with a trade gap	Average day (whole workers)	High-demand day (90th percentile)	Peak-demand day
100% (main results)	about 73%	9% to 12%	17% to 22%	31% to 34%
90%	70% to 73%	9% to 11%	16% to 20%	29% to 31%
75%	69% to 72%	8% to 10%	15% to 19%	26% to 27%
66.7% (two-thirds)	68% to 71%	7% to 10%	14% to 19%	24% to 25%
50%	64% to 69%	6% to 9%	11% to 16%	21% to 22%

Trade gaps remained frequent: With all recorded multiskilling hours treated as necessary, a one-trade workforce would have had at least one trade gap on about 73% of workdays. Even at the 50% level, trade gaps remained on 64% to 69% of workdays, and all 18 project records still had days that needed added workers.

Peak-demand needs stayed well above average needs: At the 50% level, added workers equaled 6% to 9% of the base core workforce on an average day, 11% to 16% on a high-demand day, and 21% to 22% on the peak-demand day. Needs fell as fewer multiskilling hours were included, but peak-demand-day needs stayed more than twice the average-day needs.

The one-trade peak-to-average ratio also stayed high, falling from about 1.96 to 2.01 at the 100% level to 1.82 to 1.84 at the 50% level. Both are above the 1.6 level from the NECA research (Section 5.2). These ratios point to possible staffing pressure, not measured productivity losses.

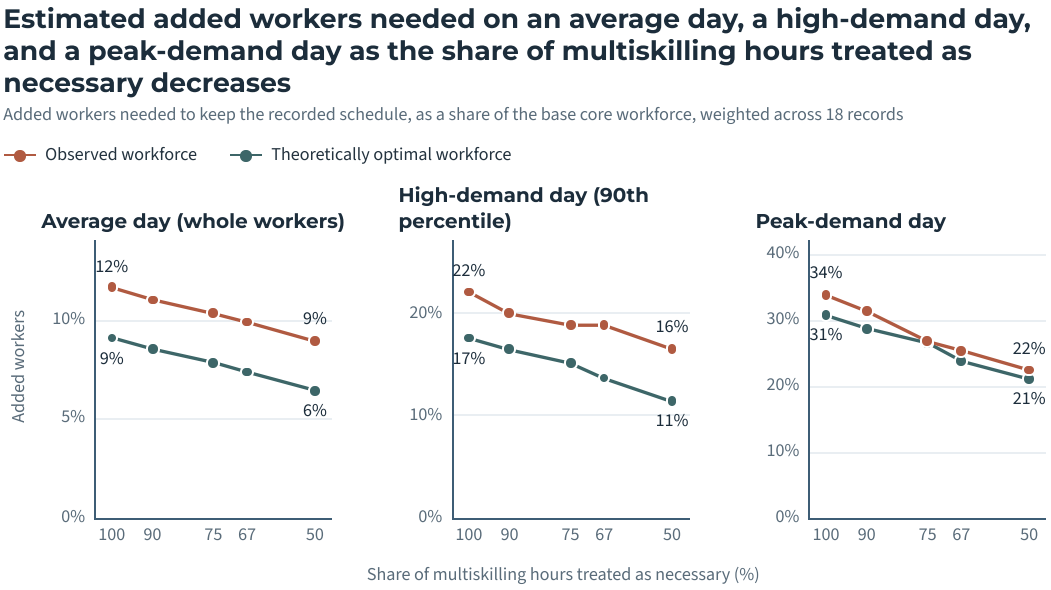


Figure A2. Estimated added workers needed on an average day, a high-demand day, and a peak-demand day as the share of multiskilling hours treated as necessary decreases. Values are percentages of the base core workforce, weighted across the 18 project records.

A.3. What the Sensitivity Analysis Shows

The findings do not depend on treating every multiskilling hour as necessary on the day it was recorded. Even if only half of those hours had to be done that day, limiting workers to one trade would still have required 19% to 44% more workdays under the central assumption, trade gaps would still have occurred on 64% to 69% of workdays, and the one-trade peak-to-average ratio (1.82 to 1.84) would still have been above the 1.6 NECA level.

The results also changed gradually and predictably. Removing half of the multiskilling hours lowered the central schedule effect by about 30%, not 50%, and no measure rose as the share of hours fell. Peak-demand day needs stayed more than twice average-day needs at every level.

The test does not identify which hours could have been done on another day, and it does not estimate what would have happened on the actual projects. It shows that the main conclusions hold across the full range of levels tested.

Appendix B · Key Terms Used in This Report

Project record: The labor record for one project or one subcontractor's scope within a project, covering the period the contractor supplied.

Entire-project record: A record in which the contractor performed the whole project with its own workforce.

Subcontractor record: A record covering one subcontractor's scope within a larger project.

Craft hours: Hours of craft work on site, after removing supervisory and salaried time, leave, travel, and payroll adjustments.

Workday: A day with recorded craft hours in a record.

Core crew: The smallest group of workers who together recorded at least 80% of a record's craft hours.

Core hours: Craft hours recorded by core workers.

Primary trade: The trade in which a core worker recorded the most hours.

Multiskilling hours: Hours a core worker recorded outside their primary trade.

Trade combination: The set of trades one worker recorded hours in over a record's period.

One-trade restriction: The modeled condition in which each worker can work in only one assigned trade.

One-trade workforce: A modeled version of a record's crew in which each worker can work in only one trade. The report tests two: the observed workforce and the theoretically optimal workforce.

Observed workforce: The recorded crew, with each worker limited to their primary trade, except where a worker is moved so every trade has someone assigned.

Theoretically optimal workforce: The one-trade workforce in which the same workers are assigned to the trades that, taken together, keep the modeled impact smallest (each worker's theoretically optimal trade).

Trade-coverage role: A modeled role added only where a crew had fewer workers than trades, so every trade had someone assigned. Not a recorded worker. Each could cover up to 10 hours a day in its trade.

Base core workforce: Recorded core workers plus trade-coverage roles (202 across the 18 records); the base for staffing percentages.

Trade gap: Recorded work in a trade on a workday that the workers assigned to that trade could not cover.

Trade-gap hours: The total hours of trade gaps before any workers are added.

Added workers: Workers added to a trade on a workday to cover its trade gap, counted as whole workers who can each cover up to 10 hours in one trade.

Core-worker day: One core worker with recorded hours on one workday; the weight used to combine records.

Average, high-demand, and peak-demand day: The mean, 90th-percentile, and largest daily number of added workers in a record.

Peak-to-average ratio: The largest daily count of core workers divided by the average daily count.

Labor curve: The number of workers a project needs over time, day by day.

Crew makeup: The mix of trades on a crew.

Schedule assumptions: Three rules for how unfinished work carries forward: lower bound (Trade Parallel), central (Global Day Package, with carryover), and upper bound (Global Day Package, no carryover).

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