Work-Time Utilization and Staffing Level Impacts in Construction Crews

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

SIMPLAR FOUNDATION

About the Simplar Foundation

The Simplar Foundation is a collaborative team of university faculty and researchers whose mission is to discover, share, and promote research findings that enable organizations of all types and sizes to improve their ability to operate, better meet the public need, implement best practices, and more effectively train the workforce. Learn more at simplarfoundation.org.

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

FUNDING AND RESEARCH INDEPENDENCE

This research was financially supported by Associated Builders and Contractors (ABC) under a research agreement with Simplar Foundation. The agreement states that Simplar Foundation owns the research data results and that, subject to specified review rights, the publishing party retains final authority over the scope and content of its publications. ABC was entitled to receive a draft at least 30 days before publication and could reasonably require removal of confidential information or information reasonably identifying ABC, or a delay of up to 60 additional days to permit patent or other intellectual-property filings. Without mutual written agreement, publication could not be delayed more than 90 days after receipt of the draft. The agreement did not give ABC general authority to approve or reject the research findings or conclusions, and it did not condition publication rights on whether the results were favorable, unfavorable, mixed, or null.

The research protocol, sampling, data collection, classification, analysis, interpretation, conclusions, authorship, and publication, decisions were controlled by the research team.

Work-Time Utilization and Staffing Level Impacts in Construction Crews

Report 1 of 6 in Volume 1

Multiskilling in the U.S. Construction Industry

ISSN pending | ISBN 979-8-952789-00-5 (PDF)

https://doi.org/10.22361/b7k6r4jkyb

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**	THIS REPORT
02	Productivity in Multi-Trade Construction Workflows	
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	

Copyright and Use

RECOMMENDED CITATION

Lines, B., Ogundare, I., Kassa, R., Smithwick, J., & Sullivan, K. (2026). *Work-Time Utilization and Staffing Level Impacts in Construction Crews*. Multiskilling in the U.S. Construction Industry. Report 1 of 6 in Volume 1. Simplar Foundation. https://doi.org/10.22361/b7k6r4jkyb

Table of Contents

Study at a Glance **1**

Executive Summary **2**

Section 1 · Background **4**

Multiskilling in Construction 4

Labor Availability, Schedule Pressure, and Workforce Flexibility 5

Key Terminology Used in This Study 6

Section 2 · Review of Previous Studies **7**

Limitations of Existing Multiskilling Research 7

Prior Studies Found Many Benefits Yet Rely Heavily on Assumptions 9

Addressing the Gaps in Previous Studies 10

Counterfactual Analysis as a Recommended Method of Analysis 11

Section 3 · Research Methodology **12**

Objectives 12

Protocols for On-Site Data Observations 12

Work-Sampling Procedures 13

Method of Analysis 17

Section 4 · Field Observations Dataset **23**

Project Selection and Sampling Approach 23

Observed Projects and Site Visits 24

Section 5 · Results **26**

Extent of Cross-Tasking Observed in Multiskilled Crews 26

Impact of Multiskilling on Crew-Level Work-Time Utilization 27

Impact of Multiskilling on Equivalent Staffing Requirements 28

Section 6 · Discussion **30**

What the Findings Mean at the Crew Level 30

Why the Results Vary by Context 31

Relationship to Prior Literature 34

Potential Relationship with Safety, Quality & Schedule 35

Section 7 · Practical Implications **37**

Shared Principles Across All Stakeholders 37

Individual Workers 38

Taxpayers, Communities, and End Users 39

Policy Makers at the Local, State, and Federal Levels 40

Contractors 41

Owners and Buyers of Construction Services 42

Summary of Central Takeaways by Audience 43

Section 8 · Limitations and Recommendations for Future Research **44**

Section 9 · Conclusion **46**

Section 10 · References **47**

SIMPLAR FOUNDATION

STUDY AT A GLANCE

Work-Time Utilization and Staffing Level Impacts in Construction Crews

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

1 THE NATIONWIDE DATASET

Trained researchers used structured work sampling to document multiskilling during normal operations on active U.S. construction projects.

40
site visits across **24 states**

36
projects observed

22
unique project types

30
participating contractors

60
multiskilled crews

644
workers observed

11,407
work-sampling observations (2,757 labor-hours)

2 THE EXTENT OF MULTISKILLING OBSERVED

Workers were observed performing tasks beyond their primary trade as a regular part of normal operations:

36%
average cross-tasking share
of observed crew work time (crew range 2% to 96%)

128
unique trade combinations
e.g., ironworkers assisting with concrete formwork

2.7
skill classifications
per worker on average, with up to 6 in a single day

26
unique primary trades
represented among the 644 observed workers

3 BENEFITS OF MULTISKILLING

Compared with the same-sequence single-skilled comparison, the observed multiskilled crews achieved:

+39%
higher direct-work share

−68%
lower idle-time share

31–42%
equivalent staffing reduction

All effects statistically significant beyond the 99% confidence level ($p < 0.001$)

4 PRACTICAL TAKE-AWAYS

Target multi-trade scopes
Benefits were largest where work had multi-trade interdependent tasks and frequent handoffs

Use where qualified
Cross-tasking depends on training, competence, safety qualification, and supervision

Deploy selectively
A context-dependent strategy, not a replacement for trade specialization

Enable flexibility
Owners can review their contracts & work rules to allow for qualified cross-tasking

Interpret at crew level
All results are at the crew-level and do not represent project-wide impacts

Executive Summary

Background & Motivation

Construction owners and contractors are aligned on a central question: how can the U.S. construction industry make the best use of available craft labor? This question is especially important because the industry faces three related challenges: labor availability, schedule pressure, and workforce flexibility.

Multiskilling is one potential solution to these challenges. In this report, multiskilling refers to a labor strategy in which workers and crews are qualified to safely and competently perform selected work activities across more than one trade, craft, or skill classification. This report specifically measures how multiskilling affects crew-level work-time utilization and equivalent staffing requirements.

Collection of a Nationwide Dataset

This study is grounded in the most comprehensive field-collected dataset of multiskilling assembled to date. A structured work-sampling approach was used to document multiskilling in real-time as it occurred in day-to-day construction operations across the U.S.

Dataset at a Glance

40 site visits in 24 states

36 projects & 22 unique types

30 participating contractors

60 multiskilled crews

644 workers

2,757 labor hours observed

128 unique trade combinations

11,407 work-sample observations

The final dataset recorded 11,407 work-sample observations of 644 individual workers in 60 crews. Every observation documented the task and trade being currently performed by each worker, whether the activity represented cross-tasking, and the productivity classification of the activity as representing direct work, support work, or idle time.

Productivity was measured at the crew level using work-sampling indicators: the share of observed labor time spent in direct work, support work, and idle time. These measures capture how effectively crew work-time utilization was allocated during observed work periods.

Key Findings

1. **A wide range of project types leveraged a multiskilling approach.**
   A multiskilled labor strategy was observed on 36 active construction projects across 24 states, representing 22 unique project types ranging from <$1M to $1B+ in total project size.

2. **Construction crews spent considerable time performing multiskilled activities.**
   Workers spent about 36% of observed crew time performing work outside their primary trade. Individual workers performed an average of 2.7 distinct skill classifications during observed work periods. Several workers performed as many as 6 distinct skill classifications in a single day.

3. **Multiskilled crews demonstrated improved work-time utilization.**
   Workers in multiskilled crews were able to spend substantially more of their active work periods directly advancing construction work. Analyzed against the same-sequence single-skilled comparison, observed multiskilled crews had a 39% higher direct-work share and a 68% lower idle-time share.

4. **Multiskilled crews required fewer workers to preserve the observed work sequence.**
   Limiting workers to one trade would require approximately 45% to 72% more workers to accomplish the same work sequence observed in the field. For example, a crew of 10 multiskilled workers provided work coverage that would otherwise require approximately 14 to 17 workers limited to one trade.

5. **Multiskilling was observed to be a context-dependence practice.**
   The range of observed effects shows that multiskilling is best understood as a workforce flexibility strategy that can be optimized for project-specific scopes, constraints, and opportunities.

THE FINDINGS IN BRIEF

39%
higher direct-work share

68%
lower idle-time share

31–42%
equivalent staffing reduction (lower to upper bound)

SECTION 1

Background

This section describes the concept of multiskilling and its relevance across the full spectrum of market conditions that the construction industry can experience. A list of key terms used throughout the study is also provided for clarity.

Multiskilling in Construction

Multiskilling in construction refers to workers performing tasks beyond a single trade or job-role classification. More than 100 unique skill combinations were observed in the field during this study. Examples include structural ironworkers assisting with concrete formwork preparation, pipefitters performing sheet metal and insulation work, equipment operators placing and finishing concrete, electricians operating heavy equipment, and more.

Multiskilled workers can routinely shift between related tasks, assist adjacent trades, and support complementary activities to maintain a productive workflow. This enables workers to remain productive across multiple activities and potentially reduces time that would otherwise be required to coordinate with (or wait for) other crews or trades.

Examples of Multiskilling Combinations

OBSERVED IN THIS STUDY

- Electrician & Operator
- Ironworker & Carpenter
- Pipefitter & HVAC
- Painter & Insulator
- Plumber & Operator
- Rigger & Laborer
- Concrete Finisher & Welder

and **100+ more combinations**, including individual workers who performed up to **6 skill classifications** in one day

Labor Availability, Schedule Pressure, and Workforce Flexibility

Multiskilling is relevant to the U.S. construction industry for three related but distinct reasons: labor availability, schedule pressure, and workforce flexibility.

First, many contractors and owners face persistent difficulty securing enough qualified craft labor to meet project demand. Multiskilling may help contractors more effectively use a constrained labor pool by expanding the range of tasks that qualified workers can perform.

Second, construction projects are often delivered under compressed schedules where short-duration tasks, trade handoffs, interdependent work sequences, access constraints, inspections, and material availability can interrupt crew workflow. In these conditions, a worker who can safely and competently perform an adjacent task in the current work sequence may help the crew continue productive work rather than waiting for another trade or crew to become available.

Third, multiskilling provides workforce flexibility at the crew level. Construction work is a dynamic environment; crews regularly encounter small gaps, sequencing changes, and coordination needs. A multiskilled crew may be better positioned to respond to these conditions because workers can shift between related tasks as field conditions require. For this reason, multiskilling should be understood not only as a response to labor scarcity, but also as a project execution strategy that may improve the use of labor time during active construction operations.

Key Terminology Used in This Study

The terminology used throughout the report is provided in Table 1.

Table 1: Key Terminology

Term	Definition
Multiskilling	A workforce strategy in which workers are qualified to perform selected tasks safely and competently across more than one trade, craft, or skill classification.
Multiskilled worker	A worker qualified to perform selected tasks safely and competently outside the worker's primary trade.
Multiskilled crew	A crew containing one or more multiskilled workers who can perform selected tasks across more than one trade or skill classification.
Primary trade	The trade or role to which a worker was principally employed or assigned within the observed crew.
Cross-tasking	An observed instance in which a worker performs a task outside the worker's primary trade.
Cross-tasking share	The percentage of observed crew labor time classified as cross-tasking, estimated from work-sampling observations collected during the observation window.
Work-sampling observation	A recorded activity classification for one visible worker at a randomly selected observation interval.
Direct work	Time spent physically installing, assembling, removing, modifying, or otherwise completing the intended construction work.
Support work	Time spent on necessary activities that enable direct work, such as handling materials, obtaining tools, planning, coordinating, or traveling within the work area.
Idle time	Observed time during an active work period in which a worker was not performing direct or support work.
Crew-level work-time utilization	The distribution of a crew's observed labor time among direct work, support work, and idle time.
Work-time utilization	A percentage derived from work-sampling observations that describes how crew labor time was allocated among direct work, support work, and idle time.
Single-skilling	A workforce condition in which workers perform only work associated with their primary trade.
Single-skilled worker	A worker restricted to primary-trade work who does not perform cross-tasking.
Same-sequence single-skilled comparison	A structured counterfactual that holds the observed work sequence and site conditions constant while restricting workers to primary-trade work.
Equivalent single-skilled staffing requirement	The estimated worker-equivalent capacity needed to preserve the same observed work sequence under the same-sequence single-skilled comparison.
Equivalent staffing reduction (ESR)	The percentage by which the observed multiskilled crew size is smaller than the equivalent single-skilled staffing requirement.

SECTION 2

Review of Previous Studies

This section summarizes previous scientific studies and their findings related to multiskilling. Please refer to the fifth report in this series for full treatment of the prior literature.

Limitations of Existing Multiskilling Research

A systematic review of previous peer-reviewed studies on multiskilling in construction reveals a critical limitation: relatively few studies have attempted to quantify multiskilling's impact on project performance outcomes such as cost, schedule, productivity, or labor resources. Among the studies that did attempt to quantify performance impacts, only six used any form of data from onsite construction projects, and no U.S. construction projects were directly observed.

Most prior studies are derived from simulations and mathematical models. While these approaches offer useful theoretical insight, they depend heavily on the assumptions defined by researchers (such as assumptions about productivity, crew sizes, trade combinations, and project conditions) rather than on measurements taken from projects being built in the field.

Of the 23 studies that investigated project performance impacts, 6 did not incorporate contractor participation or cost estimates and were instead based upon scenarios that depended entirely on researcher-defined assumptions. The remaining studies that incorporated data from construction projects used it primarily as an input to broader simulations; their final analyses were not direct observations of multiskilled performance on real U.S. construction jobsites.

Although the literature does include site visits, interviews, and surveys, there has not been field-based measurement of project-performance outcomes on active U.S. jobsites. The industry still lacks direct U.S. project evidence showing how multiskilling performs in real construction conditions. Therefore, there is a need to prioritize the collection of field data from active construction projects in the U.S. market, which can then validate or challenge the theoretical findings that currently dominate the literature.

WHAT WE DON'T KNOW

Gaps in the Multiskilling Research

01 **Scarcity of project performance impacts:** few studies have attempted to investigate multiskilling's effect on project performance outcomes such as cost, schedule, and productivity.

02 **Heavy reliance on simulations:** most of these studies relied on computer simulations, mathematical models, or hypothetical scenarios.

03 **Almost no field data:** only 6 studies incorporated data from construction projects being built in the field.

04 **Zero U.S. construction projects:** None of the construction projects used for analysis were build in the United States, which is a major market for multiskilling activity.

05 **Heavy reliance on surveys and perceptions:** Much of the broader literature relies on questionnaire surveys and interviews, which captures attitudes and perceptions rather than measured performance impacts.

Prior Studies Found Many Benefits Yet Rely Heavily on Assumptions

While the evidence base has clear limitations, the existing literature is notably consistent in its assessment that multiskilling can lead to favorable project performance outcomes.

In schedule performance, 16 studies reported shorter project or production durations under at least one multiskilling strategy or scenario. Reported schedule reductions ranged from approximately 2% to 58%. No studies reported that multiskilling made schedules worse. However, all studies relied on scheduling models, simulations, optimization algorithms, or related analytical methods and generally lacked inputs from field data.

For cost, 11 studies examined financial impacts associated with multiskilling. Reported savings ranged from approximately 0.3% to 58%, while reported cost increases ranged from approximately 4% to 26%. Labor-cost and production-cost studies showed mixed results, with some multiskilling arrangements reducing costs and others increasing costs under different modeling assumptions and workforce configurations.

Productivity evidence remains especially thin: only three studies reported productivity-related outcomes, and these measured production-flow indicators such as throughput, waiting time, and cycle time rather than traditional field productivity. Reported improvements ranged from about 2% to 77%, including a 28% increase in daily throughput and reductions in waiting and cycle time. However, all three studies relied on simulation analysis rather than direct onsite comparisons showing more installed work per labor hour.

Studies examining staffing and workforce requirements reported reductions of approximately 2% to 53%, with an average reduction of about 39%. In four studies, multiskilling reduced the number of workers required or allocated, while one study found that it reduced the labor deficit under constrained conditions. These result ranges are wide because they reflect different simulation assumptions, project types, and degrees of multiskilling, but the overall direction is consistently positive.

The overall message is that the literature reports that multiskilling may achieve directly beneficial impacts to cost, schedule, productivity, and labor staffing requirements, but the magnitude of benefit varies widely because the studies use different assumptions, different project types, and different definitions of success.

WHAT PREVIOUS STUDIES CLAIM

Reported Performance Impacts of Multiskilling

2% to 58%
reduction in schedule durations

0.3% to 58%
decrease in costs

2% to 77%
improvement in production times

2% to 53%
reduction in staffing requirements

Addressing the Gaps in Previous Studies

A multiskilling approach can act through several mechanisms, each pointing to benefits worth investigating further. Figure 1 summarizes the logic by which cross-tasking in a multiskilled approach is expected to affect project outcomes. The center of the figure describes mechanisms, meaning changes to how the work gets done. Work shifts to where it is needed, because a crew with overlapping capabilities can redistribute tasks as field conditions change rather than standing by until the right trade arrives. Handoffs and the waiting that accompanies them are reduced, because small cross-trade tasks can be absorbed on the spot instead of being deferred to another crew's mobilization. And the same scope is covered by leaner crews, with fewer workers occupying the workface.

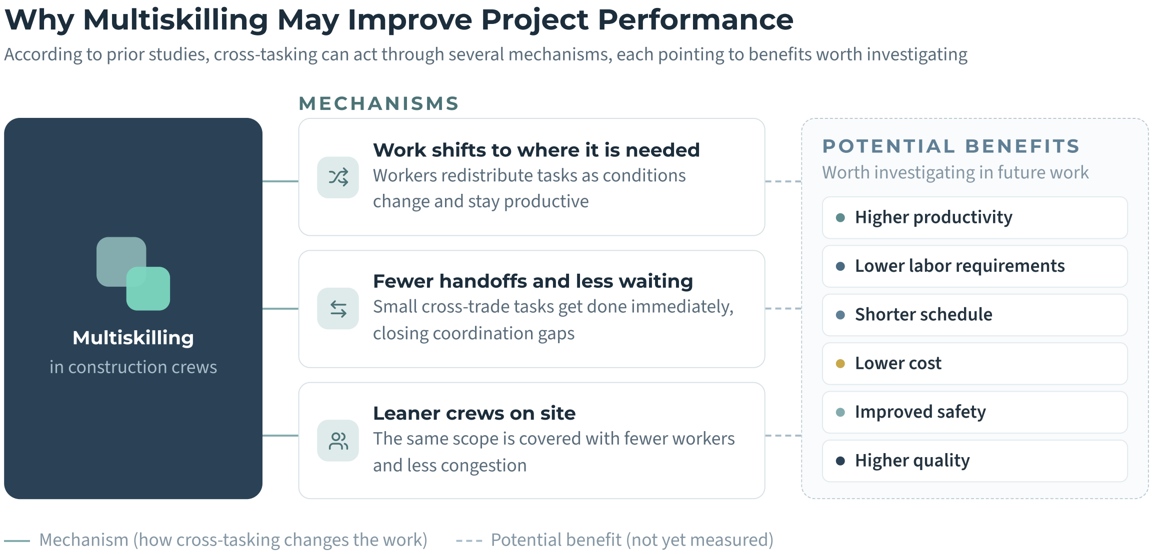


Figure 1: Mechanisms from the Literature which explain the Potential Benefits of Multiskilling

Each mechanism is well represented in the literature: reduced idle time and flexible reassignment are the central justifications offered by Burleson et al. (1998), Haas et al. (2001), and Hyari et al. (2010); reduced waiting from uneven trade durations is the mechanism Korb et al. (2019) and Barkokebas et al. (2023) model directly; and reduced staffing requirements are among the most frequently claimed benefits, with reported reductions of 18% to 53%. The right side of the figure lists the outcomes that would follow if those mechanisms operate as described. The arrows connecting them are dashed for a reason; these are benefits worth investigating, not benefits that have been measured in prior research.

The distinction matters because the prior literature has not established these outcomes empirically. Nearly all of this evidence is simulated. A small number of studies drew on field data, but in each case the data served as an input to a model rather than as an observation of a multiskilled crew performing work, and none of the projects were located in the United States. The consequences are visible in the reported results, which span wide ranges likely reflecting the assumptions each modeler selected more than they describe multiskilling. Establishing whether the mechanisms on the left of Figure 1 occur on real U.S. jobsites, and at what magnitude, is therefore a precondition for making any credible claim about the outcomes on the right.

Counterfactual Analysis as a Recommended Method of Analysis

A promising future approach to assess multiskilling's impact on project performance is counterfactual analysis. This approach is a structured "what-if" comparison in which researchers observe real work as it is naturally performed and then apply a single definitional constraint to ask what would have happened under a different workforce strategy.

For example, if field observations show a pipefitter erecting scaffolding between piping tasks, the counterfactual asks: what happens to crew-level work-time utilization if that worker is limited to primary-trade piping work and does not cross-task into scaffold erection activities?
This type of analysis is well-established in the social sciences as a rigorous method for measuring the effect of a practice when side-by-side controlled experiments are not practical (Shadish, Cook, and Campbell 2002), and is consistent with the "with-and-without" framework commonly used in engineering economics and project evaluation (Boardman et al. 2018).

Unlike simulation models that require researchers to build scenarios from many layered assumptions, a counterfactual approach begins with observed field data and then adjusts only the analytical lens through which the data is interpreted. Applying this methodology to multiskilling using work-sampling data from real crews and real trade combinations would produce findings directly traceable to jobsite conditions. A recommended analytical framework is illustrated in Figure 2.

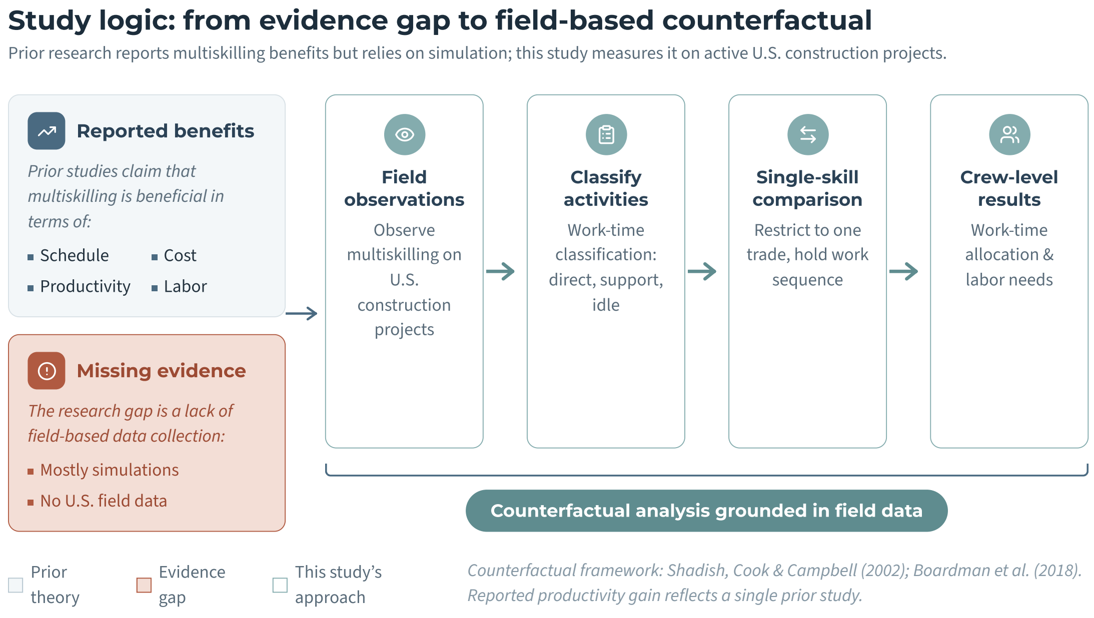
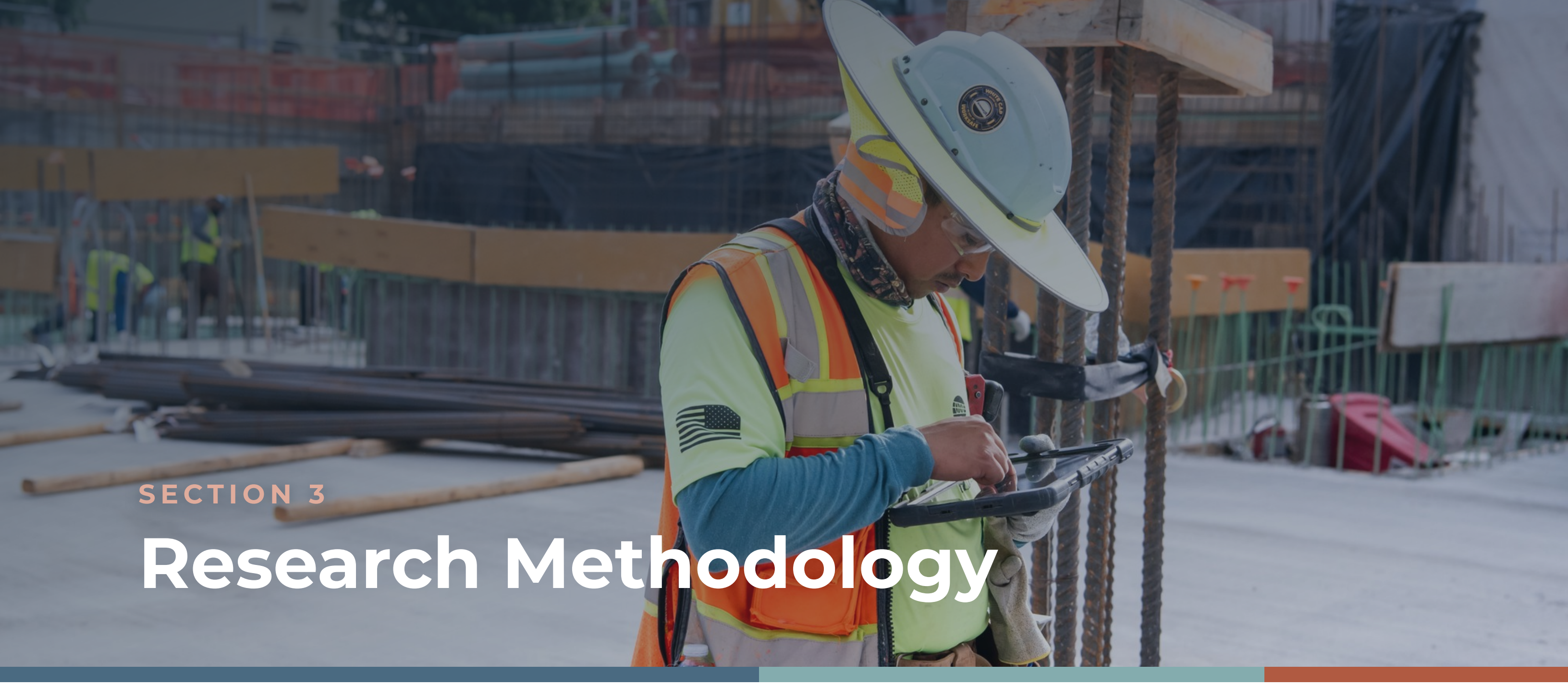


Figure 2: Recommended Analysis Framework to Address the Evidence Gap in the Current Literature



SECTION 3

Research Methodology

This section details the methodology used in the study, including the overall research objectives, protocols for on-site observations, work-sampling procedures, and method of analysis.

Objectives

The purpose of this study was to examine multiskilling as it occurs in construction activities on projects across the United States. The specific objectives were to:

- Document the extent to which multiskilled crews were observed to perform cross-tasking activities on active U.S. construction projects.
- Measure how multiskilling affects crew-level work-time utilization using work sampling data collected via field observations on active construction sites.
- Estimate the equivalent single-skilled staffing requirement needed to preserve the same observed work sequences without the use of cross-tasking.

Protocols for On-Site Data Observations

Field observations were conducted by trained construction researchers, including construction faculty, PhD-trained construction researchers, and doctoral students in construction-related fields.

The observation protocol was designed to measure the work-time utilization of multiskilled crews during active construction operations. Observation sessions generally lasted between 2 and 6 hours per project site, with several site visits extending across multiple workdays. Observations were conducted during normal work periods without altering crew composition or work sequencing. Within each site visit, observations were recorded at randomized intervals, typically every 2 to 5 minutes. At each random observation interval, observers recorded every visible worker in the selected crew or crews. In some cases, more than one crew was visible and recorded during the same observation interval.

Crews were purposively selected because they were performing work in a multiskilled manner. This sampling approach was appropriate because the purpose of the study was to measure multiskilling where it was occurring in practice.

Observed labor-hours were calculated by summing the observed duration for each individual worker. For example, if five workers were observed for three hours, the observation period produced 15 observed labor-hours. If the number of visible workers changed during an observation period, the labor-hour calculation reflected the actual observed duration for each worker rather than assuming a fixed crew size for the full session.

Field Observation Protocols

Typical observation interval:
every 2–5 minutes.

Researcher Time on Site:
2-6 hours, some across two workdays.

Site Conditions:
normal work periods.

Work-Sampling Procedures

A structured work-sampling approach was used to record worker activities at random intervals over extended observation sessions. Work sampling is a well-established method for measuring construction activity distribution and labor time utilization (Gong et al., 2011; Lee et al., 2024; Thomas 1991; Thomas and Daily 1983).

Researchers recorded the following information for each work-sampling observation:

1. **WORK-TIME UTILIZATION CLASSIFICATION**
   each worker's activity was classified in terms of the traditional work-sampling productivity measures of direct work, support work, or idle time.

2. **TRADE CLASSIFICATION**
   each observed activity was classified as a primary-trade or cross-tasking activity. A primary-trade activity was one that fell within the worker's primary trade, while a cross-tasking activity was one that fell outside the worker's primary trade.

This structure allowed each observation to be analyzed along two dimensions: the worker's activity status and the trade alignment of the task being performed. These classifications were recorded separately. For example, a cross-tasking activity could be classified as direct work if it advanced installed construction work, or as support work if it enabled direct installation. Idle observations were recorded as idle time during active work periods and were not treated as direct or support work.

Work-Time Utilization Classification

The work-sampling productivity classifications were based on traditional work-sampling techniques that have been used for decades in scientific literature (e.g. Oglesby, Parker & Howell 1989; Liou & Borcherding, 1986; Thomas et al., 1990). Definition and examples for each classification are shown in Figure 3. Rest breaks were included in the observations; however, lunch periods and extended breaks were excluded from the observation denominator. Therefore, idle time in this study refers to idle time observed during active work periods.

Work-Sampling Activity Definitions

Every observation is classified into one of three categories, ordered from value-adding work to non-productive time.

Direct work
Creates installed output

Tasks that physically install, assemble, fabricate, or directly advance final construction output.

EXAMPLES

Pouring concrete · Pulling wire · Hanging pipe · Installing insulation · Excavating foundations · Erecting steel · Hanging drywall · Framing carpentry · Installing ductwork · Welding metal

Support work
Enables direct work

Tasks necessary to enable or sustain direct work but that do not themselves create final installed output.

EXAMPLES

Material handling · Staging materials and tools · Form setup · Access preparation · Tool & equipment prep · Reviewing plans & specs · Relocating equipment · Transporting tools · Layout · Job-related planning

Idle time
No output produced nor enabled

Periods during active work time when workers were not engaged in direct or support activities.

EXAMPLES

Waiting for:

Access · Materials · Equipment · Inspection · Approval · Weather clearance · Coordination · Information · Another task

Personal and discretionary:

Socializing · Rest Breaks

Value-adding · Enabling · Non-productive

Figure 3: Work-Sampling Activity Definitions

Trade Classification

The trade classification of each worker was recorded in every site observation in two ways. First, the primary trade was noted as the trade or role classification in which the worker was principally employed or assigned to the observed project. Second, the trade which corresponded to the activity being performed by each worker was also classified in each observation. This means every observation was classified along two dimensions: the activity status of the worker (direct work, support work, or idle time), and the trade alignment of the task (primary-trade work or cross-tasking). These two classifications are separate. For example, a cross-tasking activity could be direct work if it advanced installed work, or support work if it enabled direct installation. Table 2 illustrates the trade classification framework.

Table 2: Examples of the Trade Classification Framework used in Field Observations

Activity	Direct work	Support work	Idle time
Primary-trade	Example: electrician installs conduit	Example: mason stages materials for own crew	Example: pipefitter waits for pipe material to be delivered for installation
Cross-tasking	Example: electrician operates excavator to dig a trench for conduit	Example: mason erects 60-foot-tall scaffolding	Example: pipefitter waits for insulation material that they will install

To improve consistency in activity and trade classification, the research team conducted a post-visit review of the recorded observations from each site visit. Multiple researchers reviewed the observations and resolved classification questions through consensus. An illustration of worker skill combinations observed in the study is provided in Figure 4.

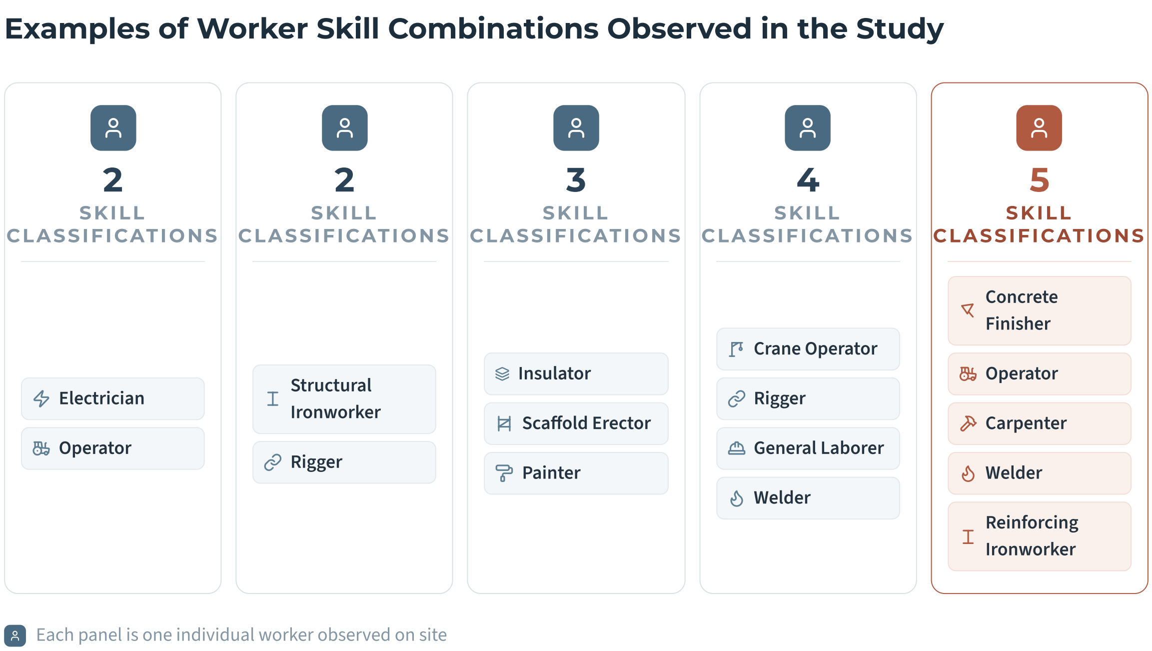


Figure 4: Examples of Worker Skill Combinations Observed in the Study

Trade and task classifications were assigned using a structured hierarchy of reference sources. The first reference was the Plan for the Settlement of Jurisdictional Disputes in the Construction Industry (Building and Construction Trades Department, AFL-CIO 2011), abbreviated hereafter as the Plan. In this study, the Plan was used as a primary reference for identifying conventional trade-task relationships only to support consistent classification of observed activities; the study does not take a position on craft jurisdiction, labor relations, work assignment policy, or the legal permissibility of any observed task assignment.

The Plan is a labor-management framework used to resolve disputes over which construction trade is properly assigned particular work activities on site. Its purpose is to provide an orderly, industry-recognized process for work-assignment disputes so projects can continue without strikes, stoppages, or disruption, while stabilizing construction employment and improving efficiency in the delivery of construction services. The Plan is a valid and respected source of industry norms because it was jointly established by the Building and Construction Trades Department, AFL-CIO (American Federation of Labor and Congress of Industrial Organizations), on behalf of national and local building trades unions, together with major employer associations; has been in effect since 1984; replaced earlier national dispute-resolution systems such as the Impartial Jurisdictional Disputes Board and the National Joint Board; and is published with formal procedural rules plus “Agreements and Decisions of Record” covering trade jurisdiction in the U.S. and Canada. Its decision criteria expressly rely on prior agreements, decisions of record, established trade practice in the industry, and prevailing local practice, which makes it directly relevant for explaining trade classifications and coding in a site visit report as grounded in recognized construction-industry practice rather than an ad hoc categorization.

When the Plan did not provide sufficient classification guidance for an observed activity, the research team consulted wage classifications using the federal wage determination database maintained on SAM.gov for the relevant county and construction type (U.S. General Services Administration, n.d.). These classifications were used as externally published job-role references, regardless of whether the observed project was federally funded or legally subject to Davis-Bacon requirements.

In some cases, especially in heavy civil contexts where the wage classifications provided in Davis-Bacon were more limited, the published classifications did not provide sufficient detail for the observed task. In those cases, the research team used conventional trade definitions from prior construction literature. Ambiguous classifications were reviewed by the research team and resolved through consensus.

Again it is noted that the use of the Plan, SAM.gov wage determinations, and prior trade literature was limited to research coding and classification. The study does not evaluate, endorse, or challenge any legal, contractual, jurisdictional, or labor-relations requirements governing work assignments.

Method of Analysis

This section describes the method by which the study calculated the primary outcome measures of crew-level work-time utilization and equivalent staffing requirements for the same-sequence single-skilled comparison.

Unit of Analysis

The crew was the primary unit of analysis. While the study recorded 11,407 individual work-sampling observations of individual workers, the overall results and statistical tests were calculated at the crew level using the 60 observed crews. Crew-level results were calculated first and then averaged across crews. This approach prevents crews with more workers, longer observation periods, or more individual observations from disproportionately determining the overall findings.

Statistical testing was also conducted using the crew as the unit of analysis. Therefore, the reported statistical results reflect variation across the 60 observed crews rather than treating each individual work-sampling observation as an independent data point.

Same-Sequence Single-Skilled Comparison

A counterfactual analysis was selected to answer the question: what happens to crew-level work-time utilization and equivalent staffing requirements if workers in a multiskilled construction crew are limited to their primary trade?

The method starts with thousands of real work-sampling observations collected by trained observers on active construction sites across the country. These observations capture exactly how work was being performed by real workers, on real projects, under real jobsite conditions. The underlying field observations remain unchanged. The analytical comparison applies a defined counterfactual reclassification or staffing estimate to those observations. The purpose of the analytical step is to ask: what would these same crews look like if multiskilling were not an option?

Counterfactual analysis is a type of structured comparison that is well-established in both the social sciences (Shadish, Cook, and Campbell 2002) and engineering economics (Boardman et al. 2018) as a rigorous way to measure the effect of a specific practice when a controlled side-by-side experiment is not practical.

The analysis uses two related but distinct counterfactual analyses. The first is a work-time utilization comparison. It holds the observed crew and work sequence constant and asks how the observed workers' time-use profile would change if they were restricted to primary-trade work. The second is an equivalent staffing requirement analysis. It asks how many additional single-skilled workers would be required to perform the cross-trade work that the multiskilled crew completed. The first comparison estimates crew-level work-time effects; the second estimates equivalent staffing requirements. The structure of the two analyses is shown in **Figure 5**.

How the Single-Skilled Comparison Works

Starting from real field observations, the analysis applies one rule: a *same-sequence* single-skilled worker can only do their primary trade.

STEP 1 · OBSERVED MULTISKILLED CONDITION

A worker performs a task outside their primary trade, when they are qualified to do so.

cross-tasking observed

↓ Apply the *same sequence* single-skilled comparison

STEP 2 · SAME SEQUENCE SINGLE-SKILLED COMPARISON

The same worker **cannot** perform that task, because cross-tasking does not occur.

Primary-trade only

two questions from one comparison

ANALYSIS 1 · WORK-TIME UTILIZATION

The same worker would not have performed the task, so that time is reclassified as idle, keeping the work sequence intact exactly as observed in the field.

Multiskilled work-time result: **+39% direct, 68% less idle**

ANALYSIS 2 · EQUIVALENT STAFFING

Another worker must perform that task, so additional equivalent single-skilled staffing is estimated

Multiskilled equivalent staffing reduction: **31% to 42% fewer workers**

The observed field data is never altered; the analysis only applies the *same sequence single-skilled* condition to it.

Figure 5: Field Observations as the Basis for Two Counterfactual Analyses

Assessing the Impact on Crew-Level Work-Time Utilization

To estimate what crew-level work-time utilization would look like without multiskilling, the analysis applies one definitional constraint: a single-skilled worker can only perform tasks within their primary trade. The observed work sequence is held constant, and all primary-trade observations remain exactly as recorded in the field.

When a worker was observed performing a cross-tasking activity, that activity was reclassified as idle time for the same worker under the same-sequence single-skilled comparison. This does not claim that a contractor would always leave the worker idle in practice. Rather, it isolates the effect of removing cross-tasking while holding the observed crew, work sequence, and field conditions constant. The result is two comparable work-time profiles for the same crew performing the same observed work sequence: one reflecting the multiskilled conditions directly observed, and one reflecting the same-sequence single-skilled comparison. All primary-trade observations remain exactly as they were recorded in the field.

This comparison is reasonable because the field data reflects the natural flow of work for the observed multiskilled crews. Workers performing cross-tasking activities were doing so as part of the ongoing work sequence their crew was already performing. The analysis intentionally holds that sequence constant to isolate the effect of removing cross-tasking from the observed crew.

In practice, a contractor might respond to a primary-trade restriction represented by the same-sequence single-skilled comparison in several ways, including adding another worker, resequencing work, moving workers to another area, or delaying the task until the appropriate trade is available. Those alternatives are not modeled here. Instead, the comparison asks a narrower and more defensible question: how did cross-tasking affect the observed crew's work-time profile during the work sequence that actually occurred on site in the natural flow of construction activities?

Assessing the Impact on Equivalent Staffing Requirements

The equivalent staffing requirement analysis estimated how many single-skilled workers would be needed to preserve the same observed work sequence if workers were limited to their primary trade. This is relevant because removing multiskilling from a crew does not eliminate the need for cross-trade work; instead, it just means someone else must do it. Cross-tasking activities completed by the multiskilled crew were converted into equivalent single-skilled staffing requirements.

The analysis estimated how many additional single-skilled workers would be needed in the same work sequence using two estimation methods to create lower- and upper-bound equivalent staffing requirements. The lower bound is treated as the default assessment technique throughout this study. Together, these bounds provide a practical range reflecting how a contractor would likely need to staff a single-skilled crew to accomplish the same scope of work.

Lower-bound equivalent staffing requirement: The total cross-tasking work volume in each trade was aggregated across all workers in the crew and converted into observation-window worker-equivalents. Multiple workers could cross-task in the same trade, but their combined work volume might require less than one additional worker-equivalent. The estimate therefore represents the minimum equivalent single-skilled staffing capacity needed to cover the observed cross-trade work. It is an FTE-based observation-window estimate, not a prediction of the number of whole workers a contractor would hire or assign over a full project. Crew-level estimates were calculated for each of the 60 analytical crews and then summarized across crews. An illustrative example of the lower bound labor equivalent is shown in Figure 6.

Illustration of the Lower-Bound Equivalent Staffing Requirement

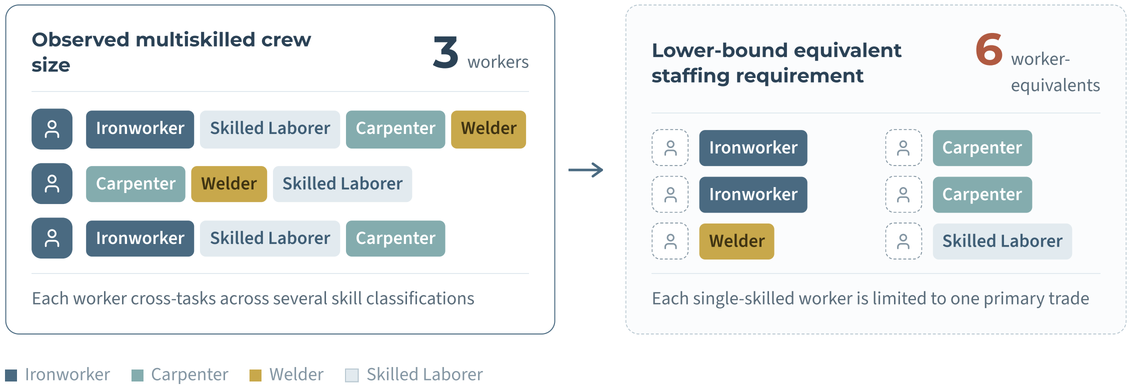


Figure 6: Illustration of the Lower-Bound Equivalent Staffing Requirement

Upper-bound equivalent staffing requirement: Each distinct cross-tasking trade observed on a crew requires the addition of one single-skilled worker. If a multiskilled crew cross-tasks into three different trades, then three workers are added. The upper-bound estimate represents a stricter single-skilled staffing condition in which each distinct cross-tasking trade would require separate staffing to preserve the observed work sequence. Together, the lower- and upper-bound estimates provide a practical range for interpreting how much additional single-skilled staffing capacity would be required to complete the same observed work without multiskilling.

The equivalent staffing reduction at the crew-level was calculated via **Equation 1**.

$$\text{ESR } (\%) = \frac{SS - MS}{SS} \times 100$$

Equation 1: Equivalent Staffing Reduction

where:

- ESR (%) = percentage by which the observed multiskilled crew size is smaller than the equivalent single-skilled staffing requirement, calculated relative to SS
- SS = equivalent single-skilled staffing requirement, in worker-equivalents
- MS = observed multiskilled crew size, in workers

This formula was calculated for each crew and then summarized across the 60 analytical crews. The result is a crew-level ESR, not a project-wide headcount or cost-savings estimate. For example, if the observed multiskilled crew size is 3 workers and the equivalent single-skilled staffing requirement is 6 worker-equivalents, ESR is 50%. This means that the observed multiskilled crew size is 50% smaller than the corresponding equivalent staffing requirement for the same observed work sequence.

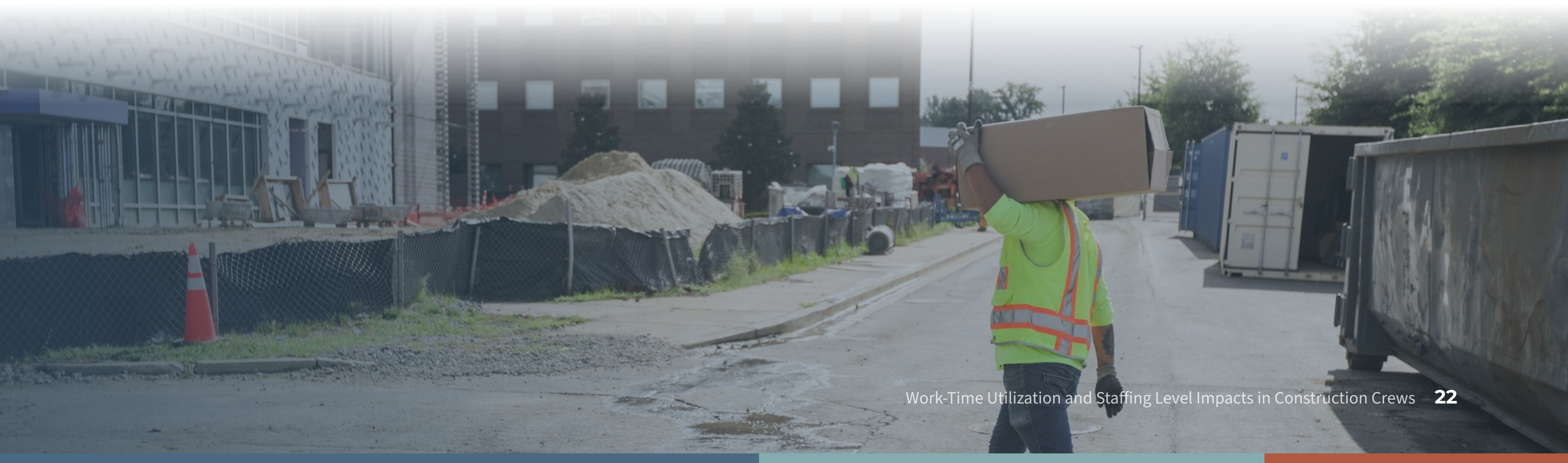
The inverse relationship can also be derived to report the additional workers required in the single-skilled comparison relative to the multiskilled crew size that was directly observed in the field. Taking the prior example, an observed multiskilled crew of 3 required an additional 3 worker-equivalents, which is equivalent of requiring a 100% crew size increase be for the single-skilled comparison to perform the same work sequence that was observed in the field.

How This Differs from Prior Research

Prior studies examining multiskilling's impact on project performance have relied almost entirely on simulation and optimization models, in which researchers construct project scenarios and test multiskilling under defined assumptions about crew composition, productivity rates, learning curves, and project schedules. While useful for theoretical insight, small changes in inputs can produce dramatically different results (as shown by the range of cost, schedule, and labor resource data reported in the prior literature).

This analysis takes a fundamentally different approach. The field data consists of thousands of individual observations across dozens of projects and is not modified, supplemented with assumed values, or fed into an optimization model. Every finding is directly traceable to observed jobsite conditions, not to how a model predicts work might be performed under theoretical conditions.

The only analytical step is the application of a single definitional constraint: single-skilled workers cannot perform cross-trade tasks. The key analytical boundary is that the comparison preserves the observed work sequence. It does not attempt to simulate all possible contractor responses to the primary-trade restriction represented by the same-sequence single-skilled comparison, such as resequencing, reassignment, or changes in supervision. This makes the comparison narrower, more transparent, and directly traceable to observed field conditions.



SECTION 4

Field Observations Dataset

This section details the dataset collected during the study, including the project selection and sampling approach, observed projects and site visits, and relevant quantities to describe the size and extent of the data collected.

Project Selection and Sampling Approach

Projects were selected using a purposive sampling strategy, a well-established method for studying specific phenomena that do not occur uniformly across a population (Patton 2015; Creswell and Creswell 2018). Because multiskilling is not universally practiced across the U.S. construction industry, a random sample of projects would likely yield many crews that do not use multiskilling at all, making it impossible to observe the very practice that is the focus of this research. The research team therefore sought projects where multiskilling was actively occurring so that cross-trade work could be observed and measured as it naturally takes place on active jobsites.

Project Types where Multiskilling was Observed

Waste Water Treatment	Laboratory	Manufacturing
Industrial	Multi-Family Residential	Commercial
Hotel & Lodging	Heavy Civil	Roadway
Rail	Substation	Fuel
Data Center	Amusement Park	Hospital
Power Generation	Bridge	Airport
Sports & Recreation	Library	Prefabrication Facility
Military		

Observed Projects and Site Visits

The resulting sample included 36 projects which were observed during 40 site visits, with a small number of projects visited more than once. These projects spanned 24 states as shown in Figure 7. Observations included 30 different contractors and 22 distinct project types representing a substantial cross-section of the work that the U.S. construction industry builds. Project sizes ranged from less than one million dollars to multi-billion-dollar megaprojects.

The diversity of the sample demonstrates that multiskilling was observed across a wide range of U.S. construction contexts. The findings are most directly relevant to projects where contractors have the workforce flexibility, training, supervision, and contractual conditions needed to deploy cross-tasking crews safely and effectively.

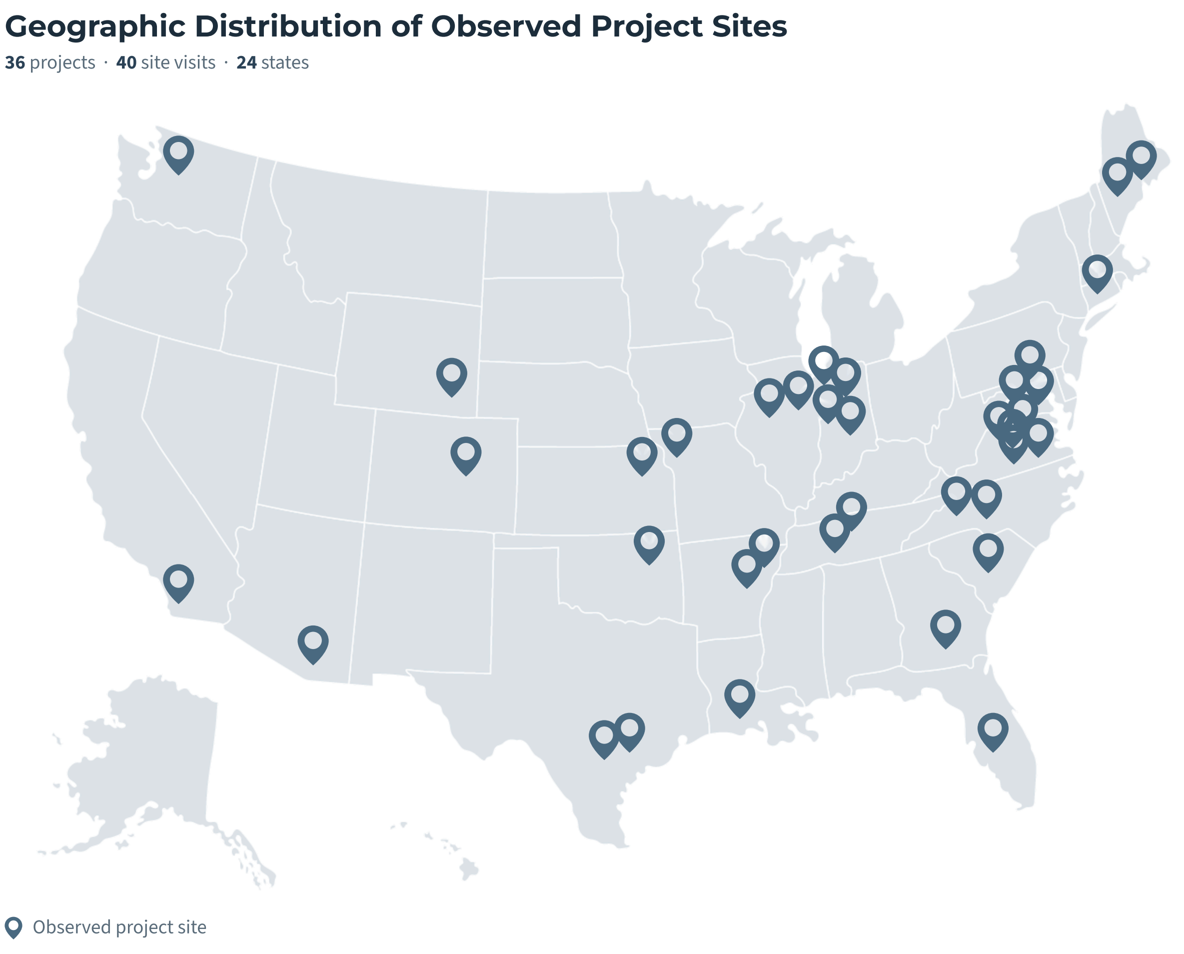


Figure 7: Geographic Distribution of Observed Project Sites

Across the sites, 60 multiskilled construction crews consisting of 644 individual workers were observed as part of the work-sampling method used to measure crew-level work-time utilization and cross-tasking as it occurred in the field.

The research team performed observation sessions at each site ranging from multiple hours to multiple days, with an average of 5 hours of non-break observation time per site visit. Work activities reflect tasks performed by workers during normal site operations.

During these sessions, 11,407 individual work-sampling observations were recorded, corresponding to 2,757 labor-hours of observed on-site work performed by the multiskilled workers who were observed.

A summary of the workforce and observation effort is provided in **Table 3**. These values represent the overall volume of field activity captured across sites rather than intensive observation at a small number of projects. The field-observation dataset describes the full site-visit data-collection effort. The analytical crew sample consisted of the 60 multiskilled crews used in the crew-level outcome calculations and statistical testing.

Table 3: Summary of Field Observations

Total site visits by the research team	**40**
Total projects visited	**36**
Unique project types observed	**22**
Number of U.S. States included in observations	**24**
Number of participating contractors	**30**
Multiskilled Crews Observed	**60**
Individual Workers Observed	**644**
Typical Crew Size	**~6 workers (range from 2 to 32)**
Work Sampling Observations	**11,407**
Observed Labor-Hours During Active Work Periods	**2,757**

SECTION 5

Results

This section details the key findings of the study, including the extent of cross-tasking that was observed in multiskilled crews and the impact of multiskilling on both endpoints of work-time utilization and lower-bound and upper-bound ESR.

Extent of Cross-Tasking Observed in Multiskilled Crews

Across the site visits, individual workers representing 26 unique primary trades were observed to participate in more than 100 unique skill combinations. During the observed work periods, individual workers performed an average of 2.7 distinct skill classifications, with several workers reaching six unique skill classifications within a single observation period. These observations illustrate that, among crews where multiskilling was occurring, cross-tasking was a routine part of work execution rather than an isolated exception.

The degree of multiskilling varied across crews. The crew-level cross-tasking share averaged 36% and ranged from 2% to 96%. A crew-level value of 2% means that no cross-tasking was recorded for that crew during its observation window; a value of 96% means that all recorded crew labor time was classified as cross-tasking. This range indicates that multiskilling was applied to site-specific conditions; in any given day that was observed, some crews relied on cross-tasking minimally whereas others used it extensively.

The observed variation suggests that multiskilling is best understood as a context-dependent practice shaped by project demands and work organization rather than a standardized approach applied uniformly across sites.

These findings show that multiskilling occurs with measurable frequency on U.S. construction projects and reflects a project-specific approach to optimize workflow under real project conditions.

Unique Skills Observed During Site Visits

CARPENTRY & FINISHING

Carpenter · Drywaller · Framer · Insulator · Painter · Tile Installer · Tile Finisher

MECHANICAL & ELECTRICAL

Electrician · Pipefitter · Plumber · Sheet Metal / HVAC Worker · Sub Station Technician

LABORERS

Concrete Pipe Layer · Flagger · General · Skilled · Utility

HEAVY CIVIL & STRUCTURAL

Concrete Finisher · Ironworker (reinforcing) · Ironworker (structural) · Rigger · Scaffold Erector · Surveyor · Teamster · Welder

OPERATORS

Boat Captain · Crane · Crawler · Excavator · Forklift · Hauler · Loader · Low Boy · Maritime Boat Captain · Roller Compactor · Skid Loader · Steam Roller · Telehandler · Trackhoe · Trench Roller

Impact of Multiskilling on Crew-Level Work-Time Utilization

Clear differences in crew-level work-time utilization emerged between the observed multiskilled crews and the same-sequence single-skilled comparison. Analysis across the 60 observed crews showed the following results:

1 DIRECT WORK INCREASE

Multiskilling resulted in an average 13-percentage-point increase in the proportion of observed time spent on direct work, with a full crew-level range from 0 to 63-percentage points. This corresponds with an average 39% increase in multiskilled crew time spent on direct work. These results represent situations in which workers were able to continue direct work by performing qualified cross-tasking activities rather than waiting for another worker, trade, or crew to become available.

2 IDLE TIME DECREASE

Multiskilling resulted in an average 31-percentage-point lower idle-time share during active work periods, with a full crew-level range from 2 to 92-percentage points. This corresponds with an average 68% decrease in multiskilled crew time spent on idle activities during active work periods. These results suggest that multiskilling allowed crews to address short-duration or adjacent tasks more quickly, reducing waiting time that would otherwise accumulate under strict trade boundaries.

Statistical Testing of Work-Time Utilization Results

Statistical testing was performed using the crew as the unit of analysis. The differences in direct-work time and idle time between observed multiskilled crews and the same-sequence single-skilled comparison were statistically significant beyond the 99% confidence level ($p < 0.001$). This supports the conclusion that the observed crew-level work-time differences are unlikely to be explained by random variation across the 60 observed crews. Results from Wilcoxon signed-rank testing are shown in **Table 4**.

Table 4: Statistical Testing for Work-Time Utilization Results

Result	Unit of analysis	n	Mean effect	95% CI	Standardized Wilcoxon statistic (Z)	p-value
Direct work increase	Crew	60	+13-percentage-points	+9 to +17 pp	-5.713	**< 0.001**
Idle time decrease	Crew	60	-31-percentage-points	-25 to -37 pp	6.737	**< 0.001**

Impact of Multiskilling on Equivalent Staffing Requirements

The equivalent staffing requirement analysis compared the observed multiskilled crew size with the equivalent single-skilled staffing requirement needed to preserve the same observed work sequence without cross-tasking. For each crew, ESR was calculated relative to the corresponding equivalent single-skilled staffing requirement. Thus, an ESR of 40% means that the observed multiskilled crew size was 40% smaller than the equivalent single-skilled staffing requirement. Crew-level ESR values were calculated for each of the 60 analytical crews and then summarized across crews. The lower-bound ESR averaged 30.7%, rounded to 31%, and the upper-bound ESR averaged 41.9%, rounded to 42%.

Converted to their additional staffing requirements, the results showed that limiting workers to one trade would require approximately 45% to 72% more workers to accomplish the same work sequence that was observed in the field. For example, a crew of 10 multiskilled workers provided the work coverage that would otherwise require approximately 14 to 17 workers limited to one trade.

As shown in Table 5, the reduction was statistically significant across the 60 multiskilled crews (Wilcoxon signed-rank test, one-sided, $p < 0.001$) and was observed in essentially every crew, with no observed multiskilled crew requiring more workers than its equivalent single-skilled staffing requirement. This range should be interpreted as a crew-level ESR estimate, not as a project-wide headcount, hiring forecast, or cost-savings estimate.

Table 5: Statistical Testing of ESR Results

ESR Estimate	n	Mean ESR	Median ESR	Hodges-Lehmann	95% CI	W	p (one-sided)
Lower-bound ESR	60	30.7%	33.3%	30.6%	22.5% to 39.5%	1540	**< 0.001**
Upper-bound ESR	60	41.9%	45.4%	41.7%	33.3% to 50.0%	1830	**< 0.001**

The largest opportunity for multiskilling to reduce the number of workers required was in cases when crews had frequent task handoffs or coordination of the work sequence among multiple interrelated trades, where multiskilled workers were able to complete short-duration or intermittent tasks without interrupting production.

Examples include:

- A crew of concrete finishers who built and stripped forms, tied rebar, welded anchor bolts, and operated various types of heavy equipment.
- A crew of insulators who applied paint coatings and later mixed and applied epoxy flooring materials.
- A crew of sheet metal workers who also erected scaffolds, insulated pipes, and performed pipefitting activities.
- A heavy civil crew whose workers interchangeably performed rigging, crane lifts, welding, and pile-driving activities.

These findings indicate that multiskilling provides a substantial opportunity to improve crew-level staffing flexibility in a wide variety of construction project contexts.

SECTION 6

Discussion

This section discusses what the findings mean at the crew level, why the results vary by context, the relationship between the results and prior literature, and practical implications for both contractors and owners.

What the Findings Mean at the Crew Level

The findings indicate that multiskilling is most directly understood as a crew-level labor flexibility strategy. In the observed crews, workers were not simply performing unrelated tasks at random; rather, they were often shifting into adjacent or supporting tasks that allowed the crew's work sequence to continue. Under the study's same-sequence single-skilled comparison, those cross-tasking intervals would have required either waiting, resequencing, reassignment, or the presence of additional single-skilled workers. The measured effect was an increase in direct-work time, a reduction in idle time, and a reduction in equivalent staffing requirements as summarized in Figure 8.

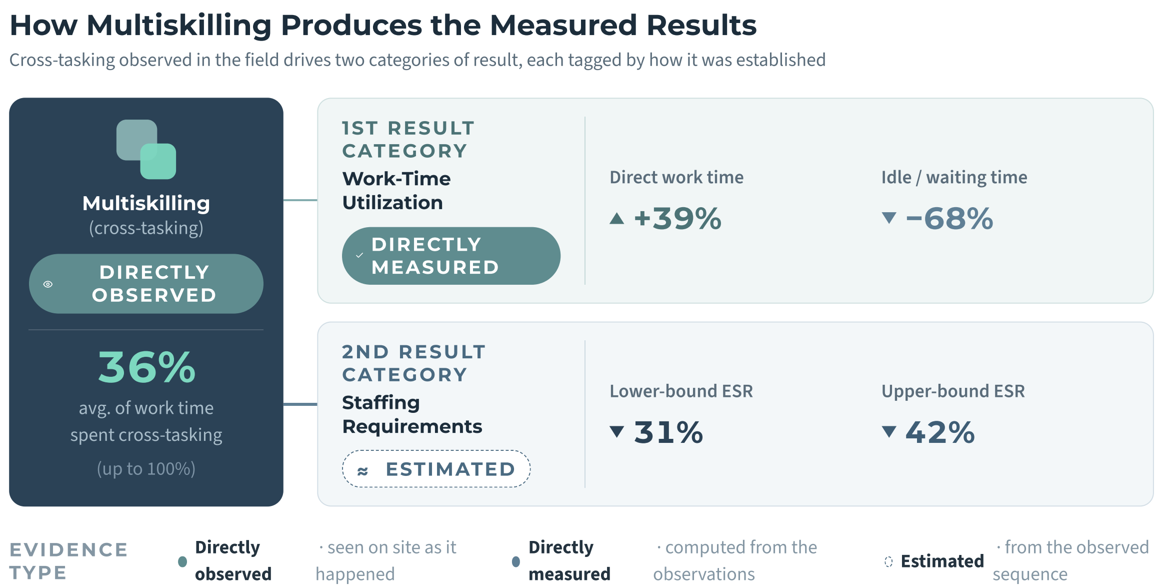


Figure 8: Summary of Findings

These results suggest that multiskilling can improve how crews use available labor time during active construction operations. The primary contribution of the study is not that it proves project-wide cost or schedule savings, but that it provides field evidence showing how multiskilling changes the work-time profile of construction crews. In practical terms, multiskilled workers can help close short workflow gaps by performing necessary tasks that would otherwise require another trade, another worker, or another crew to become available.

Why the Results Vary by Context

The results also show that multiskilling is context-dependent based on the project-specific circumstance, particular scope or assembly being constructed, and trade combinations observed. The magnitude of observed benefit varied substantially across crews, which indicates that multiskilling should not be treated as a uniform practice that produces the same effect in every setting. Its value depends on the structure of the work, the frequency of task handoffs, the degree of interdependence among activities, the specialization required for the work, and the contractor's ability to assign workers safely and competently across task boundaries.

Figure 9 provides a summary of the relationship between the time each crew spent on cross-tasking activities and the corresponding values for the gain in direct work time, reduction in idle time, and lower-bound ESR. Some crews cross-tasked only occasionally (a few percent of observations); others did so nearly all the time. The three lines trace how each measured benefit changes across that range.

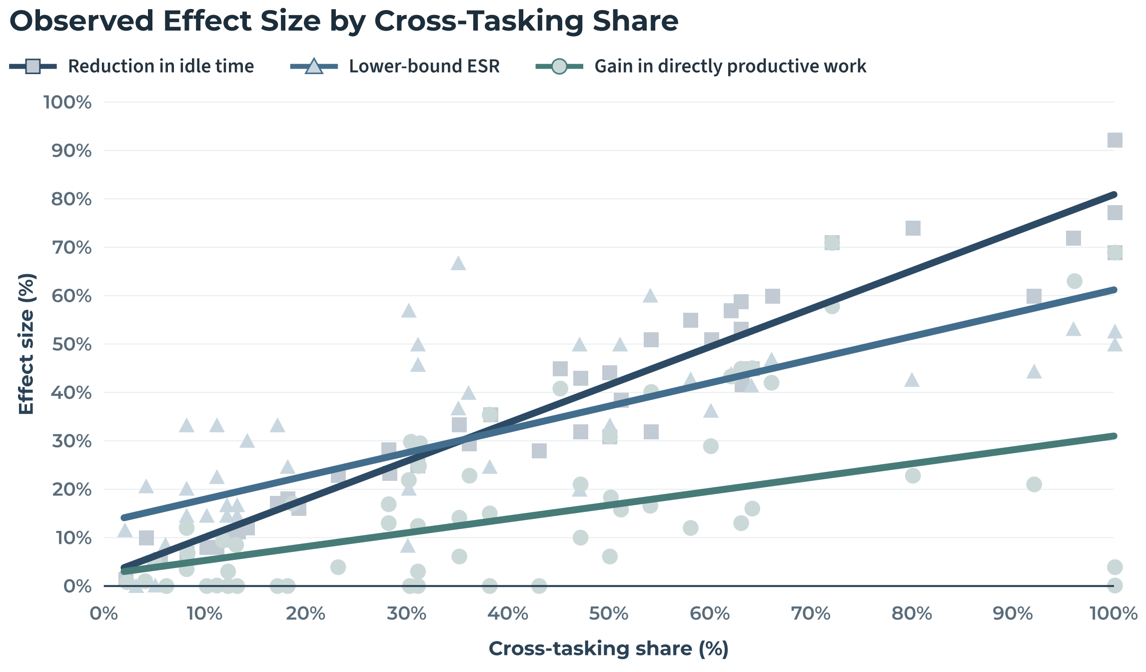


Figure 9: Relationship between the amount of cross-tasking and multiskilling benefits across 60 construction crews

The pattern is consistent across all three measures: the more crews cross-tasked, the larger the benefit. Crews in the low band (20% of time or less) showed a median idle-time reduction of 8 percentage points and a median lower-bound ESR of about 17%. In the moderate band (over 20% up to 50%), those medians rose to 30 points and roughly 35%. In the high band (over 50%), they reached 59 points and about 44%, with direct work time up by a median of 21 percentage points. As a rule of thumb from the fitted trends, every additional 10 percentage points of time spent cross-tasking was associated with roughly 8 points more idle-time reduction, 3 points more direct-work gain, and a 4- to 5-percentage-point higher lower-bound ESR. Notably, the benefits were not confined to heavy cross-tasking crews: 20 of the 23 low-band crews still had a positive lower-bound ESR, and no crew in the study required more workers than its equivalent single-skilled staffing requirement.

Therefore, a useful way to describe the range in observed effect variation is in terms of the opportunity to cross-task that each project presents. Opportunity here refers to how much the work itself invites cross-tasking: the variety of adjacent tasks a qualified crew encounters and the natural gaps in pacing that allow effort to be shifted to where it is needed. **Figure 10** profiles three field-observed crews arranged from high to limited opportunity, and that same ordering governs the magnitude of every effect, even though all three crews were skilled and worked across trades.

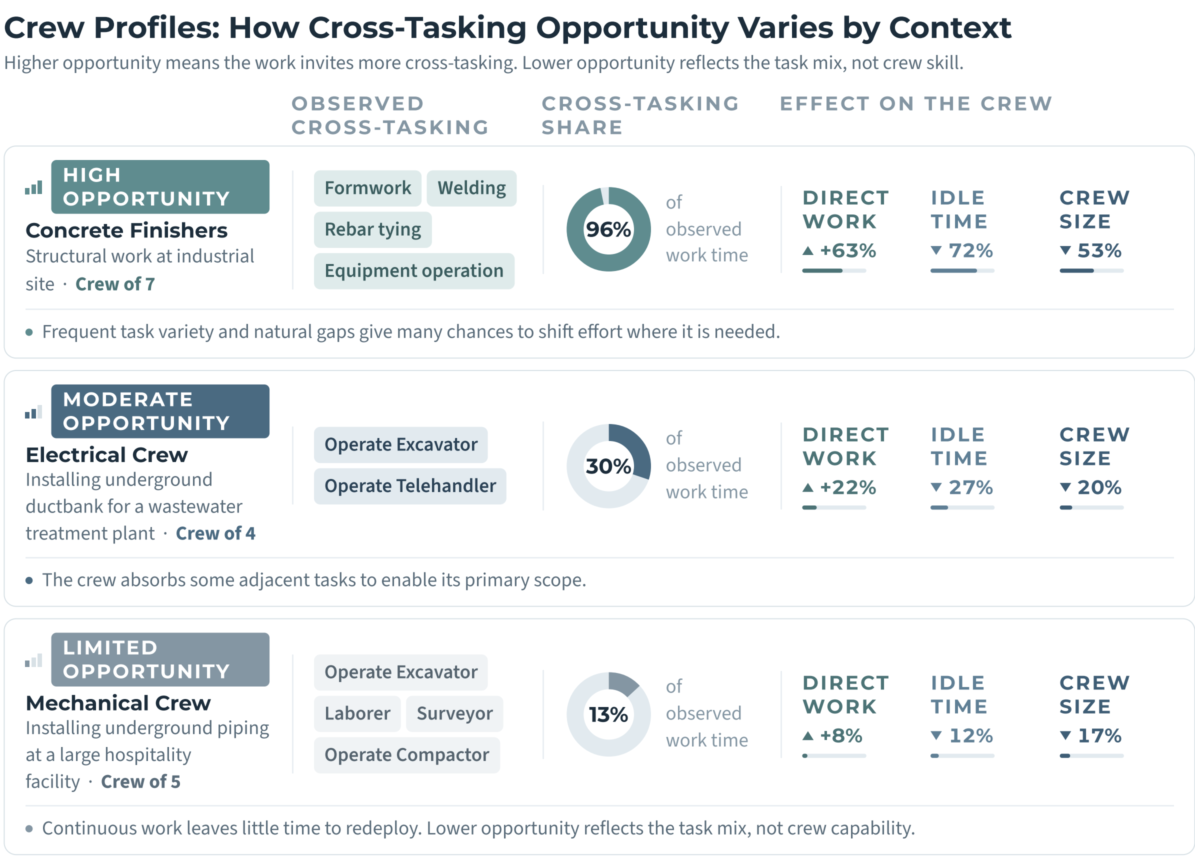


Figure 10: Example Crew Profiles for How Cross-Tasking Opportunity Varies by Context

- The Concrete Finishers crew, performing varied structural work at an industrial site, sit at the high end: cross-tasking occupied 96% of their observed work time, and the crew shows the largest effects across every measure, with direct-work time up 63-percentage-points, idle time down 72-percentage-points, and a lower-bound ESR of 53%.
- The Electrical Crew installing underground ductbank falls in the middle, cross-tasking during 30% of observed time and absorbing a few adjacent tasks to keep its primary scope moving, with more moderate effects (direct work up 22-percentage-points, idle time down 27-percentage-points, ESR of 20%).
- The Mechanical Crew running continuous underground piping sits at the limited end, cross-tasking only 13% of the time and showing the smallest effects (direct work up 8-percentage-points, idle time down 12-percentage-points, ESR of 17%).

The equivalent single-skilled staffing requirement that each scope would otherwise require follows the same pattern, largest for the high-opportunity crew and smallest for the limited one. Critically, the low figure for the Mechanical Crew is not a sign of a weaker crew: continuous, single-focus work simply leaves little slack to redeploy, so it reflects the task mix, not crew capability.

This pattern points to the conditions under which multiskilling is most and least valuable. Multiskilling is likely to be most valuable where work consists of short-duration, sequential, or interdependent tasks. In these situations, the inability to perform a small adjacent task can create waiting time that is disproportionate to the task itself, and a qualified crew that can absorb that task converts the wait into productive work. Multiskilling may be less beneficial where work is highly specialized, continuous, heavily regulated, or already organized around efficient single-trade production with limited waiting or handoff losses.

The variation in findings should therefore be interpreted as useful information rather than as a weakness of the study. It shows that the practical value of multiskilling depends on where and how it is deployed, and that there is no single, transferable effect that policy can assume or mandate. Multiskilling is better understood as a strategy that morphs to the opportunity a given project presents, delivering substantial gains where the scope is varied and gap-rich and comparatively little where it is continuous and tightly sequenced. This has a direct implication for how constraints on cross-tasking are evaluated. Limiting a crew's ability to work across trades, where its members are qualified to do so, does not carry a uniform cost: the impact is minimal on low-opportunity scopes but potentially large on high-opportunity ones, where restricting that flexibility forgoes exactly the shifts that convert idle time into productive work and ease staffing pressure. Judging multiskilling by any single project, or applying a blanket rule across all of them, therefore risks both overstating its effect where opportunity is low and understating the cost of restricting it where opportunity is high. The results support a targeted implementation approach: multiskilling should be considered for scopes where cross-tasking opportunities are frequent, safe, legally permissible, and operationally useful.

Relationship to Prior Literature

These findings help clarify the relationship between field evidence and prior multiskilling research. Much of the prior literature has used simulations, mathematical models, optimization techniques, or hypothetical crew configurations to estimate the potential benefits of multiskilling. Those studies have been useful for showing that multiskilling can theoretically reduce crew staffing requirements, improve schedules, or increase productivity under certain assumptions. However, simulation-based findings depend heavily on the assumptions built into the model, including assumptions about crew size, task duration, trade combinations, productivity rates, and project sequencing.

The present study contributes a different type of evidence. Rather than modeling how multiskilling might perform under theoretical conditions, this study measured multiskilling as it occurred on active U.S. construction projects. The field observations show that cross-tasking is not only a theoretical workforce strategy; it occurs in real project settings and can be measured at the crew level using structured work-sampling methods.

At the same time, this study should be viewed as complementary to prior simulation research rather than as a replacement for it. Field observations provide evidence of real work-time behavior, while simulation and optimization models can test how those behaviors might scale across longer project durations, different crew configurations, or alternative sequencing scenarios. Future research can build on this study by using field-observed data to calibrate more realistic project-level models.

Potential Relationship with Safety, Quality & Schedule

While this study did not directly measure safety, quality, or schedule outcomes, the findings related to crew-level work-time utilization and equivalent staffing requirements suggest plausible mechanisms that may affect those outcomes. These implications should be interpreted as hypotheses for future validation rather than as direct findings of this study.

Prior research on crowding (also directly named as "overmanning" in prior research, which refers to adding workers beyond suggested staffing ratios) and trade stacking (when multiple trades or crews are scheduled to work in the same limited physical space simultaneously) provides a useful lens for interpreting why fewer required workers, fewer handoffs, and reduced idle time may matter beyond the crew-level measures captured in this study.

- Crowding has been associated with productivity losses of 0% to 41% (Hanna et al., 2007), and ELECTRI International and NECA (2007) identified higher accident rates, rework, and communication breakdowns as direct consequences of excess workers on site, driven by the congestion and supervisory dilution that additional headcount creates. In these prior studies, crowding refers to the addition of workers to a single trade's crew beyond the optimal size needed to perform the work within the allocated timeframe, resulting in a peak-to-average staffing ratio that exceeds planned levels.
- Trade stacking produces median productivity losses of 24% to 32% (ELECTRI International & NECA, 2018; Hanna, 2009), and both Toole (2005) and Mahamid (2020) linked excessive workforce loading and poor inter-trade coordination to rework and quality defects. Prior studies define trade stacking (also known as overcrowding) as occurring when craftsmen from multiple different trades are working simultaneously in the same physical work area, reducing the available square footage per worker and creating inter-trade congestion and coordination demands. These prior studies typically investigated each trade operating as separate crews often employed by separate contractors (e.g. in line with a single-skilled labor strategy). Conversely, the present study directly observed a multiskilled labor strategy wherein contractors deployed crews qualified to safely and competently perform tasks across multiple trade categories.

DOCUMENTED IN PRIOR RESEARCH

Productivity Losses When Trades Crowd the Workface

0% to 41%
productivity losses associated with crowding
(Hanna et al., 2007)

24% to 32%
median productivity losses from trade stacking
(ELECTRI International & NECA, 2018; Hanna, 2009)

The present study's findings suggest that multiskilling may simultaneously lessen the negative impacts from both crowding and trade stacking:

- The potential for multiskilling to require fewer workers on site reduces the physical congestion and coordination burden that prior research has tied to safety incidents, quality failures, and schedule erosion
- The observed gains in productive work time and reduction in idle time indicate that multiskilling has the potential to improve site efficiency and reduce coordination time between separate trades.

Taken together, the results suggest plausible mechanisms through which multiskilling may influence safety, quality, and schedule performance: fewer required workers, fewer handoffs, less waiting, and reduced inter-crew coordination. However, this study did not directly measure safety, quality, or schedule outcomes. Future research should directly test whether the crew-level mechanisms observed in this study translate into measurable project-level performance improvements.

PLAUSIBLE MECHANISMS

From Crew-Level Effects to Project Outcomes

Multiskilled crews → Fewer required workers | Fewer handoffs | Less waiting | Reduced inter-crew coordination → **Safety, quality & schedule performance**

SECTION 7

Practical Implications

The implications below include direct applications of the measured findings and practical implications suggested by the amount of multiskilling observed in the field.

Shared Principles Across All Stakeholders

1. Target the right work.

The measured effects varied considerably across the observed crews. The largest opportunities appeared where work involved task variety, short interdependent activities, frequent trade interfaces, and realistic opportunities for qualified workers to shift among related tasks. Multiskilling should therefore be treated as a targeted workforce strategy rather than a universal approach for every worker, scope, or project.

2. Plan the interfaces between traditional trades.

Cross-tasking represented more than one-third of observed crew work time. When that cross-tasking was removed in the same-sequence comparison, direct-work time declined and idle time increased substantially. Trade handoffs, small adjacent tasks, work-area access, and waiting for another trade should therefore be treated as crew-planning issues. Where qualified workers can complete an adjacent task, the crew may be able to continue advancing the work rather than stopping or waiting.

Shared Principles

01 Target the right work.

02 Plan the interfaces between traditional trades.

Individual Workers

The field observations show that multiskilling was not limited to occasional assistance outside a primary trade. Work beyond the primary trade represented a substantial share of normal crew operations, and many workers used several skill classifications during the observed periods.

1. More opportunities to earn hours on the project.

Cross-tasking accounted for 36% of observed crew work time, indicating that a sizeable share of the work available to the observed crews extended beyond each worker's primary trade. A worker who is qualified to perform selected complementary tasks may be able to contribute to more of the available work, remain productive when primary-trade work temporarily slows, and earn more hours on the project while helping the crew maintain continuity. Worker hours were not directly measured, but the amount of cross-tasking observed indicates a meaningful opportunity.

2. Opportunities to participate earlier and remain longer.

Workers performed an average of 2.7 skill classifications during the observed periods, and some performed as many as six in a single day. Capabilities used during different project phases may allow a worker to contribute earlier in the project schedule, continue into later phases, move among appropriate related scopes, and remain useful when demand for the primary trade temporarily declines.

Individual Workers

01 More opportunities to earn hours

02 Participate earlier and remain longer

03 Broader assignment opportunities

04 Maintain depth and qualification boundaries

3. Broader project and work-package opportunities.

The field observations documented 128 trade combinations across a broad range of project types. Broader qualified capability may expand the types of projects, work packages, phases, equipment, or systems for which a worker can be considered. Workers should prioritize additional capabilities that recur in the projects and scopes where they want to work.

4. Maintain primary-trade depth and clear qualification boundaries.

The opportunity for cross-tasking was not the same on every crew. Some scopes created frequent opportunities to shift among tasks, while continuous, repetitive, highly technical, or specialized work created fewer opportunities. Workers should maintain strong primary-trade capability while selectively adding complementary skills. They should also understand which tasks they are qualified and authorized to perform, which work requires supervision, and which credentials, licenses, or equipment authorizations apply.

Taxpayers, Communities, and End Users

This report provides a direct crew-level basis for considering how publicly funded construction can leverage paid labor time. Although this study did not measure a specific dollar savings, it did show that the observed multiskilled crews used substantially more of their time devoted to directly installing construction work.

1. More productive use of paid crew time and public dollars.

Compared with the same-sequence single-skilled condition, the observed multiskilled crews had a 39% higher direct-work share and a 68% lower idle-time share. For each hour of crew labor time, those differences are equivalent to approximately eight additional minutes spent directly advancing construction and nineteen fewer minutes spent idle. Where the work is suited to qualified multiskilling, these shifts represent more productive use of the workforce already being paid and better crew-level "benefit for each tax dollar."

2. Focus on public work where interruptions between trades matter.

The observed multiskilled crews were 31% to 42% smaller than the estimated equivalent single-skilled staffing requirement needed to preserve the same work sequence. Public owners should examine scopes where several trades must work in close sequence, where a small adjacent task can stop the next activity, or where separate workers or crews would otherwise be required for short periods. These conditions may occur in shutdown, closure, renovation, maintenance, or turnover work, although this report did not directly measure whole-project schedule or public disruption.

Taxpayers

01 More productive use of paid crew time and public dollars.

02 Focus on public work where interruptions between trades matter.

Policy Makers at the Local, State, and Federal Levels

This report did not evaluate specific laws, regulations, labor agreements, procurement rules, or public workforce policies. However, it does provide field evidence showing that multiskilling can represent a substantial part of normal crew operations and that restricting workers to primary-trade work can materially change crew work-time utilization and equivalent staffing requirements.

1. Recognize qualified multiskilling as an established field practice.

Multiskilling was documented during normal operations across 60 crews, 36 projects, 24 states, and 22 project types. The study recorded 128 trade combinations, demonstrating that the observed practice was not limited to one trade, sector, region, or standard combination. The sample was not designed to estimate national prevalence, but it shows that qualified workforce flexibility is being used across a wide variety of actual construction settings.

2. Encourage development and fair competition of multiskilling labor strategies.

In the same-sequence comparison, restricting workers to primary-trade work reduced direct-work share, increased idle-time share, and required more worker-equivalent capacity to preserve the observed sequence. Policymakers should consider whether existing or proposed requirements unnecessarily prevent qualified workers from completing appropriate adjacent tasks or prevent contractors from offering different qualified workforce strategies.

Policy Makers

01 Recognize qualified multiskilling as an established field practice.

02 Encourage development and fair competition of multiskilling labor strategies.

Contractors

For contractors, the central finding is that multiskilling created value when qualified workers could cover work outside their primary trade without interrupting the observed crew sequence. The findings also show that the size of the opportunity varied substantially by scope and task mix.

Contractors

- **01** Identify scopes with substantial cross-tasking opportunity.
- **02** Select skill combinations that solve actual crew problems.
- **03** Deploy qualified capability to improve crew flexibility.
- **04** Measure crew-level results and improve future deployment.

1. Identify scopes with substantial cross-tasking opportunity.

Look first for scopes involving frequent trade handoffs, several short interdependent activities, workers waiting for small adjacent tasks, shared or constrained work areas, recurring bottlenecks, or work that repeatedly stops and restarts. Continuous or highly specialized work may offer fewer opportunities. Contractors should evaluate the actual task mix rather than assume that every crew or project will produce the same result.

2. Select skill combinations that solve actual crew problems.

The study documented 128 trade combinations rather than one standard form of multiskilling. This indicates that useful combinations depend on the contractor's work, equipment, project types, and recurring crew interfaces. Additional capability should be selected because it addresses an actual handoff, bottleneck, intermittent task, equipment need, or work-sequence problem, not simply to maximize the number of skills held by each worker.

3. Deploy qualified capability to improve crew flexibility.

Give foremen and supervisors a practical way to deploy qualified workers to appropriate adjacent tasks as conditions change. This can help cover short or intermittent work without leaving workers idle or adding a separate worker for every classification represented in the sequence. Multiskilling should supplement specialization where it solves a real workflow problem.

4. Measure crew-level results and improve future deployment.

Track the same types of crew-level measures used in this report, such as cross-tasking share; direct, support, and idle time; waiting; crew size; worker-presence requirements; and worker and supervisor feedback. Measure the selected scope where the strategy is applied rather than relying only on whole-project averages. Use the results to identify which skill combinations created value, where workers continued to wait, and how future crew deployment should be adjusted.

Owners and Buyers of Construction Services

Owners influence whether contractors can apply qualified workforce flexibility through procurement, work packaging, contract requirements, preconstruction planning, and performance measurement. This report indicates that generic encouragement of multiskilling is less useful than identifying the specific project conditions where cross-tasking can affect crew work-time utilization or equivalent staffing requirements.

1. Assess each project for multiskilling opportunities.

Review the project at the work-package, assembly, and crew level. Look for frequent trade-to-trade interfaces, several short activities performed in close sequence, shared work areas, small tasks that can stop the next activity, and scopes that repeatedly wait for another trade or crew. Multiskilling should be considered in a project-specific manner based on each project's work sequence and constraints.

2. Ask how the multiskilling can benefit each project's specific circumstances.

Ask bidding or proposing contractors to identify where and how they would use qualified multiskilled labor on the specific project. Contractors should explain the scopes or assemblies involved, the capabilities that would be combined, the waiting or staffing problem being addressed, the workers or crews that would perform the work, the expected crew-level benefit, and how the result would be measured.

3. Review contract requirements that affect qualified workforce flexibility.

The analysis conducted in this report illustrates what can happen when workers are restricted to primary-trade work while the observed work sequence is held constant. Owners should review specifications, work-assignment provisions, inspection procedures, subcontracting arrangements, and owner rules for unintended restrictions on qualified workers completing appropriate adjacent tasks. This review should preserve applicable credentialing, work-role, wage, apprenticeship, safety, quality, contractual, and supervision requirements.

4. Include workforce strategy in preconstruction planning and measure selected scopes.

During preconstruction, examine major handoffs, shared workfaces, short tasks that may interrupt larger activities, areas vulnerable to waiting, and specialized work that should remain with dedicated specialists. For scopes where multiskilling is used, measure waiting, direct/support/idle time, cross-tasking, crew size or worker-presence requirements, and worker and supervisor feedback. Measuring the selected scope allows the owner and contractor to determine whether the strategy created value under that project's actual circumstances.

Owners and Buyers of Construction Services

- **01** Assess each project for multiskilling opportunities.
- **02** Ask how the multiskilling can benefit each project's specific circumstances.
- **03** Review contract requirements that affect qualified workforce flexibility.
- **04** Include workforce strategy in preconstruction planning and measure selected scopes.

Summary of Central Takeaways by Audience

This report does not suggest that every worker should perform every trade or that every project should use the same workforce strategy. It shows that qualified cross-tasking was a substantial part of the observed crews' normal work and that it was associated with material differences in crew work-time utilization and equivalent staffing requirements. The practical opportunity is to identify where multiskilling can help the crew continue working, reduce idle time, and cover the required sequence with the available qualified workforce.

AUDIENCE	CENTRAL TAKEAWAY FROM THIS REPORT
Individual Workers	Build complementary capability that creates more ways to contribute, earn hours, and remain useful across the project.
Taxpayers, Communities, and End Users	Expect public projects to direct more paid crew time toward advancing the work.
Policymakers	Encourage the development and fair competition of multiskilling labor strategies.
Contractors and Construction Companies	Target the right scopes, verify capability, deploy selectively, and measure crew-level results.
Owners and Buyers of Construction Services	Ask how the strategy can be used to benefit each project's specific circumstances.

SECTION 8

Limitations and Recommendations for Future Research

This study provides field evidence of the crew-level effects of multiskilling, but several limitations should be considered when interpreting the results. First, the unit of analysis is the construction crew rather than the full project. The study measures how multiskilling affects observed work-time utilization and equivalent staffing requirements during selected work periods. It does not directly measure total project cost, total project duration, total labor productivity, safety performance, quality performance, or rework.

Second, the productivity measures used in this study are based on work-sampling classifications of direct work, support work, and idle time. These measures are valuable indicators of how labor time is used, but they are not the same as installed quantities per labor-hour. Future research should combine work sampling with installed-quantity data to evaluate whether higher direct-work time produces measurable improvements in unit-rate productivity.

Third, the same-sequence single-skilled comparison used in this study holds the observed work sequence and site conditions constant while restricting workers to primary-trade work. The comparison isolated what changes when cross-tasking is removed from the observed crew's work sequence. This is useful for estimating the crew-level effect of multiskilling, but it does not simulate every possible way a contractor might respond in practice, such as resequencing work, moving workers to other areas, changing crew size, or adjusting supervision.

Fourth, the projects were purposively sampled because multiskilling was actively occurring. This sampling design was appropriate for studying the performance implications of multiskilling where it occurs, but it should not be interpreted as a measure of how common multiskilling is across the entire U.S. construction industry. Future research should use broader sampling methods to estimate the prevalence of multiskilling by market sector, geography, project type, contract structure, and labor environment.

Fifth, observation periods captured selected work windows rather than complete project lifecycles. The results therefore reflect the observed work periods and should not be assumed to represent every phase of the project. Future studies should collect longitudinal data across longer project durations to evaluate whether crew-level work-time effects persist over time.

Finally, future research should directly examine the project-level outcomes that this study could not measure. Important next steps include measuring cost, schedule, safety, quality, rework, training costs, wage premiums, labor retention, and worker motivation. Research should also examine how licensing requirements, prevailing wage classifications, apprenticeship rules, project labor agreements, and trade jurisdiction affect the feasibility and value of multiskilling in different project settings.

Future research should:

- Compare multiskilled and single-skilled crews performing similar scopes on comparable projects, work sequences, or assemblies.
- Collect installed-quantity data alongside work-sampling observations to estimate unit-rate productivity.
- Measure the extent to which direct-work gains affect critical path or near-critical path activities.
- Quantify training, wage premium, supervision, safety qualification, and rework costs.
- Test results by project type, trade combination, crew size, and contract environment.
- Study safety and quality outcomes directly at the company, crew, and worker levels.
- Develop guidance on which trade/task combinations are most suitable for multiskilling.
- Study worker motivation, retention, career development, and annual employment continuity.
- Evaluate how foremen and superintendents identify and assign cross-tasking opportunities, including their satisfaction perspectives on achieving optimal crew staffing by leveraging a multiskilled labor strategy.

SECTION 9

Conclusion

This study examined multiskilling as it occurs in practice on U.S. construction projects and measured its effects at the crew level using field-observed work-sampling data. Within the observed crews, multiskilling was a regular part of day-to-day work execution. Workers were frequently observed performing tasks outside their primary trade, with the extent of cross-tasking varying across projects and crews. This variation suggests that multiskilling is best understood as a context-dependent workforce strategy shaped by project scope, work sequence, crew organization, and field conditions.

Based on the field-observed crew-level work-sampling data, the same-sequence comparison showed that multiskilling was associated with a higher direct-work share, a lower idle-time share, and positive lower- and upper-bound ESR estimates. On average, the direct-work share was 39% higher, the idle-time share was 68% lower, the lower-bound ESR was 31%, and the upper-bound ESR was 42%. These findings provide evidence of crew-level labor efficiency benefits, while project-level cost, schedule, safety, and quality impacts require further validation.

The equivalent staffing requirement analysis further showed that restricting workers to primary-trade work produced a larger equivalent single-skilled staffing requirement for the same observed work sequence. These estimates reflect workforce capacity embedded within multiskilled crews and show how assumptions about trade rigidity affect equivalent staffing requirements.

Overall, the findings show that multiskilling can play a practical role in how crews maintain progress under real site conditions. As labor availability remains constrained, understanding how multiskilling affects work time and equivalent staffing at the crew level is important for realistic workforce planning and construction execution. However, the results should be interpreted within the study's measurement boundary: they show crew-level work-time utilization and equivalent staffing effects, not direct project-wide cost, schedule, safety, or quality outcomes.

SECTION 10

References

Barkokebas, B., Al-Hussein, M., and Hamzeh, F. (2023). Assessment Of Digital Twins to Reassign Multiskilled Workers in Offsite Construction Based on Lean Thinking. *Journal of Construction Engineering and Management*, 149(1), 04022143.

Boardman, A. E., Greenberg, D. H., Vining, A. R., and Weimer, D. L. (2018). *Cost-Benefit Analysis: Concepts and Practice*. 5th ed., Cambridge University Press, Cambridge, UK.

Building and Construction Trades Department, AFL-CIO. 2011. *Plan for the Settlement of Jurisdictional Disputes in the Construction Industry: Including Procedural Rules and Regulations, Covering the U.S. and Canada*. Washington, DC: Building and Construction Trades Department, AFL-CIO.

Burleson, R. C., Haas, C. T., Tucker, R. L., and Stanley, A. (1998). Multiskilled Labor Utilization Strategies in Construction. *Journal of construction engineering and management*, 124(6), 480-489.

Creswell, J. W., and Creswell, J. D. (2018). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. 5th ed., Sage Publications, Thousand Oaks, CA.

ELECTRI International & NECA. (2007). *Factors affecting labor productivity for electrical contractors*. National Electrical Contractors Association, Bethesda, MD.

ELECTRI International & NECA. (2018). *Factors affecting labor productivity for electrical contractors (updated edition)*. National Electrical Contractors Association, Bethesda, MD.

Gong, J., Borcherding, J. D., and Caldas, C. H. (2011). Effectiveness Of Craft Time Utilization in Construction Projects. *Construction Management and Economics*, 29(7), 737-751.

Haas, C. T., Rodriguez, A. M., Glover, R., and Goodrum, P. M. (2001). Implementing A Multiskilled Workforce. *Construction Management & Economics*, 19(6), 633-641.

Hanna, A. S. (2009). *Stacking of trades*. ELECTRI International & National Electrical Contractors Association, Bethesda, MD.

Hanna, A. S., Chang, C.-K., Lackney, J. A., & Sullivan, K. T. (2007). Impact of overmanning on mechanical and sheet metal labor productivity. *Journal of Construction Engineering and Management*, 133(1), 22–28.

Hyari, K., El-Mashaleh, M., and Kandil, A. (2010). "Optimal assignment of multiskilled labor in building construction projects." *International Journal of Construction Education and Research*, 6(1), 70–80. https://doi.org/10.1080/15578771003590284

Korb, S., Telyas, A., Sacks, R., and Duka, A. (2019). Evaluating Multiskilling in Residential Construction Projects Using Regional Industry Simulation. In *Annual conference of the international group for lean construction* (Vol. 27).

Lee, T. Y., Ahmad, F., and Sarijari, M. A. (2024). Activity sampling in the construction industry: A review and research agenda. *International Journal of Productivity and Performance Management*, 73(5), 1479-1501.

Liou, F.-S., & Borcherding, J. D. (1986). Work Sampling Can Predict Unit Rate Productivity. *Journal of Construction Engineering and Management*, 112(1), 562-565.

Mahamid, I. (2020). Study of relationship between rework and labor productivity in building construction projects. *Revista de la Construcción*, 19(1), 30–41.

Oglesby, C. H., Parker, H. W., and Howell, G. A. (1989). *Productivity improvement in construction*. McGraw-Hill, New York.

Patton, M. Q. (2015). *Qualitative Research and Evaluation Methods*. 4th ed., Sage Publications, Thousand Oaks, CA.

Shadish, W. R., Cook, T. D., and Campbell, D. T. (2002). *Experimental and Quasi-Experimental Designs for Generalized Causal Inference*. Houghton Mifflin, Boston, MA.

Thomas, H. R. (1991). Labor productivity and work sampling: The bottom line. *Journal of Construction Engineering and Management*, 117(3), 423–444. https://doi.org/10.1061/(ASCE)0733-9364(1991)117:3(423)

Thomas, H. R., & Daily, J. (1983). Crew performance measurement via activity sampling. *Journal of Construction Engineering and Management*, 109(3), 309–320.

Thomas, H. R., Maloney, W. F., Horner, R. M. W., Smith, G. R., & Handa, V. K. (1990). Modeling Construction Labor Productivity. *Journal of Construction Engineering and Management*, 116(4), 705–726.

Toole, T. M. (2005). Increasing engineers' role in construction safety: Opportunities and barriers. *Journal of Professional Issues in Engineering Education and Practice*, 131(3), 199–207.

U.S. General Services Administration. (n.d.). Wage determinations. SAM.gov. Retrieved July 4, 2026, from https://sam.gov/wage-determinations

SIMPLAR FOUNDATION

Research that improves how organizations operate, meet the public need, and train the workforce.

simplarfoundation.org