Project Evaluation System (PES®)

Quantifying the Value of Union Labor in Construction Projects

Prepared for Mechanical Industry Advancement Fund (MIAF)[1]

Independent Project Analysis (IPA)

December 2022
Revised FINAL

[1] Mechanical Industry Advancement Fund, a national joint labor management cooperative committee established and operated by trustees appointed by the United Association of Plumbers and Pipefitters and Mechanical Contractors Association of America.

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This IPA report analyzes the performance of union labor versus non-union labor and subcontracted versus direct hire labor on cost and schedule performance using IPA's extensive database of capital projects.

This study references an earlier study, "The Looming Labor Shortage," that Edward Merrow presented for a panel discussion at the UA/MCAA Labor Relations Conference on October 30, 2008.

The December 2022 Revised Final now includes performance comparisons between Union, Open Shop, and mixed labor projects; the earlier version showed performance comparisons between only Union and Open Shop projects. We have also changed how we display labor productivity in the graphs to make it easier to interpret.

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About IPA

Since its founding in 1987, IPA has rapidly evolved into the preeminent consultancy in project evaluation and in project system benchmarking and has become the industry leader in quantitative analysis of project management system effectiveness worldwide. IPA improves the competitiveness of our customers by identifying the practices that generate effective use of capital in their businesses. It is our mission and unique competence to conduct research into the functioning of capital projects and project systems. We then apply the results of that research to help our customers create and use capital assets more efficiently. Our clients depend on our research results and quantitative measurements to enhance the value generated from their capital projects.

Our approach to increasing the success rate of a capital project is both simple and effective: IPA has developed detailed, carefully normalized databases that contain data about the entire project life cycle from the business idea through to early operation. We have used these data to develop powerful statistical tools that enable us to compare project performance in numerous areas.

IPA works on behalf of project owners and views project success from the vantage point of owners rather than contractors. IPA alone is responsible for the data review, analysis, and findings contained in the report.

Executive Summary

This study expands on an earlier study[2] that found that union labor is more productive than open shop labor and projects that employed union labor cost less, despite the higher average all-in wage rate paid to union labor. Other studies have similarly found that higher craft labor costs for prevailing wage projects, which often reflect union wage rates, do not result in higher total project costs than non-prevailing wage projects.[3] The current study confirmed the findings from the earlier IPA study and examined some of the underlying differences in union labor versus open shop labor that may explain the differences in productivity as well as the overall effect on project outcomes. The study found:

- Productivity for union labor is 14 percent higher versus open shop labor
- Projects that use a mix[4] of union and open shop labor have 8 percent better productivity than projects that use all open shop labor
- The use of union labor reduces the total cost of projects by an average of 4 percent versus when open shop labor is used
- The union craft labor and foremen have demonstrated a significantly higher level of skills versus open shop labor
- Strong relationships exist between higher craft skills and lower project total costs as well as better construction schedule predictability
- Projects are 40 percent less likely to experience a shortage of skilled labor when union labor is sourced versus open shop labor
- Projects that are short on skilled labor are twice as likely to have a 10 percent or higher cost overrun and are more likely to have schedule slip of 25 percent or higher
- Turnover of labor on projects is one-third less likely when union labor is employed versus open shop labor
- Turnover of labor is linked to worse project cost and schedule outcomes
- Projects using a mix of union and open shop labor saw benefits from the presence of union labor in each of the measures of performance versus projects that employ solely open shop labor

The overall findings indicate that the combination of better skills, more reliable sourcing of sufficient skilled labor, and better labor stability (e.g., less labor turnover) all contribute to better productivity and better project outcomes.

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[2] Edward W. Merrow, *The Looming Labor Shortage*, presented at the UA/MCAA Labor Relations Conference, October 30, 2008.
[3] Gerard M. Waites, Esq., Prevailing Wage Laws: Research Report – Comprehensive Review of Public Policy Benefits, 2022, O'Donoghue & O'Donoghue LLP 5301 Wisconsin Ave N.W., Suite 800 Washington, DC 20015.
[4] Projects that are referenced as using mixed labor are projects involving both open shop as well as union labor. The details of the make-up of the two labor sources are unknown, apart from the fact that both union and open shop labor were used.

Background & Objectives

The MIAF is interested in promoting the value of union labor to the American industry. Since the initial 2008 IPA study on the productivity advantages of union sector labor on capital projects relative to open shop or mixed projects and the allied advantages of subcontracted union work relative to direct hire performance, the MCAA and UA have been tracking productivity and related workforce development and performance issues in a variety of ways related to the prevailing wage policy, project labor agreements, and overall private and public sector construction project policy forums that help build, maintain, and foster the high skill construction workforce training and performance.

In June 2022, the MCAA and UA decided to commission another more detailed study from IPA that is reflected in this report. The current study confirmed and expanded on the findings from the previous study and showed that although the hourly all-in labor rates[5] are higher for union labor, this is more than offset by the value gained from the better productivity; in other words, the cost of labor cannot be viewed simply through the lens of the hourly all-in rates charged for the work as labor productivity plays a significant role not only on labor costs, but also on the overall project cost and potentially other outcomes that capital project owner's value.

Labor productivity is a function of many things. The skill of the labor is a key driver of overall productivity, but multiple factors influence labor productivity, such as management practices, weather, project size and project complexity, and others. The study Edward Merrow presented to the MCAA[6] in 2008 focused on the drivers of labor productivity, which included the source of labor. Merrow's study showed how labor productivity is highly variable from project to project driven by practices such as Front-End-Loading (FEL), which is a measure of the completeness of planning done prior to project execution; execution discipline (e.g., not deviating from the original plan); construction labor work schedules (e.g., use of long work weeks or excessive overtime, etc.); and the source of labor (e.g., union versus open shop and subcontracted versus direct hire labor). After controlling for project scope (e.g., office building versus chemical plant, etc.), project size, and project type (e.g., brownfield [work at an existing site] or greenfield [work at a brand new site], etc.), the project-to-project labor productivity variability is very large, as shown in Figure 1 below. The key findings from the 2008 study are that the labor productivity is strongly driven by the practices both the owner and contractor employed in managing the project. Another finding is that the source of labor is strongly linked to lower project costs.

The current study will focus on further understanding how the source of labor—in this case, union versus mixed and open shop labor and subcontracted versus direct hire—drives productivity and how that links more broadly to project performance.

[5] The all-in wage rate is the base rate *(total earnings before payroll deductions)*, plus indirect labor, indirect material, and other indirects (including small tools and miscellaneous consumables allowance, bonds insurance, and contractor fees) *plus* overtime premiums, incentives, and travel allowances.
[6] Edward W. Merrow, *The Looming Labor Shortage*, presented at the UA/MCAA Labor Relations Conference, October 30, 2008.

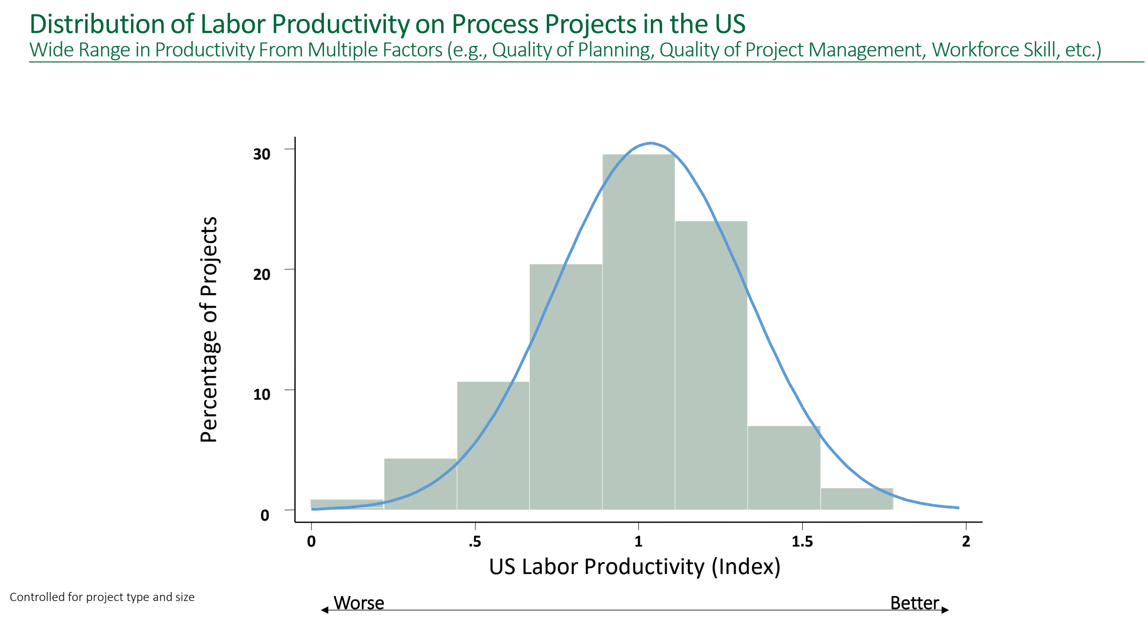


Figure 1

The current study focuses on how the source of labor is linked to project performance through better productivity and what drives the better productivity of union labor. Below in Figure 2 is an illustration of the framework that the study follows. We will focus on the topic of labor source and refer the reader to the earlier study in which the other drivers of productivity were analyzed.

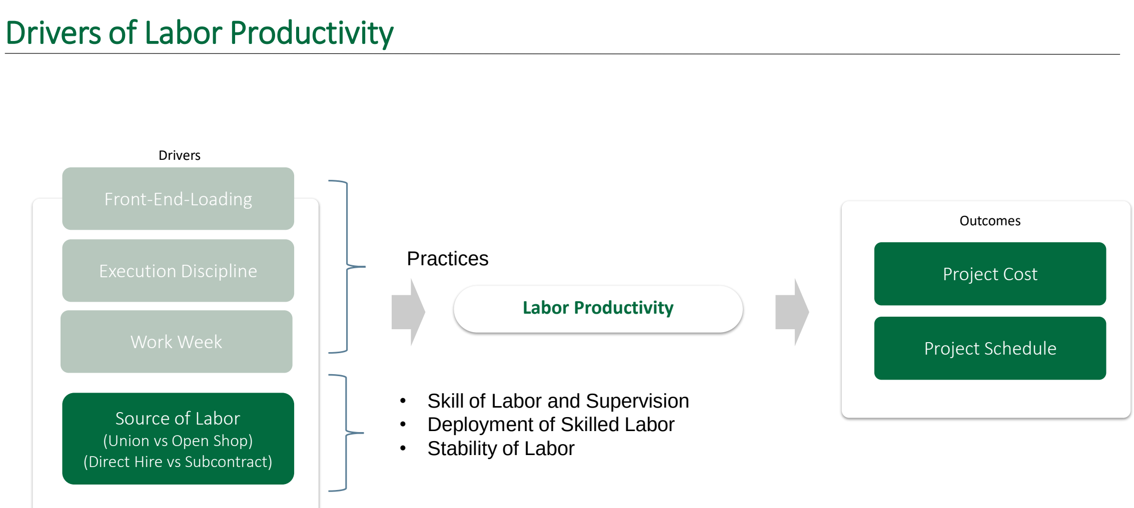


Figure 2

To determine the inherent productivity associated with the skill of the labor, it is important to be able to account for and remove these other factors. IPA has collected detailed information on thousands of capital projects, allowing us to analyze the differences in performance of union versus open shop labor on capital projects by isolating and removing the other influences of labor productivity to identify the effect of labor productivity, labor costs, and overall project performance. In this study, we seek to answer a set of questions that hopefully will shed additional light on the value of union labor to the project owner. These include the following:

- How do labor productivity and all-in wage rates compare between union and non-union labor?
- What are the benefits of using union labor on a project?
- What are the benefits of using subcontracted versus direct hire labor?
- What may explain the higher productivity performance differences?
    - Higher level of skill for both craft and foremen?
    - Lower turnover of craft during project construction?
    - More reliable deployment of sufficient labor to the projects?
    - Higher productivity leading to the need for less craft?

Study Database & Methodology

Each chapter will have a chapter-specific description of the database and methodology; however, this section describes the overall study database and methodology that will be referenced throughout.

Study Database

Since its founding in 1987, IPA has rapidly evolved into the preeminent consultancy in project evaluation and in project system benchmarking and has become the industry leader in quantitative analysis of project management system effectiveness worldwide. IPA improves the competitiveness of our customers by identifying the practices that generate effective use of capital in their businesses. It is our mission and unique competence to conduct research into the functioning of capital projects and project systems. We then apply the results of that research to help our customers create and use capital assets more efficiently. Our clients depend on our research results and quantitative measurements to enhance the value generated from their capital projects.

Our approach to increasing the success rate of a capital project is both simple and effective: IPA has developed detailed, carefully normalized databases that contain data about the entire project life cycle from the business idea through to early operation. We have used these data to develop powerful statistical tools that enable us to compare project performance in numerous areas.

IPA's capital projects database includes over 20,000 projects with more than 21 million data points regarding project drivers and project outcomes. The database includes projects executed in over 100 countries by more than 550 companies. The quality of the data is ensured by face-to-face data collections and extensive reviews of project histories. IPA's capital projects database is ever expanding as we evaluate approximately 600 projects every year. The database is supplemented with client documentation, including native cost and schedule documents, risk registers, change logs, bases of design, P&IDs, block flow diagrams, and other critical project documentation.

From this larger database of projects, we have selected a dataset of 1,550 projects that were executed in the United States over the past 20 years, which are described in the table below. These projects primarily come from the process industries, but include a good number of conventional building projects, such as offices, labs, and warehouses. From this dataset, we have coded the projects as having been executed using either union labor, non-union labor, or a mix of both. The project sizes range from $200,000 to more than $6 billion. About half of the projects employed open shop labor, one-quarter employed union labor, and one-quarter employed a mix of union and open shop labor. The projects included greenfield construction (e.g., construction at a new site, add-on, or expansion projects [new construction, but at an existing site], and revamp projects [e.g., construction projects that update existing facilities]). The projects also come from many different industrial sectors.

The dataset project characteristics are shown in Table 1 below.

Database Description

Recent Industrial Projects in the Unites States

Characteristic	United States (n = 1,550) Mean and Range
Project Size (^{2002}US$ millions)	89 (median) 0.2 > 6,000
Authorization Year	2007 (2000 – 2022)
Labor Force Make up for Project	51 percent Open Shop 25 percent Union 24 percent Mixed
Project Type	21 percent Greenfield/Colocated 37 percent Add on/Expansion 39 percent Revamp 3 percent Other
Industrial Sector	29 percent Oil Refining 38 percent Chemicals 8 percent Pharmaceuticals 8 percent Consumer Products 9 percent Distribution 5 percent Mining, Metals, and Minerals 3 percent Pulp and Paper/Other

Table 1

Analysis—Source of Labor and Project Performance

In the following section, we examine the different hypotheses tested with the goal of gaining a better explanation of what is driving the project performance differences between union and open shop labor.

Methodology—Assessing Labor Productivity

Labor productivity is usually defined as a measure of the hours required to complete a certain measure of scope. For craft labor, we often look at hours per unit of installed material (e.g., feet of pipe, tons of steel, cubic yards of concrete). The analysis that follows employs two distinct approaches to measure productivity. The first is to produce labor productivity for the entire project that represents the work done collectively by all trades (e.g., civil, electrical piping, steel, etc.). The second is to look at the craft-level productivity by using a single craft (in this case, pipe fitting craft labor as the base case, given the significance of this craft on industrial projects), but the same was done with the other labor crafts (e.g., mechanical, civil and electrical, and instrumentation).

Labor Productivity at the Overall Project Level

To measure labor productivity at the overall project level, IPA employs a method we call twinning in which we compare projects that are similar to each other (e.g., office building to office building, chemical plants to chemical plants) and adjust for other differences like project size as well as normalize for wage differences from location to location and over time, as described earlier in the General Methodology Description section. We can then compare construction costs for like-to-like projects to create a productivity index for each project (e.g., actual productivity/benchmark productivity). A higher index means higher productivity (e.g., fewer labor hours per installed material). The productivity index can then be used to quantify the relationships between practices, unusual events (such as severe weather, labor source, etc.), and their effect on the relative productivity. The value of this approach is that it provides a measure of the relative labor productivity for the composite of all labor on a project. It also provides a way to determine the labor productivity when individual material quantities are not available (e.g., details on the pipe or steel are not provided).

Labor Productivity at the Craft Level

The second methodology involves the more traditional hours per unit quantity installed. We can do this for each of the major crafts (e.g., installation of pipe, steel, concrete, and electrical). For the current study, we focused on pipe fitting craft productivity, which is component of the mechanical trade. IPA has developed a methodology to normalize for feet and size of pipe as well as for other site factors that can influence a pipe installation. For every project for which IPA has collected both hours as well as quantities and characteristics of the pipe installed, we can produce a relative productivity index for the piping craft for each project. A higher index means better labor productivity (i.e., fewer labor hours required per installed quantity of pipe).

Overview Source of Labor and Project Value

The previous study linked source of labor to productivity and project costs; the current study updates and expands on that analysis to explain how the labor source is linked to other project outcomes and why. In Figure 3 below, we compare productivity for union versus mixed and open shop labor using the two methods described above. Based on the overall labor productivity method, union labor was found to be 14 percent more productive than open shop labor and 7 percent more productive than a mixed labor force. Looking specifically at the installation of pipe (part of the mechanical trade), union craft labor was found to be 15 percent more productive than open shop labor and 12 percent more productive than a mixed labor force. In other words, both methods had similar results. We looked at labor wage rates and found union labor to be 9.7 percent higher than open shop labor, on average. All of these relationships were found to be statistically significant.[7] We also looked at the differences between subcontract and direct hire labor, but no statistically significant differences between these groups were found.

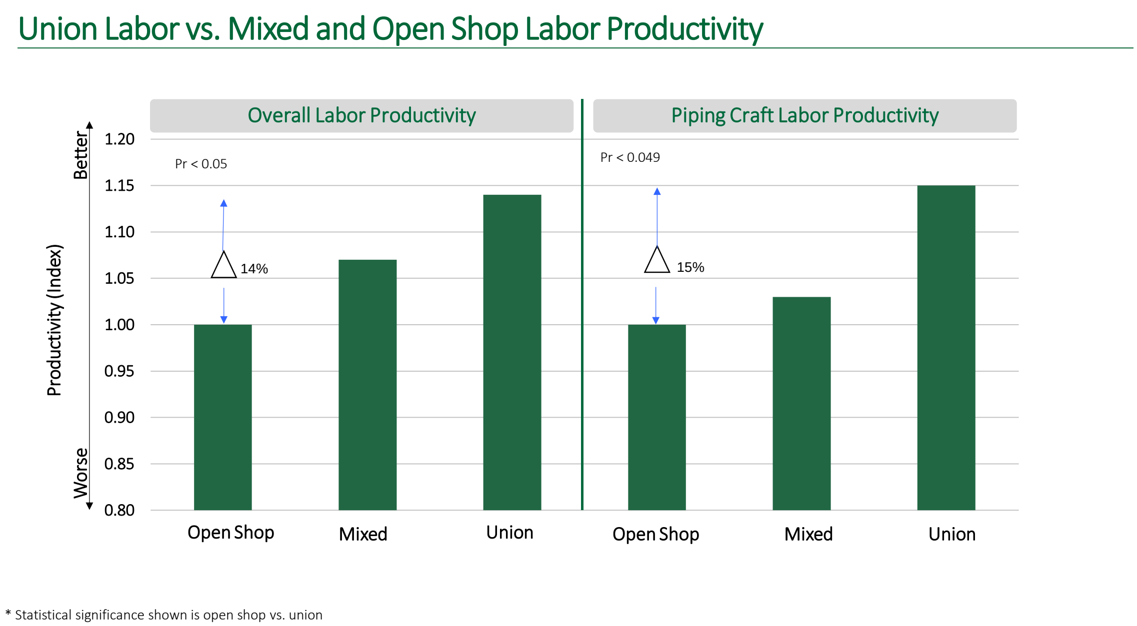
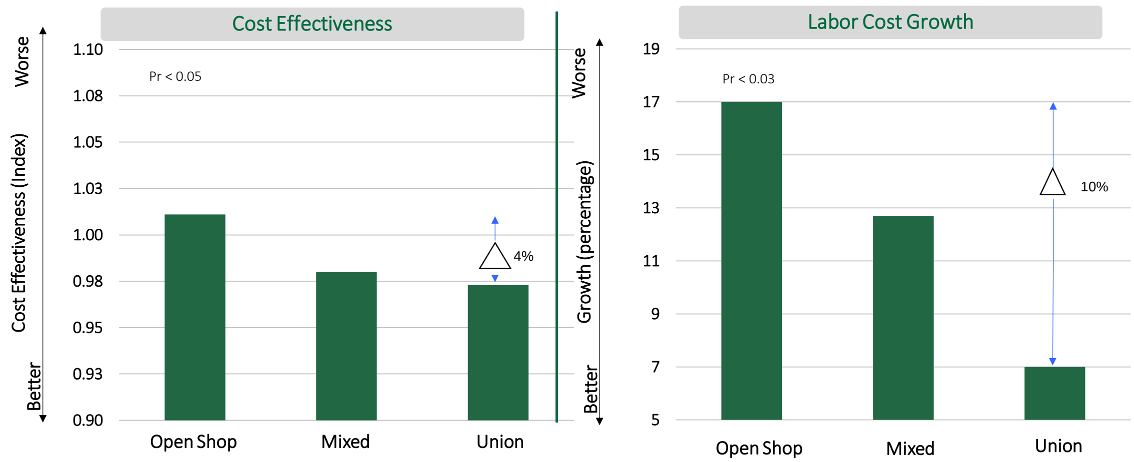


Figure 3

We also looked at cost and schedule performance by comparing projects that employed union labor versus projects that employed open shop labor. As shown in Figure 4 below, projects employing union labor have 4 percent lower costs (better overall cost effectiveness) and 10 percent lower labor cost growth. Although a 4 percent lower overall cost seems modest, there is very little opportunity to reduce the materials costs that make up roughly half of the costs for a typical project in the United States. Therefore, savings from higher labor productivity represent one of the primary ways that owners can reduce costs. Projects employing a mixed labor force have both cost effectiveness and cost growth performance in between open shop and union labor. In addition, we found that projects employing union labor average 8 percent less construction schedule slip than open shop.

[7] We use a measure of statistical significance that is shown as a p value in which a p value of <0.05 indicates that the findings have a less than 5 percent chance of being random; in other words, there is a 95 percent chance that the effect being tested can be considered real.

Union Labor vs. Mixed and Open Shop Project Cost Performance



* Statistical significance shown is open shop versus Union

Figure 4

Given that labor is typically 25 to 35 percent of the total project cost and the wage rate difference, combined with the better productivity, cannot account for the 4 percent overall project cost savings, we did a deeper dive to determine the source of these cost savings. The costs of materials (e.g., equipment steel, concrete, pipe, wire, etc.) are generally competitively sourced. Therefore, significant differences in the materials costs are generally not big contributors to the lower project costs. Cost savings on projects generally come from some efficiency gains in the field coming from some combination of lower labor, construction supervision, and construction indirect costs and/or efficiency gains in office costs coming from lower project management, engineering/design, and project definition costs. Looking at both field and office costs and controlling for project scope, size, and ratio of equipment and bulks (steel, pipe, concrete and electrical), as shown in Table 2 below, we found that union projects have both lower field and office costs versus the materials installed, on average, than projects that use either mixed or open shop labor. The savings come from labor as well as other construction costs (e.g., construction supervision and construction indirect costs) and lower project management costs that contribute to the lower office costs.

Project Cost Ratio Analysis

Cost Ratio	Open Shop	Mixed	Union	Statistical Significance** P > |t|
Field to Materials Cost	0.70	0.65	0.64	0.007
Office to Materials Cost	0.36	0.32	0.27	0.005

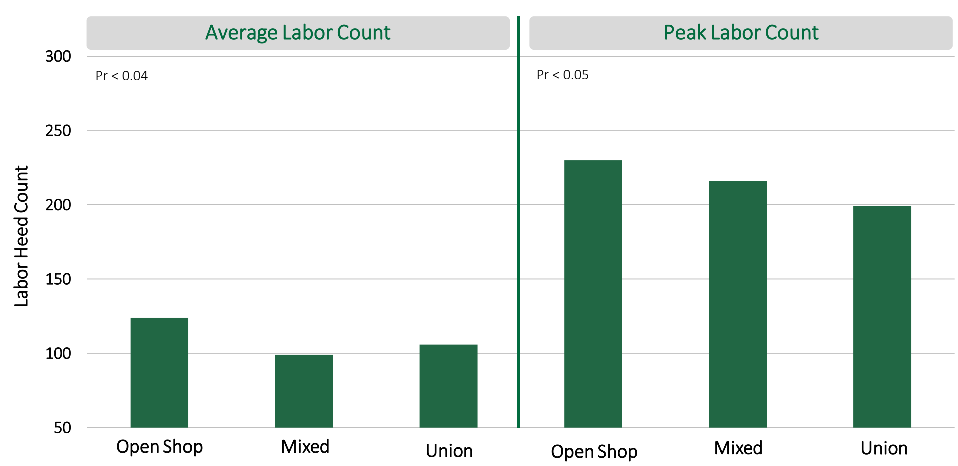
* Controlled for project size ($100 million), ratio of bulks to equipment, and project complexity

** Statistical significance shown is open shop vs. union

Table 2

To support this finding, it was found that projects that employ union labor require nearly 10 percent fewer craft workers, on average, and have a nearly 10 percent lower peak number of craft workers, on average, than projects employing open shop labor, as shown in Figure 5 below. This finding suggests that the higher productivity from union labor translates into both fewer hours overall as well as fewer individuals being required to accomplish the same work. A reduction in the peak number of craft workers is also desirable by reducing the density of workers during periods of highest construction activity. Projects with mixed labor are similar to projects employing union labor with regard to the average number of craft workers required and higher than projects employing union labor with regard to peak number of craft workers required.

Average and Peak Labor Required



* Based on a $100 million project

** Statistical significance shown is open shop vs. union

Figure 5

We also looked at the cost performance of projects by comparing those that used direct hire labor versus those that subcontracted their labor. As Figure 6 below shows, projects that use subcontracted labor have 3 percent lower costs than the projects that use direct hire labor. However, we did not find differences in productivity or head counts between direct hire and subcontracted labor projects. We suspect the better cost effectiveness is a result of the subcontracted labor often being made up of cohorts of workers who have worked on multiple projects together, resulting in some efficiencies that our other measures could not identify.

Subcontracted vs. Direct Hire Labor and Cost Effectiveness

Figure 6

Methodology—Assessing Labor and First Line Supervisory Skills

Skill assessments for construction craft can be done using measures such as frequency of errors or defects and other means that quantify the quality of their work. As an alternative to these types of measures, IPA assess craft labor and foremen skills by asking the project owners to rate the skill level for four of the major trades (piping, mechanical, electrical, and civil) for both craft labor as well as the foremen that worked on their project. We ask them to rate the skills for each trade on a scale of 1 to 5, with 1 being unskilled, 2 being below average skill, 3 being average skill, 4 being above average skill, and 5 being highly skilled. Although this is based on judgement, it comes from owner construction and project management leads who are generally very familiar with the construction trades. IPA has gathered this information on thousands of projects and found that the rating of skills by the owners is correlated with several expected performance measures. In the following section, we show the relationships between craft and first line supervisory skills and project outcomes.

Labor Source and Skills

Overview Source of Labor and Skill

There is a strong correlation between skill and productivity. It has been reported by others that the union sector has historically funded and promoted craft training through its join labor/management apprenticeship program. In contrast, open shop labor has lacked standardized training.[8] The difference in productivity between union and open shop crafts suggests that some of that performance difference arises from better skills. Figure 7 below shows how

[8] Allison L. Huang, Robert E. Chapman, and David T. Butry, Metrics and Tools for Measuring Construction Productivity: Technical and Empirical Considerations, U.S. Department of Commerce, National Institute of Standards and Technology, Office of Applied Economics, NIST Special Publication 1101 (2009) ("Typically, training programs are funded by both owners and contractors through union and collective bargaining agreements. While open shop training programs exist, they tend to be rare."), p. 23 see citing Construction Industry Institute, Construction Industry Craft Training in the United States and Canada. RS 231-1 (Austin, TX: Construction Industry Institute, 2007).

frequently owners rated the skills of craft and foremen *(those who supervise the craft workers)* for the mechanical trades installing pipe using a scale of 1 to 5 (low to high), as described earlier. The installation of pipe on many industrial projects is the dominant craft in terms of labor hours and therefore is an important indicator of project success. When we compare the skill ratings for the craft employed on union, mixed, and open shop projects, union workers were much more likely to be rated as above average or highly skilled versus open shop and mixed workers. In other words, 75 percent of the project owners rated the craft installing piping as above average or highly skilled for union workers compared to only 63 percent of the open shop workers being rated as above average or highly skilled. Union labor was also less likely to be rated as only average or unskilled. Similar results are found for the foremen and this same pattern is also seen across the other craft disciplines (e.g., iron workers, electrical and instrumentation, and civil).

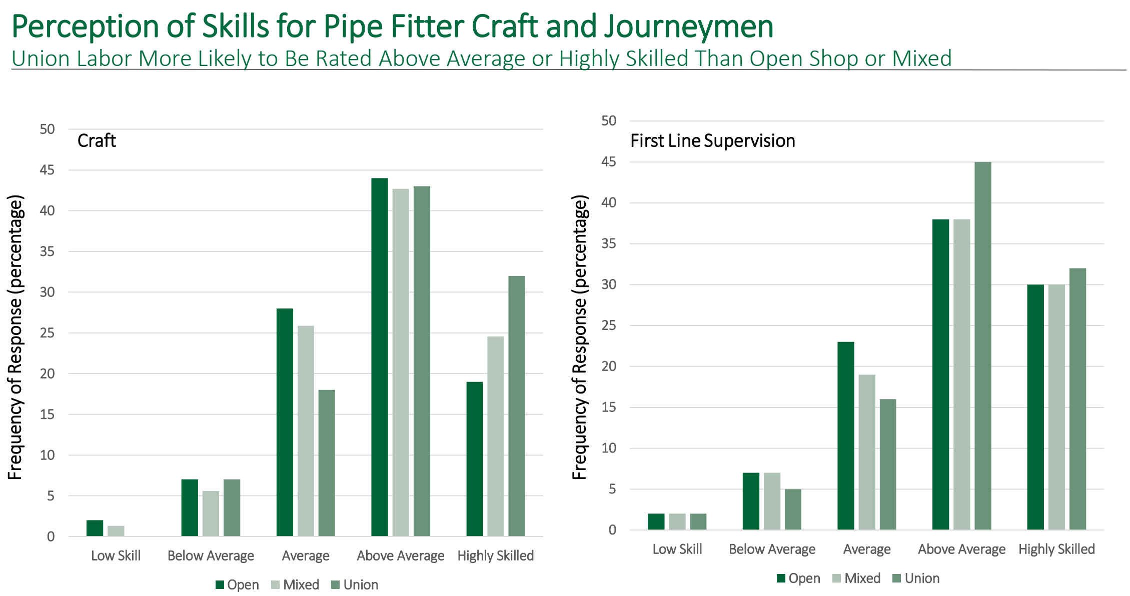


Figure 7

When we look at the relationship between craft and foremen skill and project performance, it was found that both craft and foremen skills drive cost competitiveness and cost growth. Union labor go through regular training and an apprenticeship program, both of which raise the skill levels for the craft and foremen. As Figures 8 and 9 below indicate, the projects that are able to attract the mechanical trades higher skilled craft labor and foremen to install pipe have better cost outcomes. We see the same effect for the other major crafts. In addition, we see that projects that have highly skilled labor for one craft are more likely to have highly skilled labor for the other crafts. The higher skill level that union labor brings to the project is why union labor is more productive and driving the relationship with better cost effectiveness.

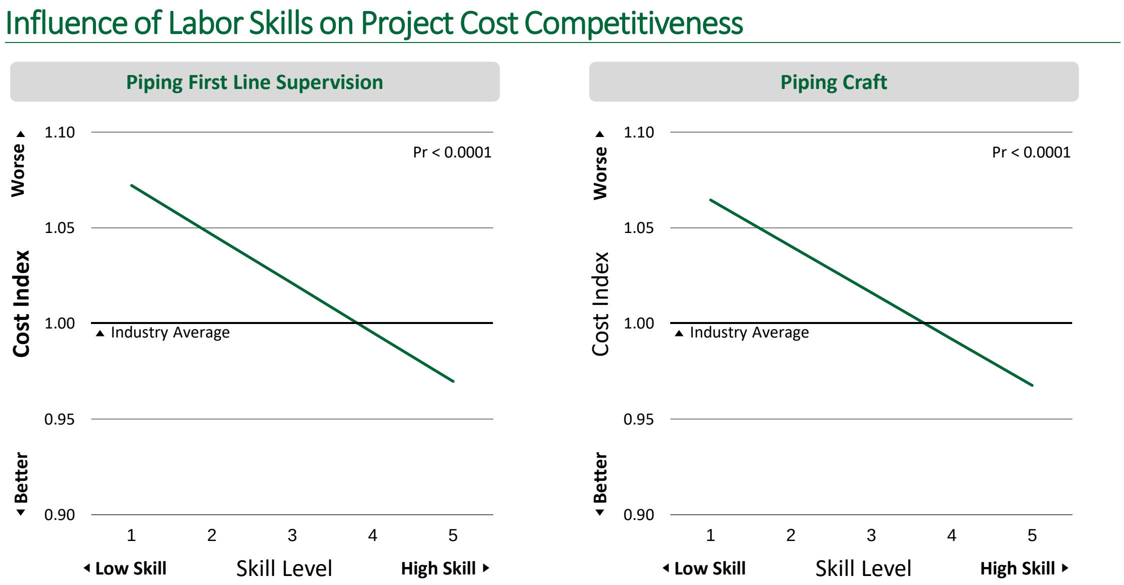


Figure 8

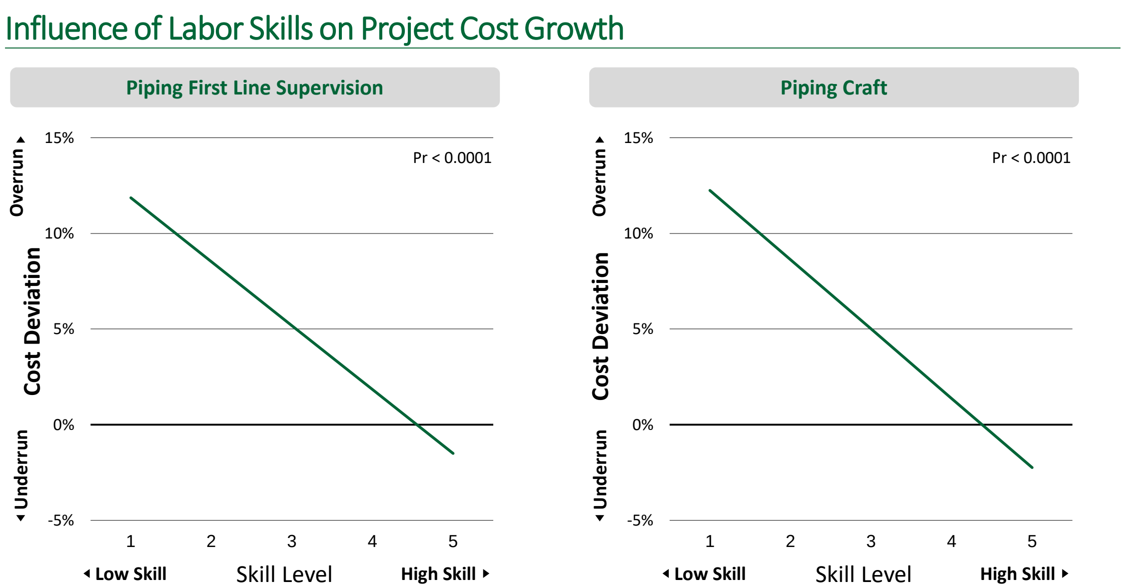


Figure 9

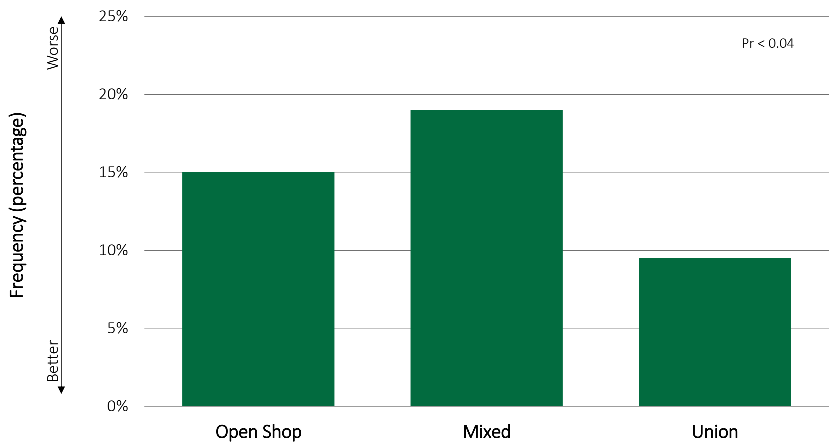
Methodology—Assessing Labor Deployment

In addition to the effects of labor skills on project outcomes, projects are sensitive to other things that force the project to deviate from the plan, which dictates the need for the number and mix of craft required for a project's execution. Any deviation from the plan often creates inefficiencies through the need for workarounds and rework and having to do work out of sequence to account for insufficient craft labor, which implies that the projects that cannot meet their labor requirements will suffer. For each project, IPA asked the owner whether sufficient skilled labor was available for the project; in other words, was there a shortage of skilled labor? We use this measure to assess whether adequate labor was deployed for each project.

Labor Source and Deployment

Over the past 20 years, about one in seven projects experienced a shortage of skilled labor, and the lack of having sufficient skilled labor has significant negative consequences on project outcomes. Other studies have asserted, that one of the greatest challenges facing the construction industry is its ability to attract and retain qualified workers. This is underscored by the fact that shortages of skilled workers continue to plague the construction industry[9]. The sourcing of labor that can meet the required number, mix, and skills of labor for the project plan is an important consideration. As figure 10 below shows, projects employing union labor are nearly 40 percent less likely to experience a shortage of skilled labor compared to the projects that employ open shop labor. Despite the value shown in the figure below for mixed labor being higher than open shop labor, there was no statistical difference between mixed and open shop projects, on average. Union contractors have access to local union referral systems and, especially on large projects, contractors can access additional support from neighboring local unions facilitating more effective deployment of labor. The findings suggest that union halls are more effective at meeting owner's requirements for sufficient skilled labor than when labor comes from open shop sources. This difference holds up in both hot as well as normal labor markets.

Frequency of a Shortage of Skilled Labor



* Statistical significance shown is open shop vs. union

Figure 10

A shortage of skilled labor creates risk for projects. Projects that experience skilled labor shortages, on average, have 10 percent higher cost growth and 6 percent greater schedule slip than projects that found enough skilled labor. They are also at greater risk of significant cost growth and schedule slip. As Figure 11 below indicates, projects that are short on skilled labor are twice as likely to have a 10 percent or higher cost overrun and are more likely to have schedule slip of 25 percent or higher.

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[9] Allison L. Huang, Robert E. Chapman, and David T. Butry, Metrics and Tools for Measuring Construction Productivity: Technical and Empirical Considerations, U.S. Department of Commerce, National Institute of Standards and Technology, Office of Applied Economics, NIST Special Publication 1101 (2009)

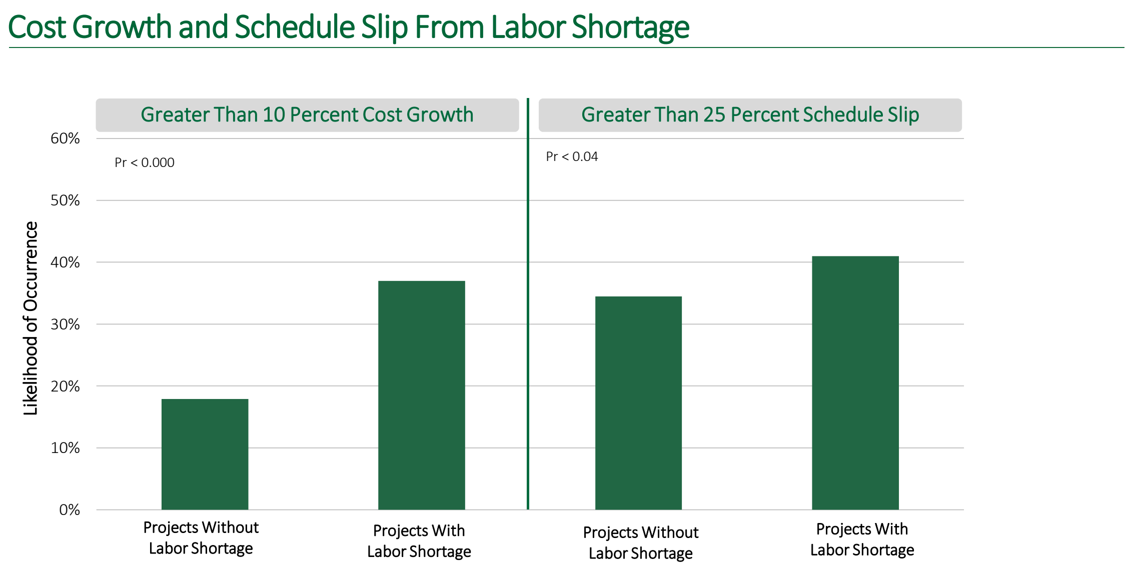


Figure 11

Methodology—Assessing Labor Turnover

For each project, IPA asks the following question to the team: what was the average monthly turnover for each craft and foremen (e.g., pipe fitting, mechanical, electrical and instrumentation, and civil)? We use this information to relate the effects of turnover on project performance.

Labor Source and Turnover

The turnover of craft and foremen can also degrade productivity as the loss of a skilled craft or supervisor leaves a gap in the workforce and bringing a new individual onto the project requires an onboarding process as well as time to become familiar with the work environment, etc. Figure 12 below shows the monthly average turnover of the mechanical trade pipe fitting craft, which compares projects that employ union, mixed, and open shop labor. On average, projects that employ union labor have monthly turnover rates that are one-third lower than open shop labor and one-quarter lower than mixed workforces for pipefitters. Similar findings were also found for the electrical, civil, and steel workers. This finding suggests that union labor is more likely to remain on the project, whereas open shop labor is more likely to leave. This finding is even more pronounced during hot labor markets during which the rate of turnover for open shop labor increases as union labor turnover remains unchanged.

Frequency of Turnover of Labor

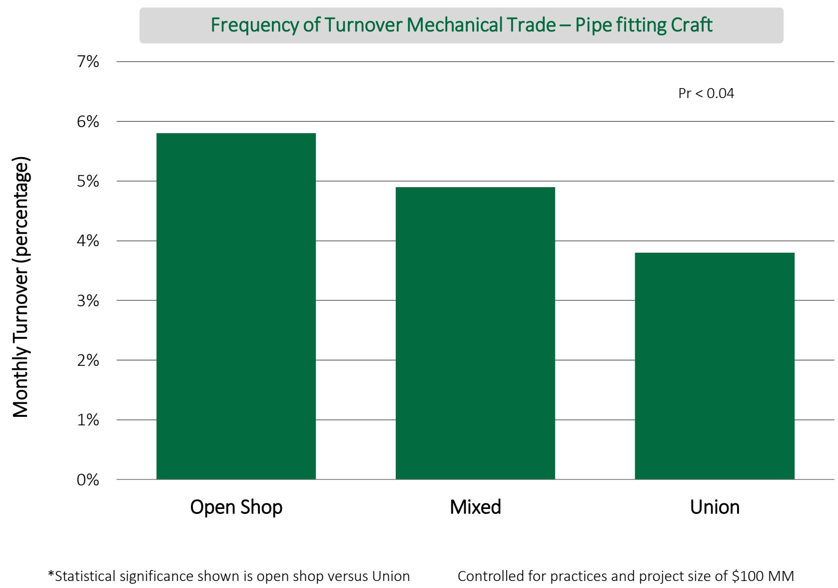


Figure 12

As with shortages of skilled labor, turnovers of skilled labor, especially unwanted turnovers, create manpower gaps that can cause projects to have to deviate from plans to work around these missing crafts until new craft and first line supervisors can be found, hired, and on boarded. The turnover of skilled labor has a negative effect on project performance. As Figure13 below indicates, the turnover of skilled craft is linked to higher cost growth as well as higher project costs.

Influence of Labor Turnover on Project Cost Performance

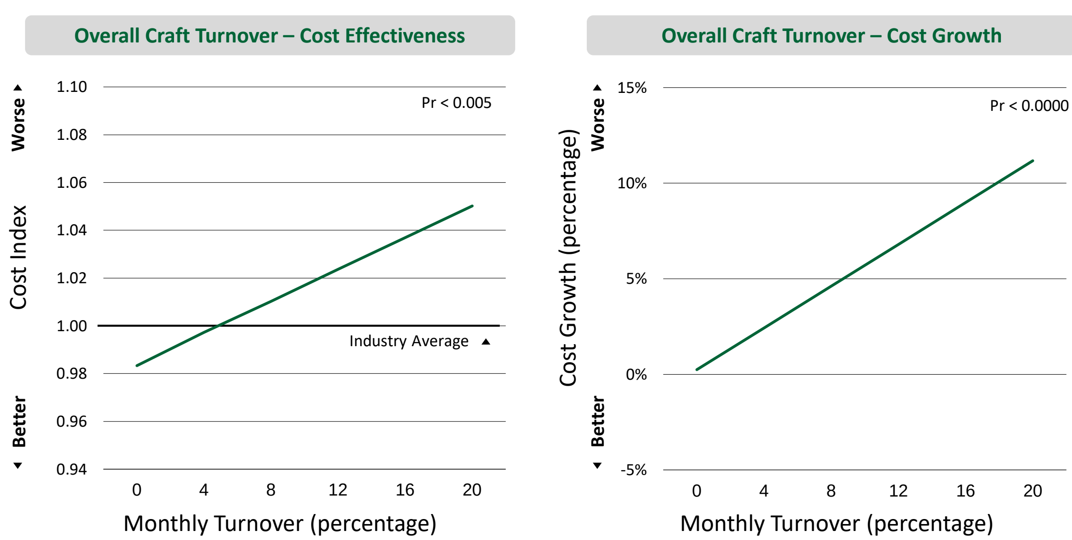


Figure 13

Conclusions

This study confirms earlier work that found that union labor delivers lower and more predictable project costs and more predictable schedules. Subcontracted labor also delivers lower overall project costs. The study confirmed union labor is significantly more productive than open shop labor and this higher productivity is linked to significant overall cost savings. Projects with mixed labor still see benefits in productivity and cost savings by having union labor on their projects as compared to open shop projects. The current study unpacked the drivers of this better productivity. As hypothesized, owner experts reported that union labor across all crafts has higher skills for both craft and foremen. One key finding is that the union labor and supervision are much more likely to be highly skilled and far less likely to be rated as average or lower skilled. The level of craft skill is directly related to overall project cost and schedule performance.

The second difference between union versus open shop and mixed labor is around the ability to reliably source the labor when needed. Projects that sourced labor from union halls are 40 percent less likely to be short on skilled labor than when projects sourced labor from open shop sources or mixed labor. Skilled labor shortages create significant challenges to projects. Our study found that skilled labor shortages are linked to worse cost and schedule performance, including increased risk of major cost growth and schedule slip. Therefore, the source of labor should be considered an important risk management practice.

Finally, we looked at the turnover of labor as another potential explanation for the higher productivity of union versus open shop labor. The study found that projects that employ union labor report significantly lower monthly turnover rates for their workers than projects employing open shop labor. Projects employing mixed labor appear to benefit from the presence of union labor with lower turnover than projects employing open shop labor. Again, labor turnover is linked to cost and schedule performance.

The combination of higher skills gained through more consistent training and better deployment of labor from union halls along with lower turnover of craft once they are on the job helps to explain the significantly higher productivity of union labor that drives lower and more predictable project costs, lower risk of major cost and schedule deviations, and a reduced labor count that may reduce the exposure hours for the project. The presence of union labor in projects employing mixed labor is evident in nearly all of the key success measures. Overall employing union labor creates significant value for owners through lower costs and more predictable schedules and acts as a risk mitigation strategy that reduces the risk of major cost and schedule deviations.

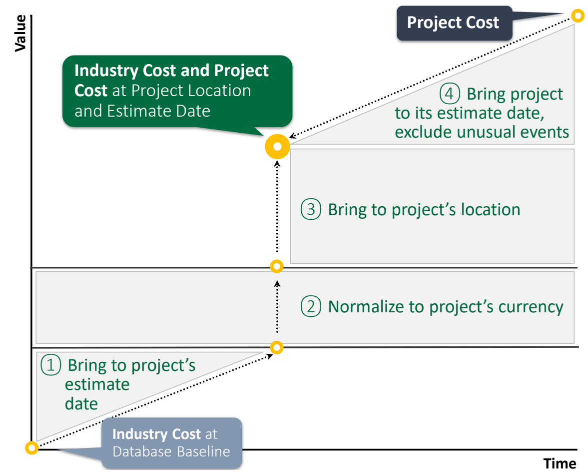
Appendix Methodology

Cost Normalization

IPA’s analytic techniques include data normalization methods that allow us to make valid comparisons across different time periods and regions of the world. The goal of normalization is to neutralize any inherent advantage or disadvantage of a project’s timeframe and location, which allows us to analyze and compare projects on an equal basis, thus ensuring benchmarking accuracy.

IPA's PES Database stores project cost values normalized to a constant reference location, time, and currency, and with unusual events excluded., IPA's analytic methodology accounts for:

- Time period
  - Industry costs are escalated from the PES Database reference time period to a project's estimate date based on inflation data obtained from the projects evaluated by IPA and selected public sources
  - IPA captures inflation data for each major cost category and accounts for recent extraordinary inflation (see below for further discussion)
  - Because industry costs are presented as of the project's estimate date, escalation is removed from the project's cost estimate, while actual costs are de-escalated to the estimate date based on an expenditure profile established from the project's schedule

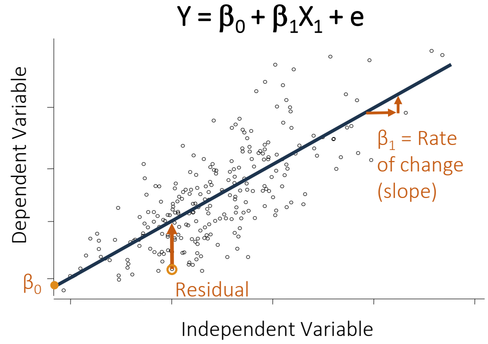


- Location
  - Industry cost data are converted from the reference currency in the PES Database *(note that in the case of this study, all projects are from the United States and all project costs were in U.S. dollars; therefore, no currency adjustment* was needed)
  - Differences in local labor rates are used to convert field labor costs from the reference location to the project's location
  - Office services and materials procurement typically follow World Open Market (WOM) pricing; for some regions, these costs are also adjusted from the reference location to the project's location
  - These location-adjustment factors can change over time, and IPA updates them as needed
- Unusual events
  - Costs in the PES Database exclude the effect of workers' strikes, natural disasters, global pandemics, etc.

Statistical Models

IPA uses multivariate statistical (regression) models to establish benchmarks for project outcomes (contingency used, cost, schedule, and operability) based on industry data that control for specific project characteristics. Fairly comparing targets and outcomes between a project and Industry requires the outcome models be derived from PES Database projects that have been normalized to a constant location, time, and currency, as described in the previous section. The benchmarks and distributions generated by the models account for the fact that a project outcome has multiple drivers. Controlling for these drivers simultaneously allows us to quantify the effect of each driver on that outcome. The figure below shows a simple illustration of a single-variable regression model and its associated uncertainty.

$$Y = \beta_0 + \beta_1 X_1 + e$$



Y = Dependent Variable

X_1 = Independent Variable

β_0 = Constant

β_1 = Slope of Independent Variable

e = Residual—variance in Y that is unexplained by the variance of the independent variable(s)

IPA's models are multivariate (i.e., they account for multiple independent variables [drivers] simultaneously). Because IPA's models are based on actual project data and cannot control for every conceivable driver of a project outcome, the models control for the most leveraging drivers, derived from empirical observations and hypotheses of what drives project performance. IPA's models are periodically updated as needed to capture recent project performance and ensure critical drivers remain relevant.

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