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# Skilled Worker Shortage Across Key Labor-Intensive Construction Trades In Union Versus Nonunion Environments

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# Skilled Worker Shortage across Key Labor-Intensive Construction Trades in Union versus Nonunion Environments

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**Abstract:** Skilled labor plays a crucial role in ensuring that construction projects are completed on time, within budget, and to the required standards of quality and safety. However, the construction industry has been facing a labor shortage in recent years, which poses a significant challenge to the industry's growth and sustainability. Therefore, it is important to examine the characteristics of the construction skilled labor market to understand the factors that contribute to the shortage of skilled workers and develop strategies to address the issue. This paper fills this knowledge gap. To this end, the authors (1) collected and processed project documentation in relation to 67 construction projects to identify key construction labor-intensive trades, (2) conducted an expert-based survey to collect data in relation to union participation rates and degrees of skilled labor shortages across the identified trades, (3) performed clustering analysis to examine the observed levels of labor shortage across the identified trades, (4) applied a binomial test to analyze the levels of union participation for each of the labor trades, and (5) used a chi-square test of independence to investigate the correlations between workforce location and union participation on the one hand and union participation and labor shortage on the other. As such, the authors identified 10 key labor-intensive trades. It was found that plumbing and electrical trades have the highest degrees of skilled labor shortage, whereas finishing work trades (i.e., plastering and painting, flooring, and waterproofing) had the lowest. Results also showed a significant correlation between high union membership rates and the availability of skilled workers in 3 of the 10 identified trades (i.e., ironworking, flooring, and waterproofing) and that union reach in urban locations is less than that in rural areas where workers are employed. Ultimately, this paper adds to the body of knowledge by offering a closer look into the construction skilled labor market. Such knowledge can be used to mitigate the current labor shortages. **DOI: 10.1061/JMENEA.MEENG-5649.** *© 2023 American Society of Civil Engineers.*

## Introduction

The construction industry is a labor-intensive one. Labor costs constitute a significant portion of a project's total cost, typically ranging from 30% to 50% (McTague and Jergeas 2002). Therefore, managing labor issues and improving labor productivity have a critical role in the financial success of projects (Ernzen and Schexnayder 2000), especially given their narrow profit margins (Hanna et al. 2005). However, a persistent challenge that hampers the progress of this industry is the shortage of skilled labor. The construction industry has been facing skilled labor shortages for over a decade (Oh et al. 2023). Current national events have further exacerbated the issue. For example, the Great Resignation has impacted every industry in the United States as workers continue to demand higher wages and better benefits from employers. The construction industry is no exception, with a reported labor shortage of around 650,000 construction workers in 2022 (ABC 2022). On the other hand, demand is expected to continue increasing in response to the Infrastructure Investment and Jobs Act, which entails investing $1.2 trillion in construction projects nationwide. As a results, contractors in the US have been facing increasing difficulties in employing enough workers to meet current demands. The scarcity of skilled workers has far-reaching consequences, affecting project timelines, project costs, quality of work, and overall productivity (Hovnanian et al. 2022).

Extensive research has been conducted to shed light on the factors contributing to this skilled labor shortage in construction. However, one crucial aspect that remains relatively understudied is the relationship between skilled labor shortages and the presence or absence of trade unions in construction environments. Trade unions have long been recognized as powerful entities representing the interests of workers, advocating for their rights, and negotiating better working conditions. Union membership can provide workers with collective bargaining power, higher wages, improved benefits, and enhanced job security. On the other hand, nonunion workers often enjoy more direct relationships with their employers, greater flexibility in job selection, and the potential for higher immediate earnings.

The debate surrounding the impact of unions on skilled labor shortages is complex and multifaceted, with proponents on both sides presenting compelling arguments. As such, a deeper understanding is necessary to assess the relationship between trade union participation and workforce availability. Therefore, this paper aims to contribute to the existing body of knowledge by conducting an analysis of skilled labor shortages in union versus nonunion environments within the construction industry.

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## Knowledge Gap and Research Questions

The literature emphasizes the critical nature of the skilled labor shortage in the construction industry. Although some factors contributing to the shortage have been studied, further research is needed to explore all potential aspects related to skilled labor shortages. One aspect that remains relatively understudied is the relationship between union and nonunion environments and labor shortages. The influence of unions on labor shortages is complex and requires comprehensive investigation. Union membership can provide workers with collective bargaining power, higher wages, better benefits, and improved job security. On the other hand, nonunion workers may have more direct relationships with their employers, flexibility in job selection, and the potential for higher immediate earnings. Proponents of unions argue that they can help address labor shortages by negotiating better conditions and attracting skilled labor. On the other hand, proponents of nonunion construction highlight that worker flexibility and potential cost savings are important attractors of skilled labor. Nonetheless, considering the arguments presented from both perspectives, it is evident that the presence or absence of trade unions has a significant impact on skilled labor shortages. Therefore, it becomes crucial to evaluate the potential effects of union and nonunion approaches on labor shortage issues. This paper intends to fill this knowledge gap. As such, the research questions that this research aimed to address are:

1. What are the labor-intensive trades most affected by the shortage of skilled labor?
2. What is the current status of union participation of skilled workers across key labor-intensive trades?
3. How does the presence or absence of trade unions influence the availability of skilled labor in the construction industry?

## Goal and Objectives

The goal of this paper is to study skilled labor shortages across key labor-intensive trades in union versus nonunion environments. To this end, the associated objectives include: (1) identifying key labor-intensive trades, (2) examining the degree of labor shortage associated with each trade, (3) assessing the reach of trade unions among skilled labor within each of the identified labor-intensive trades, and (4) investigating the relationship between labor shortages and union participation rates across the trades.

## Background

This section presents an overview in relation to: (1) causes of skilled labor shortages in the construction industry, (2) previously studied aspects within the construction sector responsible for the industry's skilled labor shortages, (3) comparative analysis of the benefits of union versus nonunion participation in the construction industry, and (4) union and nonunion environments and their relation to skilled labor shortages.

### *Skilled Labor Shortages in the Construction Industry*

Previous studies have illustrated diverse reasons for construction workforce shortages. One significant factor is associated with workforce demographics such as the aging population of skilled laborers (Watson 2007). This drop in supply not only causes a decrease in the available workforce, but also when older skilled laborers retire or leave, the industry loses proficient skills and knowledge, lowering the skill level of the construction workforce as a whole (Han et al. 2008). This is further exacerbated by the fact that the construction industry has become less appealing to young, potentially skilled workers (Olsen et al. 2015), which has led to declining rates of younger people entering the industry compared to the rate of retirement (Kashiwagi and Massner 2002). Another major reason for skilled labor shortages is low wages and benefits (Watson 2007; Kashiwagi and Massner 2002). Problems related to low wages and job security have made it challenging for the construction industry to retain skilled labor within its workforce, with workers choose to seek better opportunities in other industries once acquiring the required skill level (Kashiwagi and Massner 2002). Further, the poor image of the industry has made people reluctant to choose it as a career (Shah and Burke 2005; Olsen et al. 2012). The construction sector is renowned for its dangerous working conditions and prevalent safety concerns, as it accounts for 8.9% of total recorded cases of injury in the United States (BLS 2002). Demanding skilled workers to perform dangerous tasks has made both recruitment and replacement difficult in construction (Olsen et al. 2015). Last, lack of information and training has also contributed to the limited attraction construction occupations have among competing professions (Watson 2007). It also inhibits workers from reaching the skilled level currently needed by the industry (Olsen et al. 2012).

It is important to differentiate between skilled and unskilled labor within the context of construction labor shortages. Research has shown that there is an ongoing shortage of both skilled and unskilled workers across all regions. However, the shortage of skilled labor is particularly significant and poses a greater challenge for the industry (Delvinne et al. 2020). Construction occupations requiring minimal skills and instruction exhibit relatively low levels of labor shortages compared to more specialized trades in the construction field (Vereen 2013). Accordingly, the impact of shortages of specifically skilled labor on construction projects has been extensively studied. Gomar et al. (2002) have highlighted that such shortages compel projects to rely on unskilled laborers, who generally exhibit lower productivity levels. As a result, more time is needed to complete construction tasks, consequently causing significant delays in project schedules and consequently cost overruns (Allmon et al. 2000; Kaming et al. 1997).

Ultimately, the literature emphasizes the critical nature of the skilled labor shortage within the construction industry. Although existing studies shed light on certain factors contributing to the skilled labor shortage in construction, it is important to acknowledge that further research is necessary to comprehensively explore all potential aspects that may be related to or affect skilled labor shortage in construction. The following section provides an overview of the main aspects examined in the literature that have been found to be associated with skilled labor shortages.

### *Previous Work Addressing Skilled Labor Shortages*

Extensive research efforts have been dedicated to examining various aspects within the construction sector responsible for the industry's skilled labor shortages. One significant aspect explored in the literature is the presence of inequality, biases, and discrimination based on characteristics such as race, ethnicity, and gender. These factors have been identified as contributing to labor shortages by creating barriers for certain individuals to enter and thrive in the construction workforce (Choi et al. 2018; Flori 2003). Consequently, promoting diversity and inclusivity within the industry has emerged as a potential solution to address these shortages (Choi et al. 2018). Studies have also explored the impact of immigrant workers on labor shortages, particularly the impact of immigration reform policies on the supply of immigrant labor, which has direct implications for the availability of skilled workers in the construction industry (Golden and Skibniewski 2010). The poor image of the construction industry



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has also been identified as a key aspect influencing labor shortages (Flori 2003). Efforts such as those extended by ASCE's National Construction Image Steering Committee have been made to improve the industry's image and showcase the diverse and rewarding career paths available within construction to mitigate the impact of the industry's image on driving potential entrants away from construction trades as a career choice (Schleifer 2002). Inadequate workforce investment strategies have been recognized as another contributing factor to skilled labor shortages. Poor training, recruitment practices, and hiring policies have limited the industry's ability to attract and retain skilled workers (Srour et al. 2006). Low wages, wage gaps, and insufficient benefits and other incentives have also been identified as issues affecting the industry's ability to attract and retain skilled workers (Goodrum 2004). Last, the safety environment in the construction industry has a significant impact on the availability of skilled labor. Concerns regarding on-site accidents, injuries, and fatalities (Ammar and Dadi 2023), as well as the industry's response to natural events such as earthquakes, can deter individuals from pursuing careers in construction (Kisi et al. 2020).

Despite the extensive research conducted on various aspects contributing to skilled labor shortages in the construction industry, the relationship between union and nonunion environments and labor shortages remains relatively understudied. The influence of unions on labor shortages can be complex and multifaceted. As such, the extent to which unionization affects labor shortages, either positively or negatively, is a topic that necessitates more comprehensive investigation. Therefore, research efforts should delve into understanding how unionization impacts workforce availability.

### Unions and Nonunions in the Construction Industry

Trade unions in the construction industry play a crucial role in advocating for workers' interests and addressing various issues (Dhal 2020). Two key areas where trade unions negotiate on behalf of workers are securing higher wages and better working conditions (Fairbrother 2015). Statistics indicate that union construction workers earn higher average wages compared to their nonunion counterparts (BLS 2022). Even in cases where wage raises cannot be achieved, unions have the ability to negotiate other wage concessions, such as providing affordable housing options in exchange for employers' commitment to using union labor (Slowey 2016). Further, unions act as intermediaries of social protection for workers by supporting them in registering for governmental welfare schemes and social protection systems (Wetlesen 2010).

Furthermore, trade unions are instrumental in promoting the health and safety of workers. They actively participate in developing and implementing health and safety management systems in construction projects, collaborating with government agencies to ensure compliance with safety standards (Allen and Burke 2022). In cases of injuries or fatalities, unions play a crucial role in ensuring that workers receive proper care and compensation, safeguarding their well-being (Slowey 2016). Additionally, some unions focus on addressing mental health issues among workers, providing support and resources to combat challenges like mental illnesses, addiction, and substance abuse. This is especially important in the construction industry, where 60% of workers have reported struggling with mental health (Skill Signal 2022). In fact, the construction industry has the highest suicide rate of all industries (CDC 2018). As for workers' safety, research demonstrates that safety standards established by OSHA are more strictly enforced and inspected in unionized workplaces. Union sites undergo more inspections and face greater scrutiny, with union employers being compelled to promptly address safety and health violations (Weil 1992). Despite constituting approximately 14% of the construction workforce, unionized workers only represent 5% of the industry's OSHA violations (Ford and Freund 2022).

Trade unions also prioritize training and education for workers. They invest a significant portion of their bargaining power in delivering comprehensive training and apprenticeship programs (Wang et al. 2008). By reaching collective agreements with employers on funding schemes, unions ensure the continuity and quality of these programs (Cuadra 2022). These training programs typically consist of classroom training, hands-on instruction, and on-the-job training (Teizer et al. 2013). Some unions even provide training in AutoCAD, software, and other technical subjects (Slowey 2016).

Despite the significant role trade unions play, union membership in the United States has experienced a decline in recent decades, with around 1 in 10 workers being a member of a union (Western and Rosenfeld 2011; Teizer et al. 2013). This decline can be attributed to several factors that inhibit construction labor from joining trade unions, the most important of which is the short-term employment nature of the industry. Workers often find no incentive to join a union due to the short-term or sporadic nature of their jobs (Holdcroft 2013; Breman 1996). Some workers are reluctant to join unions because they do not see an immediate material benefit (Wetlesen 2010). Others opt not to join trade unions out of fear that they would lose their jobs (Holdcroft 2013).

In addition to these reasons, there are several benefits to being a nonunion worker in the construction industry. Nonunion workers have the ability to approach their employers directly. This direct employer–employee relationship can prove advantageous in situations of wage, benefits, or contract negotiations, potentially allowing them to secure more favorable terms based on their individual skills, experience, and performance (Dontigney 2019). This is especially important for productive, well-performing skilled labor. Because unions negotiate for the entire union membership, outperforming skilled workers can miss out on such opportunities (Breman 1996). Another important advantage is that nonunion workers may have more opportunities for career advancement based on merit and individual performance. This limits advancement opportunities for new and high-performing workers. As such, unions may undervalue the education and experience of workers because seniority often takes precedence over merit (Stevenson 2023). Unions tend to prioritize the seniority of workers. This limits advancement opportunities for new and high-performing workers. As such, unions may undervalue the education and experience of workers because seniority often takes precedence over merit (Stevenson 2023).

Further, nonunion workers are not required to pay union dues, which can be a significant financial benefit. However, in some union construction sites, nonunion workers can still be obligated to pay mandatory dues imposed by unions, which is seen as a financial burden, impacting their net income. These fees can reach 1.5%–2.5% of the workers' pay. Thus, they can significantly reduce or diminish the pay gain that the worker would have had by moving from a previous job to a new one (Stevenson 2023). However, workers working in a nonunionized workplace can avoid the financial burden imposed by the union and potentially increase their net income (Dontigney 2019).

### Union and Nonunion Environments and Their Relation to Skilled Labor Shortage

The arguments presented previously demonstrate varying perceptions regarding the union versus nonunion work environments in the construction industry. A closer examination of such arguments also reveals that the presence or absence of trade unions has a significant impact on skilled labor shortages. For example, trade unions have the ability to negotiate on behalf of workers, leading to improved working conditions, higher wages, and benefits (Bryson et al. 2013). This can attract skilled labor to the construction industry because workers are more likely to choose jobs with better compensation and safer environments (Abdul-Aziz 2001). Further, unions provide a collective voice for workers, enabling them to address concerns collectively and ensuring that their interests are represented. Skilled laborers may be more inclined to remain involved in an industry that values their input and safeguards their rights (Pohler and Luchak 2014). Last, unions often offer training programs and apprenticeships that can help develop a skilled workforce. This training can attract individuals interested in honing their skills and becoming proficient in their craft (Marchand 2008). On the other hand, unions can introduce inflexibility in work arrangements and decision-making processes, slowing down projects and potentially increasing project costs. This rigidity might discourage skilled laborers who prefer more dynamic work environments (Santos 2009). Also, unions can drive up labor costs through higher wages and benefits, potentially leading to reduced competitiveness and fewer job opportunities in the industry (Lindbeck and Snower 2001). Last, trade unions can create barriers to entry for new workers, making it harder for newcomers to join the workforce. This can limit the influx of fresh talent, exacerbating skilled labor shortages (Cooper and Ellem 2008).

The literature shows varying perceptions regarding union versus nonunion construction environments. Considering the arguments presented from both perspectives, it is evident that the presence or absence of trade unions has a significant impact on skilled labor shortages. Therefore, it becomes crucial to evaluate the potential effects of union and nonunion approaches on labor shortage issues.

## Methodology

To achieve the goal and objectives of this study, the authors used a multistep research methodology. Fig. 1 shows the methodological approaches used to fulfill each of research questions and objectives as well as the outcomes of each step. The following subsections detail each methodological step.

### *Identification of Labor-Intensive Trades*

As previously mentioned, the construction literature suffers from a limited focus when it comes to identifying and addressing issues associated with key labor trades. To avoid such a shortcoming, the authors resorted to data from real-life construction projects to identify key labor-intensive construction trades. In this research, labor-intensive trades are defined as construction works that require a significant amount of manual labor and skilled workers to complete and rely less on equipment and technology (Sui Pheng et al. 2019). The purpose of resorting to data from real-life construction projects was not to establish new trades but rather to identify the key labor-intensive trades that are most commonly found within the construction industry. By examining the actual practices and trades employed in construction projects, the authors aimed to gain a deeper understanding of the trades that play a crucial role in construction activities. This approach allowed them to ensure that their findings align closely with the challenges faced in the construction field. Such an approach of resorting to the industry to acquire knowledge has been used by previous studies as an alternative to theoretical and empirical research (Hwang and Lim 2013).

#### Data Collection

To identify the key labor-intensive trades of the industry, the authors conducted quantitative content analysis of project documentation

| Research Question | Objective | Methodological Approach | Outcome |
|---|---|---|---|
| What are the labor-intensive trades most affected by the shortage of skilled labor? | Identify Key labor-Intensive trade | • Quantitative content analysis of project documentation for 67 construction projects.<br>• Panel of industry experts to validate the list of identified key labor-intensive trades. | • Identify a comprehensive list of 10 key labor-intensive trades. |
| | Examine the degree of labor shortage associated with each trade | • Expert based survey.<br>• Descriptive analysis.<br>• Clustering analysis (K-means clustering). | • Quantify the level of labor shortage for the identified labor trades.<br>• Determine the trades that have the highest and lowest degrees of skilled labor shortages. |
| What is the current status of union participation of skilled workers across key labor-intensive trades? | Assess the reach of trade unions among skilled labor within each of the identified labor-intensive trades | • Expert based survey.<br>• Statistical analysis (Binomial Test). | • Quantify the union participation rates for the identified labor trades.<br>• Examine trades with statistically significant differences in the proportion of skilled workers in unions compared to the proportion of workers not in unions<br>• Classify labor-intensive construction trades into clusters based on proportion of union participation |
| How does the presence or absence of trade unions influence the availability of skilled labor in the construction industry? | Investigate the relationship between labor shortages and union participation rates across the trades. | • Statistical analysis (Chi Square Test of Independence). | • Determine trades with a statistically significant correlation between union participation rates and degrees of labor shortage. |

**Fig. 1.** Research questions, objectives, methodology, and outcomes.

related to construction projects that span six main sectors, residential, infrastructure, health care, commercial and mixed-use, civil and transportation, and institutional. Considering a large number of projects allows the list to be as comprehensive as possible, which contributes to more generalizable findings (Antillon et al. 2018). Qualitative content analysis focuses on grouping data into categories (Chan et al. 2009). It is a widely used technique for collecting and organizing information and for identifying trends and patterns in documents (Krippendorff 2013). In this paper, qualitative content analysis entailed the following steps. First, project documentation related to 67 construction projects was collected. Collected documents included daily and monthly reports, labor productivity rates for project activities reports, risk reports, design change briefs, minutes of meeting for on-site meetings, master schedules, and schedule updates. Second, a preliminary assessment of the documents was performed to identify a number of common labor-intensive trades and categorized in accordance with the type of work performed in each trade. Third, a thorough analysis of the documents was conducted to apply the identified trades and determine a comprehensive description of the works associated with each trade. Ultimately, the authors were able to compile a list of 12 labor-intensive construction trades, which are: carpentry, ironworking, concreting, plumbing, false ceiling/dry wall installing, masonry, plastering and painting, finishes, flooring, insulation, electrical, and HVAC.

### Validation of the Identified Trades

To ensure the validity and comprehensiveness of the compiled list, the authors referred to industry professionals for their expert opinion. Professionals with strong knowledge of both technical and management aspects of the construction industry were selected and included in an expert panel for this study. The panel consisted of 13 experts from 8 leading contracting companies that are involved in various building sectors, including commercial and mixed-use, residential, civil and transportation, infrastructure, distribution and warehouse, and manufacturing and industrial. The selection of participating experts was based on the following criteria: the experts are industry practitioners in upper-level administrative and management positions, and the contracting companies are medium-scale to large-scale construction contractors. The purpose of the study was explained to the panel. After the experts agreed to participate in the study, the 12 identified labor-intensive trades along with a brief description of the works entailed in each trade were shared with them. The participating experts were invited to critique the classification of the trades and suggest modifications.

In their review, the expert panel recommended changes in the terminology used for some trades. These changes included deleting some trades and aggregating others together. For example, one expert recommended changing the term "false ceiling/dry wall installing" to "framing and drywall." The panel also suggested changes in the definitions of some trades such that they were more comprehensive, precise, and in accordance with standard practices of the construction industry. One expert commented that "finishes" is too broad and should be broken down into more specific trades. Based on the received feedback, the terminology and definitions of the identified labor-intensive trades were modified. Finally, the experts approved a list of 10 key labor-intensive trades along with the type of works associated with each trade (refer to Table 2 for the list of identified trades). This list enabled the authors to conduct further in-depth analysis of skilled labor at the trade level.

## Expert-Based Survey

### Survey Design

An expert-based survey was administered to collect data in relation to union participation rates and degrees of skilled labor shortage across the identified labor-intensive trades. The survey consisted of three sections. Instructions on how to fill out the questions and explanations of the question types and scales preceded each section. The first section was an introductory paragraph that explained the research and survey objectives. The second section consisted of seven multiple-choice and text entry questions meant to profile respondents. The questions collected information regarding the respondent's position, role of the company, years of work experience, current location of employment, location of the project they were currently involved in, and contact info (if the respondent opted to provide such information). Last, the third section was composed of two sets of questions. The first set of questions collected information regarding the union participation rates of skilled labor in projects where the respondent had been involved. As such, respondents were asked to specify for each labor-intensive trade whether workers employed in such projects were predominantly union or nonunion workers. For each trade, the respondent was to select either union or nonunion. The second set collected data in relation to the degree of skilled labor shortage witnessed in each of the identified labor-intensive trades. Respondents were asked to rate the degree of shortage of skilled labor for each of the trades based on their experience in the construction industry. All questions in this set used a five-point Likert scale. Table 1 highlights the developed scale for quantifying the degree of skilled labor shortage. In filling out the survey, respondents were asked to consider their industry and project experience collectively, with special focus on their current work. Further, they were asked to provide responses only for the trades in which they had prior experience or were involved in. As such, respondents were allowed to skip the trades that were not within their domain of expertise. This ensures the reliability and accuracy of the collected data. For further details regarding the percentage of respondents selecting each trade please refer to Fig. 3. The survey was developed online using Qualtrics, which is a platform for online survey design and distribution.

### Survey Distribution

This research followed the purposive sampling technique to distribute the developed survey. Purposive sampling is a common type of nonprobability sampling that entails randomly selecting respondents from a particular section of the population that is believed to yield samples that will give the best estimate of the population parameter of interest (Guarte and Barrios 2006). This decision is based on prespecified criteria such as having the required experience

**Table 1.** Developed scale for the degree of skilled labor shortage

| Rate | Description |
|---|---|
| 1 | Negligible shortage, very low degree, occurs in only exceptional circumstances. |
| 2 | Minor shortage, workers not available at project location but available within the company. |
| 3 | Moderate shortage, workers are not available within the company, and moderate efforts would be exerted to recruit workers. |
| 4 | Significant shortage; extensive efforts would be exerted to recruit workers. |
| 5 | Extreme shortage; exceptional efforts would be exerted to recruit workers. |

or ability to educate on a specific subject, concept, or phenomenon that is in line with the researcher's interest (Verma et al. 2017). Purposive sampling was used in this paper due to its various advantages, which include selecting qualified and experienced respondents and providing higher-quality insights and more precise findings (Taherdoost 2016).

In this paper, purposive sampling entailed the following steps, as specified by Etikan et al. (2016). First, the research problem and the type of information needed were identified. The research problem is as defined in the "Knowledge Gap and Research Questions" section of this paper. As for the type of information needed, it includes the questions stated in the previous subsection, "Survey Design." Second, the criteria for selecting the respondents or groups of respondents were defined. In this paper, the criteria for selecting respondents included being: (1) construction professionals currently working in the US construction industry; and (2) one of the central project stakeholders, including owners, engineers, general contractors, and trade contractors. Third, respondents were selected based on the defined criteria. Contacts for survey respondents were sourced from various databases, including databases of the Associated General Contractors for states that are accessible for use and websites of large and midscale construction companies nationwide. Additionally, eligible participants were identified from trade union groups and construction trade associations. Fourth, survey distribution commenced. In this research, the survey was sent to the selected construction professionals through Qualtrics, emails, and social media platforms. The fifth and last step was to document the data and interpret the results. The remaining subsections in this section provide a detailed account of how the survey data were analyzed.

**Data Reliability**

Checking that the collected responses form a representative sample is crucial to ensure that the data constitute a solid basis for analysis (Abdul Nabi and El-adaway 2021). To this end, the Cochran formula (Cochran 1977), shown in Eq. (1), was used to determine the minimum number of responses required for a statistically valid survey

$$n = \frac{N \times X}{X + N - 1} \tag{1}$$

where $X = Z^2_{\alpha/2} \times p \times (1-p)/D^2$; $n$ = the sample size; and $N$ = the population size. Because the population size is of a large but unknown value, it is recommended to assign $N$ a value of 100,000. The sample size becomes less sensitive for population changes larger than 100,000. The value of $Z$ is the test statistic for a two-tailed $Z$ hypothesis test. At a 95% level of significance, the critical value $Z_{\alpha/2}$ of the normal distribution at $\alpha/2$ is 1.96. A 95% confidence level is commonly used and widely acceptable. The value of $p$ is the proportion of the respondents in a sample who would select the same answer. In this paper, $p$ was 0.5, which represents the worst-case scenario (Lattouf et al. 2014). The value of $D$ is the acceptable margin of error, which is the width of the confidence interval. The lower the margin of error, the larger the required sample size to achieve results within the confidence level. In this case, $D$ was set equal to 0.10 to maintain a low margin of error within the selected confidence level (Garg and Misra 2021; Lattouf et al. 2014). According to Cochran's formula and the parameters set previously, the calculated minimum sample size was around 97 respondents. In this paper, 106 complete and valid survey responses were collected (please refer to the "Results, Analysis, and Discussion" section), which is higher than the threshold set by the Cochran formula for a statistically acceptable sample. Therefore, it can be concluded that the survey is reliable and constitutes a representative sample. Also, the number of respondents in this study exceeds those in previous similar research efforts, including—just as an example—100 in Assaad et al. (2022) and 56 in Hasanzadeh et al. (2018), among many others within the literature.

### Clustering Analysis

To further examine the observed levels of labor shortage across the identified trades, the authors conducted $K$-means clustering. Clustering is a form of unsupervised machine learning technique that groups objects such that the similarities between objects within the same group are maximum and similarities between groups are minimum (Madhulatha 2011). One popular and efficient algorithm for conducting cluster analysis is $K$-means clustering (Ratrout 2011). $K$-means clustering is a centroid-based clustering technique that groups instances into a pregiven number of clusters. Instances are assigned to clusters by finding the optimum locations of the centroids of the clusters such that the square distances to those centroids are reduced (Ostrovsky et al. 2013). In other words, the objective function of $K$-means clustering is minimizing the distance between the centroids and the instances. Such an objective function may represent a set of variables, making the distance between the instance and the centroid a multidimensional real vector (Eghbali et al. 2017). This enables the partitioning of the data based on several criteria simultaneously. In this paper, clustering was based on the trade, ratings for labor shortages for each trade, and proportion of survey respondents selecting each rating for each trade. Before applying the $K$-means algorithm, the authors preprocessed the data and used the elbow plot method to identify the optimum number of clusters $k$. The remainder of this subsection provides further details on how data preprocessing and selection of the optimal number of clusters was performed in this research.

To ensure the reliability of the clustering results, data preprocessing must first be performed before applying the $K$-means algorithm. The different variables included in the clustering have different magnitudes.

This is problematic for methods such as $K$-means clustering that rely on distances because high-magnitude variables would have greater influence on the analysis. Accordingly, data preprocessing in this paper entailed normalizing the data set to a scale from 0 to 1.

As previously mentioned, $K$-means clustering relies on a prespecified number of clusters ($k$) as a key feature. There are several methods to determine $K$, such as the Hubert statistic, the score function, the silhouette score, and the elbow plot method (Pai et al. 2021). In this paper, the authors used the elbow plot method to identify the optimal number of clusters. This method has been used widely in the literature and thus had proved efficient and reliable (Yuan and Yang 2019; Eghbali et al. 2017). In this method, $K$-means clustering was applied on the data for a range of values for $k$. Following, a distortion score was calculated and plotted for each value of $k$. The distortion score is the sum of square distances from each instance to its assigned center. Generally, as the number of clusters $k$ increases, the distortion score decreases. The optimal number of clusters is at the point after which the distortion decreases in a linear manner. This point indicates that further increasing the number of clusters would yield a diminishing improvement in the distortion score. Graphically, the plot of distortion scores versus $k$ takes an elbow shape, where the optimal number of clusters $k$ is at the elbow point of the curve. The algorithms for $K$-means clustering, data preprocessing, and elbow plot method were all implemented using the Python programming language.

### Binomial Test

To further examine the levels of union participation across the identified labor-intensive trades, the authors used the binomial test to

(1) examine trades with statistically significant differences in the proportion of skilled workers in unions compared to the proportion of workers not in unions; and (2) classify labor-intensive construction trades into clusters based on proportion of union participation. As such, it was applied twice in this research. The binomial test is used to assess if the proportion of "success" of a two-level dependent categorical variable significantly differs from an expected value (SPSS 2021). Accordingly, the null hypothesis is that the proportion of success in one sample is not significantly different from that in another sample. Rejecting the null hypothesis indicates that there is a statistically significant difference in the proportion of successful observations between the two samples.

In the first test, trades were analyzed based on the distribution of the workforce between unionized labor and nonunionized labor. In this context, the binomial test was used to assess if the proportion of the workforce in a union is significantly different from that not part of a union for each of the identified labor-intensive trades. The null hypothesis of this test is that the percentages of unionized and nonunionized skilled workers in a given trade are equal. The null hypothesis is rejected if the Pearson chi-squared $P$ value is less than 0.05, which is mandated by a significance level of 5% bilateral error. Rejecting the null hypothesis indicates that there is a statistically significant difference in the proportion of unionized skilled workers compared to the proportion of nonunionized skilled workers.

In the second test, the binomial test was used as a clustering technique to divide data into groups of similar frequencies (Fidal and Kjeldsen 2020). Thus, it was applied to group labor-intensive trades into clusters based on the proportion of unionized workforce corresponding to each trade. As such, trades were sorted and analyzed in pairs to assess whether they belonged to the same cluster. The null hypothesis of this test is that the percentage of union participation in one trade is the same as that in another. Similar to the first binomial test, the null hypothesis in this test is also rejected if the Pearson chi-squared $P$ value is less than 0.05 (5% significance level). Rejecting the null hypothesis suggests that there is a statistically significant difference in the proportion of unionized skilled workers compared to that of unionized skilled workers in another trade, indicating that each trade belongs to a different cluster.

### Chi-Square Test of Independence

The authors performed the chi-square test of independence to examine the correlation between union participation and labor shortage. The chi-square test of independence is a type of Pearson's chi-square test that is used to examine the association between two variables (SPSS 2021). The null hypothesis of the test is the independence of variables, whereas rejecting the null hypothesis indicates that there is a relationship between them (Ketchman et al. 2018). In this research, it was applied to each of the identified labor-intensive trades to determine the correlation between union participation rates and degrees of labor shortage. In each test, the null hypothesis indicates that the union participation rate and degree of labor shortage within a given trade are independent of one another. Conversely, a rejected null hypothesis would suggest a significant relationship between them.

Whereas chi-square tests typically require that all cell values of the contingency table be more than 5, Fisher's exact test has no sample size restrictions. Accordingly, in cases where cells have values less than 5, Fisher's exact test is usually used instead of chi-square tests (McHugh 2013). Similarly, a 95% confidence interval was used in the Fisher's exact test (Forcada et al. 2013).

## Results, Analysis, and Discussion

This section presents the results, analysis, and discussion of the key findings in relation to: (1) the identified labor-intensive trades, (2) characteristics of the survey respondents, (3) labor shortages in labor-intensive trades, (4) union participation rates in each of the identified labor-intensive trades, and (5) the relationship between labor shortages and union participation rates across the trades.

### Labor Intensive Trades

Following analysis of the documentation of 67 projects and referring to industry professionals for their feedback, the authors identified 10 key labor-intensive construction trades. Table 2 shows the identified labor trades and their description within the context of construction works performed on site. As can be seen from the table, some of the trades aggregate more than one type of work together. Accordingly, the authors provided a brief account of the works entailed within each trade to avoid overlapping and misinterpretations.

### Characteristics of the Respondents

As mentioned in the "Methodology" section, the expert-based survey was sent to potential respondents through Qualtrics, emails and social media platforms. The survey was sent out to 492 potential respondents. A total of 114 responses were received. Out of the 114 responses, 8 were eliminated for being incomplete. Thus, a total of 106 responses were complete and valid, with a survey response rate of around 22%. Because the minimum required number of respondents is 97 responses according to Cochran's formula, it can be concluded that the survey data are reliable and constitute a representative sample of the key stakeholders of the US construction industry.

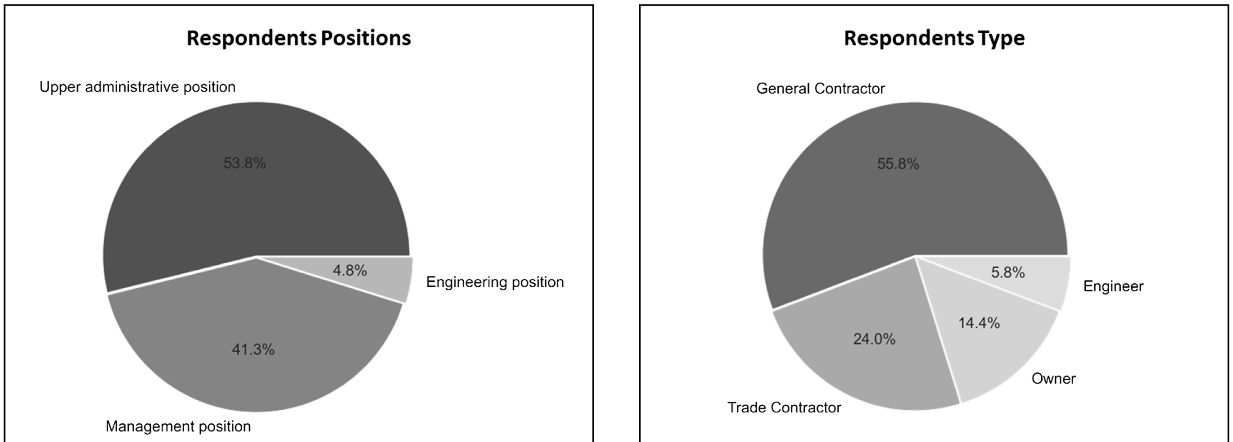
In addition to statistical validation, the authors conducted an empirical examination of previous research work to examine commonly used response rates for survey-based research work in the construction domain. The average response rate for questionnaire surveys in the construction industry is 20%–30% (Akintoye 2000). Further, it is known that the response rate for online surveys is between 10% and 15%, which needs to be considered when designing them (Bernold 2016; Porter 2019). For example, Hartono et al. (2019) reported that of 746 firms that were invited, 68 provided useful responses, with a 9% response rate. Similarly, Jaapar and Torrence (2009) reported a 7.5% response rate for a survey on the practices of value management in the construction industry. Based on the aforementioned information, the obtained response rate of 22% is within the acceptable range of survey-based studies in construction research.

#### Positions, Years of Experience, and Stakeholder Categories of Respondents

Fig. 2 shows the distribution of survey respondents according to their positions and stakeholder group. As can be seen, around 95% of the survey respondents held upper administrative and management positions within their companies, whereas the remaining 5% had engineering positions. Upper administrative positions included chief executive officers, chief operating officers, presidents, vice presidents, and department directors. Management positions included project managers, departmental and regional managers, and operational managers. Last, engineering positions included project engineers, assistant project managers, and senior superintendents. Moreover, the distribution of the respondents among the main stakeholder categories indicates that the majority of the respondents were general contractors, with a percentage of 56%. As for the

**Table 2.** Identified labor-intensive construction trades and their descriptions

| No. | Labor-intensive construction trade | Description |
|---|---|---|
| 1 | Concreting | Includes concrete pouring, spreading, grading, and smoothing as well as concrete curing and finishing. |
| 2 | Ironworking | Includes installation of:<br>• Rebar and expansion joints.<br>• Cold-formed steel framing (metal framing activities necessary for installation of drywall and ceiling tiles).<br>• Precast beams, columns, and panels. |
| 3 | Framing and drywall | Farming includes wood framing activities necessary for installation of:<br>• Drywall and ceiling tiles.<br>• Concrete formwork.<br>• Scaffolding.<br>Drywall activities include installation of drywall, ceiling tiles, and other plaster base assemblies. |
| 4 | Masonry works | Includes activities that depend on laying bricks, concrete and concrete blocks, and natural and human made stones to build structures. |
| 5 | Plastering and painting | Includes wall and ceiling finishing activities such as:<br>• Plastering.<br>• Basecoat applications.<br>• Application of paints, wallpapers, claddings, or other decorative materials. |
| 6 | Flooring | Includes finishing activities such as rendering works and tiling installation. |
| 7 | Waterproofing | Includes the application of waterproofing materials such as fluid-applied membranes or sheet systems. |
| 8 | Plumbing | Installation of water supply, drainage, and firefighting systems, including activities such as:<br>• Installation of pipes and fixtures.<br>• Installation of equipment. |
| 9 | Electrical | Includes installation and wiring of electrical systems, including power equipment and light current systems. |
| 10 | HVAC | Installation of heating, ventilation, and air conditioning systems, including activities such as:<br>• Fabrication, installation, and insulation of duct work.<br>• Installation and insulation of pipework.<br>• Installation of equipment. |




| Position | Years of Experience | |
|---|---|---|
| | Avg. | STD |
| Upper administrative position | 29.82 | 9.25 |
| Management position | 15.46 | 10.82 |
| Engineering position | 5.80 | 6.38 |
| **All Respondents** | **22.73** | **12.58** |

| Type | Years of Experience | |
|---|---|---|
| | Avg. | STD |
| Owner | 25.93 | 13.78 |
| Engineer | 28.67 | 17.32 |
| General Contractor | 18.65 | 10.74 |
| Trade Contractor | 28.84 | 11.73 |

**Fig. 2.** Distribution of survey respondents.

remaining stakeholders, they were owners, 14%; engineers, 6%; and trade contractors, 24%. Trade contractors included key specialties such as concrete, masonry work, iron work, and miscellaneous works.

Fig. 2 also presents the average years of experience of the survey respondents. It can be seen that the average years of experience of all survey respondents was 22.7 years. More than 50% of the respondents (upper administrative positions) had an average experience of around 30 years. Respondents in management positions had an average of 15.5, years and those in engineering positions had an average of 5.8 years. Furthermore, the average experience of respondents within each stakeholder group ranged from 18.6 to 28.8 years.

Trade contractors had the highest average experience, followed closely by engineers. Only one respondent had less than 3 years of experience in construction.

Respondents who are in upper administrative and management positions and with extensive experience typically have an overview of whole operations. Therefore, they are able to provide a holistic perspective of a project as well as the skilled workers participating in such project. This is in contrary to workers and entry-level engineers, who are involved in the industry at a much lower level. Therefore, they are not subjected to this type of comprehensive exposure. Furthermore, to ensure that the respondents represented an acceptable range of experience in the industry, the authors compared the experience of the professionals surveyed in this paper with similar survey-based research studies in the construction domain. For example, Votano and Sunindijo (2014) conducted a survey where 22.5% of the respondents had less than 3 years of experience, 25% had worked for 3 to 5 years, 32.5% had 6 to 10 years of experience, and 20% had worked for more than 11 years. Ameyaw et al. (2017) collected data from survey respondents, 65% of whom had 21–30 years working experience in the construction industry. To that end, it can be concluded based on these distributions that the collected data represent the opinions of highly experienced experts at both the industry and project level.

## Expertise of Respondents

As previously explained, questions in the expert-based survey are mostly based on the identified labor-intensive trades. Accordingly, the reliability of the collected information relied on the expertise of the respondents in such trades. This is why respondents were asked to provide information in relation to only the trades where they had prior experience. Nonetheless, they were given the choice to select any number of trades for which they opted to provide their input. Fig. 3 shows the percentage of respondents selecting each trade for each of the identified labor-intensive trades.

As Fig. 3 shows, concreting was the most selected trade. Of the 106 surveyed respondents, 75% selected the concreting trade and thus provided data in relation to the union participation rate and degree of labor shortage within that trade. The relatively high expertise of construction professionals in concreting in comparison to the rest of the trades can be attributed to a number of reasons. First, the cost of the concreting trade contributes to around one third of the total cost of reinforced concrete structures (Illingworth 2000). Another study estimated that concreting represents 14% of the cost of vertical construction and thus is considered a major vertical construction activity (Palaniappan et al. 2012). Second, it is the trade most impacted by change orders (Kim et al. 2020). Third, concreting labor cost constitutes around 30% of the cost of concreting activities (Jarkas 2012). Concreting was followed by ironworking, electrical, and framing and drywall, which were selected almost equally at around 57%. Palaniappan et al. (2012) classified framing, drywall, and electrical trades as major trades within construction projects, with framing alone contributing from 22% to 29% of the cost of vertical construction. Last, it was noticed that trades that lie within finishes works (i.e., flooring, waterproofing, and plastering and painting) were selected the least by respondents, with an average selection rate of 32%.

## Geographic Distribution of Respondents

This section details the geographic distributions of the survey respondents based on two key aspects: (1) current location of employment; and (2) location of project a respondent is currently involved in. Fig. 4 demonstrates the geographical distribution of the location of employment of the survey respondents. It shows the employment locations by state and the percentage of responses employed in each location. It was found that survey responses were collected from

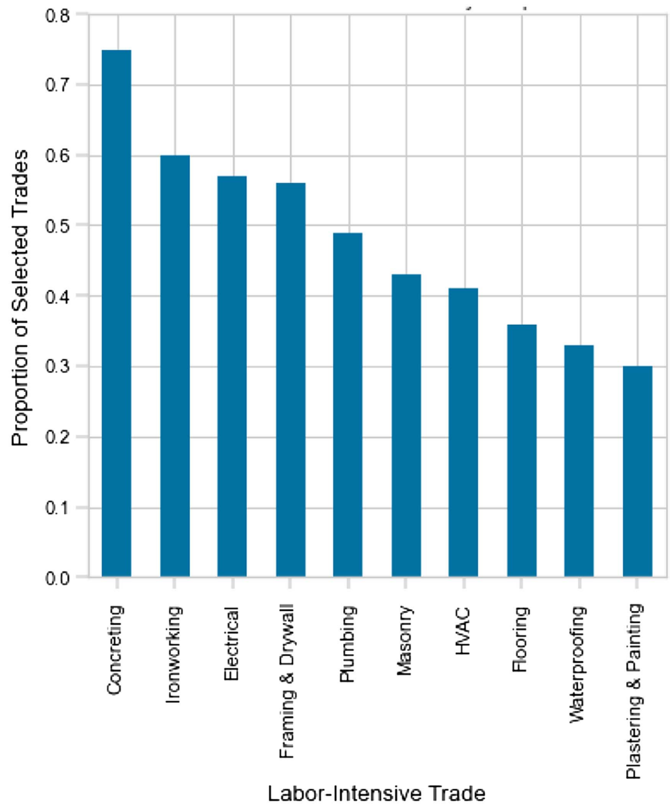



**Fig. 3.** Distribution of trades selected by respondents.

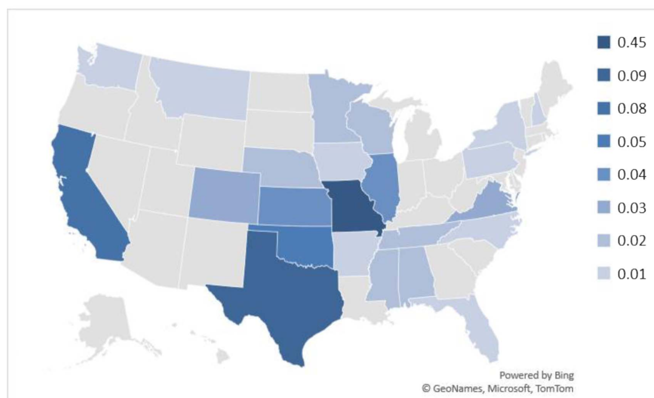



**Fig. 4.** Geographical distribution of respondents' current location of employment. (Powered by Bing, © GeoNames, Microsoft, TomTom.)

52 construction companies working in 23 states across the United States. Higher response rates were witnessed predominantly in midwest and southern states. Professionals employed in Missouri, Texas, and California had the most responses to the survey, with 45%, 9%, and 8% participation rates, respectively. On the other hand, New York, Iowa, and Florida were among the lowest-responding states.

In addition to respondents' location of employment, the location of projects in which they were involved at the time of completing the survey was also analyzed. To this end, Fig. 5 shows project locations by state and the percentage of respondents involved at projects in each location. Unlike the location of employment, where higher response rates were noticed in midwest and southern states, project

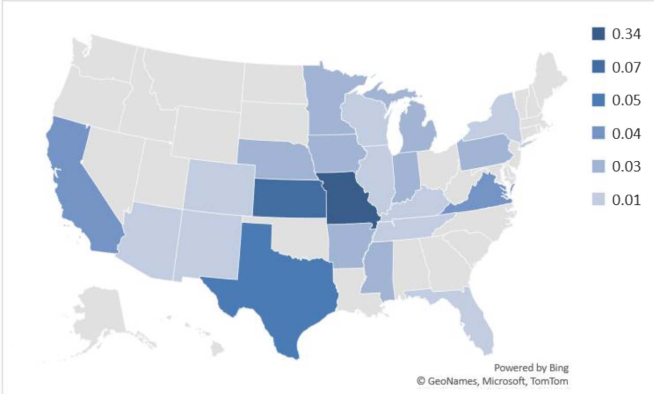



**Fig. 5.** Geographical distribution of location of projects respondents are currently involved in. (Powered by Bing, © GeoNames, Microsoft, TomTom.)

locations were more widespread across the country, with respondents reporting from projects in 25 states. Still, Missouri, Kansas, and Oklahoma were the top-represented stated in terms of project locations reported by respondents, whereas Colorado, Kentucky, and Tennessee were among the lowest states.

As mentioned before, the survey covered 25 states. As such, not all states were included. Although this is a limitation of this research (please refer to the "Research Limitations" section for further details), the analysis can still provide valuable insights because there are often similarities and common trends among states within the same geographic region or with similar economic characteristics. Therefore, even though specific states may have been absent from the data reported by the respondents, the findings can still provide meaningful information and trends that can be indicative of labor shortages in a broader context.

## Labor Shortages in Labor Intensive Trades

### Analysis of Survey Results

In this section, the authors analyze the data provided by survey respondents in relation to labor shortages witnessed in the construction labor market. Table 3 provides a description of the survey results for the degree of skilled labor shortage witnessed in each of the identified labor-intensive trades. The mean response rating value for the degree of labor shortage ranged from a maximum of 2.879 (plumbing) to a minimum of 2.345 (plastering and painting). According to the scale developed in this paper for quantifying the degree of skilled labor shortage (refer to Table 1), the shortages experienced across the various trades fall within minor to moderate shortages. In minor shortages, workers may not be available at the project location but can be relocated from other projects within the company, whereas in moderate shortages, workers are not available at any project within the company, and thus some effort needs to be extended to employ new workers. As for the standard deviation, it ranged from 1.075 (HVAC) to 1.285 (plumbing). This indicates that for each trade, around 70% of the ratings provided by survey respondents fell between the 1 and 3 ratings of degree shortage. Table 3 also provides the rankings of labor trades regarding the mean degree shortages. It can be seen that the plumbing and electrical trades had the highest mean degrees of labor shortage, followed by civil trades such as masonry works and framing and drywall. On the other hand, finishes trades (flooring, waterproofing, and plastering and painting) had the lowest labor shortage means.

**Table 3.** Degree of labor shortage mean, standard deviation, and rankings for labor-intensive trades

| | | | | Distribution shape | |
|---|---|---|---|---|---|
| Labor-intensive trade | Mean | SD | Rank | Skewness | Kurtosis |
| Concreting | 2.5405 | 1.137 | 7 | 0.2419 | −0.5861 |
| Ironworking | 2.5833 | 1.1718 | 6 | 0.2798 | −0.6109 |
| Framing and drywall | 2.7096 | 1.1507 | 4 | 0.3321 | −0.6012 |
| Masonry works | 2.7966 | 1.2564 | 3 | 0.2372 | −0.8856 |
| Plastering and painting | 2.3454 | 1.1740 | 10 | 0.7075 | −0.1182 |
| Flooring | 2.4074 | 1.0905 | 8 | 0.2915 | −0.8432 |
| Waterproofing | 2.4074 | 1.1413 | 9 | 0.4740 | −0.6726 |
| Plumbing | 2.8793 | 1.2852 | 1 | 0.2327 | −0.9080 |
| Electrical | 2.875 | 1.2535 | 2 | 0.0935 | −1.0249 |
| HVAC | 2.6034 | 1.0750 | 5 | 1.1607 | −0.6425 |

Fig. 6 presents the distribution of ratings of degree shortage for each of the identified labor-intensive trades. In addition to having the highest mean degrees of labor shortages, the plumbing, electrical, and masonry works trades also had the highest proportion of respondents selecting the rating 5 for the degree of labor shortage. On average, 15% of industry professionals suffer severe degrees of labor shortages when employing skilled workers in the plumbing and electrical trades, meaning practitioners tend to exert exceptional efforts to recruit and retain skilled workers in those trades in construction projects. These results are further corroborated by the Associated General Contractors of America (AGC), which reported in its annual Workforce Survey that construction firms have 78%, 80%, and 85% difficulty filling hourly craft positions in electrical, mechanical, and plumbing trades, respectively (AGC 2021). Further, the Construction User Round Table stated in its report that electricians were one of the most affected trades by labor shortages (CURT 2001).

Labor shortages in the masonry works, framing and drywall, and HVAC trades fell in the midrange. Masonry works was ranked third by respondents in terms of the witnessed degree of skilled labor shortage. The percentage of industry professionals who reported significant to extreme degrees of labor shortage in those trades ranged from 3% to 15%. This is considerably lower in comparison to the plumbing and electrical trades, which ranged from 12% to 23%. About 6% of the firms surveyed in AGC's annual Workforce Survey reported major difficulties in hiring masonry workers (AGC 2021).

Concreting and ironworking were perceived to have relatively lower degrees of labor shortage. Respondents reported analogous patterns of shortages in both trades. This implies that industry professionals often spend similar levels of effort when hiring concrete and ironworkers. For example, around 35% of survey respondents reported moderate shortages in both trades, where workers may not be available within the contractor's company and thus moderate efforts are exerted to recruit labor. Following, 13% of the respondents experienced significant shortages and had to spend extensive efforts in labor recruitment. Last, 6% of the respondents indicated a severe shortage in skilled labor within the construction market.

Finishing works trades (plastering and painting, flooring, and waterproofing) had the lowest levels of skilled labor shortage among the identified labor-intensive trades studied in this paper. More than 50% of survey respondents reported negligible to minor skilled labor shortages when hiring plastering, painting, flooring, and waterproofing workers.

### *K*-Means Clustering

To further analyze labor shortages in labor intensive trades, the degrees of labor shortages were clustered based on three variables:

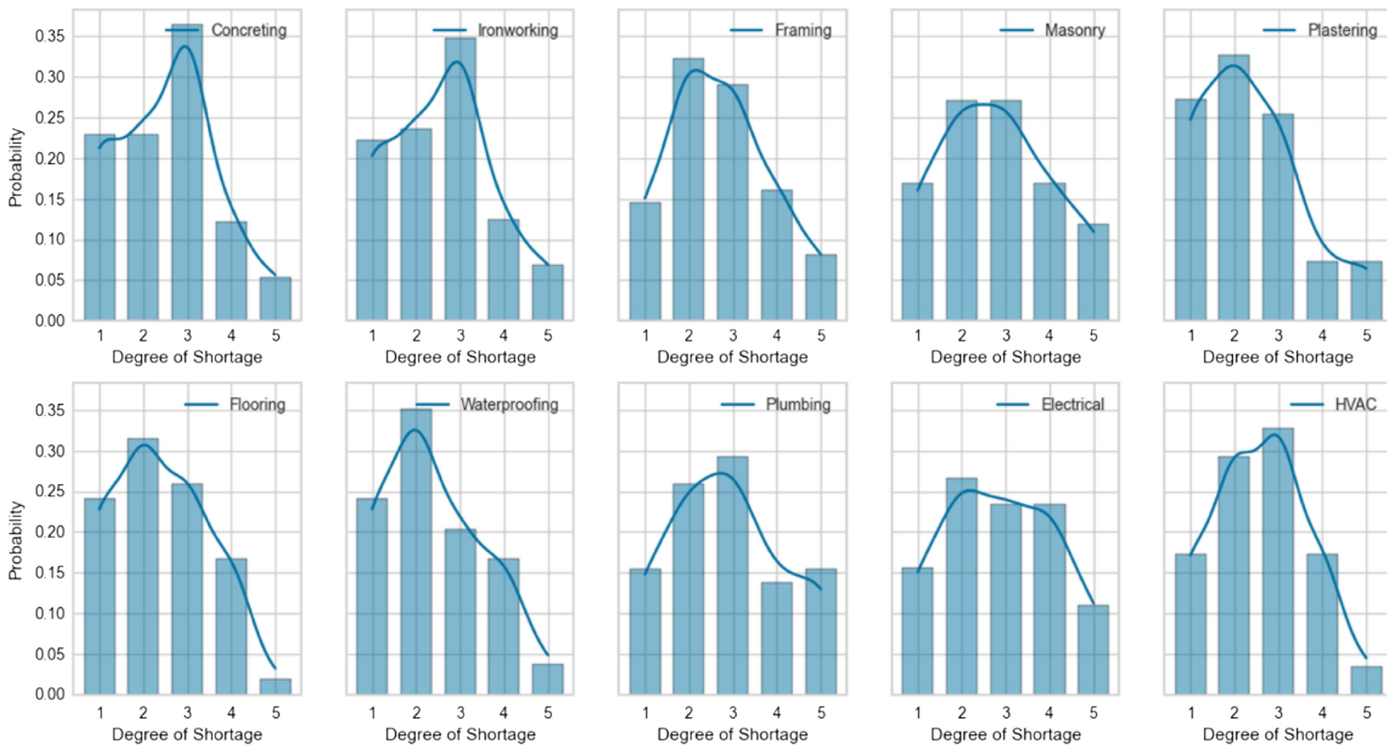



**Fig. 6.** Distribution of ratings of degree of skilled labor shortage across labor intensive trades.

(1) labor trade, (2) ratings for labor shortage, and (3) proportion of survey respondents selecting each rating for each of the trades. After normalizing the data set, the elbow method was used to determine the optimal number of clusters. This method was applied by running $K$-means clustering for values of $k$ that ranged from 2 to 16. For each value of $k$, the distortion value was calculated and recorded. Fig. 7 demonstrates the calculated distortion score for each value of number of clusters $k$. As can be seen in the figure, the location of the bend (elbow) in the plot is found at a $k$ value of 4. Accordingly, it can be concluded that the optimum number of clusters for the data is four clusters.

Following scaling the data and identifying the optimum number of clusters, the $K$-means algorithm was applied using three features, (1) labor trade type, (2) ratings provided by survey respondents for labor shortages for each trade, and (3) proportion of respondents selecting each rating for each trade. Given that there are five labor shortage ratings and 10 labor trades, the clustering analysis is composed of a total of 50 instances (data points). Each instance represents a proportion of survey respondents selecting a labor shortage rating for a labor trade. As such, the clustering partitioned these instances into four clusters based on the selected features. Fig. 8 demonstrates the results of the $K$-means clustering where each node represents an instance; the color of the node represents the cluster to which each instance belongs; the size of the node represents rating given by survey respondents for that given instance; the $x$-axis represents the percentage of respondents selecting each labor shortage ratings; and last, the $y$-axis is the identified labor-intensive trades. Results show that there are 11 instances in Cluster 1 (C1), 11 instances in Cluster 2 (C2), 18 instances in Cluster 3 (C3), and 10 instances in Cluster 4 (C4).

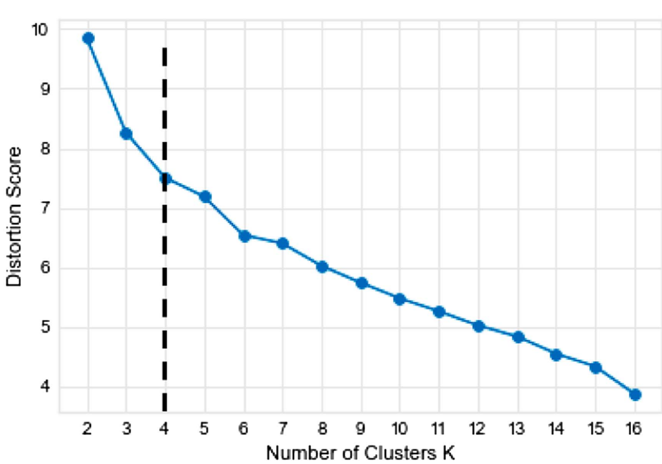



**Fig. 7.** Elbow plot demonstrating optimal number of clusters.

The goal of clustering is to highlight the similarity of data within each cluster and the dissimilarity of data in distinct clusters. As such, C1 shows that on average, 5% to 10% of industry professionals suffer from significant to extreme degrees of skilled labor shortage. This observation was witnessed in all the identified trades except for the electrical trades because it was not included in C1. C2 shows that around 18% of industry professionals experience moderate to significant degrees of labor shortage in one or more of the labor trades. This cluster also includes all the identified trades except for concreting. Compared to C1, C2 had a higher percentage of respondents selecting a given rating. For example, Nodes 1 and 2 (indicated in Fig. 8) represent the percentage of respondents selecting the rating 4 for the degree of labor shortage in the concreting and electrical trades, respectively. Whereas Node 1 belongs to C1, Node 2 belongs to C2. This can be explained by the fact that Node 1 has a smaller percentage of respondents selecting rating 4 for concrete compared to the those selecting rating 4 for the electrical trade. Next, C3 contains instances where the majority of industry professionals reported moderate to minor degrees of skilled labor shortage. As the figure shows, 26% to 34% of survey respondents experienced intermediate levels of labor shortage across all trades.

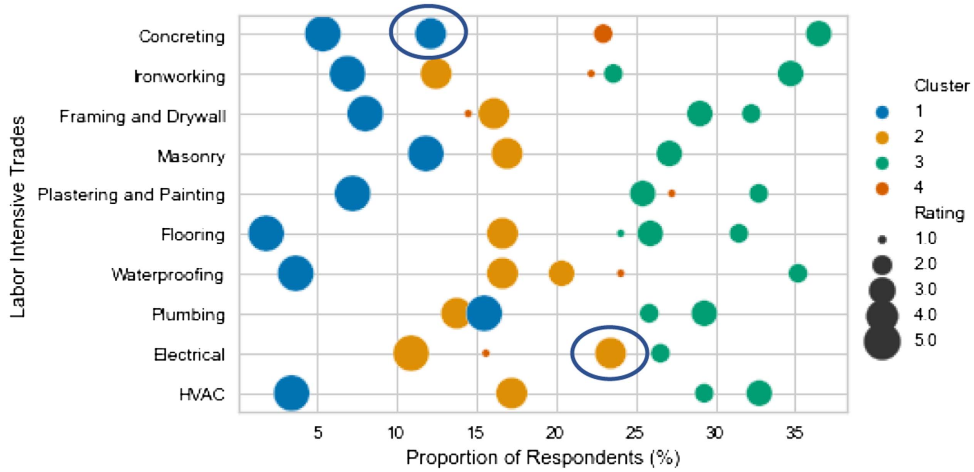



**Fig. 8.** Results of the *K*-means clustering.

Last, cluster 4 consists mainly of instances of negligible degrees of labor shortage for all trades. The percentages of survey respondents reporting such minimal shortages varied from one trade to the other. This is why the nodes belonging to C4 are spread out across the chart, as demonstrated in Fig. 8.

It can be seen that the clustering results are successful because the percentage of survey respondents and rating selected for the degree of skilled labor shortage have similar patterns within each cluster and varying patterns in different clusters. For example, whereas instances in C1 and C2 may have comparable degrees of skilled labor shortage, they have distinct percentages of respondents selecting such ratings. This enables the recognition of trades that exhibit consistent and significant labor shortages as observed by a diverse group of industry professionals such as electrical, masonry works, and HVAC. It focuses on identifying patterns rather than less common incidents where labor shortages may occur in specific companies or organizations such as those witnessed in flooring and waterproofing.

Accordingly, the clustering analysis conducted in this paper highlighted the priority of key labor trades based on their skilled labor shortage patterns. The results revealed that trades that consistently exhibit significant labor shortages such as plumbing, electrical, HVAC, and masonry works emerged as top priorities because they had a significant percentage of respondents reporting extreme to significant degrees of labor shortage. Following closely behind were trades such as concreting, ironworking, and framing and drywall. On the other hand, trades like plastering and painting, flooring, and waterproofing were positioned at the bottom of the priority list.

The authors believe that prioritizing trades is an important step in addressing skilled labor shortages effectively. By prioritizing these trades, industry stakeholders can allocate their resources, efforts, and interventions where they are most needed. By focusing efforts on trades with the most significant shortages, resources can be channeled where they are most needed, maximizing the impact of interventions. It also enables industry stakeholders to develop targeted strategies, policies, and initiatives tailored to the specific trades facing shortages rather than adopting a one-size-fits-all approach. Further, prioritizing trades that play a vital role in meeting the demands of the industry ensures that the industry has a sufficient supply of skilled labor to support ongoing projects. By focusing on trades that have a high demand and contribute significantly to the industry, labor shortages can be addressed more effectively.

Based on the previously mentioned insights, corrective actions in the industry could involve implementing strategies to address the identified labor shortages. This may include efforts to attract more individuals to the most affected trades through targeted recruitment and educational programs. Additionally, measures to enhance training and apprenticeship opportunities, improve industrywide coordination, and address potential barriers or inefficiencies in labor supply and demand can also be considered.

### *Union Participation in Labor-Intensive Trades*

This section presents a description and analysis of the data provided by the survey respondents in relation to the union participation rates reported for each of the labor-intensive trades. According to the survey results, approximately 62% of the skilled workers in labor intensive trades are represented by trade unions, leaving the remaining 38% as nonunion laborers. According to the US Bureau of Labor Statistics, union representation among the entire construction workforce (i.e., skilled and unskilled labor) has remained around 14% in the last decade (BLS 2021). As such, union participation rates of skilled labor among labor-intensive trades are significantly higher than that of the overall construction workforce. Fig. 9 visualizes the union versus nonunion distribution of skilled construction labor per labor-intensive trade according to the survey results. The top three trades in terms of union participation rates are (1) ironworking, with 75% of skilled ironworkers members of labor unions in the US; (2) electrical, with 68% of skilled electricians union workers; and (3) HVAC, with around 67% of HVAC are union members. As can be seen in the figure, the percentage of skilled workers represented by a trade union is higher than that of skilled workers not in a union for all the surveyed trades. This is the case for all trades except for flooring, where the percentages of unionized and nonunionized skilled workers are equal. In fact, according to the statistical analysis conducted by the authors, there is strong evidence to support the presence of significant union participation rates among skilled construction workers in 8 out of the 10 identified trades, meaning all the identified trades, except for flooring and waterproofing, had considerably high proportions of union workers as opposed to nonunion workers.

After establishing that there are significant union participation rates in most of the identified trades, further analysis was conducted to determine trades that had considerably higher union participation compared to others. This was achieved by using the binomial test to statistically cluster the data into different groups of similar data points, meaning data in the same cluster should have comparable union participation rates. Fig. 10 shows the results of the statistical clustering performed as well as the proportion of union members

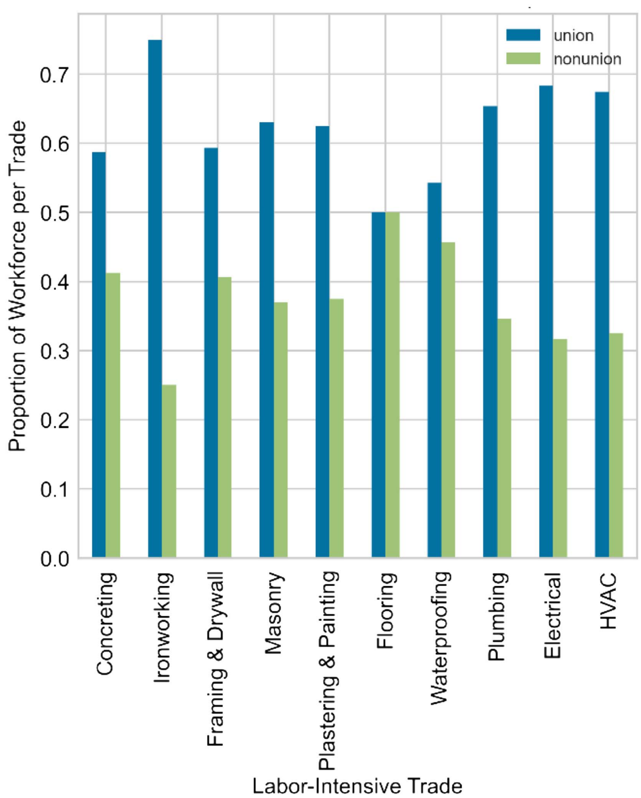



**Fig. 9.** Union versus nonunion distribution of skilled construction labor across labor-intensive trades.

for each of the identified trades. Results show that the trades were grouped into two clusters of statistically significant union participation rates. Cluster 1 contains the top six trades in terms of skilled worker union membership, namely plumbing, electrical, ironworking, plastering and painting, masonry works, and HVAC. On the other hand, Cluster 2 contains the remaining four trades that had significantly lower union participation rates compared to Cluster 1. The trades in Cluster 2 are framing and drywall, concreting, flooring, and waterproofing.

Generally, union membership rates among the skilled construction workforce were found to be considerably higher than that of the entire industry (skilled and unskilled labor). The Bureau of Labor Statistics reported that union memberships among the entire construction labor market averaged around 12.6% in 2021 (BLS 2022). However, the results of this study show that the union participation rate of skilled workers across the identified trades averaged around 63%. In fact, all the identified trades had a statistically significant larger proportion of unionized skilled workers than nonunionized skilled workers, except for flooring and waterproofing. Nonetheless, these two trades still had a higher proportion of union workers than nonunion workers. This can be attributed to the fact that union workers have significantly higher training completion rates compared to their nonunion counterparts (Wang et al. 2008). Unlike nonunion training efforts, which rely on contributions and thus are usually poorly funded, trade unions invest a considerable proportion of their bargaining power to deliver workers' training and apprenticeship programs. Trade unions work with workers and employers to reach collective agreements on possible funding schemes that ensure the consistency and continuation of such programs (Cuadra 2022). These training programs typically consist of classroom training, hands-on instruction, and on-the-job training (Teizer et al. 2013). Some unions even provide training in CAD, software, and other tech subjects (Slowey 2016).

The ironworking trade had the highest proportion of unionized skilled labor in the construction industry, with a union participation rate of around 75%. Further, union memberships of skilled workers in all MEP trades (electrical, HVAC, and plumbing) were also found to be among the highest of all the identified trades, with enrollment rates ranging from 65% to 70%. On the other hand, waterproofing and flooring were the lowest, with skilled labor membership percentages ranging from 50% to 55%.

### *Union Participation and Labor Shortages*

In this section, the chi-square test of independence was used to examine the relationship between union participation and skilled labor shortages. The test was applied to each of the identified labor-intensive trades to determine the correlation between union participation rates and the degree of labor shortage within such trade. All tests were constructed as described in the methodology. Results of the chi-square tests for all labor trades are presented in Table 4.

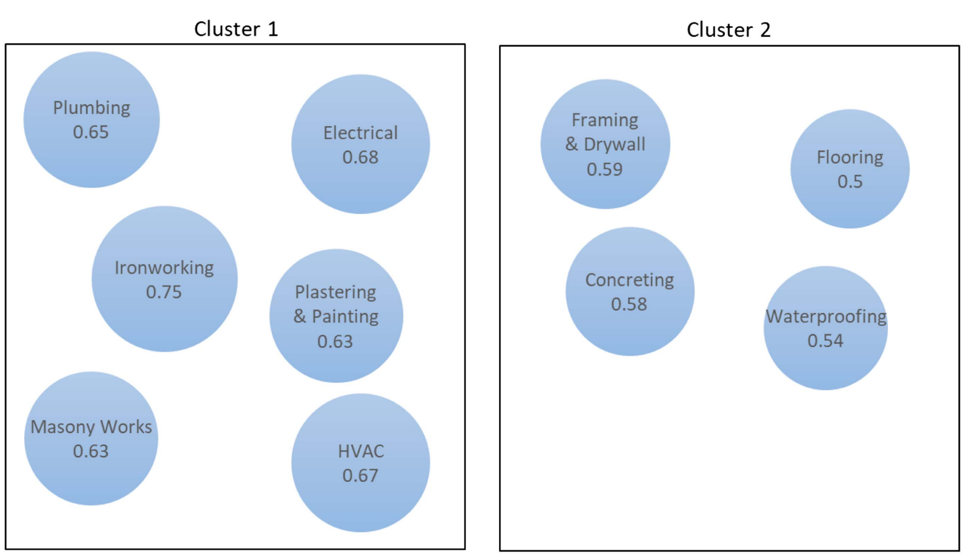



**Fig. 10.** Results of statistical clustering based on proportion of union participation.

**Table 4.** Results of Chi-square test of independence

| Trade | Test statistic[a] | $P$-value | Conclusion |
|---|---|---|---|
| Concreting | 0.0018 | 0.559 | No statistically significant relationship found |
| **Ironworking** | **0.001**[b] | **0.023**[b] | **A statistically significant relationship**[b] |
| Framing and drywall | 0.0014 | 0.328 | No statistically significant relationship found |
| Masonry works | 0.0027 | 0.314 | No statistically significant relationship found |
| Plastering and painting | 0.037 | 0.958 | No statistically significant relationship found |
| **Flooring** | **0.000283**[b] | **0.018**[b] | **A statistically significant relationship**[b] |
| **Waterproofing** | **0.00043**[b] | **0.028**[b] | **A statistically significant relationship**[b] |
| Plumbing | 0.00126 | 0.249 | No statistically significant relationship found |
| Electrical | 0.0085 | 0.885 | No statistically significant relationship found |
| HVAC | 0.0109 | 0.560 | No statistically significant relationship found |

[a]Chi-square/Fisher's exact statistic value.
[b]Statistically significant relationship between degree of labor shortage and union participation.



As the results show, no statistically significant relationship was found between the proportion of skilled labor in trade unions and the degree of labor shortage in 7 out of the 10 tested labor trades.

Findings suggest a significant correlation between high union membership rates and the availability of skilled workers in the ironworking, flooring, and waterproofing trades. In ironworking, industry professionals experienced relatively low degrees of skilled labor shortages when operating in unionized environments. Moreover, respondents who worked with unionized flooring and waterproofing labor experienced negligible to minor shortages in hiring skilled workers. This indicates that craft unions related to those trades have a recognizable role in supplying and retaining skilled labor to construction projects. However, apart from the three trades mentioned previously, no relationship was identified between unionization rates and labor shortages in the rest of the identified labor-intensive trades. In other words, high enrollment in trade unions is not associated with the availability of skilled labor in construction projects or vice versa. For example, union memberships in all MEP trades (electrical, HVAC, and plumbing) were found to be the highest among skilled labor in all MEP trades, with enrollment rates ranging from 67% to 75%. Still, those trades ranked on the higher end in terms of the unavailability of skilled labor.

### Recommended Strategies for Labor Trade Unions

The authors recognize the multifaceted nature of the skilled labor shortage issue within the construction industry. As mentioned in the background section of this paper, factors that impact skilled labor shortages include the industry's biases and discrimination (Choi et al. 2018), immigrants and immigration reform policies (Golden and Skibniewski 2010), the poor image of the construction industry (Flori 2003), and inadequate hiring and training strategies (Srour et al. 2006). Therefore, it is imperative to clarify that the authors neither assert that trade unions offer the exclusive remedy for the ongoing skilled labor shortages, nor do they advocate for the universal unionization of all skilled construction workers. Nonetheless, findings of this study offer valuable insights into potential strategies related to trade unions aimed at addressing the shortage of skilled workers.

The first strategy underscores that although trade unions are not the sole solution to labor shortages, they can play a role in addressing the issue. As previously indicated, union membership rates of skilled construction workers are significantly higher than those of the overall industry. This discrepancy implies that union memberships among unskilled construction workers remain notably low. By tapping into this reservoir of nonunionized unskilled labor, trade unions possess the potential to catalyze improvements in both skill levels and working conditions for these individuals. Leveraging their collective bargaining prowess, trade unions can collaborate with employers to establish training and apprenticeship initiatives aimed at augmenting the skillsets of unskilled laborers. As such, the ununionized unskilled sector of the workforce can be turned into an opportunity for alleviating the skilled labor shortages currently reported nationwide by the industry. From an employer's vantage point, a more readily available pool of skilled labor can readily meet the escalating demands of the industry. From the workers' perspective, heightened skill proficiency translates to improved wages and standards of living. As for the trade unions, higher membership rates mean greater bargaining power and higher leverage when negotiating with employers.

The second strategy is based on the finding that although the results of this study underscore the effectiveness of certain trade unions such as ironworking, flooring, and waterproofing unions in ameliorating labor-related issues such as skilled labor shortages, not all trade unions have achieved comparable success. This discrepancy in effectiveness among unions can be attributed to the varying levels of involvement some exhibit in enhancing the labor conditions of the construction workforce. Research attests that not all unions exert equal momentum in advocating for issues faced by their members, including concerns like inadequate wages. Consequently, their impact on the availability and retention of the construction workforce remains limited. Another contributing factor to the inefficacy of certain trade unions is the absence of robust regulatory mechanisms at the national level. The lack of governmental oversight not only fosters an environment where employers may disregard establishing satisfactory working conditions but also dampens the motivation of trade unions in their pursuit of safeguarding labor rights effectively (Inshyn et al. 2021). To illustrate, in labor markets where union membership is high, employers often opt to relocate to regions with lower union participation to evade higher wage commitments. The efficacy of labor unions hinges on the enactment of protective legislation preventing companies from relocating solely to access lower-wage regions (True-Funk and Poleacovschi 2020). Hence, an effective solution entails implementing governmental oversight and protective legislative measures to shield workers who opt for nonunion work environments, thereby elevating their labor conditions encompassing wages and benefits.

## Contributions to the Body of Knowledge

This paper makes important contributions to the body of knowledge. First, this study identifies 10 labor-intensive trades and analyzes the levels of labor shortage and union participation among skilled labor for each trade. The latter provides critical insights into the current labor shortage status and the associated union participation rates among key labor-intensive trades, which have not been quantitatively analyzed before. Second, this paper investigates the relationship between skilled labor shortages and union participation rates. This analysis is important for several reasons: (1) it provides insights into the factors that attract or repel skilled workers in different labor market settings. This understanding can help industries optimize their approaches to attract and retain skilled labor, ensuring their competitiveness in the market. (2) Labor shortages impact both union and nonunion workers. Exploring the relationship between union participation rates and labor shortages can foster collaboration between unions, employers, and workers' organizations. It encourages stakeholders to work together in finding solutions that benefit all parties involved and improve labor market conditions. (3) It contributes to the understanding of the broader dynamics within labor markets. It sheds light on how different labor market structures, such as union and nonunion environments, influence the availability of skilled workers. This knowledge can help shape labor market policies and guide organizations in effectively managing their workforce. Finally, (4) it proposes strategies that can be implemented through the use of labor trade unions to alleviate skilled labor shortages. These strategies serve as one potential solution to the multifaceted problem of labor shortages. In other words, they ought to be considered in conjunction with other solutions such as increasing labor wages and benefits and investing in training and hiring efforts.

Overall, the paper's contributions to the construction management domain are both significant and timely through providing construction firms, policymakers, and other stakeholders insights into how unionization can impact the availability of skilled workers. The findings of such investigations can assist in informed decision making and development of policies and regulations related to labor markets and unionization, potentially offering solutions to mitigate shortages. Ultimately, the authors acknowledge that there are varying perceptions regarding the role of trade unions in the construction industry. They also recognize that trade union popularity varies across different states due to various reasons such as the socioeconomic attributes of each state. As a result, it is not the authors' intention to change such perceptions but rather offer insights that readers can take at their own benchmarking to mitigate labor shortages.

## Research Limitations

One limitation of this research is the geographical distribution of respondents' employment locations and project locations. As mentioned in the results, the survey includes responses from 25 states, meaning that not all states were represented. However, it is important to note that responses were obtained from key geographical locations in the US that are perceived to share similar industry dynamics and economic characteristics with other locations across the nation. As such, the findings provided in this paper can still yield valuable insights and meaningful trends that can be indicative of labor shortages in a broader context.

## Conclusion

With the current skilled labor shortages experienced in the construction industry, it is a pertinent time to investigate the characteristics of skilled labor in the construction industry and the attributes related to such shortages. Whereas numerous studies have investigated various aspects related to skilled labor shortages in construction, the impact of union versus nonunion environments on labor shortages remains an understudied area. To this end, this research examined skilled labor shortages across a number of key labor-intensive trades in relation to union versus nonunion environments. Specifically, the study investigated skilled labor shortages, trade union reach, and the relationship between labor shortages and union participation in the trade level. Findings show that plumbing and electrical trades experience the highest levels of skilled labor shortages among the identified labor-intensive trades, followed by masonry works, framing and drywall, and HVAC. In contrast, finishing works trades (plastering and painting, flooring, and waterproofing) experience the lowest levels of skilled labor shortages. Results also show the rate of union membership among skilled construction workers is higher than the industry average, with all identified trades having a larger proportion of unionized skilled workers than nonunionized skilled workers. Further, it was found that a significant correlation exists between high union membership rates and the availability of skilled workers in only three trades, which are the ironworking, flooring, and waterproofing trades.

The authors do not assert that trade unions are the only solution to the current skilled labor shortages experienced in the construction industry, nor do they advocate for all skilled construction labor to become trade union members. Nonetheless, the study's findings offer insights into potential strategies to address the shortage of skilled workers. These strategies include: (1) tapping into the pool of ununionized unskilled labor for training and potential recruitment in trade unions; and (2) executing governmental oversight and protective legislation to protect workers who prefer nonunion environments to enhance their working conditions such as labor wages and benefits.

Future research can build on the work presented in this paper by further examination of the characteristics of skilled labor in the construction industry across key labor-intensive trades. This includes studying the impact of labor shortage on the cost and schedule performance of construction projects on the trade level. This enables the prioritization of critical labor trades where skilled labor shortages may have severe consequences on project activities.

## Data Availability Statement

All data, models, and code generated or used during the study appear in the published article.

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