Impact of Crew Diversity on Worker Information Access and Performance

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Abstract –

Labor shortage has consistently been a challenge in the construction industry for decades. As a data-heavy industry, information access and technological innovations are critical for pique performance. Currently, the industry is witnessing a global trend of workforce diversity, as industry leaders are emphasizing its importance. Research shows that gender and ethnic diversity and inclusion strategies can mitigate the impact of the construction labor shortage. Despite the importance and potential benefits of crew diversity, no research has yet studied how crew diversity impacts the worker's perceived difficulty of the process to access needed information, and their performance. The objective of this paper is to analyze and understand the impact of crew diversity on 1) the difficulty of the process to access information 2) the self-evaluated performance record and, of construction craft workers and construction frontline supervisors in the construction industry. To achieve the research objective, 2394 construction craft workers and frontline supervisors were surveyed using an online questionnaire. The survey participants were asked to self-evaluate 1) the difficulty of the process to receive or get access to information, and 2) their work personal performance record. The participants were asked to report the ethnic and gender composition of their work crew. The collected data was then analyzed. Key findings indicate that the gender and ethnic crew diversity showed a statistically significant positive impact on worker's information access and performance.

Keywords –

Information Access; Performance; Crew Diversity; Technology;

1 Introduction & Background

The aging infrastructure of the United States is in serious need for renovations as we face a major shortage of labor and craft workers [1]. Current trends show that the construction workforce is aging rapidly causing an industry-wide labor shortage [2]. Most industry leaders and experts believe the construction industry will look drastically different over the next 20 years [3]. At the same time, construction technologies are not being implemented as fast as they are being developed, and the industry is yet to benefit from their full potential [1]. A McKinsey & Company analysis of Venture Capitalist (VC) investments data concluded that VC investment growth in construction technologies has outpaced VC investment growth in other industries by approximately 15-fold, with no clear indication of this momentum slowing down [4].

On a construction project, information is considered the lifeblood of the modern construction industry [5]. Considering the massive amount of knowledge created throughout the different phases of a construction project, the proper management of this information is indispensable due to the compartmentalized nature of the industry [6,7]. The transition from paper-based information to digital information and e-construction has been gaining momentum through the industry [8]. Adequate information access has been found to add massive benefits to the industry. Information can improve construction safety and performance [9,10]. Information access and information technologies improve external and internal collaboration, enhance communication, and employee satisfaction [11]. Information access and management improve work quality, simplify difficult tasks, and increase worker productivity [12]. Information management within an organization eases the process of disseminating critical information to related projects, which potentially facilitates on-time project completion. Among members of construction teams, it facilitates the communication between workers and supervisors, and promotes collaboration, coordination and effective decision-making [13]. Researchers have studied and examined construction 4.0 and information technologies at length [14,15], including the most recent developments in blockchain technologies [16–18], and construction

digital twins [19–22]. The existing literature has highlighted the numerous benefits of such construction technologies, particularly information technologies. One study examined the impact of several technologies on construction performance and information access found that the use of several information technologies improves information access and performance for construction craft workers, particularly for frontline supervisors [23].

In the construction industry, construction craft workers and frontline supervisors play unique and different roles. Still, there is a persistent perception that low productivity is the result of inadequate performance from craft workers. In reality, any problems are more likely to be caused by the lack of adequate supervision and failure of frontline supervisors to provide the necessary planning, information, support, and motivation [24]. Frontline supervisors have the responsibility of ensuring a safe and healthy workplace, and bridging the missing communication link between management and the craft workforce [25–27]. There is a wealth of studies that have thoroughly highlighted the importance of and influence frontline supervisors have on construction efficiency [28–30]

Along the rapidly changing technology landscape, the construction industry, is witnessing a global workforce diversity trend [31]. Still, as the importance of workforce diversity is being emphasized by industry leaders, demographic diversity is a serious concern to the industry, as unconscious biases and structural prejudices have negatively impacted the construction workforce [32]. The impact of ethnic diversity on project productivity is unclear as there are competing theories. A study by [33] claims ethnic diversity can negatively impact project performance and the communication of information and data due to cultural and linguistic barriers. On the other hand, [34] argues that ethnic diversity can benefit a company's performance because diverse groups can outperform uniform groups in problem-solving ability. As for gender diversity, it has been theorized that mixed-gender groups are better equipped to complete tasks, and therefore, potentially benefiting project performance [35,36]. Still, the construction industry faces major headwinds for women in construction. A recent study found that women in construction are on average more likely to feel disrespected at work, treated unprofessionally, and be subjected to derogatory remarks [37].

While the importance and benefits of technology use and crew diversity have been evaluated and highlighted in existing work, no research has yet studied how crew diversity impacts the worker's ability to access needed information and performance. This study attempts to bridge this gap of knowledge using a survey of construction workers and frontline supervisors that investigates, the demographics of crew composition, the respondent's performance record, and the difficulty of the information access process. The aim of this paper is to analyze and understand the impact of gender and ethnic crew diversity on 1) the difficulty of the process to access information, and 2) the self-evaluated personal performance record of construction craft workers and frontline supervisors in the construction industry.

2 Methodology

The objective of this paper is to analyze and understand the impact of crew diversity on the self-reported difficulty of the process to receive or get access to information, and the personal performance record of construction workers and frontline supervisors in the construction industry. To achieve the research objective, an online questionnaire was developed in "Qualtrics" and distributed to US construction workers. Among other questions, the survey asks construction workers about gender and ethnic diversity of their crew, the types of information technologies used on their construction sites, how hard it is to gain access to information, and their performance. The survey received 2394 responses from all 50 states. Figure 1 details the geographic distribution of the responses. States contributing most to the survey were large population states including New York, California, Texas, Pennsylvania, and Illinois.

Overall, the responses have a gender breakdown of 94.8% male and 4.9% female. This sample breakdown is representative of the US construction craft workforce, where females constituted 3.9% of the construction craft workforce in 2021 according to the bureau of labor statistics [38].

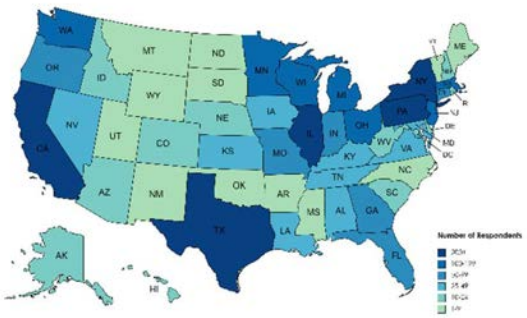

Figure 1. Geographic distribution of the number of respondents across the states – generated by mapchart.net

The breakdown of the survey participants by age showed that 30% are over the age of 55, 25% are in the 45-54 age group, 25% are in the 35-44 age group, 17% are in the 25-34 age group, and 3% are under the age of

25. Additionally, by job title, 41% are craftspersons/ journeymen, 14% are foremen, 13% are superintendents, 13% are apprentices/helpers, 7% are general foremen, 3% are project managers, and 9% stated that they have another title. By education, 42% of the respondents indicated that they have received some college education, 29% have a high school equivalent education or less, 16% have completed a technical program, 11% hold a bachelor's degree or a graduate/post-graduate degree, and 2% indicated that they have another type of education.

In this study, the survey asked the construction workforce to select all the information technologies that they are using on their construction sites to measure the current level of technology implementation on US construction sites. The following is a list of information technologies that can be selected: RFID Chip Tracking, Virtual or Augmented Reality (VR or AR), Artificial Intelligence, Barcode Scanning, Building Information Modeling (BIM), Drones, and Robotics The respondents were allowed to list any "Other" information technologies that they use on their construction site.

Another section of the survey asked the construction workforce to list the number of men and women on their crew, as well as the number of workers of different ethnic backgrounds (White, Black or African American, Hispanic, Asian or Asian American).

Finally, the survey asked participants the two following questions relating to the level of difficulty to gain access to information and their performance record:

- On a scale of 0 to 10, 0 being "instantaneous access", and 10 being "very hard", how hard is the process to receive or get access to required information?
- For the last year, please rate your personal performance record (including safety, attendance, quality, productivity, and initiative) on a scale from 0 to 10, 0 being "weak", and 10 being "superior".

A higher value on the response to the personal performance record indicates a more positive outcome, while a lower value on the response to how hard the process to receive or get access to required information indicates a more positive outcome.

To compare 1) the difficulty of the process to receive or get access to information and 2) the personal performance record based on whether the respondent indicated that their crew includes gender diversity and ethnic diversity, the data was grouped based on whether the crew includes such diversity or not. The corresponding average of the difficulty level of accessing information and the performance record and of these groups is calculated and compared.

In order to examine if the difference between the two groups is statistically significant, the non-parametric Mann-Whitney U- test was completed to obtain the p-value. This test was used to err on the conservative side of the statistical analysis due to large discrepancies in sample sizes of two groups being compared [39]. The students' t-test was not used due to the large discrepancies in sample sizes between groups. If sample sizes in both conditions are equal, the t-test is very robust against unequal variances. However, if sample sizes are unequal, unequal variances can influence the Type 1 error rate of the students' t-test by either increasing or decreasing the Type 1 error rate from the nominal alpha significance level. In such cases, the Mann-Whitney U-test performs better and is better behaved than the t-test [39]. Thus, the Mann-Whitney U-test was selected for this statistical analysis. A significance level, α, of 0.1 is considered for statistical significance (i.e., 90% confidence level).

This analysis was performed for 1) the survey population as a whole representing the overall construction workforce, 2) among frontline supervisors as one group, and 3) among craft workers as another group.

3 Results and Analysis

3.1 Information Technology Use

Survey respondents were asked what kind of information technologies are used on their sites. Figure 2 shows the current levels of different "Information" technology use on construction sites in the United States. Among information technologies, as can be seen in Figure 2, *Barcode Scanning and BIM* have the highest level of implementation at 23% and 21% respectively. *Drones* are used on 9% of construction sites, while *Virtual or Augmented Reality* is used on 7% of construction sites. *Robotics* are used on 6% of sites, and *RFID Chip Tracking* is used on only 5% of construction sites. *Artificial Intelligence* had the lowest implantation percentage at 2%. Finally, 12% of the survey participants indicated that they use other types of information technologies that were not among the listed technologies including laser alignments, tablets, GPS, and telematics, etc. A study of the impact of several technologies on construction performance and information access found that the use of several information technologies improves information access and performance for the construction workforce, particularly for frontline supervisors [23].

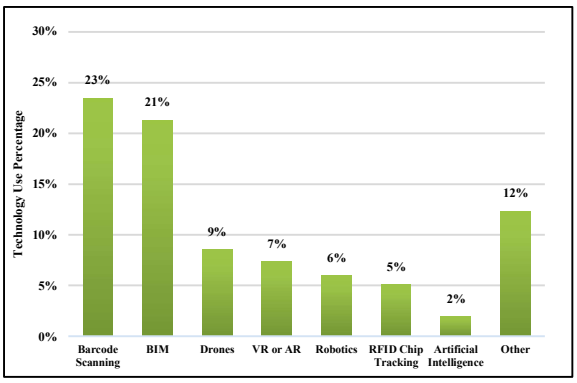

Figure 2. Current implementation level of different information technologies on construction sites in the united states

3.2 Crew Diversity in the Construction Industry

Survey participants were asked about the gender and ethnic composition of their crews. Figure 3 shows the percent of crews in the construction industry in the United States that include and don't include each of gender diversity and ethnic diversity.

The results in Figure 3 show that only 34.8% of construction crews include gender diversity (i.e., the membership of the crew includes women), while 65.2% of construction crews are all men crews that don't include gender diversity. However, a significant majority of construction crews, 70.6%, are ethnically diverse, while 29.4% of construction crews are all white crews that don't include any type of ethnic diversity.

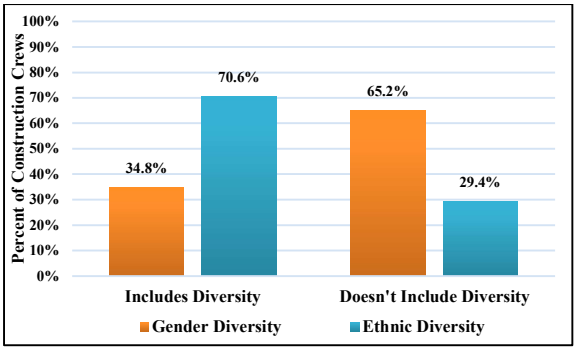

Figure 3. Percent of crews that includes gender and ethnic diversity in the construction industry

3.3 Impact of Crew Diversity

The impact of gender and ethnic crew diversity on the 1) the difficulty to receive or get access to required information, and 2) the personal performance record for the construction workforce, based on whether the respondents indicated their crew includes such diversity is presented in Tables 1-4. The tables show the average responses for the difficulty of information access and the average personal performance record for respondents who specified whether their crew includes each type of diversity or doesn't. The tables present the p-value of the Mann-Whitney U-test to examine whether any difference in the averages is statistically significant. This analysis was performed for 1) the overall construction workforce, 2) frontline supervisors, and 3) craft workers.

Table 1 shows the average difficulty of information access for the construction workforce based on gender diversity on a scale of 0-10. The results of Table 1 show that gender diversity of the crew, on average, eases the process of information access. This positive impact is statistically significant for the construction workforce as a whole. However, when the analysis is broken down by categories, the positive impact is only statistically significant among frontline supervisors, but not among craft workers. While frontline supervisors benefit greatly from gender diversity with regards to information access, the benefit seen among craft workers is not as significant.

Table 1. Average difficulty of information access of the construction workforce based on gender diversity on a scale of 0-10

Gender Diversity	Includes	Doesn't Include	P-value
Overall Workforce	3.221	3.423	0.02*
Frontline Supervisors	2.930	3.212	0.01*
Craft Workers	3.542	3.597	0.39

**Difference in averages is statistically significant at the 90% level*

Table 2 shows the average personal performance record for the construction workforce based on gender diversity on a scale of 0-10. The results of Table 2 show that gender diversity of the crew, on average, improves the personal performance record for the workforce. This positive impact is statistically significant for the construction workforce as a whole. However, when the analysis is broken down by categories, the positive impact is only statistically significant among frontline supervisors, but not among craft workers. While frontline supervisors benefit greatly from gender diversity with regards to performance, the benefit seen among craft workers is not as significant.

Table 3 shows the average difficulty of information access for the construction workforce based on ethnic diversity on a scale of 0-10. The results of Table 3 show that ethnic diversity of the crew, on average, eases the process of information access. However, this positive impact is not statistically significant for the construction workforce as a whole, for frontline supervisors, or for craft workers.

Table 2. Average personal performance record of the construction workforce based on gender diversity on a scale of 0-10

Gender Diversity	Includes	Doesn't Include	P-value
Overall Workforce	8.687	8.537	0.03*
Frontline Supervisors	8.821	8.676	0.10*
Craft Workers	8.477	8.402	0.39

**Difference in averages is statistically significant at the 90% level*

Table 3. Average difficulty of information access of the construction workforce based on ethnic diversity on a scale of 0-10

Ethnic Diversity	Includes	Doesn't Include	P-value
Overall Workforce	3.359	3.428	0.229
Frontline Supervisors	3.123	3.144	0.464
Craft Workers	3.615	3.681	0.393

**Difference in averages is statistically significant at the 90% level*

Table 4 shows the average personal performance record for the construction workforce based on ethnic diversity on a scale of 0-10. The results of Table 4 show that ethnic diversity of the crew, on average, improves the personal performance record for the workforce. This positive impact is statistically significant for the construction workforce as a whole. However, when the analysis is broken down by categories, the positive impact is only statistically significant among frontline supervisors, but not among craft workers. While frontline supervisors benefit greatly from ethnic diversity with regards to performance, the benefit seen among craft workers is slightly smaller.

Table 4. Average personal performance record of the construction workforce workers based on ethnic diversity on a scale of 0-10

Ethnic Diversity	Includes	Doesn't Include	P-value
Overall Workforce	8.652	8.486	0.01*
Frontline Supervisors	8.820	8.613	0.02*
Craft Workers	8.472	8.372	0.14

**Difference in averages is statistically significant at the 90% level*

4 Discussion

Having a better understanding of crew diversity on worker performance, and ability to access information, is critical to helping construction industry leaders identify strategies that improve construction productivity as we face the next chapter of labor challenges in an increasingly diverse industry. This study presents a statistical analysis of the impact crew diversity has on the construction workforce of the United States. Using the data collected from craft professionals and frontline, survey participants described the gender and ethnic composition of their crews, and then self-evaluated the difficulty of the process to receive or get access to needed information and their personal performance record.

The results show that gender diversity on average, both improves performance and eases the process of information access. These results are statistically significant for the overall construction workforce and frontline supervisors, but not among craft workers. As for ethnic diversity, the results show that it statistically improves performance for the overall construction workforce and frontline supervisors. The improvement in performance among craft workers is not statistically significant. While ethnic diversity, on average, eases the process of information access across all three groups, the positive impact is not statistically significant in any of them. Considering the labor shortage in the industry, industry leaders should actively ramp up the recruitment of diverse demographics to acquire desired benefits, particularly women. Women only represent 4% of the workforce when they make up half the population. This presents a significant opportunity to fill the labor gap from an untapped resource, because not only do women not hurt the difficulty of information access, and construction performance, but the results presented in this paper also show a statistical improvement in information access performance when women are working among the crew.

5 Conclusion, Limitations, and Future Studies

Over the past decade, technological innovations have played a key role in the growth and advancement of an increasingly diverse construction industry. While research has extensively studied workforce diversity, little existing work has studied its direct impact on worker information access and performance. The objective of this paper is to analyze and understand the impact of crew diversity on the worker's self-evaluated difficulty of the process to receive or get access to information, and their personal performance record in the construction industry. Using data from a survey of 2394 construction workers, statistical analysis showed that there are substantial benefits for increasing workforce gender and ethnic diversity. This study found that on average, for the overall construction workforce, gender diversity had a statistically significant positive impact on both information access and performance. While ethnic diversity had a positive impact on both information access and performance, only the results of the impact on

performance had results that were statistically significant.

While this study presents a robust statistical analysis of the impact crew diversity on information access and personal performance, the study does have certain limitations. The survey of construction workers does not ask any multiple-choice questions or open-ended questions that discuss specific benefits, challenges, or perceptions gender and ethnic diversity, or factors that resulted in enhanced access to information and performance. Therefore, while this analysis can empirically measure a positive impact on performance and information access, the study cannot answer the questions related to why crew diversity resulted in improvements. Future research can build on this study and attempt to answer these specific questions, to build a roadmap for the leaders of the construction industry to identify paths that will maximize potential benefits based on their specific construction needs. Further work can also study the ideal demographic composition of work crews to enhance information access, work productivity and workforce cohesion.

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