Impact of Technology Use on Time Needed for Information Retrieval for Frontline Supervisors in the Construction Industry

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Abstract –

In the construction industry, information is considered to be the lifeblood of modern construction projects. As a data-dependent industry, information retrieval and technological innovations are essential for optimizing construction performance. The construction industry is currently experiencing rapid adoption of new technologies and innovations. Existing research highlights the positive impact of technological use on construction sites, particularly on performance and information access. However, no research has yet evaluated how technological adoption impacts the time needed to receive or gain access to requested information. The objective of this paper is to analyze and understand the impact of technological adoption on the time needed to receive or gain access to requested information among frontline supervisors in the construction industry. To achieve the research objective, 1138 construction frontline supervisors were surveyed using an online questionnaire. The participants in this survey were asked to specify which technologies are being used on their construction sites; and evaluate the average time needed to receive or gain access to requested information. Key findings show that the adoption of six out of 13 technologies had a statistically significant positive impact in decreasing the time needed to receive or gain access to requested information among frontline supervisors in the construction industry.

Keywords –

Information Access; Technology Use; Frontline Supervisors.

1 Introduction & Background

The United States' aging infrastructure is urgently in need of renovations amid a significant shortage of labor and skilled craft workers [1]. Recent trends highlight a rapid aging of the construction workforce, contributing to an industry-wide labor shortage [2,3]. One study found that labor-related challenges are among the top challenges contractors currently face [4]. Forecasts by industry leaders and experts still suggest a substantial transformation in the construction sector over the next two decades [5]. Despite the industry's need for advancements, construction technologies are not being implemented at a pace matching their development, preventing the sector from fully realizing their potential [1]. According to a McKinsey & Company analysis of Venture Capitalist (VC) investments data found that VC investment growth in construction technologies has surged approximately 15-fold compared to other industries, with no apparent signs of this momentum slowing down [6].

In the contemporary construction industry, information is regarded as the lifeblood of any construction project [7]. Given the extensive amount of knowledge generated across various phases of the construction project lifecycle, effective information management becomes indispensable, particularly due to the compartmentalized nature of the industry [8,9]. The industry is experiencing a noteworthy shift from traditional paper-based systems to digital information and e-construction [10,11]. Recognizing the substantial benefits, adequate information access has been identified as a catalyst for improvement in construction safety and performance [12,13]. Moreover, the integration of information access and technologies has been shown to enhance both external and internal collaboration, communication, and employee satisfaction [14]. In addition to these advantages, effective information access and management contribute to elevated work quality, simplification of challenging tasks, and increased worker productivity [15]. Organizational information management further streamlines the dissemination of critical information across related projects, potentially facilitating on-time project completion. Within construction teams, it fosters communication between workers and supervisors, promoting coordination, collaboration, and effective decision-making [16].

Extensive research has been conducted on Construction 4.0 technologies [17], including recent advancements in blockchain technologies [18–20]. The existing body of literature underscores the versatile benefits of these construction technologies. Notably, a study highlighted that the adoption of diverse information technologies enhances information access for the construction workforce [7]. For instance, the efficiency of object identification and information collection is significantly improved through barcode scanning technology [21]. Augmented or virtual reality has proven instrumental in real-time project visualization and data collection, contributing to heightened productivity, improved quality, and enhanced communication and collaboration [22]. Radio Frequency Identification (RFID) chip tracking optimizes information collection and management throughout different project phases by efficiently tracking construction materials, resources, equipment, components, and systems [23]. The utilization of Building Information Modeling (BIM) facilitates faster, more efficient, and more accurate planning and construction. It enables simultaneous contributions from all project stakeholders and promotes information sharing [10,24–26]. Artificial intelligence has furthered the advancement of services and business operations, enhancing the automation processes of companies to gain a competitive advantage [27]. Drones, which have been proven to be contributors to overall cost reduction and fewer project delays, have improved safety records and provided high-resolution aerial imagery for more accurate data collection and surveying [28]. The utilization of robotics and autonomous machinery in construction processes has streamlined operations, leading to significant reductions in costs and time spent on tasks. Additionally, these technologies have proven effective in enhancing the overall quality of the executed product [29]. Prefabrication/ modularization techniques enable faster on-site construction, diminish on-site work requirements, enhance quality, lower energy consumption and emissions, and ultimately reduce overall construction costs [30]. Finally, quick connection systems have been identified as effective in reducing work hours, minimizing the number of required work packages, improving quality, and facilitating construction processes [31].

Within the construction industry, there persists a prevailing notion that insufficient productivity stems from inadequate performance by craft workers. In reality, the root of such issues is more likely attributed to inadequate supervision and the failure of frontline supervisors to provide essential planning, information, support, and motivation [32]. Frontline supervisors bear the responsibility of ensuring a safe and healthy workplace while serving as a crucial communication link between management and the craft workforce [33–35]. Numerous studies extensively underscore the pivotal role and influence that frontline supervisors wield in determining construction efficiency [36–39].

While the existing literature has assessed and emphasized the benefits of technology, and research has studied the impact of several factors on performance and the difficulty of information access on construction sites, including workforce skills [40], workforce training [41], and crew diversity [42], no research has yet studied how technology use on construction sites impacts the time needed to retrieve or gain access to needed information. Construction frontline supervisors' prompt access to project information is critical for their ability to do their job. Equipping construction frontline supervisors with tools that help decrease the time needed to receive or gain access to information would improve overall construction performance and efficiency. The goal of this study is to bridge this gap of knowledge using a questionnaire of construction frontline supervisors that investigates technology use and the time needed to retrieve or gain access to needed information. This paper aims to analyze and understand the impact of construction on-site technology adoption on the time needed to retrieve or gain access to needed information among frontline supervisors in the construction industry.

2 Methodology

The objective of this paper is to analyze and understand the impact of construction on-site technology adoption on the time needed to retrieve or gain access to needed information among frontline supervisors in the construction industry. To accomplish the research objective, an online questionnaire was created using "Qualtrics" and disseminated to construction frontline supervisors in the United States. The survey includes questions about the time needed to receive or gain access to needed information; and enquires whether specific technologies are employed on their construction sites. The survey was developed based on a thorough review of the literature, where gaps in research were identified and addressed. The questions were reviewed and approved by the Internal Review Board (IRB). A total of 1138 responses were received from participants across all 50 states. States including New York, California, Texas, Pennsylvania, and Illinois were among the biggest contributors to the survey in terms of respondents. The geographic distribution of the respondents is presented in Figure 1.

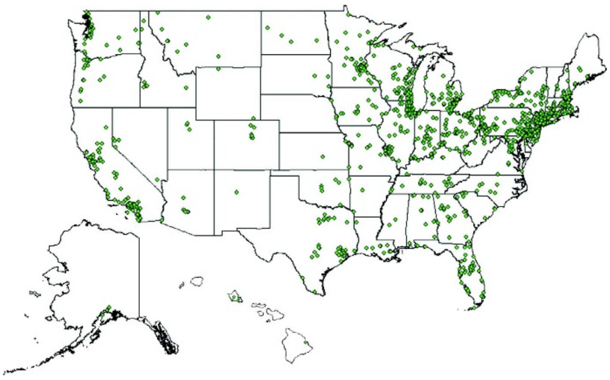

Figure 1. Geographic distribution of the survey respondents

The responses have an overall gender distribution of 97.5% male and 2.0% female. Among the supervisors, 31% hold the title of foremen, 29% are superintendents, 17% are general foremen, 2% are craft superintendents, 2% are assistant superintendents, and 19% indicated having another title. The breakdown of the survey respondents by job title is presented in Figure 2.

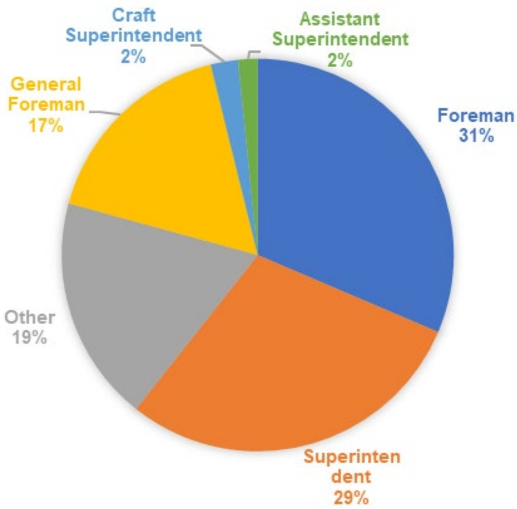

Figure 2. Survey respondent's breakdown by job title

Regarding age distribution, 33.2% of respondents are aged over 55, 33.2% fall within the 45-54 age group, 25.3% are in the 35-44 age range, 8.0% are in the 25-34 age group, and 0.3% are below the age of 25. The breakdown of the survey respondents by age is presented in Figure 3.

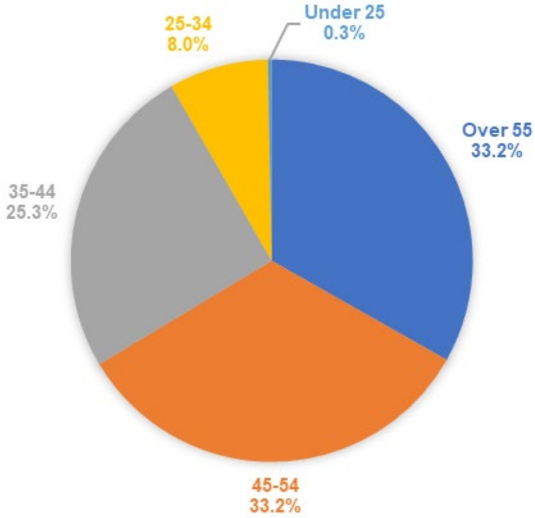

Figure 3. Survey respondent's breakdown by age

In this research, participants were prompted to choose from a list of information technologies employed on their construction sites. The available options for selection included RFID Chip Tracking, Virtual or Augmented Reality (VR or AR), Artificial Intelligence, Barcode Scanning, Building Information Modeling (BIM), Drones, and Robotics, Prefabrication/Modularization, Quick Connection systems, Autonomous Machinery, Battery Powered Tools, and New types of Hand Tools or Construction Machinery developed in the last five years. Respondents also had the option to specify any additional "Other" technologies they utilize on their construction sites.

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

- If you need access to project information for your work, how long does it typically take (in Days and Hours) to receive this information or get access to it?

For this question, a lower numerical value on the response to the time needed to receive or get access to required information indicates a more positive outcome.

To compare the time needed to receive or get access to required information for frontline supervisors based on whether technologies are used on construction sites, the data was grouped based on whether each specific technology is or not. The corresponding average of the time needed to receive or get access to the required information of each of these groups is calculated and compared.

To assess the statistical significance of the difference between the two groups, the non-parametric Mann-Whitney U-test was employed to obtain the p-value. This choice was made to adopt a conservative approach in statistical analysis, given substantial variations in the sample sizes of the two compared groups [43]. The student's t-test was not utilized due to the significant differences in sample sizes between the groups. When 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 instances, the Mann-Whitney U-test demonstrates better performance and behavior than the t-test [43]. Hence, the Mann-Whitney U-test was chosen for this statistical analysis. A significance level, α, of 0.1 was considered for statistical significance, corresponding to a 90% confidence level.

3 Results & Analysis

3.1 Impact of Technology Use on Time Needed to Receive or Access Needed Information

The impact of technology use on the time needed to receive or access needed information based on whether the frontline supervisors indicated each specific technology is used on their construction is shown in Table 1. The table presents the average responses for the difficulty of information access and the average time needed (in Days) to receive or access needed information for respondents who specified whether each technology is used or not. The table additionally shows the p-value resulting from the Mann-Whitney U-test, aiming to assess the statistical significance of any observed differences in averages.

The results in Table 1 show that the on-site use of only four out of the 13 technologies resulted in a higher average time needed to receive or access needed information for construction frontline supervisors. However, the results are statistically significant for only two of those technologies, including *Artificial Intelligence*, and *New Hand Tools developed in the last five years*. While artificial intelligence is a new emerging technology with significant potential, it remains a sophisticated technology that is rarely used on construction. Potentially, lack of training on such complicated technologies can be a contributing factor as to why it has not caused a positive contribution to the average time to access information.

On the other hand, the on-site use of nine out of the 13 analyzed technologies resulted in a decrease in the average time needed to receive or access needed information for construction frontline supervisors. However, only six of those technologies showed results that were statistically significant. The technologies that have statistically improved the average time needed to receive or access needed information include *Barcode Scanning, RFID Chip Tracking, Building Information Modeling, Drones, Prefabrication/ Modularization, and Quick connection systems*. While *Virtual or Augmented Reality and Battery-Powered tools* did have a slight positive impact, the difference in the results was not statistically significant between those two groups.

Table 1. Average time needed to receive or access needed information based on technology use among construction frontline supervisors (in Days)

Technology	Used	Not Used	P-value
Barcode Scanning	0.86	1.25	0.00*
Virtual or Augmented Reality	1.07	1.16	0.31
RFID Chip Tracking	1.06	1.16	0.02*
Building Information Modelling	1.09	1.18	0.01*
Artificial Intelligence	1.61	1.14	0.09*
Robotics	1.15	1.15	0.43
Drones	0.88	1.19	0.02*
Prefabrication/ Modularization	1.13	1.17	0.09*
Quick Connection Systems	1.01	1.18	0.09*
Autonomous Machinery	1.54	1.14	0.16
New Hand Tools	1.27	1.12	0.03*
Battery Powered Tools	1.13	1.30	0.23
New Type of Construction Machinery	1.34	1.12	0.12

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

4 Conclusion, Limitations, and Future Studies

Over the last decade, technological advancements have played a crucial role in fostering growth and progress within a rapidly transforming construction industry. While the existing body of literature has extensively examined construction technologies and information access, no existing work has assessed its direct impact on the time needed to receive or gain access to needed information among construction frontline supervisors. The objective of this paper is to examine the impact of on-site technology use on the average time needed to receive or gain access to needed information. This research used data from a survey of 1138 construction frontline supervisors. The statistical analysis of this data showed that there are substantial benefits for on-site technology use in terms of information access. This study found that for the construction frontline supervisors, on average, on-site technology use has a positive impact in decreasing the time needed to receive or access needed information when eight out of the 13 technologies are used, six of which had results that were statistically significant.

While this research presents results of a robust statistical analysis of the impact of technology use on the average time needed to receive or gain access to needed information, the study does have certain limitations. The survey of construction frontline supervisors doesn't ask any open-ended or multiple-choice questions that discuss specific benefits, challenges, or factors that resulted in enhanced access to information. Consequently, although this analysis empirically measures a positive impact on performance and information access, it cannot address the "why" or "how" behind the improvements resulting from technology use. Future research endeavors can build upon this study, aiming to answer these specific questions using structured interviews and focus groups with construction workers and industry experts, thus, providing a roadmap for construction industry leaders. This roadmap could help identify paths that maximize potential benefits tailored to the unique needs of specific construction projects.

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