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Effect on Labor Productivity Due to Construction Digitalization: A Pilot Study

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This research was conducted to analyze the impacts of the growing technology and implementation of Construction Digitalization with the 4th revolution in the construction industry and how it has affected labor productivity. Industry 4.0 is a formation of technologies that digitize, mechanize, and merge the construction process at different stages. With the growing trends of digitalization, there have been various predictions as to how this will positively or negatively affect the workforce for both skilled and unskilled labor. The negative effects have mainly been predicted to impact unskilled workers while slightly affecting skilled workers significantly. This research is aimed at determining the impacts of the adoption of digitalization on labor productivity. This study used an online survey method hosted by Qualtrics and was emailed to industry professionals and students in April 2023. The study also utilized literature reviews of articles related to the topic from 2010 until 2023 to analyze trends in the adoption of digitalization on labor productivity accurately. While the majority of respondents agreed that Construction 4.0 would be a great addition to the industry, the survey found that some companies still have not adopted the concept and did not have a plan for it. The literature review did not raise any major concern about the cost and suggested that any cost incurred would be offset in the long run. In conclusion, while this is a great concept, more research will need to be conducted before the concept is universally agreed upon.

Key Words: Digitalization, Mechanization, Construction 4.0, Workforce, Productivity

Introduction

The construction industry in 2021 was estimated to have a value of 1.6 trillion USD, with an annual growth rate of 2.7% in revenue from 2016 to 2021 (Zippia 2023). Based on a model developed by Associated Builders and Contractors, this industry must hire close to 546,000 workers this year to meet current demand. This projection was made based on expected retirements, possible resignations, and an

aging workforce. According to Sokas et al. (2019), the percentage of workers in the US aged 55 and older will increase to 22% from 11.9% by 2024.

Construction 4.0 is the digitalization and industrialization of the construction industry that grants instantaneous, horizontal, and vertical integration and connectivity to allow for collaboration across project timelines, increase the advancement of construction processes through mechanization, and merge physical and cyber work (El Jazzar, Schranz, Urban, & Nassereddine, 2021).

Adhikari et al. (2022) assessed the Covid-19 impacts on the Construction 4.0 implementation during the first year of the pandemic. Based on the responses, the competencies of construction professionals have enhanced in higher awareness of I4.0 due to Covid-19 (Adhikari et al, 2022). With the rise in demand for workers in the industry, Construction 4.0 is potentially a great addition and substitute for some positions, and it will make processes more aligned across the board. However, with all the benefits of technology, it has left people in the industry concerned about their jobs being replaced by machines. While technology will increase efficiency and productivity, the human factor to make quick decisions cannot be ignored or replaced. An example of such a decision would be a utility that was not located correctly and a machine operator needing a laborer to expose the utility instead of using an excavator and causing damage to the utility. Merriam-Webster (Dictionary, M. W., 2002) defines unskilled labor as labor that requires little or no training or experience, and skilled labor refers to highly trained or educated workers who can complete complex mental and physical tasks. Unel (2010) suggests that while there has not been an increase in the number of skilled laborers, there has been a decline on productivity in unskilled labor, and there is more of a balance in situations that allow for unskilled labor to be changed with skilled labor.

For this research, a survey was conducted using Qualtrics to gather qualitative and quantitative data from industry professionals. The research goal was to send it out to 20 professionals, expecting a response from all. Literature reviews will also be utilized to ultimately reach a conclusion on how technology is and will affect the workforce.

Background

The US construction industry faces a significant labor shortage to meet the construction and maintenance of buildings and infrastructure (NPR, 2023). The labor force shortage poses significant sustainability challenges economically, socially, and environmentally (Rahim et al., 2016). Further, about 22% of the construction industry workforce is 55 years or older, exacerbating the issue. The aging workforce is valuable because of their experiences, but this knowledge can be transferred to a newer generation through training and mentoring (Sokas et al., 2019, de Soto et al., 2022), which is not always the case. In addition to the issues associated with labor shortage and an aging workforce, the industry also faces challenges with productivity. Unel (2010) analyzed skilled and unskilled workers and suggested that there has not been an increase in skilled labor, but unskilled labor efficiency has decreased, leading to low productivity. Within the US, the construction sector productivity has been in decline for some decades, with indications that the sector has become "*less productive over time*" (Goolsbee and Syverson, 2023). Numerous barriers exist to high productivity, but these barriers have been lowered due to increasing requirements, demand in terms of volume, cost and quality, and new technologies and processes (Barbosa et al. 2017).

At the same time, digitalization and automation can offer potential solutions to some of the issues, reducing the need for the industry to outsource jobs (Ezra et al., 2011), and enhancing productivity within the industry. Digitalization can be defined as modifying a network or procedure to be operated using computers and the Internet. Construction Automation is often contextual, defined in numerous ways, can be interpreted as using "robotic systems on construction sites," and can alleviate the productivity issues that have impacted the construction industry (Chen et al. 2018). The concept of digitalization and automation within the construction industry can be traced to about six decades back when initial attempts to digitize the information were made (Eastman et al., 2011). Over the years, the construction industry has made significant strides in adopting and implementing technologies supporting digitization to use it towards multiple project facets to a varying degree (Langar and Pearce 2014) across various sectors supporting the construction industry (Fountain and Langar 2017) even though the industry has been perceived as historically being resistant to change (Davis and Songer 2009) due to numerous reasons (Oesterreich and Teuteberg, 2016).

With the increased adoption of technologies (Building Information Modeling, Drones, and others) (Oesterreich and Teuteberg, 2016; Fountain and Langar, 2017; Albeaino and Gheisari, 2021), there is a more significant push towards integrating various facets of the construction sector along with the integration of the data that is generated from these areas to facilitate a greater maturity towards holistic implementation of Construction Industry 4.0. Construction industry 4.0 is often referred to as the *"fourth industrial revolution*" (Kagermann et al., 2013) aims at the integration of technologies to enhance the efficiency of the construction industry (Tortorella et al., 2018; Souza et al., 2022). Construction 4.0 can also be explained as digitization and industrialization of the sector to enable instantaneous integration and connectivity across the project lifetime. There are already some instances of the adoption of automation in construction, which can lead to higher automation and greater productivity in the construction industry (Ezra et al. 2011; Delgado et al., 2019).

However, as robots and other technologies make their way into the different stages of the construction lifecycle, the concern for the future of jobs has increased. While using robotics can boost productivity and safety on construction sites, it should not completely lead to a decrease in employment in the construction sector over the long run. It is expected that existing roles will change and new roles will be created (de Soto et al., 2022). Ezra et al. (2011) uses the tile laying process as a basis for their research and conclude that while automation is a viable solution to outsourcing jobs, more work still needs to be done for the technology. There have been digitalization and automation efforts in the construction industry, but the current structure still requires the presence of operators, which leads to Calvetti et al.(2020), introduction of worker 4.0, which is the craft workforce productivity framework and proposes mixing work elements and basic motion elements to enable the mapping process of all construction tasks, providing an adequate process to increase on-site production. Along with the lack of skilled workers (worker 4.0), there is limited integration of systems and data across the facets of the construction industry and limited adoption of other technologies (such as Augmented Reality, Big Data, Cloud Computing, and, Internet of Things (IoT),) in the construction industry (Statsenko et al., 2023).

Research Method

The research used an online survey method, allowing quick data collection from the general population. The general population for the survey included Architecture Engineering and Construction professionals, academicians, and students. The online survey was designed on Qualtrics, one of the most frequently used online survey platforms. The designed instrument consisted of fourteen questions that aimed to examine the pros and cons of digitalization and how it has or could affect productivity.

The designed instrument was kept open for 14 days after the initial email. The respondents were also emailed seven reminders, and the survey was closed seven days after the initial email. All collected responses were checked for completion, and only completed responses were used. A total of fifteen completed responses from AEC professionals and academicians were used for descriptive analysis. The research aims to answer the following sample questions regarding the effect of digitalization on labor productivity.

Q1 - How many years of experience do you have in the construction industry?
Q2 - What is your job title in your organization?
Q3 - What percentage of labor is used on a typical construction project?
Q4 - How familiar are you with the concept of digitalization in construction
Q5 – How your organizations planned to adopt digitalization in construction
Q6 - Do you think digitalization could/has benefited the industry?
Q7 - In your experience and/or opinion, has there been a change in productivity since the implementation of new technology?
Q8 - In your organization, are there plans to adopt Construction 4.0?

Results

All respondents reported that they had college degrees. In terms of respondents' construction industry experience, the majority of respondents had more than twenty years of experience (20%), as indicated by Figure 1. In addition, most respondents identified their company affiliation as contractors (Figure 2). Several factors have affected productivity in construction, such as an aging workforce, adaptability to change, and, most recently, the global pandemic. A significant majority of the respondents (66.7%) indicated that there had been a decline in the workforce since the pandemic, which impacted the construction industry significantly. Thus, digitalization would be a great solution to addressing the problem, but it needs to be assessed and has been discussed in the subsequent section.

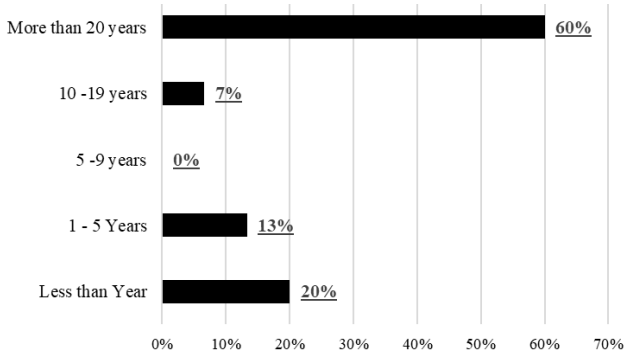

Figure 1: Respondent construction industry experience

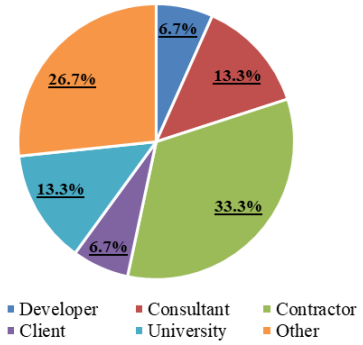

Figure 2: Respondent affiliation

When asked about the respondent's familiarity with the concept of digitalization in construction, the majority of respondents identified their familiarity as "Moderate," as indicated in Figure 3. At the same time, an overwhelming majority of respondents (93.3%) indicated that they perceived digitalization could be beneficial to the industry. The respondents were also asked how their field used technologies, and most of them identified technologies associated with traditional Building Information Models (BIM). Only three respondents indicated the usage of technologies that went beyond the traditional BIM, including the adoption and implementation of drone(s), Augmented Reality, and others. Thus, indicating the need to extend BIM implementation beyond the traditional BIM usage in the industry. However, the research aimed not to measure the extent to which BIM was implemented or BIM maturity; therefore, the pilot study's data can be used as a point of departure for future studies. Respondents (66.7%) also indicated a change in productivity since implementing new technology.

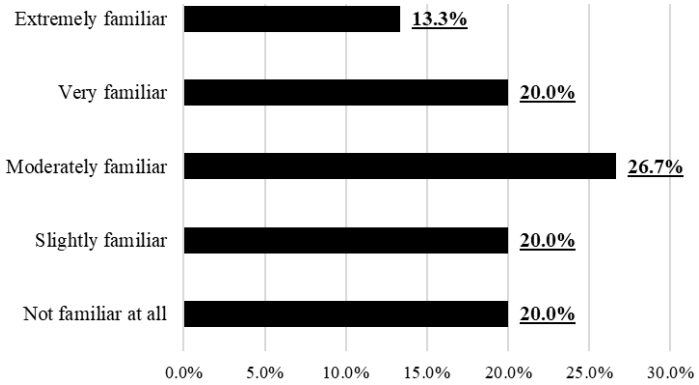

Figure 3: Respondent familiarity with digitalization in construction

Respondents were also asked how they perceived the possible effects of Construction 4.0, with the respondents having the ability to input text. The respondents provided both positive and negative effects. Positive effects stated by the respondents discussed integrating technologies into the virtual world, enhancing construction efficiency, and having a construction industry driven by information and technology. At the same time, other respondents also identified negative effects, including increased project costs, impacts of social media or peers on existing building practices, and over-reliance on technology, resulting in reduced checks on projects.

Given these perceptions, the respondents were also asked if their organizations planned to adopt Construction 4.0, and only 26.7% indicated they had already adopted it (Figure 4). The respondents were asked if their organizations required training and/or certifications for software and equipment use, and only 46.6% indicated the requirement. The finding from the pilot study is concerning as most of the technologies can be complex, and to efficiently use technology and maximize the benefits with technology adoption, training and/or certifications are important as they can point towards the competency of the individuals handling them and offer benefits to the adopting unit.

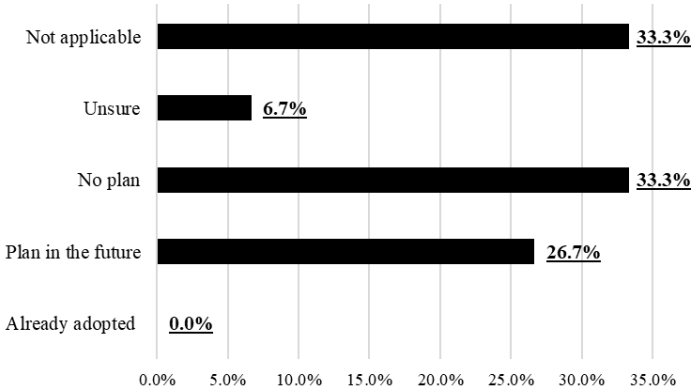

Figure 4: Respondent adoption of digitalization in construction

Conclusion and limitations

Based on the pilot study's findings, it can be established that digitalization and Construction 4.0 offer significant benefits that will increase efficiency and productivity over the long run, but also have concerns from potential adopters which, if not addressed, can have significant ramifications to the construction industry and potential adopters. Many workers are worried that their tasks will eventually become obsolete because they can be done by a machine faster. With the growth of technology, it has been predicted that some job roles will either change or completely vanish. Some of the previous research noted the several factors affecting productivity and embraced digitalization and mechanization as a solution but suggested that the workers should not just be turned away. Factors that have limited the growth and adoption of digitalization in construction is knowledge of the concept. Some organizations may have already started this process but do not have a name for it. Others do not know and are just so used to their mode of operation. Another factor is the cost arising from procurement, training, and installations. The economic concerns are serious as numerous technological innovations have experienced cost as a significant barrier. From the statistical data, it is established that most of the surveyed organizations have no plan for implementation.

For future steps, there will need to be a measurable standard put in place to analyze the growth of Construction 4.0 and more research on preserving the workforce. In the meantime, there needs to be plans to shift the existing culture to curb the fear that exists for the workers.

One of the significant limitations was the low number of respondents to the study. Since this is a pilot study, future studies need to be conducted to establish generalizable findings with a well-represented and diverse sample representative of the US construction industry.

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