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Impacts of Covid-19 on Construction Industry 4.0 adoption and implementation within Southeastern US - An exploratory study

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The exploratory research assessed the Covid-19 impacts on Construction Industry 4.0 implementation during the first year of pandemic restrictions. The research used a case study approach with industry professionals as the unit of analysis geographically located in the southeast United States. Data was collected through a survey of industry professionals, capturing their views of individual and company competencies before and during the pandemic. The survey indicates the perceptions about the application of Industry 4.0 in construction have changed during Covid-19, from March of 2020 to March of 2021, and views on expected future utilization. The industry professionals were asked to describe their opinions of Industry 4.0 abilities and how they changed during the pandemic. That data was then assessed through qualitative and quantitative analysis and supported the research aim. BIM, Big Data, and Analytics were shown to be where most professionals felt company reliance increased during the pandemic. The analysis also indicates that most participants expect a future increase in their company's support on Industry 4.0. The response to Covid-19 has changed the perceptions and implementation of these methods within construction.

Key Words: Construction Industry 4.0, Covid-19 Impact, Construction Pandemic, Industry 4.0 (I4.0), Construction after Covid-19

Introduction

The construction industry is the fourth most significant contributor to the country's Gross Domestic Product (GDP) (Trading Economics, 2021). In the fourth quarter of 2020, United States GDP from Construction reached $673B (Trading Economics, 2021). Construction companies have experienced the effects of Covid-19 restrictions in ways that could be unforeseen, such as shortages in labor, increased material cost, and others (BLS 2020). The pandemic caused the industry to analyze these

new risks/uncertainties while developing real-time responses. Industry 4.0 offers several solutions to combat the risks associated with project scheduling and delivering projects, considering the workforce shortage before Covid-19 (AGC 2021). Industry 4.0 technology's connection to Construction and Manufacturing results in it being an essential component to the future development of the US economy. "*The growth of the construction industry subset of the universal set of the gross domestic product value; thus, Industry 4.0 has a spillover effect on the engineering and construction industry*." (Maskuriy et al., 2019).

Traditionally, the construction industry has been slow to respond to technology (Cao et al., 2014; Eagan 1998). The engineering and construction sector has not kept pace in terms of technological opportunities that can help improve production and in the stagnation of labor productivity (Maskuriy et al., 2019). Various external pressures (coercive and mimetic) impact the adoption and implementation of technologies supporting Industry 4.0 (Cao et al., 2014, Maskuriy et al., 2019). New restrictions with pandemics changed the operational paradigm for construction companies and professionals, and integration among project teams became more than an ever-important part of operations.

Schönbeck et al. (2020) describe Construction Industry 4.0 as the inclusion of new technologies in the design, engineering, and construction industry, similar to Industry 4.0 (I4.0) for the manufacturing industry. The fourth revolution evolved with the maturity and interaction of automation, electrification, and digitization to improve the industry with more benefits (Schönbeck et al., 2020). Osunsanmi et al. (2020) also discovered that some of the outdated methods for information sharing among construction professionals are elements that cause a building project to be delayed. Video conferencing, cloud, and automation, among other tools, fall under Industry 4.0 (Maskuriy et al., 2019). Adopting current techniques of I4.0 will improve the effectiveness of information sharing during the construction phase.

Background

Construction entails many people with a wide range of interests, skills, and backgrounds. The essential construction stakeholder includes owners, designers, contractors, subcontractors, material suppliers, bankers, insurance and bonding agencies, attorneys, and the general public (Maskuriy et al., 2019). When Covid-19 restrictions arose in March of 2020, the construction industry was exposed to increased health and safety risks because of new social distancing laws that addressed site outbreaks and related labor shortages (AGC 2021).

Thus the global pandemic has brought into focus the need to assess previous, present, and future Industry 4.0 implementation and competencies. Industry 4.0 (I4.0) is a term that describes the fourth iteration of the Industrial Revolution. I4.0 introduces disruptive digital technologies that may help overcome traditional barriers in operations management (Tortorella et al., 2021). Construction industry 4.0 is defined as "*the application of Industry 4.0 to the construction sector*." (Construction 4.0, NAC Executive Insights) https://www.researchgate.net/publication/348690890_Construction-40 Construction Industry 4.0, at its core, describes the increased use of integrated cyber technology to improve construction project delivery. The technology is meant to enhance the activities required for construction, from manufacturing goods to team communication, and how information is shared at all stages of a construction project. In this regard, Construction Industry 4.0 can create more integrated site construction activities and improve communication among team members. Increased cloud computing focuses on better-centralized data sharing and applications while people work remotely. Furthermore, implementing site management in a virtual construction site can help enhance supply

chain management by adequately tracking and monitoring personnel, equipment, and materials (Li and Yang, 2017).

The digital transformation is crucial to the construction industry's current challenge and includes such as automation, connectivity, digital data, digital access, Augmented Reality, Virtual Reality, BIM technology, and Artificial intelligence (Dallasega et al., 2018). Some of these components can add digital information of physical components, allowing sharing informations among stakeholders (project managers, owners, contractors, and designers). All the information needed for construction operations and model components may be simulated and retrieved in a real-world context, making site activities considerably easier to manage. With the digital information modeling platform's real-time cloud services, users can obtain real-time feedback on their future design decisions and plans via mobile applications such as smartphone applications. Further, Artificial Intelligence can analyze building, construction, and operational data and improve knowledge transfer, decision-making, and efficiency.

Furthermore, the implementation of Industry 4.0 in the construction industry is projected to boost productivity and profitability while also contributing to the development of the industry (Nowotarski and Paslawski, 2017). However, the historical lack of the construction industry’s adoption of innovation and technology is a concern. Thus, the exploratory research provided the perspective of construction industry support professionals on I4.0 into the pandemic restrictions. The objectives of this research include: 1) determine perceptions of construction professionals about the adoption and implementation of technologies supporting I4.0 and 2) determine the impact of Covid-19 on the adoption and implementation of technologies supporting I4.0.

Research Method

The exploratory study used an online survey method to determine the industry professionals' perception in the southeastern US for I4.0. Survey design can provide a snapshot at a particular point in time.The online survey was selected as it allowed for the best value to the research team, especially during a pandemic. The general population of the study was construction professionals, the supporting staff, and researchers associated with the construction industry. The sample of the population was geographically constrained to the southeastern United States. The instrument had questions covering four areas, including 1) perceptions of employer-organization use of Industry 4.0 technologies; 2) reliance on I4.0 methods changed during the first year of the Covid-19 pandemic (March 2020 to March 2021); 3) determine the changes knowledge changes in I4.0; 4) perceptions of professionals about their organization’s reliance on Industry 4.0 for future and benefits. The instrument consisted primarily of multiple-choice, multiple selections, and Likert scaled questions. Further, the instrument was designed so that respondents could complete the entire survey in approximately 5 minutes provided the respondent possessed all the information. The online instrument was distributed in April 2021. The survey was distributed via interpersonal channels such as LinkedIn. A total of 18 survey responses was received by April 20, 2021.

Data Analysis and Results

A series of filters were utilized, which included: 1) respondent geographical location (southeastern United States), 2) Respondent role; 3) Survey Completion. Based on the application of the filters, the number of respondents for the study decreased to thirteen. There was an almost equal distribution of respondents, with seven identifying as male and six as female. In addition, most of the respondents were born in the 1970s (Table 1).

Table 1: Respondent year of birth

Year of birth (Decade)	Response (No.)
1950s	1
1960s	2
1970s	4
1980s	3
1990s	3

Of the thirteen respondents, 2 had roles in Engineering, 4 in Sales, and 3 in Project Management. The remaining respondents were in Executive roles (2), Academic and researcher roles (1), or Finance (1).

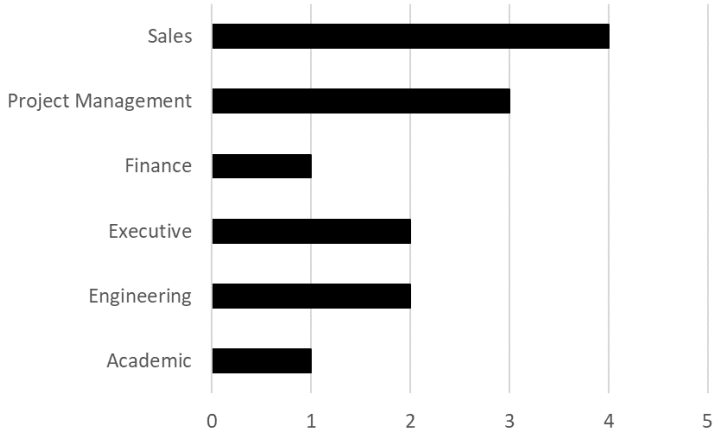

Figure 1: Respondent Industry Representation

From the perspective of respondent company size, the majority of the respondents have employed companies having 501-1000 employees and 1001-5000 employees (Figure 2).

Figure 2: Respondent Company Size

Figure 3 indicates that all professionals who did not know I4.0 as of March 2020 would consider themselves a "Novice" after March 2021. Based on their knowledge of Construction Industry 4.0, respondents were asked to describe the aspects of Industry 4.0 that impacted their roles the most. Respondents identified seven aspects impacting their profession, including 1) Big Data and Analytics, 2) BIM, 3) Building Materials, 4) Customer Communications, 5) Employee Communications, 6) Manufacturing, and 7) Site Construction. As a result of Industry 4.0 impacts, respondents were also asked to select the areas of their business where reliance changed during pandemic restrictions. The same even areas of activities were provided as possible responses.

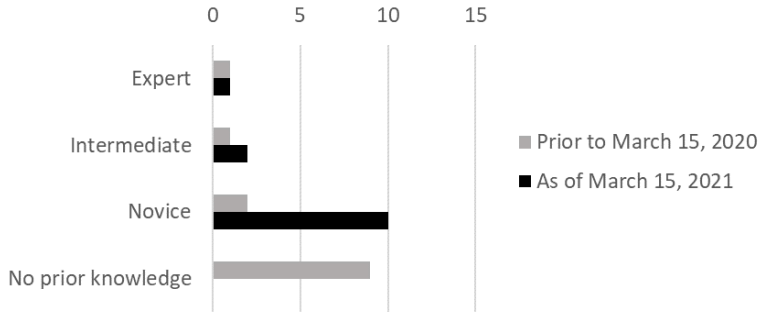

Figure 3: Respondent knowledge of Construction Industry 4.0 applications

The respondents were asked to assess their organization's awareness of Industry 4.0 in construction before the pandemic restrictions that began in March of 2020. About half of the respondents felt that the company was unaware of any I4.0 methods (Figure 4). Of the participants who felt their company had some awareness, half felt their company had slightly integrated Industry 4.0 methods, and the other half felt that their company was "very integrated." The next set of questions asked for opinions about how participants felt their company utilized construction I4.0 to respond to the pandemic restrictions. Also shown in Figure 4, participants were asked to describe whether their company's reliance on I4.0 changed as of March 2021.

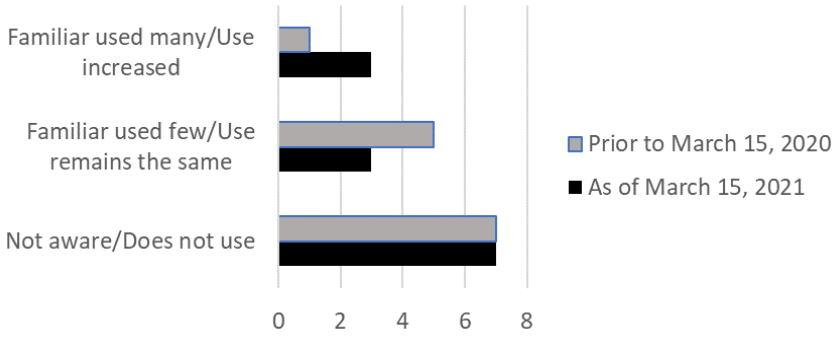

Figure 4: Integration and Reliance on construction I4.0 methods

Figure 5 shows the responses regarding Construction Industry 4.0 technologies selected in response to Covid-19. Use of Cloud applications was the most selected technology, with 9 of 14 respondents.

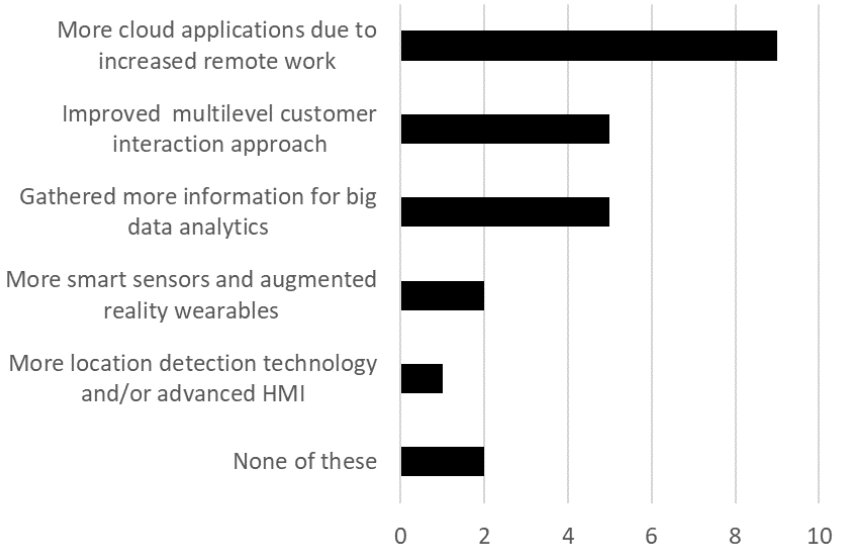

Figure 5: Construction Industry 4.0 technologies selected in response to Covid-19

Construction professionals felt that their employer's attitude changed toward I4.0 following one year of pandemic restrictions (Figure 6). More than half the respondents felt that their company did not make any attitude changes to I4.0 due to Covid-19, although they may be monitoring developments. Two respondents felt their company made changes in attitude towards I4.0 due to Covid-19.

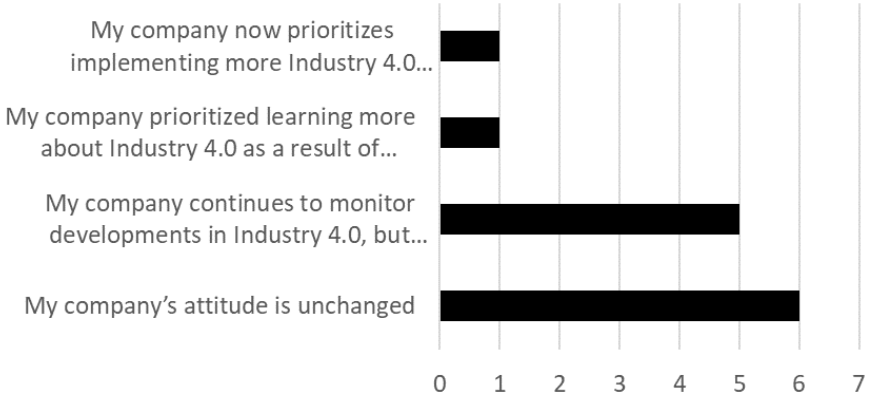

Figure 6: How has Covid-19 affected your company's attitude toward Industry 4.0?

In terms of the areas that would benefit from I4.0 integration in construction, most respondents felt that during the construction phase, the use of the cloud for Data Management would benefit from improved I4.0 competencies (Figure 7). Regarding changes in outcomes with a better understanding of construction I4.0, most respondents (61.5%) indicated a higher probability of a potential increase of I4.0 implementation (Table 2).

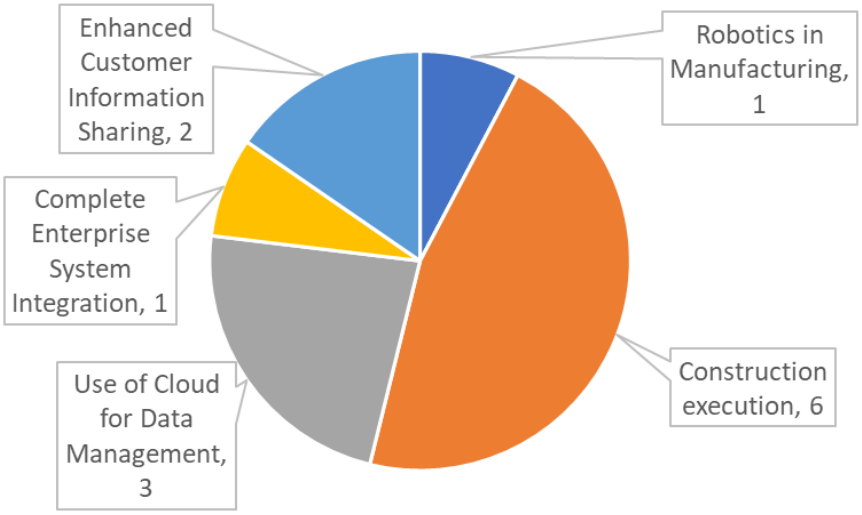

Figure 7: Areas where companies would benefit from improved I4.0 competencies based on survey respondents

Table 2: Potential Increase of Construction I4.0 Implementation (Respondent Number)

Definitely will	2
Probably will	8
Might or might not	2
Probably will not	1

Conclusion

The findings of the exploratory study are limited by the number of respondents that participated in the study, and arguments for generalizability cannot be made even for the Southeastern region of the United States. However, based on the responses, one can articulate and further investigate that the competencies of construction professionals have enhanced over the past year, which resulted in higher awareness of I4.0. One of the significant challenges with technology adoption could be a lack of awareness, as half of the respondents felt that the company was unaware of any I4.0 methods. Of the participants who felt their company had some awareness, half felt their company had slightly integrated Industry 4.0 methods, and the other half felt that their company was "very integrated." Due to limited knowledge, it can be hypothesized company-wide competencies did not grow as expected because 50% of the companies continue not to utilize the available tools. However, the hypothesis that the lack of knowledge about I4.0 needs to be tested in future studies.

Nearly half of respondents did not see a change in their company's attitude since March of 2020. Pandemic has increased reliance on the I4.0 methodologies out of necessity. Site construction and digital technologies (BIM/Data Analytics) saw substantial increases in focus, regardless of company size. The construction industry responded to Covid-19 was "use of more Cloud applications," with 9 of 13 respondents. However, some respondents did not identify any I4.0 methods used to respond to

Covid-19. The use of the cloud for data management and site construction is recognized as an area that would benefit companies the most.

As the economic recovery begins, it will be interesting to see how much digital integration becomes a priority instead of a short-term response to Covid-19. The most positive sign of change was about Industry 4.0 in the future. A combined 75% of the participants felt they would see more I4.0 in the coming years. Based on the age demographics, which showed that 38.10% of the respondents were born in the 1990s, there is a high likelihood that future leaders will share this positive outlook. The power to change the trend of industry competencies will be within their control.

Limitations and Future Studies

The initial exploratory research findings are limited to institutional and commercial professionals, mainly in the Southeastern region of the US. This study can also be expanded to the entire US to determine the national patterns for adoption and implementation. Further, the data collected only reflects the opinions of professionals one calendar year after restrictions. Therefore, it would be beneficial to determine the adoption and implementation patterns among the construction companies post-return to normalcy. Since construction, in general, has been slow to adapt, monitoring the progress in the areas of construction site robotics, manufacturing robotics, big data and analytics, and intelligent sensors is imperitive. The top concern from the survey was “Site Construction,” “Customer Communications,” and “Big Data and Analytics”; however, the participants did not describe seeing changes in this area of implementation. Future studies need to depict how the industry has dealt with this concern.

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