Increasing Health and Safety Through the Utilization of 4D Modeling

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Health and safety is one of the most important aspects of the construction industry. Every year there are thousands of work-related injuries in the construction industry. Avoiding these injuries is of the utmost importance on a jobsite. This paper will analyze how building information modeling, specifically the use of 4D building information modeling, can be utilized to increase the overall health and safety of construction jobsite. An exploratory survey was conducted amongst architecture, engineering, and construction industry professionals who hold a wide range of experience. The aim of this survey was to analyze their knowledge and experiences using building information modeling, especially 4D building information modeling, in conjuncture with health and safety. This paper also serves to lend background information on health and safety, building information modeling, and more specifically 4D building information modeling. This paper provides possibilities of future research that can be conducted as a part of the research taken from the survey.

Key Words: Building Information Modeling, Health, Safety, 4D Modeling

Introduction

The construction industry has been around since the beginning of humankind, and is not known for being an easy, or safe profession. It is one of the leading contributors for the United States economy, in terms of gross domestic product (GDP), with over 680,000 employers and housing more than 7 million employees creating more than $1.3 trillion worth of structures every year (Simonson, 2019). Every day, every month, and every year the construction industry continues to innovate and become more technologically advanced. With the construction industry advancing at such a fast pace, it is important for construction companies to keep up with the times. To keep up with the times, construction companies need to keep learning, creating, and staying trained on the latest and greatest technological innovations. Throughout the construction process, workers are put to the test performing specialized tasks, which all come with a specific risk. These tasks expose these workers directly, and indirectly to risks produced by not only themselves, but also workers performing work nearby. These risks present the ability to cause an injury if the worker is not fully alert (Carvajal Pelaez, Catala Alia, and Suarez Sanchez, 2017). Due to the uniqueness of tasks being performed, there is a high frequency of accidents that occur in the construction industry, making it an extremely dangerous industry.

Introduction to Health and Safety

According to the United States Bureau of Labor Statistics, the growth rate of the construction industry is one of the highest. Estimating between 2010-2020, there was a 1.84 million person growth in wage-and-salary jobs, which is a 33% increase. It has more than doubled the 14% growth rate of the projected overall economy (CPWR.com, 2019). The biggest part of this employment increase is the increase of labor jobs. For example, jobs such as brick masons are adding close to 39,000 new jobs increasing 56% within their own field, and roofers are expected to add close to 21,000 jobs increasing 21.5% within their own field (CPWR.com, 2019). See more job increases in Figure 1. This is an extremely important trend to follow because with more jobs, especially more labor jobs, comes an increase in jobsite accidents, and threats to health and safety of the construction industry.

The Occupational Safety and Health Administration (OSHA) was created with the Occupational Safety of Health Act of 1970 to "to ensure safe and healthful working conditions for working men and women by setting and enforcing standards and by providing training, outreach, education and assistance" (OSHA.gov, 2020, A). According to the OSHA, 1008 workers died on the job in 2018. This is 21.1% of all worker fatalities for the year with 58.6% of these deaths coming from at least one of the "fatal four," these being falls, struck by objects, electrocutions, and caught-in/betweens (OSHA.gov, 2020, B). With this many fatal accidents in the construction industry, there were 2.8 million nonfatal workplace injuries with just under 200,000 of those injuries coming from the construction industry (BLS.gov, 2020). Based off these extremely high injury and fatality numbers, there needs to be a change in the industry to bring these numbers down, and to keep the workers that build our world safe.

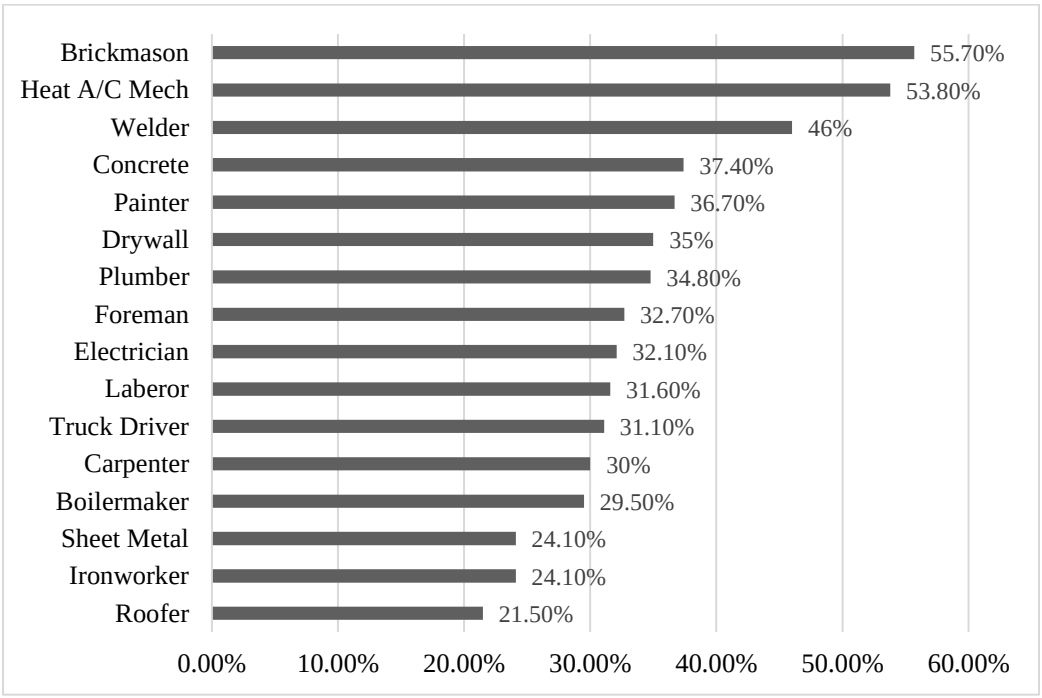

Figure 1. Labor Job Expected 10-Year Change (%)

Introduction to Building Information Modeling

According to John Eynon, author of *Construction Manager's BIM Handbook,* Building Information Modeling (BIM) is defined as "the digital representation of physical and functional characteristics of a facility creating a shared knowledge resource for information about it and forming a reliable basis for decisions during its life cycle, from earliest conception to demolition" (Eynon, 2016). This is saying that BIM is every single bit of information from every stage of construction, used to make the best decisions possible for the project, through various tools, technologies, and collaboration between different parties.

As the construction industry has continued to innovate and become more technologically advanced, the use of BIM has become a more wide spread approach to solving problems for much of the industry. According to the National BIM Report of 2018, the adoption of BIM has risen from 10% in 2011 to over 70% in 2018 (TheNBS.com, 2019). Many members of the construction industry believe that all BIM is, is "generating and sharing information authored using 3D modelling tools," when in reality, the applications of BIM are endless and ever changing (TheNBS.com, 2019). There are 5 BIM dimensions, described in table 1 (United BIM, 2019).

Table 1

Dimensions of Building Information Modeling

Dimension	Description
3D	Most familiar form. The process of gathering graphical and non-graphical information to build 3D models and sharing this information in a Common Data Environment (CDE).
4D	Brings time information into BIM to create a create an even richer source of information.
5D	Brings costs information to BIM, allowing the user to extract accurate cost data from a model, and see cost changes over time.
6D	Focuses on the sustainability of an asset, some data included may be maintenance schedules, configuration of the component for optimum performance, expected lifespan, etc.
7D	Extracts and tracks relevant asset data such as component status, specifications, maintenance manuals, warranty data, etc.

Throughout the construction industry, there is a wide variety of how BIM can be utilized and there is disagreement over just how BIM can be utilized. BIM allows different types of information to be pushed upwards in the design development to include planning and programming. Planning being an important aspect in this paper. With this added information, designers, planners, and builders can better coordinate information and details amongst different groups off people involved in the development and execution of crucial construction projects (Manning and Messner, 2007).

This paper will focus primarily on the us of 4D BIM in order to increase health and safety for a construction project.

Introduction to 4D Modeling

4D BIM modeling refers to the act of linking 3D Computer-Aided Design (CAD) components with the attribute of time or scheduling related information to parts of a model so that a view is generated

showing the construction sequence (Jacobi, 2011). Many different elements can be added to these models such as scaffolding, hoists, cranes, trucks, and much more. 4D models are used predominantly to explain some sort of construction sequence and site logistics to groups such as the site team or a client, and can be a helpful tool in winning a bid. A 4D model can be created from and interact directly with software such as Primavera and Asta. Using these types of models allows the user to create a planned sequence and can allow the user to visualize the current progress of a project at any point in time, if updated at a timely matter (Manning and Messner, 2007).

Understanding all that has currently been stated, the aim of this paper to find a trend where 4D BIM modeling can provide a way to increase the health and safety of a job site in the construction industry. These ideas are based off industry professionals, experience, and theory.

Research Methodology

In order for data to be collected, a survey was sent out to various architect, engineering, and construction (AEC) industry members in hopes to identify and compare best practices to increase health and safety through the duration of a construction project, utilizing 4D modeling. The participants were asked questions regarding their experience using BIM in conjuncture with health and safety, and more specifically if they have used 4D modeling to increase health and safety throughout their careers (See Survey Questions as listed in Appendix A.)

Data Analysis

The survey was sent out via Microsoft Forms and collected over the course of a two-month period. All responses were kept anonymous. The questions were kept the same throughout the survey. These questions were created to invoke thoughts and conclusions based of the individuals previous experience, problem solving, and original thought. Although the questions asked during the survey (refer to Appendix A.) were asked in an effort to gather specific information about how to use 4D modeling to improve health and safety, they were also asked to find trends in knowledge of BIM and 4D modeling based off experience and role in an organization.

Research Results

There were 31 AEC members that participated in this survey with various levels of experience. It is anticipated that the more people who participate in this survey, a more concise conclusion will be created about how to increase health and safety through the utilization of 4D modeling.

Demographic Analysis

The 31 AEC members who participated in this survey are all from the United States of America. See the survey results of the 31 AEC members who participated in Table 2.

Table 2

Results of Survey

How long have you worked in the Architecture, Engineering, and Construction (AEC) industry?		
Years	Participants	Percentage
1-3	3	9.7%
4-7	6	19.4%
7-10	6	19.4%
10+	16	51.5%
Have you used Building Information Modeling (BIM) to improve the health and safety of a project at any point throughout the construction process?		
Answer	Participants	Percentage
Yes	14	45.2%
No	17	54.8%
Have you used 4D modeling to improve the health and safety of a project at any point throughout the construction process?		
Answer	Participants	Percentage
Yes	2	6.5%
No	29	93.5%
Have you used BIM or 4D modeling in conjunction with health and safety?		
Answer	Participants	Percentage
Yes	5	16.1%
No	26	83.9%

The 31 participants had a real range of qualifications ranging from 1-year experience to more than 10 years. The role in their organization also had a significant range with each participant. There were superintendents, project engineers, project managers, project executives, vice presidents, a BIM manager and even a CEO. This was a good sample size, that had good diversity to obtain information based around the topic at hand.

Role vs. Experience Analysis

When analyzing the data taken from the survey, there were many trends that were noticed based around the role a participant played in their organization, and their experience using BIM and more specifically 4D modeling. When comparing the number of participants who have used BIM to increase health and safety with the participants roll in their respective organization, it was found that zero of the project engineers or project executives have used BIM with health and safety. On the flip side, it was noticed that of the participants, everyone who answered yes to using BIM to improve health and safety had 4+ years of experience and were predominantly field jobs, such as assistant super intendants and super intendants or members of the AEC industry predominantly working on or with a design team.

There were two survey participants that had previously used 4D modeling to increase health and safety. These two participants were a BIM manager, and a CEO. This is important to note because a CEO would likely want to discover, or has thought of ways of increasing the safety of his projects, as it would overall benefit their organization as well as increasing the organizations reputation. On the other hand, for a BIM Manager, this is exactly what their job is for, coming up with best practices and new implementations of BIM to benefit their organization.

Using BIM to Increase Health and Safety

The first bit of information that was noticed is that less than half of those surveyed had used BIM in conjuncture with health and safety, just 14 of the 31 participants, or 45.2%. This was lower than hypothesized, but shows good trends in the AEC industry is adopting BIM. Through this survey, it was the general consensus of those who have used BIM in this way that it is likely that implementing BIM on projects organically improves health and safety. This is most likely because the implementation of BIM leads to advanced planning of activities and results in a better coordinated design with less constructability issues and challenges that are traditionally resolved in the field. Late planning and problem solving on the fly lead to more safety issues. BIM is also implemented to coordinate between trades, reducing rework on projects, and rework is one of the largest activities associated with job-site accidents. One participant claimed that they used BIM to "identification safe access for trucks and materials, visualizing hoisting being done adjacent to an excavation, and clearances to power and utility lines both above and below grade." Preplanning and being able to see what was going to happen during a real time, time sequences reduced injury.

Using 4D Modeling to Increase Health and Safety

When specifically asked about using 4D modeling to improve health and safety, only 2 of the 31 participants answered with a yes, or 6.5% of the participants. Though more than half the participants thought that it was possible and shared their thoughts. The ways 4D modeling has been used in the past has predominantly in site logistics and proper planning. One participant claimed that "4D BIM is a great way to visualize projects and identify risk," and once risk is identified, we should do all in our power to engineer that risk out of the equation. Once it is engineered to its highest capacity, that is when you mitigate.

Conclusions

After receiving and analyzing the data, it was concluded that specifically from the research that was obtained, there is not a viable way that 4D modeling can directly improve health and safety of a certain construction project, but 4D modeling can indirectly improve health and safety of a construction project. Site logistics are one of the largest ways to avoid risk, and improve the safety of a job site. Through 4D modeling, adding the time aspect to a model can be very beneficial for the use of site logistics. One participant summarized eloquently how impactful 4D BIM could be useful. "If the jobsite is unorganized, if material is not correctly scheduled to be delivered, if storage/laydown areas are used improperly, the entire jobsite falls to pieces." They went on, "when a job is unorganized, people are forced to work in conditions they are not used to working in, which immediately puts themselves and those around them at risk. If a job can be correctly sequenced and scheduled ahead of time, and the plan is communicated effectively, the jobsite will be more productive, and in turn more organized/safe for the workers." This also shows that strong communication from the very early stages of a project will help keep the project safe. The biggest take aways are the importance communication, scheduling, and visualization when improving and maintain the health and safety of a jobsite.

Future Research

It is believed that this preliminary exploration of the topic was a great way to set up a second project-based report. Within this project-based report, the curator would use an actual construction project

and isolate specific factors about 4D BIM and employ them on the project to see if they do increase the health and safety. Some of the factors they would be able to isolate would be including safety structures, including arrival and departure of equipment, integrating organization of trade through the use of time, and updating in real time site conditions for future planning. Site logistics play a large role in health and safety, so another possible project would be the integration for 4D BIM into the planning and usage of a projects site logistics. This is one of the indirect ways 4D BIM increases health and safety of a construction project.

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Appendix A – Survey Questions

What is your role in your organization?

How long have you worked in the Architecture, Engineering and Construction (AEC) industry?

- 1-3 Years
- 4-7 Years
- 7-10 Years
- 10+ Years

Have you used Building Information Modeling to improve the health and safety of a project at any point throughout the construction process?

- Yes
- No

If so, in what capacity?

Have you used 4D modeling throughout your career?

- Yes
- No

If so, in what capacity?

Have you used 4D modeling in conjunction with Health and Safety?

- Yes
- No

If yes, please provide examples of successes and lessons learned.