The SAM100: Analyzing Labor Productivity

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The construction industry is one of the slowest when it comes to labor productivity. As a result, construction projects see an increase in duration and labor costs. New technologies are being introduced within the construction industry to increase labor productivity. It is becoming more and more important for the industry to adapt to these technologies. Among them are robots. The SAM100 is a brick-laying robot that can replace most of the masonry crew on a project. Utilizing this technology on masonry-heavy projects could have significant benefits. This paper will analyze the benefits and weaknesses of the SAM100 on the Jay and Susie Gogue Performing Arts Center project at Auburn University in Alabama. When analyzing its benefits, this paper will focus on the qualitative data concerning its implementation into the project. It will provide insight on the advantages and disadvantages of the robot, and some challenges met from using this piece of equipment. The purpose of this paper is to provide key information regarding the utilization of the SAM100 from a project that used this piece of equipment and make suggestions for its application in the future.

Keywords: Semi-Automated Mason, Labor Productivity, Construction Technologies, Bricklaying Robots, Construction Robotics

Introduction

For centuries, the construction industry has relied on the skills and labor of men and women. Because of this, implementing technology into construction has always been a difficult task. Construction technology embraces the materials, plant and equipment, organizations, procedures and information systems used in planning, designing, constructing, maintaining, repairing, altering and demolishing buildings and infrastructure (Ofori, 1994). Construction is a laborious process and often takes many years to complete a project. Introducing new technologies into the industry could have significant benefits, such as quicker building times and lower labor costs.

The construction industry faces a number of challenges related to labor. It continues to fall behind other industries in labor productivity, continually ranking relatively low in labor productivity indices. These indices measure the time a worker spends on-site over how much output is achieved. The U.S. Bureau of Labor Statistics indicates that productivity growth in construction, as a whole, has been negative or zero for half a century (U.S. Bureau of Labor Statistics, 2018). However, this issue may not be as negative as previously thought. Industries such as manufacturing, aerospace, and even the service sector have seen productivity gains through automation technologies, such as robots. Today, these technologies are beginning to make an appearance and become more readily available for construction.

Construction Robotics is a New York based company seeking new ways to increase labor productivity in the construction industry. Construction Robotics was established with the goal of advancing construction through the use of robotics, automation and the same principles used in manufacturing. They aim to develop world leading robotics and automation equipment for the construction industry, starting with the SAM100. The SAM100, short for Semi-Automated Mason, is a brick laying robot designed and engineered by Construction Robotics. SAM100 is the first commercially available bricklaying robot for onsite masonry construction (Construction Robotics, 2019).

The SAM100 has been used to build everything from grocery stores to apartment buildings. Scott Peters, CEO and co-founder of the company, says the system is precise and easy enough to use that masons can be taught how to calibrate it in just five minutes (Butterman, 2018). The SAM100 could be a key tool on future masonry-heavy projects where labor productivity is an important factor.

Literature Review

Labor Productivity

Labor Productivity is defined as the ratio between completed work and expended work hours to execute the project (Nasirzadeh & Nojedehi, 2013). Increasing labor productivity at every stage of the construction process can play a significant role in the overall project success. However, it is a difficult task to accomplish. Farnad Nasirzadeh and Pouya Nojedehi conducted research that presents a system dynamics-based approach to model labor productivity. System dynamics was introduced by Jay Forrester, a pioneering American computer engineer and systems scientist, in 1961. It is an objective-oriented simulation methodology enabling us to model complex systems considering all the influencing factors (Nasirzadeh & Nojedehi, 2013). Essentially, the model takes into account different factors that could potentially affect labor productivity. Time and cost, among others, are included as part of these factors. Labor productivity is an essential element to estimate project duration and cost (Nasirzadeh & Nojedehi, 2013). By using the proposed system dynamics model, Nasirzadeh and Najedehi were able to assess labor productivity's effect on project cost and duration. Figure 1 illustrates the effect of labor productivity on duration. It shows how the project duration will be increased from 5 to 50 months, as labor productivity is decreased from a perfect productivity rate of 20 to 1 (Nasirzadeh & Nojedehi, 2013). The second graph in Figure 1 shows how project costs will increase from $235,000 to $1,540,000 as labor productivity rates decrease from 20 to 1 (Nasirzadeh & Nojedehi, 2013).

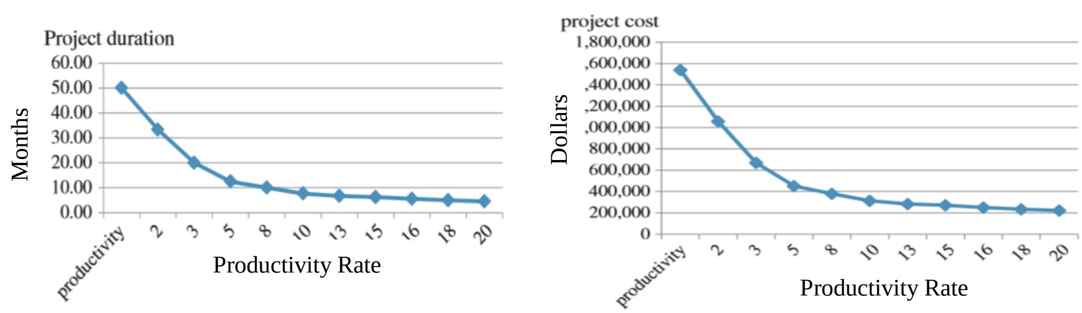

Figure 1: Labor productivity's effect on project duration and project cost

Compared to other industries, construction's labor productivity has almost always been low on the totem pole. Due to the size of the construction industry, productivity changes within it have significant direct effects on the national productivity and economic well-being of the United States (Allmon, Haas, Borcherding, Goodrum, 2000). As seen in Figure 2, the average annual percent change for labor productivity from 2007-2017 has seen a slight increase, but nothing substantial. The industrial construction industry had the greatest increase of only 2.9% (U.S. Bureau of Labor Statistics, 2019). Productivity changes can be a result of individual project uniqueness, management techniques, level of construction training, and above all the use of technology. All but the most basic of tasks on a site have seen changes due to advances in technology over recent years. Tools and machinery have increased both in power and complexity. These advances in technology can significantly modify skill requirements in the construction industry (Allmon, Haas, Borcherding, Goodrum, 2000). With lowered skill requirements due to technological advancements, labor productivity should increase throughout the various sectors of the construction industry.

Figure 2: Labor Productivity Change Trends (2007-2017)

Robotics in Construction

Since the first building was erected, mankind has looked for ways to improve the construction process. These improvements include inventions of tools and equipment. Until almost the twentieth century, one simple tool constituted the primary earthmoving machine: the hand shovel. (Haycraft, 2011). The hand shovel could be seen as one of the first tools to increase labor productivity in the construction industry. The late eighteenth-century, the beginnings of the Industrial Revolution, and the invention of the steam engine promised a practical mode of power for a wide range of applications (Haycraft, 2011). This invention became the foundation for vast improvements in construction methods. One of these improvements includes the introduction of robotics into construction.

Robotics is the science of designing, building, and applying robots. Robotics is a solid discipline of study that incorporates the background, knowledge, and creativity of mechanical, electrical, computer, industrial, and manufacturing engineering (Jackson, 1990). Robots present several advantages and benefits. First, robots bring an improved production quality to the construction industry. During operation, robot movements are very precise and accurate. This accuracy equates to higher product quality, satisfying customers and meeting their expectations. (Jackson, 1990). Secondly, robots improve the overall quality of life for laborers. The implementation of robots in the manufacturing industries has improved the quality of life for the workers. They have relieved workers of tedious jobs; humans tend to become bored and inattentive in such jobs, making them prone to accidents or mistakes. Since the robot works without mental or physical fatigue, it can perform the job consistently and safely (Jackson, 1990). Lastly, robots reduce labor costs. Robots are fully capable of working 24 hours per day, 7 days per week. They do not require wages or other compensation, fringe benefits, insurance, or pension accounts. Robots never question their assignments, never go on strike, and never vary their production rate (Jackson, 1990).

In early 2017, nearly 200,000 construction jobs were unfilled across the USA and the economic output per worker has remained flat for decades. Most major construction projects run over budget, material wastage is extensive and accident rates are high. These common issues reinforce the view that the industry could benefit greatly from more automation, such as robotics (Bogue, 2018). The future of robotics in construction looks strong. Conventional building practices that are often labor-intensive or require a high degree of skill are moving towards an automated approach.

A growing number of new companies are emerging to venture into the market of using building automation instead of conventional building practices. One of these conventional building practices includes masonry work, or bricklaying. Bricklaying is a tedious process that requires many hours of labor to complete. One company, Construction Robotics, has improved the brick-laying process with the invention of the Semi-Automated Mason 100 (SAM100).

The Semi-Automated Mason 100

Construction Robotics is a New York-based company founded in 2007. They have developed the SAM100 (Figure 3), a bricklaying robot, which formally launched in 2014. The SAM100 is priced at about $500,000 and can lay around 2,000-3,000 bricks per day using its combination of a conveyor belt, a robotic arm and gripper and a concrete pump (Bogue, 2018). Electrical power and air are provided by an on-board propane generator and the robot is equipped with a laser and suite of sensors which allow it to measure critical operational variables including orientation, angles, depths and distance (Bogue, 2018). One thing to be noted is the SAM100 does not fully automate the bricklaying process. The robot picks up the bricks, applies the mortar and positions the bricks on the wall but still requires a human to work alongside to smooth over the mortar before it places further bricks.

Figure 3: The SAM100 bricklaying robot

The SAM100 has already made its way into the construction industry and several companies are utilizing this technology. An Indiana-based construction company has incorporated the SAM100 into its construction projects, increasing daily bricklaying capacity by 400 percent (Carlson, 2017). At Willhelm Construction in Indianapolis, the average mason lays 400 modular bricks on a good day. After purchasing the SAM100, the company claims they are now laying more than 2,000 bricks a day. Its record is over 3,000 (McClister, 2018). A Colorado-based company, Berich Masonry, began using the SAM100 at the beginning of 2018. Todd Berich, president of Berich Masonry, says the company rents the robot at around $20,000 a month. However, Berich claims the benefits [of the SAM100] are twofold, [the company] can do more volume, or in other words, say 'yes' to [their] clients more often. They're already seeing that [clients] are thrilled with the quality SAM produces (McClister, 2018). The SAM100 has proven itself on previous projects to be an important player on improving the bricklaying process. But does this robot have enough of an affect to make it worth the cost?

Methodology

The primary method of research for this paper is qualitative research. The first step was to gather as much information as possible on the history of labor productivity in construction. This includes the trends, weaknesses and changes of labor productivity that have been seen ever since construction became an industry. Pulling information from numerous articles and even the Bureau of Labor Statistics is an essential step. After finding existing knowledge on construction labor productivity, the next step was to find information on technology use in construction. Specifically, this paper sought after articles regarding robotics. The final step in research was to find information concerning the SAM100. This includes what it is, how it works and any previous uses it has had.

Once all prior knowledge and research was conducted, the next step was to pursue a current project using the SAM100. For this paper, the new Jay and Susie Gogue Performing Arts Center project currently under construction at Auburn University in Alabama is used as a case study. Rabren General Contractors, the contracted company for the job, was contacted and agreed to speak on their decision to use the SAM100 for a portion of the masonry work on the structure. Matt Hearn, Project Manager on the job, was interviewed and provided valuable insight on the benefits versus the costs of the SAM100. This information provides new knowledge on the SAM100 and its effects on labor productivity.

Results

Matt Hearn is a Senior Project Manager for Rabren General Contractors and has been working for them since June of 2017. For his first ten years out of school, he worked for M. J. Harris Construction Services doing primarily hospital work. At Rabren, Hearn does all commercial work, specifically higher education construction. Since the company headquarters are in Auburn, Alabama, Rabren has built a number of projects for Auburn University. Rabren also does commercial work for the healthcare industry and the multi-family housing industry.

Matt Hearn's current project, the Jay and Susie Gogue Performing Arts Center (Figure 4), is the first time Rabren has used any sort of robotics on a project. The structure is 85,000 square feet containing two venues. Construction costs for the project are estimated to be around $56 million with an overall schedule of 20 months to complete. The structure is complex with lots of details and specialty equipment. Most performing arts center projects are typically negotiated contracts, donations or a private entity funding situation. The Jay and Susie Gogue Performing Arts Center project was a hard bid contract, a requirement of Auburn University. It is extremely unique and many vendors for the project are worldwide companies who travel the globe working on these projects.

Figure 4: Jay and Susie Gogue Performing Arts Center Rendering

During the design phase of the project, there was no intention of using the SAM100. One of Hearn's masons on the project approached him after attending a trade show in Las Vegas that featured a demo of the SAM100. The mason said "[he] wanted to use [the SAM100] on [Hearn's] job." After being approached, Hearn determined it would be valuable to have the architect as well as the owner (Auburn University) buy in on the idea of using the SAM100. The first question the architect wanted answered was "what does the quality look like?" The owner was concerned with the schedule and the cost. Since the project was not designed to use the SAM100 and the idea to use it was the masonry subcontractor's decision, the cost of the SAM100 was incurred by the masonry subcontractor. Hearn believes the cost of having a typical masonry crew would have been cheaper than using the SAM100 on the job. However, the size of the crew was significantly reduced. Instead of having a large crew of 15-20 masons, the SAM100 could do its work with only 4-5 masons. Two laborers mixed the mortar, two cut and fed the bricks into the machine and one laborer operated the machine.

The biggest benefit of using the SAM100 on the project was in regards to quality. The SAM100 is laser guided, making it incredibly precise. In addition, SAM100 is a robot and never gets tired. Naturally, mason's get tired at the end of the day and the quality of the work goes down due to laziness and fatigue. With the SAM100 taking over the most tedious task of laying the brick, the quality of the masonry work increases. In addition to quality, the SAM100 also reduces labor costs.

Labor costs are a direct cost that can be tracked. According to Matt Hearn, the brick wall, which the SAM100 constructed, would have required 12 masons and two weeks to complete. Using the SAM100 only required 4 masons and one week to complete. Indirect costs, such as rework and quality, are much harder to track. If Hearn had decided not to use the SAM100, these indirect costs could have had an impact on the overall cost of the job. However, the SAM100's precision and quality eliminate the indirect costs and reduce the direct costs of masonry labor.

After using the SAM100 on the Jay and Susie Gogue Performing Arts Center project, Matt Hearn does not believe the benefits of the machine outweigh its costs. The SAM100 is specific to a certain type of job. This job would include a structure having long runs of brick, starting from the ground, with tall elevations, such as a box warehouse. This would provide a much greater opportunity of reducing costs and increasing the overall quality of the masonry work.

A challenge found with using the SAM100 on Hearn's project was how long it took to set up the robot. The SAM100 was tasked at laying brick for the stage house (Figure 5), which started at about 30 feet off the ground. In order for the SAM100 to complete this work, the robot had to be shored and scaffolded from a roof deck below. Hearn's project team actually lost time in brick-laying activities due to increased set-up time. According to Matt, it took roughly a week and a half just to get the robot set up correctly. But once the robot was properly leveled, the tracks for the robot are aligned, it's anchored and the laser are accurately set up, the SAM100 was very efficient at laying-brick.

Figure 5: SAM100 completed work for the stage house (tallest portion of structure)

Conclusion

The construction industry has a strong history of having low levels of labor productivity. To fix this problem, new and inventive ways are being introduced into the industry. One of these ways is through the use of robots. The SAM100 is replacing typical masonry crews and doing the job at a faster rate. After analyzing the Jay and Susie Gogue Performing Arts Center project, conclusions can be drawn about the benefits and weaknesses of the machine. The SAM100 does everything it is supposed to. The quality is exceptional and it lacks the typical laziness and sloppiness of human laborers. Once the machine is up and running, it can complete its tasks at a rate that is five to six times faster than a masonry crew. In addition, a standard project will require a crew of 15-20 masons to complete the masonry work. The SAM100 only requires four to five laborers to assist the machine and operate it.

On the other hand, there are some drawbacks from using the machine. Unless the work to be performed starts from the ground, the SAM100 requires a tremendous amount of time to set up. The SAM100 needs to be perfectly leveled, the tracks on the robot must be aligned, it has to be anchored and the lasers must be accurately set up. If any of these tasks' times could be streamlined and sped up, then the incentive to use the SAM100 would be much higher.

It has been determined that the SAM100 is more effective on certain project types. These projects include large box-shape structures, such as warehouses. These structures should have an exterior composed primarily of brick or other masonry materials. In addition, the elevations of the walls should be fairly high, 30-50 feet, to get the most use out of the SAM100. The walls should also be long, around 100 feet, for the machine to be useful on the project. Smaller masonry projects do not seem fit for the SAM100 because the cost of using it does not outweigh the benefits.

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