BRICKLAYING ROBOTS IN THE SOUTH AFRICAN CONSTRUCTION INDUSTRY: THE CONTRACTORS PERSPECTIVE

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The construction industry has been slow in adopting new technological innovations, even though studies have shown that the adoption of automation and robotics would result in the construction works being executed in safer environments, with better alternative building methods, that could ensure that the works are executed with greater accuracy therefore improving the quality of construction works. This paper investigated the contractor's perception of adopting the semi-automated mason (SAM) a bricklaying robot in the South African construction industry as an alternative building method that would contribute to the introduction of automation and robotics in the industry. A qualitative research design was used. The non-probability purposive sampling method was used to select 20 construction companies based in Durban, KwaZulu-Natal for the purposes of conducting this study. Data were collected through telephonic semi-structured interviews with respondents from construction companies and were thematically analysed using NVivo 12. The study revealed that the construction industry professionals are willing to adopt the semi-automated mason into their working structures, but believe that, currently, the South African construction is not ready to implement such technological innovations. The challenges identified by the respondents where the high unemployment rate in South Africa, the risk of mass job losses among manual labourers and the cost of the robot would be great barriers to companies willing to adopt SAM.

Keywords: bricklaying robots; automation; semi-automated mason; robotics

INTRODUCTION

The demand for efficient construction processes and innovative construction techniques has increased within the construction industry, and this has been largely due to the rising competition in the globalised market, and the advancement of technology in the 21st century (Hasegawa, 2006). Automation and robotics have been identified as the main and most important means of swiftly moving the world of construction towards the simplification and computerisation of almost all construction tasks and processes (Oke, Akinradewo and Aigbavboa, 2019). For centuries, the construction industry has relied on the use of manual labour for the execution of construction tasks, resulting in a stagnant industry in terms of improving productivity,

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safety and quality, however the implementation of technology and robotics into construction has been a very slow.

The construction industry is regarded as one of the leading industries in the creation of employment, both formal and informal, directly and indirectly because of its reliance on manual labour (Klinc and Turk, 2019). However, over the centuries the construction industry has seen some major technological advances which led to construction processes becoming easier and faster to execute. These advances range from software applications like Computer-Aided Design (CAD), computer software that produce cost estimates and construction schedules such as WinQS, to tangible construction equipment, plant and machinery like cranes, tractor loader backhoes, and other bulk excavation tractors. These technological advances perform different tasks in different stages of construction processes, from the initial planning and design up to the actual construction. They move material quicker, with greater reliability and precision than human labourers. Heavy equipment for use at the job site, such as cranes, conveyors, and earth movers, continue to become more efficient as technology advances (Yates, 1988).

The adoption of robotics and automation within the construction industry has been slow, and it is a problem facing many construction industries around the world, the South African construction industry being one of them. To better understand the underlaying factors to this low adoption of automation and robotic technologies, this study investigated the intention of adopting bricklaying robots in the South African construction industry and to determine the willingness and readiness of construction companies to adopt this robot as a step in automating their work processes.

Construction automation is the utilisation of robots to improve production and minimise risk of accidents on construction sites. By shifting and re-assigning work originally performed by humans to robots, construction automation helps firms achieve better quality using less resources and in a shorter period of time. Oke, Aigbavboa and Mabena (2017) further establishes that construction automation is a self-controlling procedure that operates by using computerised machines to perform different construction tasks. Construction automated machines are designed and developed to function in conformity with a programme that regulates the behaviour of the machine and ensure efficiency at all times without imposing any risk to people operating or working besides it.

The Bricklaying Robot

The introduction of more automation and robotics is needed to overcome the challenges faced by the industry such as declining productivity and quality and on-site accidents (Oke, Akinradewo and Aigbavboa, 2019). Japan was the first country to produce the first real world single task construction robots manufactured by the major construction contractor, of Japan, Shimizu to be tested in the market (Bock and Linner, 2016). Over the past few years there has been major improvements in the industry with new technological innovations slowly being implemented.

It is through these technological advances that the world of construction has seen the introduction of the semi-automated mason (SAM), the bricklaying robot, developed in the United States by the New York based robotics and automation equipment manufacturer, Construction Robotics (Dormhel, 2017).

Bricklaying robots are single task construction robots (STCRs), which assembles brick walls with minimal input from humans. They almost totally take over the

manual labour that would be needed from human workers to lay bricks. They were developed to achieve more productivity while using less resources (Bock and Linner, 2016).

Over the years technology and machines and robotics have beensimplified, their design incorporates simple systems which are easy to work with and operate. This makes it easier for people and construction companies to be open to the idea of utilising bricklaying robots in construction and replacing human workers. The integration of innovative technologies such as SAM on construction sites has a great chance of improving the productivity, safety and quality aspects of the construction industry (ManLi, 2018).

The adoption of construction automation and robotics would be beneficial to construction industries by increasing production, reducing construction duration, improving quality, lower risks of injuries and fatalities and reducing labour and production costs (Akinradewo, Oke, Aigbavboa and Mashangoane; 2018; Bock and Linner, 2016; Dormhel, 2017).

Challenges of Adopting Bricklaying Robots

There are drawbacks identified with the implementation of automation and robotics, which includes job loss, the cost of acquiring the bricklaying robot, the uniqueness of construction sites, technical and work-culture factors and a weak business case (Bock and Linner, 2016).

RESEARCH METHOD

For this study, the researchers wanted to collect information and opinions of experienced and knowledgeable construction industry professionals about their views, attitudes and beliefs on adopting automation and robotics in the South African construction industry. Therefore, the qualitative research method was adopted because in a qualitative research process, the researcher focuses on learning the meaning, that the participants hold about the problem or issue, and gives high importance to their point of view as this would form the basis of their analysis and research conclusion (Creswell, 2020). The non-probability purposive sampling method was adopted in this study as it allowed the researchers to seek out information-rich respondents to best address the research purpose and questions (Leavy, 2017), and this was done through the use of semi-structured interviews which were conducted telephonically. In order to ensure that the respondents knew what SAM is and how it works, they were provided with a link to a tube video to ensure that they had a good understanding of what they were being asked about. Prior to conducting the interviews ethical clearance was obtained. Twenty respondents based in Durban, KwaZulu-Natal registered with the KwaZulu-Natal Master Builders Association participated in this study. Leavy (2017) suggests that 20 is an appropriated sample size for a qualitative research.

The data collected from the interviews were analysed using NVivo-12. This entailed coding all the data to accumulate and increase the understanding of the respondent's perceptions, attitudes, and beliefs in a format that is easy to read, use and understand.

FINDINGS

Sixty five percent of the participants were male and a majority of the participants (40%) were quantity surveyors. Over 40% of the participants had more than 11 years'

experience with 45% of the companies they worked for were in existence for more than 15 years.

Three clear themes emerged from the analysis of the findings which were the benefits of using SAM, the disadvantages of using SAM and the willingness to adopt the use of SAM.

Theme 1: Benefits of using SAM

There is currently no construction company in South Africa that has adopted the use of the semi-automated mason. This is also true for most construction industries throughout the world as construction robots are still being researched and there are only few practical construction robots developed and used (Kangari, 2015). The first theme provided an analysis of what the participants perceived would be the major benefits if the semi-automated mason (SAM) was to be adopted by construction companies in South Africa. The benefits of adopting SAM would be improved quality of construction works, faster construction time, increased productivity and reduced labour costs. Other benefits were the creation of new skills and improving the skills level of the current manual labourers and improving the safety in construction sites.

Improved quality

The standard of quality one achieves using manual labour is never consistent as it depends on the skills, experience and competency of the workers, therefore, this was the strongest attraction of SAM. A majority of the respondents, stated that the movement from manual methods of construction to using construction robots would eliminate factors such as human error and unskilled labour which compromise the quality of works in construction projects. Participant 20 stated that "robots are programmed to carry out a specific job and do exactly what they are told, so by that I think the precision and quality of laying of the bricks would be greater". Participant 19 supported this view by providing that "I think the technology within the robots allows them to precisely lay a brick without any error so I think they would really improve the quality without any human error involved, …more people would want to work with us as result of the quality we will be producing".

Faster construction time

The second most mentioned benefit was faster construction time. Ninety five percent of the participants were of the view that construction projects would be completed much faster if bricklaying robots were implemented. Participant 2 stated that "I believe a semi- automated machine would complete the work much quicker as compared to the most experienced worker …", Participant 8 added that the "construction duration would reduce as the works would be executed faster because the SAM can lay more bricks a day as compared to human and it never gets tired or needs any breaks".

Increased productivity

Fulford and Standing (2014) provided that one of the major challenges that are currently facing the construction industry is low productivity as compared to other industries. The respondent's believed that automating the construction industry would be a solution to this challenge. Fernando, Mathath and Murshid (2017) stated that many industries around the world like manufacturing and the automotive industries were able to increase productivity and realise greater profits after they were automated. This supports the views held by the respondents that if the semi-automated mason is applied properly and efficiently in executing construction tasks, it would greatly increase productivity in the construction industry. Participant 7

commented that the adoption of SAM by construction companies would "increase productivity by being able to start work on time, work through breaks and work longer shift hours". Participant 5 added to this view by stating that by adopting SAM, "the company could get more recognition, more people would be talking about the company that has such technology and therefore reaching more potential customers". The participants believed that the adoption of SAM would attract more clients, which would mean getting more projects and therefore increasing the productivity of the company, and the industry. Participant 10 stated that "in extreme circumstances like during the COVID-19 pandemic SAM would have been a viable asset…".

Reduced labour costs

The participants believed that the adoption of SAM into construction working processes would affect the running costs of a construction company because the adoption of SAM would lead to a lot of manual workers losing their jobs. The participants believed that this would lead to construction companies saving a lot of money on labour costs as there would be fewer manual bricklayers employed. Participant 13 stated that "another obvious value of using SAM would be the running costs. Despite the fact that SAM would be costly to purchase, it will be cheaper to run in the future when compared to having a masonry team". Participant 1 stated that "construction companies, or any other company in a labour-intensive industry such as the construction industry spend large amounts of money on salaries, wages and employee benefits. Having automatic bricklaying robots would help save on these costs", and participant 18 added that "I think it (SAM) would make the construction of buildings become cheaper as it would be replacing a lot of manual workers and finishing the work faster".

Creation of new skills and improving the skills level

The South African construction industry is a great employer of unskilled labour, people who specialise in bricklaying usually do not hold any qualification or tertiary education. Some participants were of the view that the adoption of the semi-automated mason would provide opportunities for the manual labourers to be retrained to be able to operate and maintain the robots. Participant 8 stated that "unfortunately, people would lose their jobs, but also this would be a great opportunity to learn new skills and learn how to operate the robots", Participant 3 also added that "… there would also be a lot of new job opportunities presented by the implementation of the bricklaying robots". The participants believed that even though the number of people retrained to operate would not even be close to the number of people who would lose their jobs, there would be an increase in the skills level and the retraining of workers.

Improve Health and Safety

Construction robots relieve workers of tedious jobs, as humans tend to get bored and lose focus while working, making them prone to accidents or mistakes. Since the robot works without mental or physical fatigue, it can perform the job consistently and safely. In commenting to the question of safety, most of the respondents responded in the positive and stated that having less people, would mean less risk of human error on construction sites and this will therefore minimise the chances of accidents and injuries because they believed that most accidents on sites occur due to human error or recklessness from human workers. Participant 1 stated that "… construction sites will no longer be as crowded and there will be enough space for everyone to perform their duties without risk of causing accidents".

Two of the participants believed that even though the use of the semi-automated mason would improve the overall safety of construction sites, there would still be the risk of danger from the robot itself if not properly maintained and operated by a fully qualified person. Participant 11 stated that "the robot itself can cause danger if not used appropriately …". Participant 9 stated that "in terms of accidents caused by human error I think the bricklaying robot would limit those, but the system itself could impose its own risks, like if it breaks down, loses control or is operated by an unqualified person".

Theme 2: Disadvantages of using SAM

The second theme developed from the participant's interviews was the disadvantages of using SAM in the South African construction industry. The most recurring and common answers from the participants were the increase in unemployment and loss of jobs and the cost of SAM. An additional disadvantage in SA is the possibility of riots.

Increased unemployment and job loss

The p increase in unemployment was one of the factors that would be disadvantageous in the adoption of SAM by the South African construction industry. Furthermore, the participants commented that "there would be fewer job opportunities for informal labour within the construction industry" adding to that, "some people would be laid off, hence contributing to an increase in unemployment."

Bock and Linner (2016: 156) stated that having the semi-automated mason on construction sites would mean that construction companies no longer need too many bricklayers on site and the participants believed that the introduction of SAM would lead to bricklayers losing their jobs. Participant 2 also mentioned that "… trades will become irrelevant and skills will be lost."

Costs

Construction companies willing to adopt automation and robotics are usually limited by economic factors such as all the elements that identify to the costs of acquiring, using and maintaining the robotics. The participants felt that the introduction of bricklaying robots would cost them a lot of money and time to train their employees to operate and work with SAM and after training them they would now need pay a higher rate as the employees now have a 'scarce skill'. It was also believed that there would be the additional costs of "maintaining and servicing the robot, the insurance, training and salary of the operator". Participant 1 stated that "since they are manufactured abroad, they would have to spend on the cost of the robot plus shipping costs and levies and import tax so the cost would be much higher than the retail cost". Therefore, many construction companies would feel discouraged to adopt the robots due to affordability issues.

Riots

The participants also thought that the public will not be too pleased with the introduction of SAM in South Africa because they are currently looking to the construction industry to improve the employment rate of the country. Therefore, the participants thought that having SAM in the construction industry would add to the frustrations of the society, "thinking that the robots are here to replace them, there will be a violent disturbance of peace by the society, i.e. riots." Participant 3 also added that the "unions would oppose the idea, as it would disrupt the usual work flow of the sector. Basically, SAM wouldn't be worth it in the end". The participants further added that "the robots definitely won't be used on public or government works because the contracts used stipulate that you have to use labour intensive construction

methods, sometimes you are not even allowed to dig a hole using a machine, you have to use manual labour".

Theme 3: Willingness to adopt the use of SAM

The willingness of the construction industry to adopt the semi-automated mason will be greatly influenced by the interest shown by the key role players, stakeholders, directors and the government. This theme allowed the respondents to comment on their willingness, or lack thereof to adopt the semi-automated mason in the South African construction industry.

Almost all the participants shared the same view in that South Africa is not keeping up with and is still far behind in the implementation and use of technology in the construction industry. They therefore believe that SAM will aid in "South Africa becoming more technologically advanced." Participant 5 stated that "I believe that the South African construction industry is only keeping up with the software and programming side of technological development, when it comes to the tangible technology, we are stuck with the original labour-intensive methods of construction."

Would SAM be a good investment for construction companies?
Eighteen of the participants believe that, looking at the potential benefits, adopting the semi-automated mason would be a great investment for them. But most importantly, they would have to look at cost implications, meaning "adopting SAM would have to make good business sense in that it would have to help cut costs and save money". If the costs of operating and maintaining the bricklaying robot would prove to be higher than having manual labours then the robots would not be a good investment". They believe that if adopting SAM would improve the quality of works, increase productivity, help cut down on labour costs and create safer construction sites then having the robot would be a big advantage. Some of the respondents also stated that having the semi-automated mason would be beneficial in extreme circumstances like during the COVID-19 pandemic when manual labourer were unable to work, then it would be a viable asset.

However, Participant 11 stated that "adopting the semi-automated mason would be more costly than manual labour in South Africa today, when, taking into account the cost of the robot together with its programs and the maintenance cost which would be the major issue when calculating the payback period." The respondents also believe that it would depend on the size of the company and the type of projects they usually do whether having the semi-automated mason would be a great investment or not. Participant 4 added that "for big construction companies who normally work on big development structures it would be a good investment, but for small companies who specialise on small residential projects it could be a loss".

Choosing between SAM and manual labour
Sixty percent of the participants stated that given an opportunity they would choose to use SAM over manual labour as they believed they would be able to increase productivity, reduce salaries and construction work would be executed faster with more accuracy and better quality. Participant 14 stated that "I would choose the semi-automated mason because it is fast paced, meaning more of the project can be covered in a short time", and Participant 9 added that "I would take the semi-automated mason any day, because that would mean I would work with less manual labour which results in paying less salaries, and the work is executed faster with more accuracy and better quality". The participants believed that most issues that come with having manual

labour like strikes, human error, incompetency would be avoided if they adopted SAM therefore, increasing their revenue which is what any company wants.

But forty percent of the participants stated that they would prefer using manual labour because they understand the state the country is currently in. To empower people, they would continue using manual labour, and because manual labour has been used for a long time, they are guaranteed it works, unlike SAM. Participant 17 stated that "I would choose the manual labour, I think we need to do everything to keep our people employed."

Assisting construction companies in adopting SAM

The participants believed that to help construction companies adopt the use of SAM, the government would have to take some proactive steps. They believe that the government's involvement would be the leading factor in ensuring the success of implementing automation and robotics in the South African construction industry. "Educating the general public of the benefits of adopting SAM, making training to use SAM affordable, offering incentives to companies that adopt SAM like a percentage cut in taxes and making SAM available in the country" are actions that the government could take to assist in the adoption of construction robots. Participant 10 added that "a trial phase may be needed where it (SAM) would be used in specific sites. Reports may be taken during of its operation by different members involved for circulation".

The participants further provided that the unions together with the current regulations in the construction industry would not facilitate the adoption of SAM, stating that "most companies are quite happy to adopt SAM however the unions are against them (less labour less fees)". They believe that changing the structures of regulations and unions to not force companies to utilise labour would make the adoption of SAM much easier.

Participant 2, however stated that "I don't think there currently is anything that the government or anyone can do to encourage the use of machines over manual labour. We have regulations that demand employing local labour on government projects, so if the government were to give incentives for adopting bricklaying robots that would defeat the purpose of trying to create employment".

CONCLUSIONS

The construction industry has been slow in adopting new technological innovations. The introduction of bricklaying robots will reshape how the construction companies approaches designing, planning and execution of construction projects. The adoption of the semi-automated mason will have a huge impact on the South African economy as a whole as the introduction of bricklaying robots on construction sites will affect the profitability of construction companies and the number of projects completed within a given period of time.

Human error, inconsistency and incompetency of manual labourers is believed to be the main cause of quality, safety and productivity challenges faced within the construction industry. Therefore, the adoption and use of alternative construction building methods, such as the semi-automated mason (SAM) would address these problems and improve the overall production process of construction companies and the construction industry as a whole. The advantages in the use of construction automation and robotic technologies include higher productivity, process improvement, product improvement and higher quality.

The research found that the participant's believed that that the benefits of adopting SAM outweigh the disadvantages and therefore, given an opportunity they would adopt the bricklaying robot because the adoption of SAM would be a step in the right direction towards the automation of the construction industry.

However, the participants believed that even though the semi-automated mason would be a good investment, and h benefit construction companies who adopt them, the South African construction industry is not ready to implement innovations of this kind yet. The cost of acquiring the semi-automated mason, lacking the necessary skills to operate the robot, and the uncertainty of the running costs which include regular maintenance costs and the salary for the operator, are among the barriers to construction companies to consider adopting SAM. But the main barrier to the adoption of SAM in the South African construction industry is the issue of the high unemployment rate because the adoption of SAM would cause a lot of bricklayers to lose their jobs causing dissatisfaction in communities and eventually leading to riots that interrupt ongoing projects.

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