CONSTRUCTION STAKEHOLDERS' PERCEPTIONS ON THE WIDER ADOPTION OF CONSTRUCTION AUTOMATION AND ROBOTICS: AN EXPLORATORY PRE-STUDY

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Rapid urbanization in developing countries (such as South Africa) is imposing strains on the current infrastructure project delivery models resulting in calls for structural changes in the socio-technical system of the construction industry. Automation and robotics have demonstrably improved the productivity in different industry sectors such as the automotive industry and mining, and there is growing interest in their application in construction. However, interest in their application in South Africa lags behind that of other countries, which may be due to the specific social, political, and economics circumstances of that country. This exploratory pre-study reports on the perceptions of South African industry stakeholders on the wider adoption of construction automation and robotics (CAR). Data is collected through semi-structured interviews with construction industry stakeholders. Thematic content analysis is used to analyse the results. The study considered the use of CAR as it relates to site activities in South Africa. The stakeholders' perception on the wider adoption of automation and robotics in South African sites is that the use of automation and robotics will result in permanent job losses. In a country, where unemployment is around 27,5%, the loss of jobs is undesirable and trumps other considerations such as quality and productivity. The South African urban infrastructure backlog can potentially be reduced by the use of construction automation and robotics. Wider adoption, however, will depend on stakeholder perceptions and socio-economic factors. Stakeholders in the construction industry in South Africa, particularly government, construction companies and labour unions will find the study beneficial.

Keywords: Automation, productivity, robotics, stakeholders

INTRODUCTION

WEF (2016) estimates that the urban population is increasing at a rate of 200 000 people per day. The increase in urban population puts a strain on the supply of housing and associated infrastructure in urban areas (WEF, 2016; Oke, Aigbavboa and Mabena, 2017). For instance, the housing backlog in South Africa is estimated at 2,1million (Engineering News, 2016). This backlog may be evidence that current infrastructure delivery models have reached their limits (Bock, 2015).

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The automotive and mining industry have enjoyed the benefits of the use of automation and robotics such as increased productivity since their introduction (Bock, 2015). For instance, a bricklaying machine called Hadrian 105 can lay 1000 brick per hour in comparison to human labour at 100-200 bricks per hour (Shinde and Sarode, 2018). There is some merit, therefore, in inferring that wider adoption of automation and robotics in the construction industry will somewhat yield similar results as in those sectors and thereby potentially reduce the urban infrastructure backlog.

There are conflicting views on the impact of wider adoption of technology on jobs (Brynjolfsson and McAfee, 2014). Some authors claim that wider adoption of technology has the potential to result in job losses (Hager et al., 2016; Oesterreich et al., 2016). Others claim that the wider adoption of technology does not cause loss of jobs but a displacement of workers (Figueiredo, Pereira, and Dias ,2015; Clark, 1907 in Brynjolfsson et al., 2014). They claim that technology usually creates better work environment and better opportunities for workers. To perform in an automated environment, however, usually requires new skills (Ibid). Workers may require training (Ibid). It is in this transitionary period, of moving workers from unskilled jobs to skilled jobs that there seem to be job losses (Clark, 1907 in Brynjolfsson et al., 2014). In the long run new jobs are created (Ibid).

Given the conflicting views about the wider adoption of technology in workplaces, with one camp claiming that technology causes job losses and the other claiming that it creates better jobs in the long run, what are the perceptions of stakeholders in South Africa on this issue? With a huge urban infrastructure backlog and unemployment rate of about 27,5% (StatsSA, 2018a), South Africa finds itself in a quagmire. If claims that CAR results in job losses wider adoption of CAR in South Africa will be in conflict with the South African government's plan to reduce unemployment to 6% by 2030 (NPC, 2011) and is therefore undesirable. How will the South African government reduce the urban backlog without the wider adoption of CAR? If, however, the wider adoption of CAR causes temporary job losses, then there is potential for wider adoption in South Africa, which might result in the reduction of the urban infrastructure backlog.

The authors consider the perceptions of construction stakeholders as either a barrier or an enabler to the wider adoption of CAR in South Africa. It is for this reason that an exploratory pre-study was undertaken to determine what their perceptions on wider adoption of CAR in South Africa were. The paper, therefore, reports on the perceptions of construction stakeholders in South Africa on the wider adoption of CAR. Four industry stakeholders are interviewed, and a thematic content analysis is used to analyse the results.

LITERATURE REVIEW

Construction automation and robotics (CAR) can be divided into three categories; teleoperated systems, programmable construction machines and intelligent systems (Ardiny, Witwicki and Mondada, 2015). The classification of CAR depends on the extent of their interface with humans. Humans, for instance, control tele-operated systems, through the use of a remote control (Ibid). Programmable construction machines aid the human operator to perform certain tasks, "by choosing a pre-programmed menu or function or by teaching the machine a new function."(Ibid). Intelligent systems can operate without any human and are usually semi-autonomous or fully autonomous (ibid). In this study, CAR encompasses all the three categories of CAR as described by Ardiny *et al.,* (2016).

Literature list many benefits of the use of CAR on construction sites such as; 1) improved safety 2) enhanced quality 3) increased productivity, 4) a better work environment and 5) construction cost savings (Vähä, Heikkilä, Kilpeläinen, Järviluoma and Gambao, 2013). In this paper, the discussion on the benefits of CAR is limited to 1) improved safety and 2) increased productivity and efficiency. The authors have limited their scope of discussion within these confines because of South Africa's poor safety record on site and high urban infrastructure backlog, issues that could potentially be addressed by the wider adoption of CAR. Similarly, literature identifies a number of disadvantages in using CAR. Some of the disadvantages of the use of CAR include high investment and maintenance cost; limited capabilities, frequent change in CAR technologies and job losses ((Hager *et al.,* 2016; Oesterreich *et al.,* 2016). This paper confines the discussion on CAR's disadvantages to job losses only. The creation of jobs is a priority for South Africa. If wider adoption of CAR will result in job losses instead of the creation of new ones, wider adoption of CAR in South Africa might not be feasible. Hence, the discussion on this paper is concerned with potential job losses because of wider adoption of CAR.

One of the benefits of the use of CAR is increased productivity and efficiency (Oesterreich *et al.,* 2016). By using bricklaying robotics such as, Hadrian 105, the construction of a house can be completed in 1-2 days as opposed to several weeks or months (Shinde *et al.,* 2018). Contour crafting technology is another technological method that can supposedly complete a house within a few hours (Khoshnevis, 2004). Contour crafting is defined as," an additive fabrication technology that uses computer control to exploit the superior surface-forming capability of trowelling to create smooth and accurate planar and free-form surfaces" (Khoshnevis *et al.,* 2001 in Khoshnevis, 2004:2). Khoshnevis (2004) claims that a 200m2 double storey house can be completed in less than two days by using contour crafting. Improved efficiency is achieved through time saving and improved quality of work or product (Ibid). If South Africa is to reduce its infrastructure backlog, consideration should be given to the adoption of bricklaying robotics such as Hadrian 101.

The construction industry is known for its hazardous nature (Wang, Zou and Li, 2015). The International Labour Organisation (ILO) (2005:2) claims that "one in every six work-related fatal accidents occurs on a construction site". The number of incidences is high for small contractors (Cheng, Leu, Lin and Fan, 2010). Small contractors usually do not have the means to fully incorporate adequate safety measures on site (Ibid).

To train and create jobs for the unskilled, the South African government introduced the Expanded Public Works Programme (EPWP) (Skosana, Amisi, Maseko and Lukwago-Mugwera, 2016). EPWP, creates jobs through the implementation of labour-intensive project for certain public projects (DPW, 2015). Labour-intensive projects require, where appropriate, the use of unskilled workers in, for example, excavations not exceeding 1,5m deep, backfilling to trenches, and compaction of surfaces (Ibid). Funding for EPWP is from the government (Ibid). Contractors receive funds from government to pay the unskilled labourers.

Since its implementation, in 2004, EPWP has enjoyed some relative success in reaching some of its objectives. A cross sectional study done in 2011 revealed that over 80% EPWP participants were employed after participating in an EPWP (Henderson, 2017).

The implementation of labour-intensive construction project is largely carried out by small contractors in South Africa (McCutcheon, 2018). This is usually because high capital and maintenance cost are major barriers for the adoption of CAR (Oesterreich *et al.,* 2016). Small contractors, who are least likely to adopt CAR due to its high cost, usually resort to the use of labour to implement projects. Even though the use of labour by small contractors creates jobs on one hand, on the other hand it results in low productivity. In addition, some of the site activities that are dangerous and could potentially be carried out by CAR are usually carried by labour. Labour for a small contractor is, therefore, more at risk of incidents than for a big contractor. The continuing use of small contractor in carrying out construction somewhat addresses one socio-economic issue, unemployment, but it perpetuates two problems, poor safety and low productivity.

A study by Frey and Osborne (2017) of 702 jobs in the US revealed that low skilled and low wage jobs in the construction industry will be mostly adversely affected by the wider adoption of CAR. Through EPWP, the South African governments intends to create low skilled jobs in the construction industry. Wider adoption of CAR in South Africa may, thus, be at odds with the South African government's job creation objectives such as EPWP. Even though, there are claims from the proponents of wider adoption of CAR, that job losses by CAR are temporary and in the long term, CAR tends to create better jobs, there are doubts if this will indeed be the case (Brynjolfsson *et al.,* 2014). In a developing country such as South Africa, which imperatives should trump the others? Should job creation trump over safety and infrastructure delivery brought about by the wider adoption of CAR?

In light of these conflicting views from literature, the study wanted to answer the main research question "what are the perceptions of construction stakeholders on the wider adoption of CAR in South Africa? The premise upon which the main question of the study rest is that wider adoption of CAR in South Africa is ultimately dependent upon the stakeholders in the construction industry.

METHODOLOGY

Four stakeholders were interviewed to determine their perceptions regarding the wider adoption of construction automation and robotics in South Africa. Semi-structured interviews were chosen for they study as they allow for both rigidity and flexibility (Saunders *et al.,* 2016). Researchers were, therefore, able to ask predetermined questions without restricting the respondents' opinion and further contribution. Two major limitation of interviews are researcher's bias and participants' bias (Ibid)). Researcher's bias may arise in the framing of the interview questions and the interpretation of responses (Saunders *et al.,* 2016; Kumar, 2014). The participant's bias may arise where the participant withholds certain information (Saunders *et al.,* 2016). To mitigate both biases three of the authors of this paper conducted interviews with the participants. The same three authors analysed the data. This allowed for triangulation of the data (Creswell, 2014).

Purposive sampling method was used to select a researcher from a leading research organization in South Africa, a government official from a government department responsible for the implementation of public infrastructure projects, a safety officer from one of the top big 5 construction companies in South Africa and a representative from a workers' union. The benefit of purposive sampling is that participants are selected strategically (Bryman and Bell, 2014). Only relevant participants are thus selected for the interview (Ibid). The participants that were selected were deemed

relevant stakeholders in the construction industry in South Africa as they were most likely to be affected by the wider adoption of robotics.

After receiving ethical clearance from the relevant committee at the institution where the research was carried out, the authors sent email invitations to relevant individuals to participate in the study. Only four individuals responded. Geographic reasons and time constraints prevented more interviews to be carried out. The four stakeholders who responded are based in the Gauteng Province of South Africa and it is the same location where the researchers are based. The study formed part of the Honours degree which only gave researchers less than a semester to gather data. It is for these reasons that the four respondents were deemed sufficient. Gauteng Province is the most populous province in South Africa and the highest contributor to South Africa's gross domestic product (GDP) (StatsSA, 2018b, StatsSA, 2018c). Given the time constraints and that all authors are based in Gauteng, it was considered more expedient to interview the four stakeholders who responded to the invitation for the interview.

For anonymity the four stakeholders interviewed are identified thus; participant 1 is the government official, participant 2 is the safety officer from a contractor with a Construction Industry Development Board (CIDB) grading of 9, participant 3 is the mining engineer who is also a mine and construction labour union's representative and participant 4 is the researcher from a leading research organization in South Africa..

Participant 1 was selected based on the fact that government is the biggest investor in infrastructure and the government carries the greater responsibility of providing infrastructure in South Africa. The wider adoption of CAR might possibly assist the government in meeting its constitutional mandate.

A CIDB grade provides an indication of the value of construction work a contractor is deemed capable of performing within a certain class of works (CIDB, Not Dated). It is compulsory for a contractor who wishes to engage in a public sector project to apply for a CIDB grading (Ibid). Grade 9 is the highest score on the CIDB grading scale (Ibid). A grade 8 contractor can only undertake work whose value does not exceed R130m (Ibid). There is, however, no limit for a contractor with a CIDB grade 9 score (Ibid). Big contractors are more likely than small contractors to adopt CAR as CAR has high capital and investment costs (Oesterreich *et al.,* 2016) hence the inclusion of participant 2.

The union representative, referred to in this study as participant 3, is also a mining engineer involved in labour intensive activities in mining projects. Mining fatalities are high in South Africa. 88 fatalities were reported for 2017 (Minerals Council of South Africa, 2018). CAR is suitable for use in dangerous activities such as mining (Ardiny *et al.,* 2015). Soliciting the opinion of a mine representative meant, to some extent, understanding the perceptions of workers on the wider adoption of CAR in dangerous working environments.

Participant 4 was included because of the role research contributes towards change and innovation. Their opinion is most likely to be based on scientific research.

Data was analysed using thematic analysis. By using thematic analysis, qualitative data is analysed by searching for common themes and patterns across a data set (Saunders *et al.,* 2016). Thematic analysis was the preferred choice of analysis mainly because of its flexibility and its usefulness in understanding, "factors underpinning human attitudes and actions" (Saunders *et al.,* 2016:579). Eight common themes

emerged from the data set, they are; impact, construction robotics, observation, reading, experience, strikes, skills upgrade and efficiency.

FINDINGS

In this section, major findings from the interviews are summarised. The main research question of the study is," "what are the perceptions of construction stakeholders on the wider adoption of CAR in South Africa? Oke *et al.,* (2017) claim that CAR was introduced to achieve objectives that would otherwise be impossible without them. Technology was also introduced to improve safety and improve productivity and efficiency (Cottle, 2014). The main aim of the empirical study was to determine on which side construction stakeholders' perceptions in South Africa lay; on whether they believed that the wider adoption of CAR resulted in job losses or whether the it results in temporary job losses and the creation of better jobs in future. The study was also interested in determining where the perceptions stemmed from.

The level of impact that technology had on the participants' work environments

The first set of questions were intended to determine how the participants responded to the introduction of new technology within their work environment. Through these questions, the authors sought to determine whether the intended benefits of technology were realised and if the participants' perceptions on the wider adoption of robotics were borne from their personal interface with technology within their own work environment.

All participants expressed a positive disposition towards their work environments (refer to figure 1). None of the participants was negatively impacted by technology. Technology has improved their work by making their jobs easier, their response to technology was generally positive.

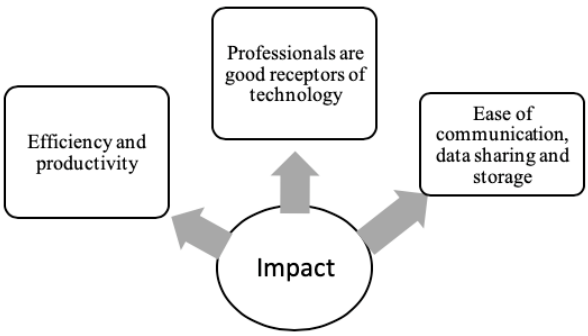

Figure 1: Participants' perceptions on technology in their own work environments

The wider adoption of CAR in South Africa

Participants were asked for their views on the wider adoption of CAR in South Africa. Questions asked sought to determine the participants' understanding of the relationship between CAR and employment. The participants are of the perception that a wider adoption of CAR will reduce employment in South Africa. Participant 3's response was that, "It will decrease the number of jobs. The disadvantages of adopting construction robotics or mining robotics is that they will take employment from people, simply. We cannot run away from the fact that machinery takes jobs from labour and worse part is when they are not assembled within the country". Participant 4's response was slightly different from the other three participants; his response was that "Introducing robotics in South Africa without raising skills level

would be catastrophic for employment. There should be a right balance to move workers to the digital economy." Thus, participant 4 acknowledged the need to train labour before wider adoption of CAR.

The source of the participants' perceptions

To establish where the participants' perceptions stemmed from, participants were asked questions relating to their personal interaction with CAR in their work experiences. All participants except for participant 3 had never had personal interaction with CAR in their work experiences. From the set of questions related to participants' perceptions, it seems like the participants' perceptions stem from television, the internet and construction related magazines.

Participant 1's perceptions seem to have largely been influenced by having watched, on television, a house being built solely by CAR;" I have seen that there is a machine that builds foam houses from excavations to the roofing." Participants 2 perceptions seem to stem largely from work experience and reading construction and related magazines. As a safety officer on construction site, participant 2, has had a real life experience of machinery replacing labour on site; "…I also have negative feelings about them because I think they behave the same way as construction machinery and even worse because they do not need operators like construction machines need. They will definitely eliminate jobs." Participants 4's perceptions were based on research, "but as a researcher I read general on technology…Robotics are topical in industry report, articles and journals."

Benefits of CAR

Participants were asked questions related to benefits associated with wider adoption of CAR in construction sites such as safety, efficiency and productivity. All participants agreed that the use of CAR on construction sites had a positive effect on safety, efficiency and productivity (see figure 2). The following are participants' 1 and 3 responses respectively, "there is no doubt that robots will improve productivity on construction sites…" and "I do not know about construction robotics, but, if the mining industry was to adopt the robotics and automate the activities, definitely productivity will improve to a greater scale compared to where it is today…"

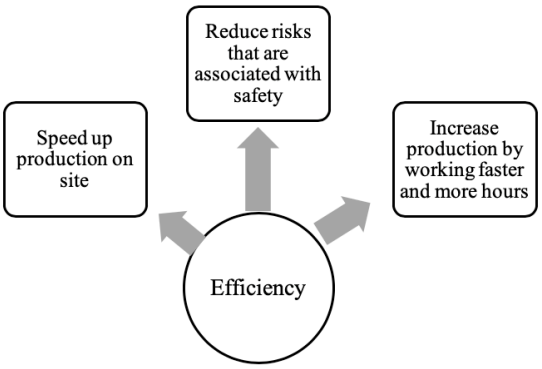

Figure 2: Participants' perceptions on the benefits of CAR

Other Possible Outcomes of Wider Adoption of CAR

Participants were asked questions related to possible outcomes of wider adoption of CAR in South Africa. One of the biggest threats expressed by participants on the

wider adoption of CAR was the fear of strikes. Participant 1's response was "…however, as mentioned before, with the current economic status of our country I don't see robots even operating on sites. Communities will revolt and ensure that no work is carried out on site." According to participant 2, "…Unions as well will suffer, leading to strikes, because if less people are employed, the unions will suffer since they will not be getting the income that they are earning when people are working." The views of participant 3 were "I think the industry may welcome it but labour will not, come on, remember I am a union representative, so I wouldn't welcome it too. There will be many strikes if they force it and yeah, those who will be affected the most will not love it." Participant 4 said that "...Such technology may fuel social tension and instability. It is therefore of critical importance that education and training keep pace with technology."

Summary of Findings

Even though all participants acknowledged that wider adoption of CAR will improve safety and productivity on site, the general perceptions of the construction stakeholders is that wider adoption of CAR will result in job losses. Only one participant, participant 4, indicated that wider adoption of CAR should be coupled with labour training. Participant 4's views stemmed mainly from credible sources such as industry articles and journals. The other participants' perceptions stemmed from media.

CONCLUSION

Literature reveals that there are many benefits to the use of CAR on construction sites, such as improved safety, better efficiency and increased productivity. One of the main disadvantages of wider adoption of CAR is job losses. There are, however, conflicting views on whether these job losses are permanent or temporary. This paper aimed at finding out what the perceptions of the South African construction stakeholders on wider adoption of CAR are, that is, whether they perceived wider adoption of CAR to cause temporary or permanent job losses.

The findings of this study reveal that the perceptions of the stakeholders are that CAR results in permanent job losses. The perceptions of the participants of this exploratory pre-study may be indicative of the general perceptions held by the majority of stakeholders whose perceptions may be based on unreliable sources such as media. If South Africa, chooses CAR to improve on safety and productivity on construction sites, educating construction stakeholders and labour may be necessary. To address the issue of job losses because of wider adoption of CAR, the industry might opt for teleoperated systems and programmable construction machines in the short and medium term as they allow for human interaction. Autonomous and semi-autonomous CAR may only be used in dangerous work environments in the short and medium term. The introduction of CAR must be coupled with the training of labour. Unless construction stakeholders including labour are educated on the advantages and disadvantages of CAR wider adoption in South Africa will continue to lag behind other developed countries.

Even though the findings of the study cannot be generalised, they can provide a basis for making propositions for future studies. This paper recommends that future studies should look at how wider adoption of CAR can create jobs in developing countries such as South Africa.

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