A Review of the Impact of Construction Automation and Robotics on Project Delivery

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Abstract. The use of construction technologies is to improve working conditions, improve health and safety, scheduling and improving quality of the construction products. Construction automation redefines construction with machines and advanced technology to mitigate the problems faced in construction, such as labour-related issues among others. To adequately understand the impact of automation and robotics in the construction industry, this study is aimed at reviewing extant literature on how automation and robotics can be put into use in the construction industry as it is being used in the manufacturing industry. The study employed a systematic literature review approach and sourced for published journal and conference articles from Web of Science and Scopus databases. The review revealed that construction automation and robotics increase accuracy of components’ dimension through the use of lasers for dimension analysis, promote design specifications through the use of computer aided designs, increase quality of construction products by ensuring standards are met, brings cost effectiveness as value for money spent is achieved, eliminate material wastage due to accurate and precise estimate of materials needed, reduce construction accidents due to the usage of machines for dangerous construction activities, improve working condition as workers’ are more secure and safety is guaranteed, and reduce labour cost given the fact that machines are deployed for construction activities.

Keywords: Automation, Construction, Industrialised Building System, Project Delivery, Robotics.

1. Introduction
Construction automation and robotics are a modern type of technology used in the construction industry. This technology involves the combination of electronics, mechanical and computer software to operate robots by using special codes to perform required functions [1]. The use of these construction technologies is to improve working conditions, improve health and safety, scheduling and improving quality of the construction products [2]. Research has shown that there is a lack of automation in the construction industry due to the cost of purchasing the necessary equipment (such as self-driving diggers, forklifts, trucks among others) hence there is a slow adaptation of this machinery...
in construction [3]. Construction automation is an integration of information technology with robots, to assist in the designing, planning and estimating the cost of the project [4]. Construction automation redefines construction with machines and advanced technology to mitigate the problems faced in construction, such as labour-related issues, among others. This is achieved by fully adopting mechanization in the construction industry by using pre-fabricated components where automation is growing very fast as compared to on-site construction [2]. Robots are electronically controlled and they use hydraulics which makes them suitable to be adopted for a large quantity of work in construction so that less work is completed by workers. This automation is adopted in pre-fabrication and road construction projects due to the higher volume of work and unsafe working condition [5,6]. The reasons for using prefabricated components is that they are done under high supervision and controlled environment to maintain temperatures that may affect the quality of the products. Final work is then carried out on-site where a minimal number of human workforce is required [7]. This is an indication that robotics are used to substitute worker mostly in dangerous work conditions [8]. To adequately understand the impact of automation and robotics in the construction industry, this study is aimed at reviewing extant literature on how automation and robotics can be put into use in the construction industry as it is being used in the manufacturing industry. The study employed a systematic literature review approach and sourced for published journal and conference articles from Web of Science and Scopus databases.

2. Impact of construction automation and robotics on project delivery

Construction automation and robotics are assisting the manufacturing industry in the production of construction components in the prefabricated construction process (such as concrete panels, steel pylons, laminated wood members, among others) at a constant speed, which makes this technology more advanced because machines are more accurate and assist in planning to avoid wastage of materials [9]. Automated machines can estimate an accurate amount of material that is required to finish the product thereby improving the working environment that has an impact on the health and safety of workers [10,11]. A specification can be produced with a computer by estimating the material type and quality during the design process [12]. This will speed up the material specification and classification process at the planning phase of the construction project. Other impacts of automation and robotics in the construction industry are discussed below.

2.1. Labour cost saving

Labour cost in countries with high wages increase faster because of the lower level of construction automation and robotics. Introduction and usage of machinery to manufacture components in construction can reduce the labour cost by 30% percent. Although, this process is going to replace demand of labour in the construction industry [13]. The use of machinery in construction is to substitute labour, by reducing the cost associated with labour such as labour wage issues, health insurance and benefits. Health insurance due to less risk of labour on sites means the level of injuries to workers is also reduced [9,12]. The use of robotics can improve the work environment hence insurance cost is reduced as the risk of a worker being exposed to accidents is lowered while productivity can be accelerated [14].

2.2. Increase productivity

Kamaruddin [15] mentioned that construction industry needs to adopt the Industrialised Building System (IBS) where components will be manufactured in a factory with a high level of construction automation and robotics. This can increase productivity since most work is carried out by machines. Research has shown that robotics and the use of construction automation increase productivity due to replacement of labour due to speed and consistency of machines [2]. More work can be completed with the use of machines in a day because human fatigues have a negative impact on production in construction. Robotics can produce and reproduce building components at a very high speed to ensure there is constant productivity which reduces loss in cost. This can be done by using automation in the factory to design, estimate and manufacture building components. Software normally use computer aided design and computer aided manufacturing to ensure high productivity of the product [16,17].
2.3. Improved design and communication between consultants
Construction cost may be affected by the design because construction starts from the design phase of the project. Designing of the construction products such as precast walls, floors, slabs among others using advanced technology may enhance the quality of the building at an effective cost. Also, applying lifecycle costing through automated value engineering in order to avoid renovation of the construction project can result in saving cost on the building project [18]. The new computer integration technology allows the design of the component to be viewed in three-dimension, carry out simulation and modelling on a computer before practical construction to avoid errors and enable verification during the design stage [18,19]. Three-dimensional view models allow the designer to detect difference between building components in a building and makes it easy to see if the design can be possible in real life construction to avoid variation orders which allows the project to be delivered to the client on time [20]. The integration of building information modelling in construction automation enables the construction professionals such as Engineers, Architect, and Construction Manager to exchange information and improve the relationship between consultants. For example, an architect can design the structure in a way that it will accommodate the civil engineers’ components [21].

2.4. Accurate estimations
Accuracy in the estimation of a project cost is a key factor in recording success on the construction project. This helps to analyse and monitor cost on the project during construction [22,23]. Project estimation requires developing budgets and summary of costs for resource planning and cost controlling. It is required for the consultants and the project manager to improve the techniques of measuring and estimating the projects to ensure having a close approximation of the cost required to carry out the project [24]. This can be done by fully making use of software used in estimating such as WinQS which is designed for making bills of quantities by automated measurement process and BIM software which turns a building model into measured quantities automatically. This will assist in simplifying the work as the traditional method of estimating and compiling bills is time-consuming and require expertise. Software allows the project manager or any stakeholder that need information about the project cost to view the amount spent on the project [25,26]. This can help to ensure that the project does not exceed scope baseline. The use of information technology in construction can be a way to mitigate problems associated with cost overrun [27,28]. Estimation of the project by the project manager may become challenging depending on the size of the project. During cost estimating, it is required to break down activities to estimate resources for each one of them [29]. Building Information modeling software technology can be deployed to improve accuracy in the construction project cost estimation and reduce the time required to do the estimates. It reduces errors that may occur when using the traditional method of estimation as the taking of can be generated automatically. If there is any variation to the design, the computer software can change the bill automatically while all documents that are linked to it is maintained [30,31]. Also, overhead costs are minimized during the estimation process since risks components allocated for the construction project to cover for errors is reduced [32,33].

2.5. Scheduling
Construction planning is the most important aspect of construction activity for construction managers and project managers. It involves estimating for the resources required to complete a project, identifying work tasks, and understanding the construction sequences activities [34]. Planning of a construction project results in better project outcome such as minimizing cost overruns and completing construction project in stipulated time [35]. Automation in construction makes planning simplified by introducing Building Information Modeling to view the project in four-dimension [35,36]. Abanda [37] opined that BIM provides the planner with scheduling picture which can show the building being built to completion in three-dimension models as shown in Figure 1. All the parties involved in the project can schedule resources accordingly as it is easier to view the sequence of activities. Time-related problems can be identified and solved during the planning stage [24,38].
2.6. Quality delivery
According to Musa [39], industrialized building system is believed to manufacture building components that results in high-quality construction products with affordable cost while speeding up the rate of construction process with minimal accidents. The industrialized building system in which components of the building structure such as wall, floor, roofs, and slabs are constructed and designed in a factory where high level of supervision is ensured to produce better quality products than using the traditional method of construction [40,41]. Musa [39] mentioned that industrialized building system is a strategy or a practice to improve the production of construction in a customized building environment through an integrated process using standardizations, mechanization and construction automation. Nawi [41] described that automation is involved in the first stage of the IBS design using construction software that has been programmed with standards of the construction industry to achieve the quality output and minimizes time for manual design and calculations.

2.7. Dimensional specification and quality controlling
Dimensional specification is the drivers of quality control. Every construction project is controlled by the size and shape of components. Hence, for good quality on construction products to be achieved, it is required to set the standard so as to minimize wastage and cost [17]. To ensure quality during construction, inspection by the professionals is required. Different types of inspection can be carried out such as lidar inspection, tube inspection, geometrical inspection, among others; however, it depends on what is to be inspected and the suitable equipment to be used to inspect. For example, to check the dimension of the component, a laser detector might be required [42]. Automation for inspection will reduce labour related errors that occur during measuring when using a measuring tape. Malik [6] submitted that the use of advanced technology such as laser scanner and total station for inspection can be more accurate to ensure quality control and quality assurance. The use of lasers is more advantageous because they require less supervision and can be linked to a computer system where information can be stored for future use. Laser scanner convert an image into three-dimension model for the professionals to track down the errors in the dimensions of prefabricated components such as precast concrete members [8,43]. During planning and design processing stage, errors are
likely to occur which leads to poor quality of construction product that is costly and can cause inaccuracy during construction. This problem is resolved during quality assurance and by doing quality control which is done manually and requires experience, evaluations, and review by ensuring quality using statistical approach or method of a survey to accept and reject the products as shown in Figure 2 [29,30]. Programs and devices are used to assist in resolving these problems that may occur due to human error, these programs usually help in sampling by verifying the work that is being performed by a human during quality control. The use of these programs has a significant impact in ensuring perfect inspection that has advantages of reducing the work of manual calculations and it is possible to have information of each product and the time inspection was conducted. This software is more accurate because they are maintained at a certain interval and may be upgraded when new ones are available [15,44,45].

Figure 2: Statistical method of quality control (Source: slidegeeks.com)

2.8. Workers’ health and safety
According to Oke [46], prefabricated construction components are usually large and too heavy to be lifted by workers during loading for transportation and assembling components to form a required structure. Handling of these components on-site often cause accidents when they are not lifted using the right equipment [47]. This problem can be dealt with by using cranes to carry heavy components and positioning the components for assembling [48,49]. Systematic planning in the industrialized building system for lifting process is taken very seriously to ensure that the final product is lifted efficiently because accidents may cause a delay in delivering the construction project [49]. Lifting of components using cranes are programmed in such a way that is prevented from falling by ensuring that the cranes are secured, checked and the cables are ascertained to be designed to carry those components [50].

2.9. Wastage control and recycling
Construction has been assumed to have a high level of wastage. Most of the construction wastage consist of reinforcement and concrete, sand and concrete [51]. This problem occurs when reinforcement is bent on site or reinforcement is not long enough to accommodate the size of the concrete due to the factory problems [52]. Precast concrete waste sometimes on site due to cutting of concrete, and there seems to be a problem with casting accurate components on sites that are caused by poor setting out of formwork causing the concrete to be cut or demolished depending on the seriousness of the damage [53]. Wastage generated in the manufacturing of prefabricated component such as walls, slabs can be recycled because these factories can be designed to adopt reuse of waste
material [54]. For example, the reinforced concrete remaining after cutting is crushed and used to produce aggregates for new concrete batching while the reinforcement steel can be reformed [53,54].

2.10. Monitoring using automation
Lee [55] stressed that computers in the manufacturing of construction component are widely used due to their benefits of monitoring manufacturing process and workers to ensure that the environment is accident-free. Pre-fabrication of components is equipped with high powered grinders and drills automated with a computer for producing high-quality components for fast production. By monitoring the system, it can result in effective reduction of cost and reducing accidents in the construction industry [56]. The industrialised building system has implemented the use of construction automation for monitoring to reduce accident on the construction sites. Cooney [57] discussed that monitoring data can be used to provide information about when the machines will need servicing or when a component needs to be changed. Early power-monitoring system gives a warning when machinery reaches their maximum determined value to avoid failure or result in an accident such as cutting grinder needs to be taken into consideration by replacing the cutting blade when they have reached their limits. This is done by a sensing technology in the grinder which detects the level of shaking [13,19].

3. Conclusion
The study was aimed at reviewing the impact of construction automation and robotics in the construction industry. The review revealed that construction automation and robotics increase accuracy of components’ dimension through the use of lasers for dimension analysis, promote design specifications through the use of computer aided designs, increase quality of construction products by ensuring standards are met, bring cost effectiveness as value for money spent is achieved, eliminate material wastage due to accurate and precise estimate of materials needed, reduce construction accidents due to the usage of machines for dangerous construction activities, improve working condition as workers’ are more secure and safety is guaranteed, and reduce labour cost given the fact that machines are deployed for construction activities. Further studies can be carried out on the different dimensions of applying automation and robotics in the construction industry.

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