**A Review of the Benefits of Automation and Robotic Application in Building Construction**

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**ABSTRACT**

Globally, building construction is complex and advanced in performance. The improvement of the economy and social benefits of building delivery depends critically on applying automation and robotic technology throughout all stages of construction. Therefore, this paper aims to identify the benefits of applying automation and robotics technologies to deliver building projects. A systematic review of the literature was utilized to identify the benefits. A total of 43 papers from conferences and journal articles from Scopus databases were utilized for the study. Findings revealed encouraging design specifications, less dependence on direct labour, increased productivity, and reduced duration of project delivery towards delivering construction projects within schedule and at a required quality standard. This study contributes to the construction automation and robotics field by providing evidence of the benefits of the application of construction automation and robotics for building delivery to stakeholders in the construction industry and policymakers.

**Keywords:** Construction industry; Buildings; Automation; Robotics; Technologies

**INTRODUCTION**

The construction industry is recognized for contributing significantly to economic sectors by employing millions of workers and contributing 13 to 15% of the global annual Gross Domestic Product (Hatoum & Nassereddine, 2020). Research in the construction industry is being conducted worldwide to improve and advance the sector from traditional construction methods to more effective modern construction technology applications (Oke et al., 2019). This new technology approach in the construction industry has proven to be effective in solving the associated problem in building construction, such as low productivity, construction waste, construction accident to workers, lack of standards quality and high cost of operation (Oke et al., 2019; Strukova & Liska, 2012; Hatoum & Nassereddine, 2020).

However, when construction is compared to other industries like manufacturing and transport, construction trails behind, especially in productivity and efficiency, some countries, like the USA, Japan, Malaysia and Hong Kong, have implemented these new technologies – such as automation, robotics and artificial intelligence, in their projects to improve their performance (Oke et al., 2019; Debrah et al., 2022). Robotics and automated technologies have the potential to revolutionize the construction sector and deliver numerous benefits to the industry (Davila Delgado et al., 2019). Furthermore, Pan *et al.* (2018) supported that construction automation and robotics are gaining increasingly recognized globally as cutting-edge technology that has the potential to revolutionize the construction industry, much like it has in other industries.

According to Rohana Mahbub (2012), automation in the construction industry is simply using automated and mechanical system equipment to carry out various self-regulating construction tasks. Meanwhile, robotics, which is defined as the science of designing, building, and applying robots, aims to improve product quality as well as the life of workers in the industry by incorporating the background knowledge and creativity of mechanical, electrical, computer, industrial, and manufacturing engineering (Hatoum & Nassereddine, 2020).

Davila Delgado et al. (2019) noted that automation and robotics were developed in the 1960s, and the technology has been used in the construction industry. Many factors still limit the implementation and application in the construction industry, which can be attributed to insufficient research findings to enlighten the construction professional on the benefits of implementing technology automation and robotics for building project delivery. Additionally, virtually little additional research has reportedly contributed to the literature on the benefits of construction automation and robotics. For instance, Oke *et al.* (2019) presented a study on the benefits of construction automation and robotics in the Gauteng province of the South African construction industry. However, the study by (Davila Delgado et al., 2019) has pointed out that there is no sufficient detailed benefit of adopting automation and robotics in the construction industry. Supported by the study of Pradhananga *et al.* (2021), who noted the necessity for the construction industry to realize the benefits of adopting automation and robotics. The review seeks to contribute to the body of knowledge on the benefits of applying automation and robotics in building construction with a systematic review of the relevant literature on the industry-specific benefits of using automation and robotics in building construction. Therefore, the study aims to identify the benefits of applying automation and robotics technologies to deliver building projects in the construction industry.

**RELATED WORK**

A review of previous relevant studies was considered while evaluating the automation and robotics benefits in the construction industry. Accordingly, the research conducted by Strukova and Liska (2012) investigated the application of automation and robotics in the Slovak construction industry on the part of contractors. They concluded that automation and robotics offer significant potential for the future, but the application of these technologies is still relatively limited. In addition, the research uncovered the following benefits that can be gained through the application of automation and robotics: cost reductions, less human labour, more productivity with less wasted time, better quality, and enhanced workplace safety. Pan *et al.* (2018) reported the economic benefits of automation and robotics in their study when examining the framework of indicators for assessing construction and robotics in the sustainability context. They revealed that economic benefit could be gained indirectly or directly from the application of construction automation and robotics, such as the replacement of human labour or collaboration, i.e., saving in labour cost, resource cost, and cost for waste management. Also, it saves time, such as rework reduction, improved building quality and incentives from the government for applying innovative technologies.

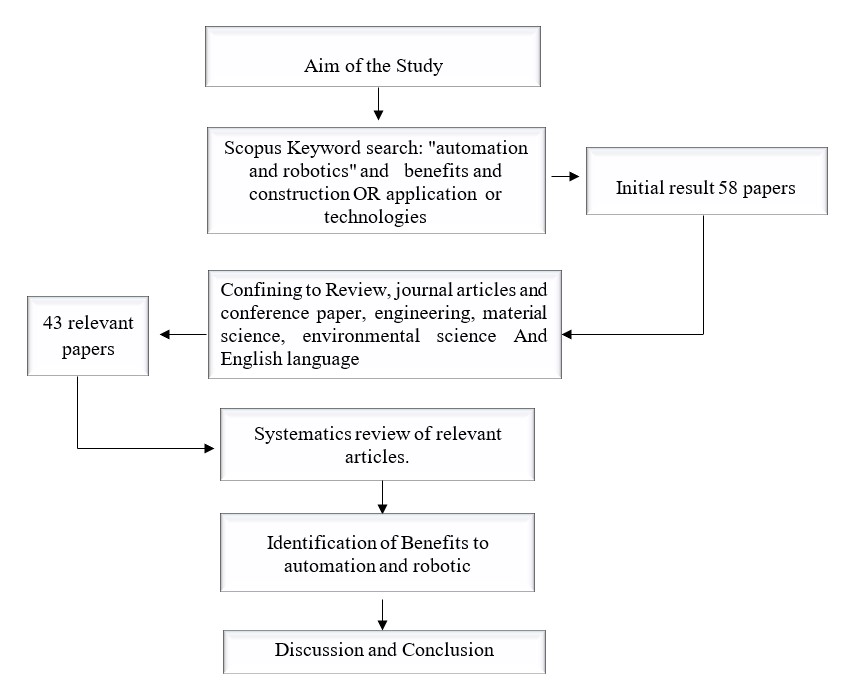
Using an experimental approach, Kontovourkis and Konatzii (2021) assessed the use of automation and robotics in determining the environmental and financial assessment of customized modular wall components based on an adaptive formwork casting. Their research showed that, compared to traditional formwork casting procedures, automation and robotics could create customized modular brick components with greater variety due to their long-term cost performance and environmental impact. By conducting a literature review, Hatoum and Nassereddine (2020) study created a suggested framework for integrating robotics into the construction industry. They outlined numerous benefits of adopting robotics and automation in the workplace, including productivity, quality, innovation, safety, and communication, which can lead to long-term benefits for the company. Kim et al. (2010) created a novel assessment process for automated construction technologies as a decision tool utilizing the benefit-cost analysis to model the economic effects of automation and robotics in the construction industry. They pointed out that the model could lead to reasonable investment for settlement of automation construction and can also minimize the trial and error that commonly occurs during the initial stage of development of new technology. Furthermore, the study revealed that the model could establish a logical structure and procedure, accumulating requisite information from important information.

Aghimien and Aigbavboa (2020) mapped out a research emphasis on robotics and automation research in construction studies using a bibliometric method. They highlighted some benefits attached to the application of robotics and automation as improvement of project delivery, 3D printing and drone to monitor the construction process for successful project delivery in the construction industry. Pradhananga *et al.* (2021) emphasized that automation and robotics in the construction industry benefit teams' efficiency, productivity, safety, and flexibility. The review by Llale, Setati and Mavunda (2020) revealed safety, increased productivity, and sustainability. In South African construction, Oke *et al.* (2019) outlined 13 benefits of automation and robotics, rating the benefits based on the mean items score and standard deviation. They concluded that the top 5 benefits of automation and robotics applications in the construction industry were improved component accuracy, the promotion of design specifications, improved product quality, and shorter project delivery times. Carra *et al.* (2018) highlighted the trend toward using robotics in construction and future opportunities to improve safety, performance, cost, and quality.

**Material and Method**

The study focuses on the application benefits of automation and robotics used in the construction industry to deliver building projects. The study identifies the benefits of automation and robotic application for building project delivery. The fundamental elements for expanding one's knowledge of a particular research field are found in an exhaustive literature review of the relevant scientific research (Ejidike & Mewomo, 2023). Therefore, exploring concepts useful for industrial and academic research becomes more straightforward. The systematic review technique was used to review the relevant literature. The systematic review technique is a methodical, protocol-driven strategy for summarizing research data relevant to a particular scientific subject (Whaley et al., 2016). The method can be performed in the following seven steps (1)Identify the research aim (2) Define the inclusion and exclusion criteria (3)Search for studies, (4)Select studies,(5)Extract data, (6)Assess quality, (7)Synthesize and present results.

With the assistance of Elsevier's Scopus search engine, the relevant literature was thoroughly searched to retrieve the articles of interest. Darko and Chan (2017) and Wasim et al. (2022) have utilized the Scopus engine similarly due to its search performance recovery precision and accuracy. The search engine used Boolean keywords like "automation and robotics", benefits and construction OR application or technologies". The Scopus search finds 58 publications in total (26 October 2022). After confining the initial search results to English language, engineering, material science, and environmental science fields, the paper types were conference papers, reviews, and journal articles. Forty-three papers were finally selected for the review study. The overview of the research procedure is shown in Figure 1.



**Figure 1. The overview of the research procedure.**

**Identification and discussion of the automation and robotics benefits**

Löfgren (2006) studied the application benefits of Information communication technology (ICT) in building construction site management, focusing on mobile computing for construction site operation. The study evaluated the benefits of applying mobile computing in construction operations from three general perspectives of financial investment: efficiency, performance and effectiveness. Picking its origin from the study of (Andresen et al., 2000), who also evaluated the benefit of construction information technology. Therefore, based on this perspective, the benefits are identified in efficiency, performance and effectiveness. The capacity of technology to enhance the company's current internal procedures can result in operational excellence, reduce the time and cost necessary to complete construction industry activities, and increase efficiency. Regarding performance benefits, technological innovation and improved learning would allow the construction industry to grow and adapt to future developments (Kanyilmaz et al., 2022). Effectiveness can result from leveraging technology to improve value for the end user and increase the financial value of management and business operations.

**Table 1.** Identified the benefits of automation and robotics

| **Code** | **Benefits** | **EF** | **PF** | **EFF** | **Source** |
| --- | --- | --- | --- | --- | --- |
| BAR01 | Cost-effectiveness | √ | √ | √ | [1]–[5] |
| BAR02 | Higher productivity | √ | √ | √ | [2]–[8] |
| BARO3 | Safety improvement | √ | √ |  | [2]–[8] |
| BARO4 | Time-saving | √ | √ |  | [2],[3],[5], [7], [8] |
| BARO5 | Improvement in measurements and estimations | √ | √ | √ | [8]–[11] |
| BARO6 | Waste management | √ |  | √ | [2], [3], [12], [13] |
| BARO7 | Promotion of design specifications | √ | √ |  | [2], [8], [14] |
| BARO8 | Increased accuracy of components | √ |  | √ | [2], [3], [5], [14] |
| BARO9 | Standard achieved | √ | √ | √ | [2], [7] |
| BAR10 | Reduction in Material wastage | √ |  | √ | [2],[5], [6] |
| BAR11 | Reduces labour cost | √ |  | √ | [2]–[4], [8], [14] |
| BAR12 | increasing competitiveness |  | √ |  | [4], [6],[7] |
| BAR13 | Creating new job opportunities for skilled workers |  |  | √ | [3], [6], [13], [15]–[17] |
| BAR14 | Greater Occupant Comfort |  |  | √ | [18]–[21] |
| BAR15 | Higher Energy Efficiency | √ | √ |  | [15], [18], [22] |
| BAR16 | Better Indoor Air Quality | √ |  |  | [18], [23], [24] |
| BAR17 | Client Satisfaction |  |  | √ | [7][25]–[27] |
| BAR18 | Reduction of labour  workforce |  | √ |  | [7], [8] |
| BAR19 | Efficiency in pre-fabrication of materials | √ | √ |  | [8], [28]–[30] |
| BAR20 | Improvement in site monitoring | √ | √ |  | [8], [9], [31], |

**Note\*:** EF: Efficiency PF: Performance EFF: Effectiveness [1] Strukova and Liska (2012), [2] Oke, Akinradewo, Aigbavboa, and Akinradewo,(2019), [3] Kumar *et al* (2020), [4] Son, et al (2010), [5] Javed, M. Mantawy, and Azizinamini (2021), [6] Carra, et al (2018), [7] Najib et al.(2019), [8] Boya, Akinradewo, and Aigbavboa, (2022), [9] Kim, Chen, and Cho (2018), [10] Abeywardena, *et al* (2013),[11] Cheng, *et al*  (2011), [12] Pradhananga, *et al*  (2021), [13] Pan, *et al*  (2018), [14] Gharbia *et al* (2020), [15] Melenbrink, Werfel, and Menges, ( 2020), [16] Bogue, (2017), [17] García de Soto *et al* (2022), [18] Shehu and Abba, (2019), [19] Chae, *et al*, (2020), [20] Mantha *et al* (2015), [21] Noye, North, and Fisk (2018), [22] Davila Delgado et al.,(2019), [23] Musa *et al* (2014), [24] Vähä *et al* (2013), [25] Santos, Pereira, and Vasconcelos (2019), [26] Kumar and Balaramachandran (2018), [27] Weintrop et al., (2018), [28] Wagner *et al* (2020), [29] Davtalab, Kazemian, and Khoshnevis, (2018), [30] Helm, *et al* (2012), [31] Saidi, Bock, and Georgoulas (2016)\*

**Discussion**

Based on the findings of the systematic review of the benefits of automation and robotics applications for building constriction – increased productivity, safety improvement, cost-effectiveness, time-saving, the accuracy of components, waste management, and reduced labour cost, were identified as the top benefits of applying automation and robotics in building construction as these benefit factors had a high-frequency count or mentioned in the research corpus. The increase in productivity is predominately noted, as these can result from the assistance the robotics give to the labourers by lessening the workload, thereby increasing productivity and saving time. Construction benefits from safety improvement through automation and robotics, which has decreased the frequency of on-site accidents. Safety improvement is one of the industry's major concerns because it deals with human life.

**CONCLUSIONS**

The study focused on the benefits of applying automation and robotics in building construction for project delivery. The Scopus search engine was utilized to acquire relevant academic articles and conference papers for this study. Therefore, the study identified that building construction could benefit from applying automation and robotics in the execution of building projects. Technologies are typically more effective than labourers because they can complete more work without growing "tired" and function well in dangerous situations. By increasing productivity and efficiency, construction projects can avoid delays and achieve specific objectives at every stage. Therefore, for construction professionals to benefit from using construction automation and robots, this study recommends that professionals be prepared to accept technological innovation for project delivery and develop valuable skills to fit into the practice. This study has significantly contributed to the field of building construction by uncovering the associated benefits of applying robotics and automation for project delivery. Likewise, it has also demonstrated the importance of technologies in building construction.

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