Role of Robotics and Automation in Construction Sector

Rakesh Kumar
Department of Mechanical Engineering, Elitte College of Engineering, Kolkata, India
Email:
rakeshraj2009@gmail.com

Abstract Construction is one of the major industries in the world. The construction industry is labor-intensive and performed in hazardous situations. Hence, the importance of Construction robots has developed rapidly. The research discovers the latest advances in robotics and sensor-based technologies that are leading developments in the construction sector to attain improvements in construction quality, efficiency, and safety. Although automation in construction was first introduced in the year 1980. It has seen little advancement in the level of application. The present study attempts to identify the recent developments in automated robotic systems and their scope in the construction sectors, namely with respect to construction robots. The application of robotic technologies in the construction industry has been known as one of the most challenging tasks. Automation in the construction industry can help to ensure production without compromising the quality of the construction products. This may be due to the fact that workers can become tired over time

Keywords Robot; Automation; Construction; Technology; Building

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Introduction

One of the most unexplored research and development fields in the robotics and automation sector is the construction industry. It is one of the oldest and major industries. The economy of developed and developing countries are substantially influenced by the construction sectors. Up to 10% of the Gross domestic product (GDP) in developed nations and more than 25% in underdeveloped nations is contributed by the construction industry (Kim *et al.,* 2015). Construction work is labor intensive and is performed in perilous circumstances, also materials and the work content alter as often as possible. In

recent years, innovation in robotics and automation technology has been developed progressively and applied to various industries directly or indirectly. The robot market is considered to be extensively large. However, the application of robotics and automation in the construction sector is much lower than in other industries such as manufacturing industries. This leads to both poor productivity and hazardous operating conditions. The application of Automation and robotics are the possibilities to resolve such problems in the construction industry (Bademosi *et al.,* 2019). Due to the rapid development of computer hardware and software in the past few decades, major enhancements may be found in robotic control, sensing, vision, localization, mapping, and planning modules (Kim *et al.,* 2015). In this regard, a variety of robot technologies have been developed and have been applied in actual construction sites. However, a great number of research topics still exist in the application of robotics technologies in the construction industry. At the end of the 20th century, it was considered to be lagging behind the significance of automation and robotics technology development in the construction industry as compared to that of other industries. The main difficulty of robotics and automation in construction is related to on-site outdoor environment situations that are very unstructured. The manipulation of heavy sections, big tolerances, low level of standardization, medium level of industrialization and pre-fabrication, and involvement of numerous non-coordinated people (architects, builders, suppliers, etc.), etc. are other significant features of this sector (Bademosi *et al.,* 2019).

The research and development in automation and robotics in the field of construction have been divided into two categories i.e, hard robotics, and soft robotics. Japanese companies and universities pioneered Research and development activities in the field of robotics and automation in construction in the 90s, focusing on the development of a teleoperated robotic system in existing machinery automation. This era of robotics and automation in construction research is known as hard robotics. These were used for interior building finishing, bricklayer masonry, modular industrialized building construction, road paver's sensor-based guidance, excavator's control, infrastructure inspection, tunnel, and bridge construction, etc.

After Japan's economic crisis, new research trends have been launched in the field of robotics and automation in construction. The research and development activities are focused on soft robotics. It defines not only software but also hardware, but not in the machinery sense. It includes on-site sensory data acquisition and processing, human operator field safety and security, chip-based process control, etc. (Balaguer 2004).

In the present study, an attempt has been taken to identify the benefits and recent developments in robotics and automation in the construction sector. In collective terms Construction involves the identification of requirements, project planning, design and engineering, construction, operation and maintenance, and decommissioning. The study explores technological interventions in the construction part of the all-inclusive classification.

Advances in Robotics and Automation in Construction

Robotics is a major part of automated construction. Robotics may be defined as the "science of designing, building, and applying robots" which aims to improve product quality and the life of workers in the industry through incorporating the "background knowledge, and mechanical creativeness, electrical, computer, industrial, and manufacturing engineering" (Jackson 1990). Autonomous machine used in automation in construction is the most common example. These are basically self-driving machines that can be used to transport materials across the work site and to haul heavy objects without posing a risk to employees.

Machine equipped with Robotic technology that allows forklifts, trucks, diggers, etc. operate without a driver. Many researchers stated that construction robots as intelligent machines operated by smart controls with varying sophistication levels and utilized by the industry to enhance speed and construction

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process precision (Buswell *et al.,* 2007).

Previous research activities have been shown to identify the benefits of implementing robotics, categorize the associated challenges and barriers, and develop solutions to overcome these problems. Aghimien *et al.,* conducted an extensive literature review on the implementation of robotics in construction (Aghimien *et al.,* 2019).

Seo *et al.* (2011) developed a robotic excavator to enhance quality productivity and safety; robots control and information system which is mostly related to research that focuses on the control systems and programming of robots to perform work independently and autonomously, in addition to integrating Building Information Modeling (BIM) and 3D manufacturing with robots (Seo *et al.,* 2011).

The application for automation in concrete floor finishing is shown in Figure 14.1. This robot was developed by the Japanese construction Kajima Corp in collaboration with four Singaporean institutions. The concrete floor finishing robot can reduce construction manpower and labor cost by 30% while enhancing construction quality and safety.

Further, Artificial intelligence is the latest technology and advancement in the field of the construction industry. Implementing this technology enables high accuracy and quicker construction, saving time, money, and other resources.

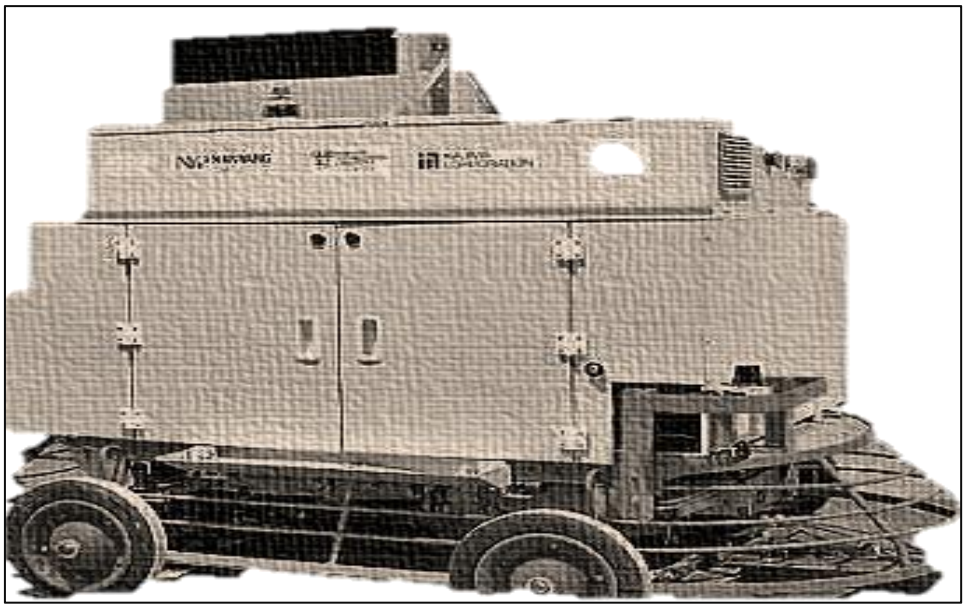

Figure 14.1. Concrete Floor Finishing Robot
(modified after https://www.constructionkenya.com/10841/concrete-finishing-robot)

Benefits of Robotics in Construction Sector

The requirement for robotics in the construction industry is vital for various reasons as it would yield different tangible and intangible benefits. Carra *et al.,* have discussed the reasons to use robotics in construction including the scarcity of building material resources (increase in cost while availability decreases), urbanization (construction within densely populated areas), aging workforce (increase in fatigue and injuries while trades suffer from a shortage of labor), enhanced connectivity and convergence (especially with workers becoming more familiar with technology and connectivity), environmental reasons (robots can be environmentally friendly and use green energy instead of electric power-strain

systems), and safety purposes (reduce the number of accidents on construction sites) (Carra *et al.,* 2018). Therefore, various studies tended to research the benefits of using robotics in the construction industry. Banik and Barnes (2002) saw automating the construction industry as a solution for the shortage of skilled labor. Elattar (2008) considered implementing robotics as a solution to deal with the increase in construction demand due to the heavy migration into cities worldwide.

Löfgren has suggested the implementation of robotics as a financial investment with tangible benefits in the perspectives of efficiency, effectiveness, and performance (Löfgren 2006). Martinez *et al.,* have proposed that implementing robotics can increase productivity, increase cost savings, and enhance safety. Robots have the ability to increase production speed, eliminate human limitations, and reduce variability in operations, all of which reflect on the quality of the end product. Robotic operations can also help engineers better control the project, which can lead to faster problem findings and an increase in quality (Martinez 2008).

In addition, robots reduce the reliance on human labor and increase cost savings as they have the potential to reduce difficulties related to quality and rework. The decrease in dependency on humans can lead to a decrease in the number of human resources needed, which usually contribute to 30-50% of a total construction project cost. This saves cost and improves time performance and better end quality (Balaguer 2000; Dabirian *et al.,* 2016; Bakir and Balchi 2018). Also, Martinez *et al.,* have advised that safety can be improved, especially with the robot's ability to work in dangerous and hazardous regions (Martinez 2008). This strengthens previous studies that indicated that robots could decrease human needs in high-risk activities and the incidence of trauma disorders in activities that need repetitive motion (Tucker 1988; Demsetz 1990).

In automated construction, lasers are used for dimension analysis, computer-aided designs are used to promote design specifications, construction products are improved by ensuring required standards, and cost-effectiveness is achieved by maximizing the value for money. Material wastage can be eliminated due to accurate and precise estimates of material requirements. Construction accidents can be reduced due to the use of the machine during hazardous construction activities, working conditions can be improved as workers are more secure and safety is guaranteed and labor costs can be reduced due to the deployment of machinery.

Barriers to Robotics in Construction

Due to high capital costs, there is a shortage of investment in heavy machinery and mechanized construction systems, which could impede the process of industrialization (Rahman and Omar 2006). Stewart *et al.,* 2004 documented the challenges of implementing information technology (IT) for robotics (Stewart 2004). The significance of these challenges depends on the fact that automating construction, especially by using robotics, will be heavily dependent on the use and expansion of IT across the construction sector. The researchers studied the challenges in a top-down effect that starts from the industry, then the organization, and down to the project. At an industry level, challenges comprised client leadership deficiency, poor operability between applications and organizations, the disintegration of the industry, and the little unveiling of IT. The challenges at the level of the organization comprised of limited resources mainly for medium and small enterprises, traditional business practices and resistance to change, and redundancy for IT investments. Fear of change, low technology, project time tightness, and security concerns were some challenges enumerated by the study at the project level.

Mahbub 2008, categorized the challenges into five classes:

(i) Economic and cost comprise the high cost of investment and implementation, high-risk investments, and high costs of holding and consuming.

(ii) The structure and organization of the industry barriers include the need for compatibility between robotics and existing design, management capabilities, labor practices, and site operations.

(iii) Construction product and work processes challenges comprise the complexity and standardization of construction products, and local conditions like weather, labor supply, and building codes.

(iv) Technology barriers include the nature of construction projects and layout, causing robots to be robust and flexible with high mobility and versatility.

(v) Cultural and Human Factor barriers call for a requirement of new people with experience in handling robots.

Robots may also be a threat to workers because it is a one-time investment that pays itself and doesn't need workers, wages, or healthcare. The author identified that the problems associated with the construction industry such as decreasing quality and productivity, labor shortages, occupational safety, and inferior working situation have highlighted the need for an innovative solution within the industry, including the push for further use of industrialization and construction automation and robotics application on-site (Mahbub 2012). The study also revealed the harsh working environment of the construction site and the risk of a cyber breach and the low awareness level of technology. Other social issues also affect the implementation of robotics (Burke, 2015; IRRSS 2015; Ruggiero *et al.,* 2016). Struková and Líška (2012) conducted a survey to rank problems against robotics. Contractors reflected "high acquiring, maintenance and updating costs" as the biggest challenges, followed by local unavailability and difficulty to acquire, incompatibility with current practices and construction operations, not considered effective in construction sites, low workforce awareness, difficulty in handling robots, and finally rejection from workers and/or management. However, Benefits such as productivity, quality, communication, innovation, and safety can result in rewarding long-term benefits at the organizational level.

Mahbub has studied "Framework on the Barriers to the Implementation of Automation and Robotics in the Construction industry" (Mahbub 2015). By examining and constructing the barrier variables, the liaison between features of the construction industry and the qualities of existing technologies and basing the schemes on data from three nations Japan, Australia, and Malaysia. The research's goal was to identify and elucidate the barriers to the application of construction automation and robots. The results and conclusions of the research, including the ranking schemes developed for the four primary categories of construction attributes on the degree of usage, barrier variables, different levels of usage between nations, and future trends, have identified a number of possible areas for further research that may have an impact on the level of implementation both globally and for specific countries.

Effects of Robotics and Automation on Construction

Unemployment and increased total cost are the main two impacts of the implementation of robotics and automation in construction. It was seen that the greatly applied automated method in the construction industry has annoyed a significant number of workers from this industry.

Kaplinski *et al.,* suggested that robotics and automation considerably rise work efficiency, with upgrading in working situations and safety of the workforce and enhancement in the quality of work done (Struková and Líška 2012). The other impacts of automation and robotics in the construction industry are:
Reduced Labour cost: The usage of robotics in the construction industry is the replacement of labor. This drops the cost associated with labor such as labor wages, health insurance, and benefits. This ultimately reduces the risk of labor accidents and hence improves work conditions and lowers the insurance cost while accelerating productivity (Kapliński *et al.,* 2013).

Increased Productivity: The use of robotics in construction has increased productivity due to the replacement of labor. Robots can do more work in a day as compared to a human. However, Human fatigue plays a negative role in productivity in construction.

Robotics can produce and reproduce building components very rapidly and maintain constant productivity which reduces loss. High productivity of the product can be analyzed by software such as

computer-aided design and computer-aided manufacturing (Xia *et al.,* 2019; Yang *et al.,* 2019; Manley 2018).

Robotics have high accuracy as compared to a human. The amalgamation of robotics technology excludes the possibility of human errors, delivering highly precise results.

Recommendations for Robotics

There is a need to overcome the various barriers that are described by researchers for the successful implementation of robotics and automation in the civil infrastructure sector. These challenges mostly centered around the short-term investment of commissioning robotics, confrontation for conversion from organizations, and the nature of the civil infrastructure projects. The study documented that automation helps in reduced labor charges, increased productivity, reduced accidents, cost-effectiveness, material saving, improved working situations, and increased accuracy (Bohner *et al.,* 2019).

The author suggested the crucial recommendation for three different aspects: Organisation which encompasses management and processes, People which incorporates engineers, working labor, administrative staff on and off construction sites, and technology.

The researchers recommended that the genetic algorithm is the most dominant approach in tackling the scheduling challenge and the applicability of the genetic algorithm to various aspects of managing a project schedule, cost, and quality (Oke *et al.,* 2019).

Figure 14.2 depicts an overview of the conceptual framework for automation and robotics implementation in the construction industry as proposed by (Mahbub 2015). In terms of laying the foundation for research on the widespread use of construction automation and robotics technologies, the contributions made through the ranking of the important categories defined within the four areas were realized.

Since the schemes may be used to establish whether a country is more likely to utilize the technologies based on the characteristics of the construction sector, they can be used to determine the potential of any country in terms of adopting the technologies.

The implementation hurdles for a nation that is deemed to be likely to adopt the technology but has not yet done so might be investigated. Some experts think that some countries don't get the most effective solutions to their problems with labor or construction by using new, innovative technologies.

This is especially true if the costs of these technologies are high. If there is a place where using technology can give you an edge, then future trends can help predict what might happen in that area.

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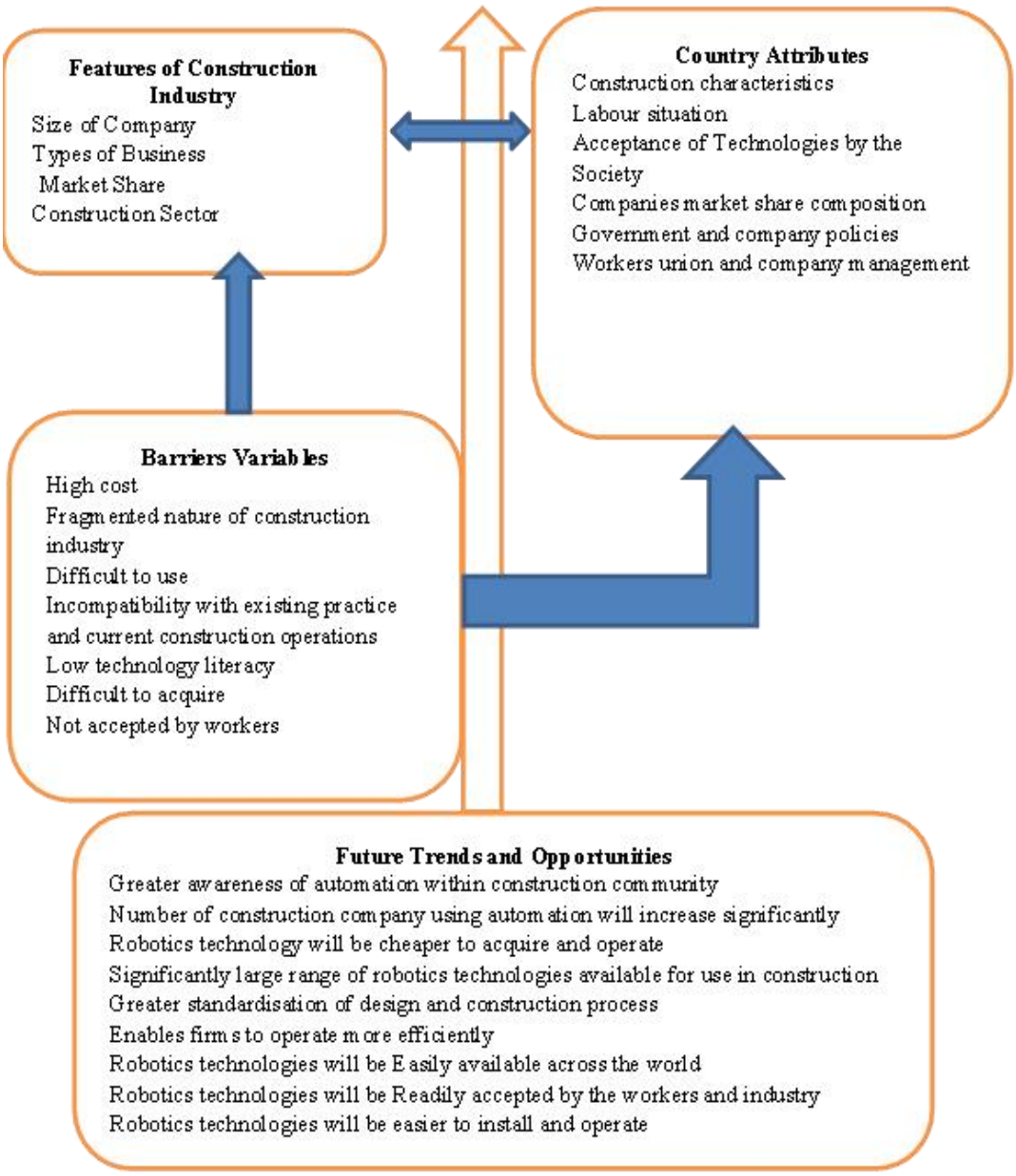

Figure 14.2. Conceptual framework on automation and robotics implementation in the construction sector

Conclusions

In this study, attention is given to the application of robotics and automation in the construction sector. The implementation and incorporation of automation and robotics, and therefore the extensive use may be the best opportunities for the construction industry to bloom in the coming future. The major impact of using robotics and automation in the construction industry will have improved project performance, improved work quality, time-saving, improved working situations, improved safety, and high productivity. This paper reviewed various investigations done on barriers and challenges and the benefits of robotics and automation in the construction sector. The associated challenges with the construction sector, such as declining quality and productivity, labor scarcities, industrial safety, and inferior working situation, have

highlighted the requirement for innovative resolutions that impulse further usage of automation and robotics in construction on site. In spite of the various challenges, research is being conducted on various applications in construction and tasks in an effort to gradually move from traditional industry practices into the new era of automation. However, automation or automated machines may be a substitute for workers, thus reducing fatality. Also, the generated dust from the construction sector frequently leads to deadly diseases like tuberculosis and other respiratory complications thus hampering work. Construction stakeholders should be prepared to take financial threats in implementing the usage of construction automation and robotics for the gains. Further, studies can be carried out on the various scope of applying automation and robotics in the civil infrastructure sector.

Conflict of Interest Statement

The author declares that there is no conflict of interest.

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