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Feasibility analysis of automation for commercial construction project

Niranjana J Vasava [1,*] and Bankim R Joshi [2]

[1] *Scholar, CEM, SNPIT and RC, Umrakh, Bardoli, India*
[2] *Assistant professor, SNPIT and RC, Umrakh, Bardoli India.*

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Abstract

The use of automation technology in the construction sector may cover a wide variety of operations, from the early design stage through on-site building construction, building maintenance, building control, and finally building disassembly or demolition. The extent of automation adoption varies greatly from one construction phase to the next. These days, as opposed to using automation for on-site operations, the use of automation in the construction sector has several important advantages, including increased worker safety at work, improved quality and cost-effectiveness above that of trained labor, and increased productivity and job efficiency. Research gaps need to be filled to address automated manufacturing process innovation. This study has been carried out most promising areas where automation is required with the help of scientific analysis through a questionnaire survey. This study identifies critical areas for improvement in automation in the work process in commercial construction projects. The respondents comprised site engineers, project managers, and supervisors of construction firms. The relative importance index is used in this study. Using the results of this study, categorized the primary variables for improvement like workers' safety alert procedures, reducing labor cost and construction delay, core test team under multiple projects, impropriate construction method, and better quality of life of the structure.

Keywords: Automation; Construction industry; Safety; Construction delay; Construction method

1. Introduction

Nowadays, buildings can control several building systems with the help of advanced building automation systems. Many buildings are still not successfully commissioned, run, or maintained even if the capabilities of building automation systems appear to have developed. Building operators' failure to understand and engage with sophisticated controls and improper maintenance are the major causes of inefficient operations and shorter equipment lifespan. Equipment that fails more frequently and lasts for shorter periods decreases availability and increases pain for occupants. There are still significant research gaps that need to be filled in connection to the issue of operational site control, because the automation of processes, especially difficult ones, is growing. The current study, which is a part of this line of research, is to answer the current demand for automated and sustainable manufacturing process innovation. Automation technologies may be used in a variety of construction-related tasks, from the early stages of building design through on-site construction, building maintenance, and building control, to final building disassembly or demolition. The amount of automation implemented varies greatly from one building phase to another. Effective maintenance and re-commissioning, on the other hand, increase equipment life and improve equipment availability. Implementing better maintenance, however, might be expensive. Because cranes can move items more rapidly and safely than people can, decreasing the chance of accidents, automation is needed to lift bulky objects. Designed to improve equipment quality and user-friendliness to lower the number of accidents in the construction sector. Construction automation may improve quality since equipment is more exact than people and advanced technology can be used in factories to automate the equipment so it can refuse things that don't match the needed criteria.

* Corresponding author: Niranjana J Vasava; Email: niranjanavsv93@gmail.com

Automation is the use of mechanical and electrical methods in construction to reduce exposure, time, and effort, and to increase quality. Robots are often used to assist human employees. The main objectives of this research identify the most critical areas where automation is required using the RII method, to check the feasibility of automation in commercial construction projects to improve work efficiency and reduce hardbound processes. Here need for study is to automate and free the team from manual, time-consuming, repetitive, and regulatory labor so that you may focus on more important tasks. Repeatability is also increased by automation, The ability of automated robots to operate overnight implies that additional work may be done without the requirement for human supervision and a project management tool provides users to track the progress of each job as well as send automatic task and scheduling reminders. More understanding of tasks, reducing the need for meetings and talks, and even on-site workers can be informed about future activities, this research work identifies factors for automation for commercial construction projects. Since the 1980s, several initiatives have been conducted in the area of automation based on research into the use of machines to construct buildings. In recent years, there has been considerable growth in the number of automation projects in the design and construction fields, involving both prefabrication and on-site building. In terms of on-site building projects, three types of machines may be identified: large-scale 3d printing, mobile robots, and flying robots. Building construction has the potential to operate more sustainably in terms of waste if automation and robots are implemented reduction, improving the quality of workplace safety, resource efficiency, and conservation, and a smart living environment (Skibniewski & Hendrickson, 1990) Productivity, health, and safety concerns, congestion on the work site, and trade relationships are typical for mechanical and electrical installation operations. These factors cause disputes and delays in project completion (Samarasinghe et al., 2019) Much research, especially those related to creative structural design for high-rise concrete modular integrated construction structures, has lately been conducted to solve these multifaceted issues (Wang et al., 2020). Single-application robot prototypes have been created by a few specialized construction contracting companies (such as bridge painting robots, concrete blasting robots, and rebar installation robots). Road maintenance robots, robots that weld steel skeletons, and robots that apply fireproof coatings. Additionally, as nighttime construction always results in dangerous working circumstances, knowledge of nighttime construction safety has been a key concern in the business (Yang et al., 2015).However, manual methods of obtaining cost data from building requirements are labor-intensive, subject to human error, and call for in-depth construction knowledge and expertise. Construction cost estimating has been the subject of many studies to enhance and automate the labor-intensive, error-prone, and manual procedures involved (Gan et al., 2019). In addition to information about loadings, support, and geometric conditions at the individual member level, these building data typically include the member-member intersection details of all beam-column joints of an RC frame structure. These details can be used for automated clash-free steel reinforcement design (Adeyemi et al., 2015) Additionally, building information modeling programs may be used with structural analysis software to increase design automation images, time-lapse films, and recordings taken every day from construction sites including a wealth of information necessary for efficient project monitoring and management. Consequently, suggesting a solution to lessen work disability among construction workers might ease significant social and financial burdens on employees, employers, industry, and even society (Staub-French et al., 2003) regarding the compatibility of communication protocols for smart homes several writes to point out that fog and edge computing can increase energy savings for Internet of thing based smart building by reducing the amount of data transmission between devices (El Kafhali & Salah, 2017) It is a complex undertaking to estimate the economic worth of automation for the precast concrete industry. Planning, component storage, lifting, and transportation optimization models, along with timely project revisions, may boost profits by approximately 40% and performance by over 95% (Liu et al., 2020).The benefit of being able to construct greater constructions than themselves belongs to mobile robots. However, because they need room to maneuver around the structure, their progress is slowed—especially when the structure is high (Dörfler et al., 2016). Through image processing techniques, smart eyewear with cameras can help monitor employees' weariness or risky behaviors(Chang et al., 2018). have demonstrated that these systems can actively identify the presence of employees, guarantee that analyzed data may be utilized to predict scenarios when people and construction equipment are in close contact, and provide operators pre-collision warnings. The failure to wear safety equipment, such as helmets and harnesses, may be detected using information about a worker's presence(Wu et al., 2019).Building projects present a difficult dissemination scenario for networked technologies like Building information modeling and exhibit high overall opposition to new technology.(Peansupap et al., 2021.) Organizations are increasingly collecting data from many sources, analyzing it, and using the results to develop plans and improve corporate performance. Several elements of the construction industry are covered by its broad range of applications, including supply chain, design, planning, monitoring, control, and energy management. The incorporation of Big data predictive analysis methods, tools, and procedures within to fully grasp the potential of Big data predictive analysis, existing organizational culture, systems, and procedures are essential (Bilal et al., 2016). Additionally, the designed optimization algorithm occasionally provided impractical solutions that did not adhere to the limits of the design code. A worker who has an injury on the job and loses all or part of their earning capability is said to have lifelong damage or incapacity for employment. Although the application of the evolutionary Genetic algorithm has been investigated in the literature, the detection and resolution of collisions of steel

reinforcements at the beam-column junction were not adequately addressed by the prior Genetic algorithm optimization(Kim et al., 2015)

Vision-based tracking techniques can be used to generate the trajectories of workers and machines on the building site to promote safety(EUROPEAN COMMISSION "State of Infrastructure Maintenance," 2021.)A real-time vision-based warning system was proposed to avoid collisions between heavy machinery and workers by tracking the two different categories of objects. (Son et al., 2019)To maintain highly accurate actions and lower hazardous risks with achieving greater control and safety, robots are growing more and more involved in construction operations.(Innella et al., 2019) possible is to expand automated construction to cover the design, engineering, and maintenance of current and future structures(Mistri & Rathod, 2020)

1.1. Data collection and analysis

Table 1 Sub-structure improvement factors

Sub-structure improvement factors
Implement problem-solving at the construction site and Communicate
Poor monitoring and control
Rework due to errors during Construction
Application of labor of jobs
Update of time and resource plans
Training needs for operators
Visualize drawings and 3D models on site
Precision in data classification
Demolition and site clearance
Costing and budgeting process
Follow up on the presence of staff and use of protective equipment
Economic benefit
Control and information system
Technical training, awareness, and education
Create and report on the environmental impact of the construction project
Follow up and improve energy consumption during the project
Reducing labor costs and construction delay
Workers' safety alert procedures
Business development
Impropriate construction method
Create, assign, and prioritize tasks
Quality Control of resource
Time efficiency & cost efficiency
Review and approval process
Better quality of life of a structure
Costly for the short-term production
Less dependency on direct labor
Quality increase
More efficient equipment operations

Data was collected using questionnaire surveys of different executives who are working in the field of construction industries in the same region. The questionnaire was created from the pilot study for automation in the construction industry. Experts assessed the questionnaire for clarity and usability. Use and worth of the information that could be obtained. For measuring the process a scale is 1 to 9 is used to rank each factor. A total of 135 questionnaires, in the Construction field, are given to stack holders of the construction industry. The chosen sample size is for the whole construction industry, specialist stakeholders, project managers, site engineers, supervisors, laborers, architects, etc. As per expert advice, there are the improvement factors are divided into two parts one is sub-structure improvement factors and the second is superstructure improvement factors.

Table 2 Superstructure improvement factors

Superstructure improvement factors
Track and update project progress
Update project Drawings
Core test team under multiple projects
Modular construction
The difficulty in attracting and retaining new workers
Construction waste management
Erection techniques of steel structures
Sustainability concerns
Lack of experience /incompetence of contractor's key staff
Track on-site productivity at a trade and worker level
Just-in-time delivery of structure members
Monitoring and controlling resource use
Material procurement procedures
Equipment management and handling
Integrating 3D visualization and simulation for tower crane operations on construction sites
Material handling system
Sending task reminders and notification
Reduced factory lead time
Worker displacement
Easy to change tasks
Instant reporting and testing
Increasing scarcity of skills
Improve the accuracy of the result
Greater control over the final result of the process

Table 1 and Table 2 describe contains basic information about the analysis of automation for commercial construction projects. The use of a quantitative questionnaire allowed for the collection of a significant number of responses from the construction industry. The purpose of the widely distributed questionnaire was to identify the present project factors affecting the feasibility analysis of automation for commercial construction projects.

Table 3 Percentage of valid respondent

Sr. No	Respondent	Questionnaire Distributed	Questionnaire Received	% of response
1	Site engineer	85	66	69%
2	Project manager	15	7	46%
3	Owner	10	6	60%
4	Other	15	10	66%

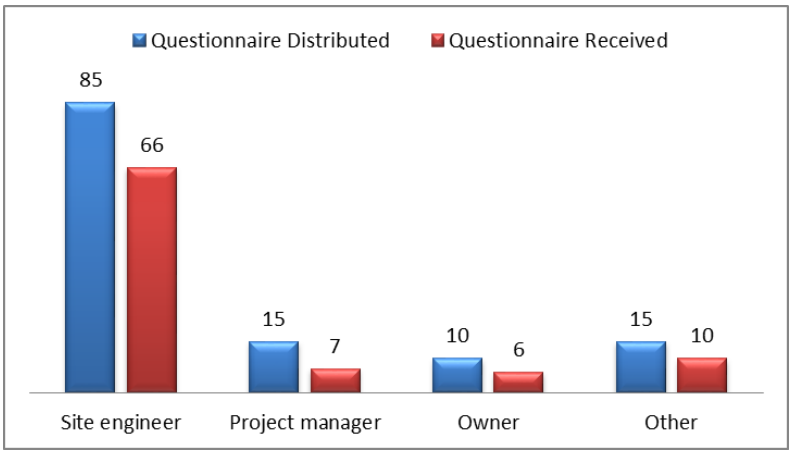

Figure 1 Percentage of valid response

1.2. Study area

We conducted a case study of a commercial construction project in Dang and Bardoli, south Gujarat. The case analysis presents the influence of Workers' safety alert procedures, reducing labor costs and construction delay, Core test teams under multiple projects, and better quality of life of the structure.

Automation improves quality in several ways: eliminating human error, improving consistency and accuracy, giving the ability to create more complex goods, and identifying errors along the way. Automation experts can help companies perform detailed risk analyses for lifting and help specify safety zones on their production floors where lifting operations are a concern. In the field service industry, wearables present an opportunity to reduce the risk of injuries, improve safety, and generally enhance the quality of life for technicians and other workers.

Table 4 Detail description of Site 1

Sr.no	Detail	Description
1	Project Name	Up-Gradation of Mahal EMRS school complex with enabling infrastructure
2	Project location	Mahal (Dang)
3	Type of project	Commercial Construction
4	Duration of project	2022-2023

Figure 2 indicates that due to obstacles faced by construction employees on the job, product development has been slow. For instance, errors in building design might cause the construction process to be severely delayed. Additionally, it might cause delays throughout the project to anticipate the length of various processes like concrete curing. To address this productivity gap, the construction sector has to think about digital transformation. Robot process automation is thought to improve productivity, save time, provide a better work-life balance, and free up employees to concentrate on more important duties.

Table 5 Detail description of Site 2

Sr.no	Detail	Description
1	Project Name	Prestige North
2	Project location	Bardoli
3	Type of project	Commercial Construction
4	Duration of project	2021-2023

Figure 2 Image of Brick masonry

Figure 3 Image of Scaffolding

Protection against falls must commonly be taken into account when work is conducted on raised platforms that are six feet or more above the surrounding area in a construction setting or four feet or more in an industrial environment, as Figure 3 describes above. The large scaffolding is needed for ceiling construction due to the height of the ceiling being beyond human reach. Changes to the work have been considered both technically and physically.

Figure 4 describes the wearables present an opportunity to reduce the risk of injuries, improve safety, and enhance the quality of life for technicians and other workers. In the field service industry, wearables present an opportunity to reduce the risk of injuries, improve safety, and generally enhance the quality of life for technicians and other worker.

Figure 4 Image of wearable equipment

The exoskeleton, also known as an exposit, is a wearable suit with motorized joints that are intended to provide enhanced strength and protection to the average construction worker. It gives the worker's arms, legs, and back a reinforced external shell that protects them from injury shields their body and helps them stand more upright. Handling heavy equipment can make workers vulnerable to body strains and musculoskeletal disorders. To reduce the toll of work on their bodies, they can wear exposits or exoskeletons, which can augment the wearer's strength and protect them from injuries.

Figure 5 Image of exoskeleton

Construction employers and project managers have the responsibility to ensure that the employees working with them have a safe working environment, as Figure 5 describes above. By using automation and smart technology, the industry is getting closer to the goal of eliminating workplace fatalities and injuries.

Here figure 6 describes Mixing pumps and conveying pumps are the two types of plastering equipment. A mixing pump will mix the dry bags so that the wet mix can be pumped all the time. This makes it possible by the fact that plasterers can spray material while it is being automatically mixed and pumped.

Having painting simple and user-friendly is the primary objective of the painting machine design. Low-cost painting equipment assists in wall painting. Chemical risks to human health in paint. Painting involves difficult painting work, which irritates people and makes the process tedious and time-consuming, as Figure 7 describes below. Every step of the construction industry is changed by automation and robotics in the precast concrete industry. Supporting workers as they use machines is one of the most difficult roles on the construction site. On the construction site, there is a requirement for smart use of planning skills, simple setup, and adaptability. The materials that require to be lifted have a significant impact on the crane-lift procedure.

Manufacturing aims to create high-quality products, but it's also essential to maintain that quality over time. Improving accuracy- A procedure needs to be accurate in addition to being consistent. Without automation, a procedure can be

easily completed many times with reasonable consistency, but many situations demand precise measurements, placements, installations, etc. Identifying error- Although automated technologies considerably enhance procedures, they are not flawless. Things can slide out of position, parts can break down, and components can fail. An automated system's beauty may be observed in more than just the end output; it can also be observed in the way faults are caught. To make adjustments or notify those who can make changes, triggers, sensors, and data collectors can keep an eye on their equipment.

Figure 6 Concrete plastering robot

Figure 7 Wall painting robot

2. Material and method

This study deals with the results obtained from a questionnaire survey with different stakeholders such as project managers, site engineers, contractors, owners, etc. data analysis through a relative importance index. Data analysis can be done from collected data by the relative importance index approach to factors can be achieved. Based on the data, the analysis will be made to find out the most suitable methodology that can be applied to factors affecting construction projects. The collected data were analyzed through statistical techniques i.e. Relative Importance Index (RII).

The relative Importance Index method helps to determine the relative importance of the various factors affecting the construction project.

The nine-point scale ranges from 9 (very important) to 1 (less important) (Harker & Vargas, 1987)

Relative importance indices (RII) for each factor are as follows:

- In this Questionnaire survey, we can use the RII (relative importance index) method(Rajgor et al., 2016)
- The relative Importance Index is calculated for each of the indicators and ranked accordingly.
- The RII is derived to summarize the importance of each indicator.

$$RII = \Sigma W / (A*N)$$

Where
W = Weightage given to each factor by the respondents
A = Highest weight (9 in this case)
N = the total number of respondents

Table 6 Rating of scale

Scale	Description
1	Equal
2	Between equal to moderate
3	Moderate
4	Between moderate to strong
5	Strong
6	Between strong to very strong
7	Very strong
8	Between very strong to extreme
9	Extreme

3. Result and discussion

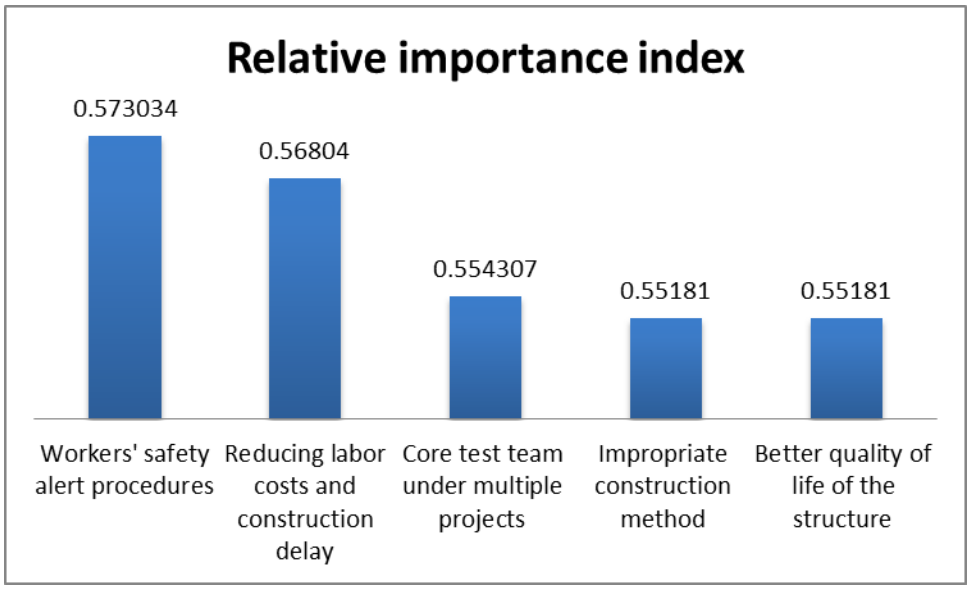

Figure 8 Top five improvement factors by relative importance index

Table 7 Top five improvement factors by relative importance index

Sr. no	FACTORS	RII	RANK
1	Workers' safety alert procedures	0.573034	1
2	Reducing labor costs and construction delay	0.56804	2
3	Core test team under multiple projects	0.554307	3
4	Impropriate construction method	0.55181	4
5	Better quality of life of the structure	0.55181	5

3.1. Workers' safety alert procedures

In this study workers' safety alert procedure is first because the protection of the workforce the general public, and the timely completion of the project all depend on safety on the construction site. To ensure that everyone is aware of the safety advice, employers should provide frequent training sessions and identify employees who consistently put safety first. Automation experts can help companies perform detailed risk analyses for lifting and specify safety zones on their production floors. Wearables present an opportunity to reduce the risk of injuries, improve safety, and enhance the quality of life for technicians and other workers. Large scaffolding is needed for ceiling construction due to the height of the ceiling being beyond human reach. Changes to the work have been considered both technically and physically.

3.2. Reducing labor costs and construction delay

By automating typical operations that would otherwise need staff to invest time and effort into, automated workflows may dramatically save labor expenses. This can free up workers to concentrate on more difficult and strategic duties, cutting down on the need for extra. As a result of the pandemic, the construction industry has encountered several difficulties, including supply chain problems, increased energy costs, and As a result, many construction companies are now looking for ways to reduce some of their costs, labor, and material shortages. Owners and contractors frequently worry about the amount of labor on construction projects. For this reason, it is appropriate to describe labor productivity for each type of building work as functional units per labor hour. Due to obstacles faced by construction employees on the job, product development has been slow. For instance, errors in building design might cause the construction process to be severely delayed. Additionally, it might cause delays throughout the project to anticipate the length of various processes like concrete curing. To address this productivity gap, the construction sector has to think about digital transformation.

3.3. Core test under multiple projects

Lack of adequate testing results in lower quality items, delayed deliveries, and higher expenses. These problems might include an unplanned test management approach, a development delay, and an incorrect estimation of the work required to create a test case. Manual testing takes time because, to verify that the problem has been fixed after each production fix, testers must run a set of related test cases across the same period. Every developer has experienced challenges with regression testing. Repeating the same test decreases a tester's overall efficiency and increases the time requirement.

3.4. Impropriate construction method

The use of excessive water content, segregation/inadequate placing, poor compaction/consolidation, inadequate cover to reinforcement, incorrect placement of steel, poor curing, inadequate formwork, incorrect placement of construction joints, and inadequate mixing are just a few examples of the poor construction practices that result from subpar workmanship and inadequate quality control and supervision. Even though there is a constant worry that technology might lead to widespread unemployment, the building industry need all available human labor. Construction has a well-known problem with a lack of skilled workers, and robots are essential to easing some of the stress. In other words, automation must be widely used since an excess of human work is considerably less likely to happen than a shortage of human labor. Construction method selection, implementation, and improvement is an important but challenging task for projects, particularly large and complex projects, which frequently face limitations like complex project environments, lack of information, and uncertainties brought on by new technologies. Construction Site Autonomous Machines- Also learning to pave are robots. Although they are still in their early years, robotic paving and concrete pouring are well on their way to becoming commonly used technology. Automated blasting systems, however, may improve job site security and general project effectiveness. Automated blasting could produce surfaces of better quality

since robots can be constantly accurate. Robots that automatically lay bricks were among the first to appear on building sites, and they still hold promise. These tools aid in addressing severe labor shortages in the masonry building industry. One of the most common robots in the business is the welding robot. Because welding is risky, automation keeps expert welders secure so they may concentrate on more difficult welds rather than repetitive ones.

3.5. Better quality of life of the structure

The success of every construction company is directly impacted by the essential aspect of construction quality. It is crucial for expansion as well as for keeping a good reputation in the industry and, most importantly, for being profitable. We need to keep moving forward by implementing technology that enables us to make a difference by increasing the safety and efficiency of our construction projects and achieving even better levels of excellence. Instead of replacing people, robots and automation can improve our quality of life and make the world a better place.

Automated systems can reduce the risk of accidents, as well as help avoid and prevent workplace injuries, resulting in a safer workplace for everyone. By making the workplace safer, uptime and productivity will also increase. Automation experts can help companies perform detailed risk analyses for lifting and help specify safety zones on their production floors where lifting operations are a concern. The construction industry has faced difficulties due to the pandemic, such as supply chain problems, increased energy costs, and labor and material shortages. Automation is said to displace rather than replace humans and their talents, according to studies on modern labor processes. In emerging countries, construction output has increased quickly, often exceeding the growth rate of the economy. Other nations have doubled their building growth and productivity, leading to a fast-expanding business that requires effective and creative solutions to boost output and job quality. Many industrialized nations have changed from the old building methods to manufacturing prefabricated components in workshops and then assembling them on-site. Automation Testing has many advantages, such as saving cost, fast development and delivery, and accurate results. However, there are some drawbacks to automation testing, such as lack of vision, wrong technology, better use of skilled staff, increased performance and efficiency, and inconsistent and repeatable results. An automation strategy defines the long-term goal and vision, and well-defined automation strategies produce the greatest outcomes. Additionally, the use of an automated compression machine increases data integrity, repeatability, and outcome consistency and accuracy. Additionally, automated procedures will invariably increase data integrity, repeatability, and outcome consistency and accuracy. Construction methods are the techniques used to create homes, workplaces, and other structures. The most prevalent form of automation in construction is the use of autonomous machines, which are self-driving vehicles that can be used to move large objects and move goods around a job site without risking the safety of personnel. Drones are also used to survey working areas and employees, allowing automatic monitoring of construction sites without active supervision. Construction organizations may carry out pre-project inspections and other crucial site monitoring tasks using drones.

4. Conclusion

The construction industry is facing challenges due to the constant demand for new buildings, the end-user desire for individuality, the low productivity of the sector, the low efficiency regarding material use, the low level of automation in design and construction, the shortage of skilled workers, and the increasing scarcity of natural resources. A literature study has identified 53 main factors that have an impact on how well a commercial building project performs. Safety alert procedures, reducing labor cost and construction delay, core test teams under multiple projects, appropriate construction methods, and better quality of life of structure are all important considerations. By improving material efficiency, automating manufacturing, raising productivity, and enhancing worker health and safety, automation may help the construction industry. Core test team across numerous projects is a crucial aspect to ensure effective health and safety management and minimize construction delays. Building a creative team and maintaining discipline is also necessary for successful test automation. The health, safety, and improper construction practices of the workforce are key factors in reducing labor costs and building delays. This research helps construction parties concentrate on the aspects that will help them solve the problem and use the concepts based on those elements to reduce delay. The most important elements in every project are workers' health and safety and reduce labor costs and construction delays. So, enough care should be taken for appropriate management of health, and safety, reducing construction delay for the successful completion of the project. It can help with improving workplace security while also reducing delays, protecting workers, and even increasing productivity. Everyone involved in the building project will always have access to the same source of truth thanks to automation in the field of document management. Without sacrificing effectiveness, automated reporting and cost projections can help lower total building costs. To reduce delays, management provides effective management of health and safety via the use of machinery. Producing individual components using a machine is significantly easier than doing so manually on-site. Although a lot of the labor in the construction business is still done manually, as the project's size and scope increase, automation will replace the

physical labor. In the context of the increasing global population, poor productivity, and growing need for sustainable housing and public buildings, this helps optimize workflow and satisfy demand. The development of technology can help the construction sector get over many of these difficulties. Lastly, to develop sustainable construction and reduce air and noise pollution surrounding the building site, we need to adopt more eco-friendly and cost-effective practices. This will demonstrate that we are aware of and responsible for environmental concerns.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study

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