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IMPROVING CONSTRUCTION PROJECT DELIVERY THROUGH AUTOMATION AND ROBOTICS

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ABSTRACT: Automation and robotic technology (ART) has been successfully applied in the manufacturing and allied industries to achieve on-time delivery of quality products at increasingly reduced costs. Meeting time, quality and cost targets still remains a big challenge in the global construction industry with prevalence of time and cost overruns. Application of ART in the construction industry could contribute to significant improvement in the efficient and effective delivery of projects to meet and exceed client expectations. However, the uptake of ART is still low in the construction industry. This study investigates the various ways in which ART could be applied to improve construction project delivery, potential areas of applications, and constraints to the uptake of the technology in the construction industry. Recommendations are made for improving the uptake of ART in the construction industry.

Keywords: Automation, construction, project delivery, robotics.

1. INTRODUCTION

The global construction industry is beset with cost and time overruns and poor perceptions of quality [7]. This has resulted in prevalence of client dissatisfaction and aggravated contractual risks [8].

At the centre of the construction industry problems is a range of human-related issues including low productivity, poor workmanship, poor supervision, and skill shortages [1,2,10]. Uncertainties and poor delivery outcomes are largely associated with the difficulty in controlling human inputs in the construction project implementation process. For instance, the US Bureau of Labor Statistics reported that while other industries have recorded worker productivity increases of up to 250 percent since 1964, construction worker productivity has declined by 25 percent [1].

ART has been successfully applied in the manufacturing and allied industries where the bulk of the production processes have been fully automated and delivered with the help of robots. In this process, human inputs and human risk elements have been drastically minimized resulting in continuous improvement in on-time delivery, high quality and reduced costs. Automation and robotics could provide solutions to the human risk elements in the project delivery process [6].

This study investigates ways in which ART could be applied to improve construction project delivery, potential areas of applications, and constraints to the uptake of the technologies in the construction industry.

2. IMPROVING PROJECT DELIVERY THROUGH AUTOMATION AND ROBOTICS

The term 'Robot' in the construction context is a reprogrammable multifunctional manipulator designed to perform a variety of construction tasks; while automated devices include other manipulators and equipment that follow a fixed sequence or remote controls [12]. Automated and robotized tasks in construction could complement or replace human inputs. Construction project delivery aims to achieve quality, cost and time targets [7]. ART could be applied to improve construction project delivery in several ways including the following.

Reduction of human risk elements: By minimizing the need for labor-intensive operations, application of ART could help to reduce the number of labor inputs and the associated human risk elements thereby improving project delivery outcomes.

Higher productivity: In the manufacturing and allied industries where ART has been successfully applied, continuous and impressive improvements in productivity have been recorded; the reverse is the case in the construction industry due to low uptake of the technology. For instance, it is reported [3] that in Japan 46 percent improvement has been continuously maintained in the manufacturing and allied industries from 1990 to 2002 due to increasing uptake of ART. This compared to a steady decline of about 24 percent in the construction industry's productivity over the same period due to low intake of the technology. Similar results have been obtained in the US and elsewhere [2,11].

The improvement in productivity that is linked to automation and robotics is due to greater control of the work processes.

Higher quality: The use of automation and robotics allows sustained quality checks and control. In fact, total quality management is more achievable through ART than is possible with human inputs. It is possible to apply Quality Function Deployment (QFD) techniques early in the procurement process from design through construction to operation phases.

Reduced project costs: Costs of construction have always been on the increase compared to other sectors of the economy. With labor costs contributing to 40-60 percent of the total project costs, it is possible to achieve 20-40 percent reduction in overall project costs by minimizing labor inputs through ART [9]

3. CONDITIONS SUITED FOR 'ART' APPLICATION

In the construction industry, ART could be leveraged in the following conditions:

Unsafe site conditions: Hazardous and accident prone sites, as well as strenuous tasks, which are not conducive for workers, and which may present health and safety compliant issues, are potential areas for ART application [12].

Repetitive but rigorous and large scale work processes: ART is more suited to projects with modular designs, off-side production and on-site assembly of prefabricated components and units.

Minimal variation/ change orders: ART relies on pre planning and clinical execution of tasks with minimal scope changes. The technology is therefore suited in conditions where the client or owner requirements can be comprehensively articulated at the onset with little or no variations at the implementation stage.

Sufficient time for pre-planning: Flawless schedules with little or no minimal idle times are favorable conditions for the application of ART. This requires sufficient time for quality planning at the onset.

Where quality is of the essence: ART is leveraged best in zero-tolerance conditions where there is a need to eliminate or minimize human errors in project execution. This is because, it is easier to carry on continuous quality inspections and controls with robots than with humans.

Large scale and on-going infrastructure development and maintenance: This condition ensures sufficient time horizon for recouping the huge investments in ART in the long run.

Shortage of skill or need to minimize human inputs: If the required technology and enabling environment exists, ART addresses conditions of acute skill shortage or is best leveraged in conditions requiring minimal human inputs for safety or quality reasons.

In-door work environment: Automation and robotics are more suited in controlled environments than the usual out-door nature of construction sites which are prone to the elements.

4. CURRENT AREAS OF 'ART' APPLICATION

In the construction industry, ART is gaining grounds and is applied in a variety of areas as teleoperated or direct control systems for work in adverse conditions or as programmed systems for process or navigation controls [12]. Some other areas of current applications are discussed as follows:

Power-floating concrete surfaces: Robots have been used to power-float concrete floor surfaces to high quality finish. The operation has resulted in savings of up to 3000 man-hours, yet at a quality standard that is far better than that of the most skilled worker manually operating a power-float machine [3].

Automated building construction system: The Japanese Shimizu Corporation now boasts of a fully automated building construction system capable of erecting multi-storey buildings. This requires setting up a temporary 'factory' on site to handle all on-site assembly of prefabricated components [3].

Demolition and industrial waste disposal: Given the hazardous nature of demolition and industrial waste handling operations, robots are increasingly used to perform these operations with more successful outcomes [4].

Rail construction: In the Netherlands, 96 km high speed rail linking Amsterdam and Antwerp was constructed using an automated system – the RHEDA 2000 Track Construction System. Compared to the conventional construction system, the automation process resulted in 25 percent reduction in cost of man-hours, improving tremendously the quality and speed of completion of the project and the total performance of the system.

Shield tunneling: Automation and robotics have been widely used to address the challenge of construction where the flow of traffic presents a huge problem. The automated shield tunneling machines have been deployed in Japan to construct underground expressways [3]. However, working cooperatively with humans rather than fully automating the work process is perceived to have more successful outcomes in this instance [5].

Other areas of applications include interior finish [13] and placement of structural elements [12].

5. CONSTRAINTS TO UPTAKE OF 'ART'

Several factors constrain the uptake of ART in the construction industry. These include the following.

Preponderance of scope change and variation: Unlike in the manufacturing and allied industries, the construction industry products are largely custom-built, with the owner playing active role in the conceptualization, design and construction. It is doubtful if the ART will be robust enough to cope with the frequent changes in scope that have characterized the construction delivery process.

Operators' reluctance to change: Application of ART requires complete overhaul of the construction procurement system, design and construction methods. Operators are stuck to their old ways of doing things and may not be prepared to undergo the adjustment that is required in the uptake of ART.

Out-door nature of the construction process: 70-90 percent of the construction processes are carried out in the open. In addition, the sites are ever-changing in size and nature, each with unique set of conditions. ART is perceived to be more suited to off-site fabrication of components and units and at best, on-site installation of prefabricated components.

Skill shortage: Admittedly, state-of-the-art tools and equipment, including ART, do not run themselves; they require skilled workers to make them effective implements of production [10]. While ART could contribute to filling the skills gap in construction trades, it requires a highly skilled IT workforce, which is equally scarce. Breakthroughs can only happen when there is ample supply of relevant IT workforce.

Limiting choices of developers: Standardization or modulation and other enabling conditions for the uptake of ART impose strict restrictions to developers' choices in the procurement process. One of the key differences between manufacturing where the uptake of ART is high, and the construction industry with low uptake, is that in the former, customers actually do not make much inputs in the decisions that inform design and production processes; whereas in the latter, customers or owners of the products control the design solutions to suit their unique set of needs, making the products unique in many ways. This imposes serious limitations to the uptake of ART in the construction industry.

Lack of leadership for new technology adoption: The building industry is characterized by a large number of small clients, vendors, designers, general contractors and sub-contractors who are often not in a position to provide leadership for the adoption of new technology and practice.

Lack of supply chain management: The construction industry is extremely fragmented with little or no integration between the raw material extraction, production, supply and construction of the product [10].ART can only thrive well in seamless integration of processes using effective supply chain management.

Economic recession and high unemployment rate: ART is not ideal in conditions where there is a need to encourage the use of abundant labour to create jobs and improve employment rate. As the construction industries slip into recession in sync with the global recession, ART will be unattractive and may even be legislated against by most governments.

Financial constraints: Uptake of ART requires huge capital outlay [12] with slow and long time returns on investment, which may not meet the loan conditions of many lenders.

6. STRATEGIES FOR IMPROVING UPTAKE OF 'ART' IN CONSTRUCTION

ART offers numerous benefits to the construction industry, which could outweigh the above constraints or shortfalls. Improvement in the uptake of the technology is critical to the strategic and financial health of the construction industry. Strategies for improving the uptake of the technology in the construction industry are modeled in Figure 1 and discussed in the section that follows.

[Figure 1]

Minimization of on-site production: In the construction context, ART is more suited to off-site production and on-site assembly of prefabricated units.

More investment in IT infrastructure support: ART is underpinned by strong IT infrastructure support and trained workforce. There should be more investment in this area to improve the uptake of ART in the industry.

IT and robotics in construction curricular: Intelligence systems, mechatronics, IT, 3D technology and related courses should form part of the curricular of construction programmes to equip current and future role players in the industry with the basic skills and knowledge to innovate using ART. For instance, in New Zealand, robotics and 3D technology have been introduced into high school curricular to encourage learners to pursue careers in automation and robotics [14].

New procurement systems: Enabling environment for the uptake of ART is created through having procurement systems that integrate design, management, construction and maintenance functions in the procurement process. Design and build, private public partnership, and other integrative approaches are preferable to the current traditional system that fragments these essential functions.

Integrated project developments: The potentials for ART are maximized where a large scale development approach is adopted on a single site, requiring repetitive units of similar designs. Though this may restrict individual developers' choice of site and designs, it has potentials for minimizing costs through economies of scale and shared resources.

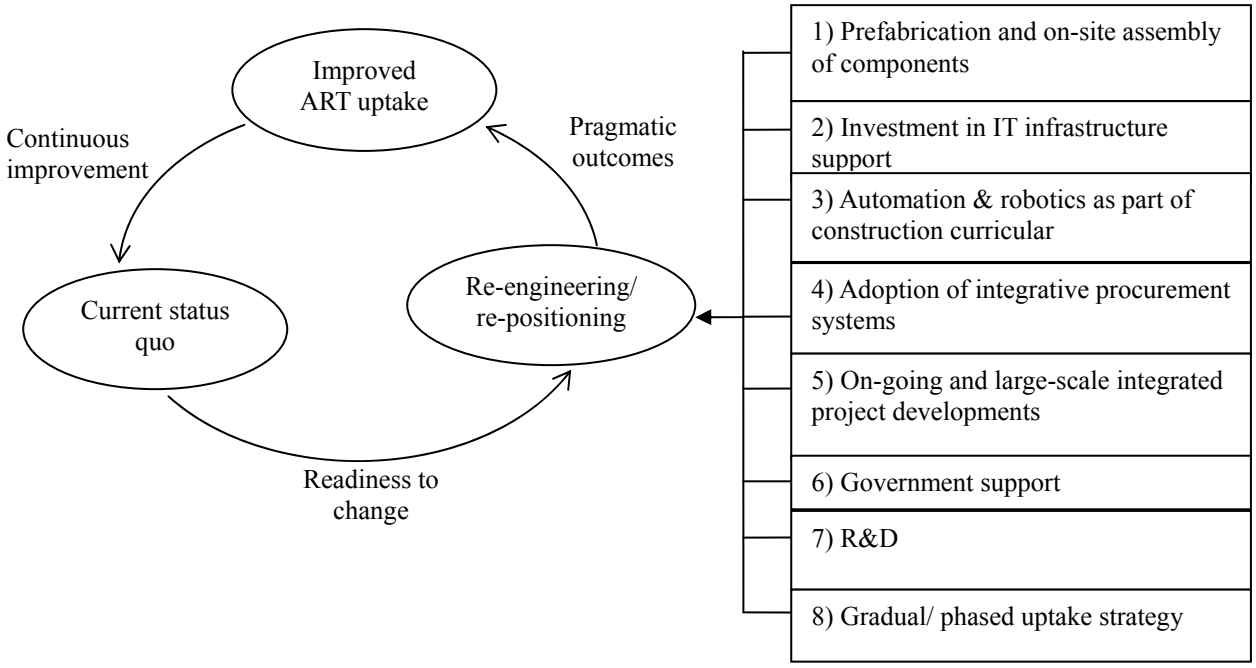

Figure 1. Strategy for improving uptake of automation and robotics technology in the construction industry

Government support: As the largest clients/ employers in the construction industry, governments could promote the uptake of ART by encouraging companies that adopt ART through tax incentives, promulgating laws and regulations that encourage the adoption of ART, and by giving preference to construction methods that draw on ART in the award of contracts.

Research and development (R&D): Sound investments in research and development projects that aim at improving ART in the construction industry could spark off interests and result in breakthroughs in finding ways of overcoming the current barriers and discovering innovative ways of applying the technology. A typical project is on developing easy-to-use software that can be adapted to suit varying project site conditions and owner requirements.

Gradual/ phased uptake of ART: Like in any other sphere of human endeavour, radical change from conventional construction methods to ART would meet stiff opposition. Phased approach involving bit by bit but steady introduction of the technology in sections or tasks will take time but surely will guarantee its successful uptake over time.

7. CONCLUSIONS

In sync with the rapid advances in technology, automation and robotics seem the way of the future. The technology has been leveraged well in the manufacturing and allied industries to bring about tremendous improvements in the delivery of quality products at reduced costs. The construction industry could benefit from the application of the automation and robotics technology (ART) in addressing the perennial problem of cost and time overruns, poor perception of quality and acute shortage of skilled workers.

This study has discussed potential areas of, and constraints to, the application of the technology in the construction industry context. Strategies for improving the uptake of the technology have been recommended to the key role players in the construction industry.

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