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DESIGN PRACTICES TO
FACILITATE CONSTRUCTION
AUTOMATION

Construction Industry Institute

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Design Practices to Facilitate Construction Automation

**Prepared by
The Construction Industry Institute
Design Practices to Facilitate Construction Automation Project Team**

**Research Summary 183-1
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Executive Summary

Automation in the construction industry involves the use of mechanical and electronic means to achieve automatic operation or control to reduce exposure, time, or effort while maintaining or improving quality. Contractors use automation to reduce costs and schedule, improve production, quality, and safety, and gain related project benefits.

Automation in construction, however, has not kept pace with other industries and remains a predominantly labor-intensive activity. Many factors limit its use. Cost, availability, and applicability of automated technologies, along with the knowledge and training required to operate the technologies, are obstacles to implementation. The design of permanent features and the means used to communicate the design may either inhibit or prohibit its use in construction.

CII created the Design Practices to Facilitate Construction Automation Project Team to investigate this issue. The resulting research has identified design practices that facilitate the implementation of automated technologies and exposed barriers to and limitations of addressing automation in design. Some recommended design practices to facilitate the use of construction automation include:

- Conduct constructability reviews during the design phase that incorporate consideration of construction automation.
- Standardize design features and elements.
- Prioritize design objectives and compare design alternatives.
- Use e-documents and make them available to the contractor.

This research summary provides an overview of the research effort. Readers are encouraged to take the findings and put them to use on real world projects.

Introduction

Improvements in productivity, safety, quality, cost, and schedule are common project objectives in the construction industry. Project success is often judged based on performance with respect to each of these criteria. Technology advances that have occurred over the past few decades, and which continue today, have provided opportunities to make great strides in project performance. This is especially true for technologies that automate the construction process. Expanded use and development of new automated technologies are looked upon as critical to the continued growth and competitiveness of the construction industry.

Performance improvements in other industries, especially manufacturing, have resulted to a large extent from the effective implementation of new automated technologies. Automation in construction, however, has been limited. Consequently, improvements in construction productivity from the implementation of automated technologies have been insignificant over the past few decades compared with other industries.

Several barriers limit the use of automated technologies in the construction industry. Constructors often cite the cost effectiveness, availability, and applicability of technologies, along with the knowledge and training required to operate them, as obstacles to technology implementation. Another barrier can be the design of the project itself. The capabilities of automated equipment are constrained by the physical aspects of the design. Furthermore, some technologies require electronic input in specific formats to make their use practical. Minor modifications to the design and the format in which the design is communicated can potentially enhance the use of automation and lead to improved project performance.

The CII Design Practices to Facilitate Construction Automation Project Team (PT 183) was formed to investigate the impact of design on the use of automated technologies during construction. For the purposes of the study, the following definition was used:

Automation: the use of mechanical and electronic means to achieve automatic operation or control to reduce potential exposure, time, or effort while maintaining or improving quality.

A survey of constructors, designers, and fabricators was conducted regarding the current use of automated technologies and the practice of addressing construction automation in the design. Interviews were also conducted with personnel in other industries regarding their approach to designing for automation. This information was used to develop and record design practices that facilitate construction automation and expose barriers and limitations that limit the consideration of construction automation in the design.

To facilitate the practical implementation of the research results, the project team developed a website that can be accessed by designers. With this online tool, designers will be able to easily access and learn about barriers that prohibit the use of construction automation and search for design practices to incorporate into their designs and design processes.

Automated Construction Technologies

The search for automation in construction resulted in a list of 87 different technologies in use or under development (see Appendix). The technologies were categorized according to the type of work performed: concrete and masonry construction, excavation and earthmoving, site inspection and surveying, painting and coatings, material and asset management, steel fabrication and erection, and finishing. The percentage of automated technologies found in each of these categories is shown in Figure 1.

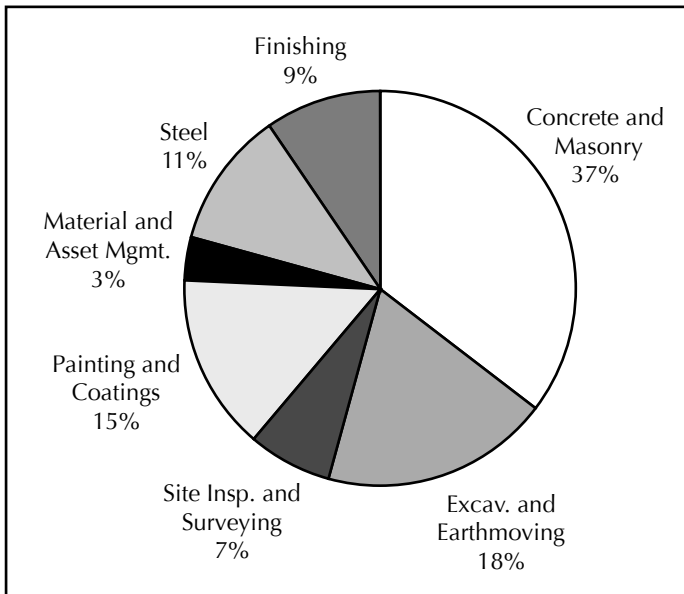


Figure 1. Categories of Automated Technologies

To gain an understanding of the extent of use of each of the automated technologies listed, a questionnaire was developed. The questionnaire asked respondents to indicate whether their firms use the technology or considered its use but do not use the technology,

and also if the firms recommend the technology for use and see value in its development. The questionnaire was sent to a total of 1,087 construction companies consisting of the Top 400 Contractors as ranked by *ENR*, construction companies located in the Pacific Northwest, and CII member organizations.

Seventy-eight companies responded to the questionnaire. Table 1 indicates those technologies that are predominantly used by construction companies and shows where value is seen in development. The survey revealed a strong prevalence in concrete and masonry construction of automated mobile screeding, rebar bending, and concrete surface treatment. Additional responses suggest the following:

- Technologies for automating reinforcing cage fabrication for beams and columns and for mobile bricklaying could be further developed.
- Remote control soil compaction is used much more than other technologies within this category.
- Automated dump trucks and global positioning system (GPS) guided excavation appear to be highly considered applications, but with little or no actual implementation.
- Inspection and surveying activities show a strong prevalence for robotic pipe inspection.
- For steel construction, metal welding, cutting systems, and robotic welders are widely used.
- Material and asset management technologies appear to have developmental value.

Interviews were conducted with 29 project managers, seven equipment operators, 15 design professionals, and five construction material fabricators. The personnel interviewed were employed in a wide range of types and sizes of firms with offices located in the Pacific Northwest. The construction companies in which the project managers

Table 1. Technologies Predominantly Used and Whose Development Is Recommended

Response	Construction Category	Automated Technology
Technology Used	Concrete and Masonry	Horizontal concrete distributor Concrete surface treatment applicator Rebar bending machine Concrete screeding machine
	Excavation and Earthmoving	Remote-controlled soil compactor
	Directional boring	Earthmoving guidance system
	Site Inspection and Surveying	Robotic pipe inspection
	Painting and Coatings	Robotic paint removal
	Material and Asset Management	Real-time equipment tracking system Remote-controlled forklift
	Steel	Robotic welding machine Automated cutting machine
	Finishing	Ceiling board manipulator Robotic glass handling machine
Value in Development	Concrete and Masonry	Robotic bricklaying machine Rebar cage fabricating machine Robotized spraying of GFRP panel
	Excavation and Earthmoving	Automated pipe laying Robotic drilling and cutting system Virtual reality Remote-controlled heavy equipment
	Site Inspection and Surveying	Aerial bridge inspection
	Painting and Coatings	Automated finishing of tank surfaces Remote-controlled paint removal
	Material and Asset Management	Real-time equipment tracking system
	Steel	Remote-controlled pile driver
	Finishing	None

and equipment operators were employed perform work in each sector of the construction industry: residential, industrial, commercial, and heavy civil. Careful consideration was given to select a range of construction companies based on annual revenue. The designers interviewed represented both architectural and engineering design disciplines, and designed a similarly wide distribution of projects. Fabricators of construction materials were also interviewed because of their close interaction with both design and construction and because their operations are essentially ongoing construction operations in a single location. Fabricators were selected for interview according to the categories of technologies available to constructors and their potential for design influence by the fabricator.

Of the construction project managers interviewed, over 70 percent of the firms they represent use some form of automated technology in construction and over 75 percent have considered the use of automated technologies. When asked about the basis for the decision to use automated technologies, project managers attributed implementation predominately to cost, followed by production and quality. The survey also asked, "Based on your experience, is the use of automated technologies a benefit to any of the following: cost, quality, safety, production, schedule, other?" Cost is the primary benefit recognized by project managers, followed by production and schedule. In response to the same questions, equipment operators perceive production, cost, and quality as the primary reasons for automation, and have found through experience that production, cost, schedule, and quality are benefits realized from implementation. Figure 2 shows the distribution of perceived benefits of automation and reasons for using automation as presented by the project managers and operators.

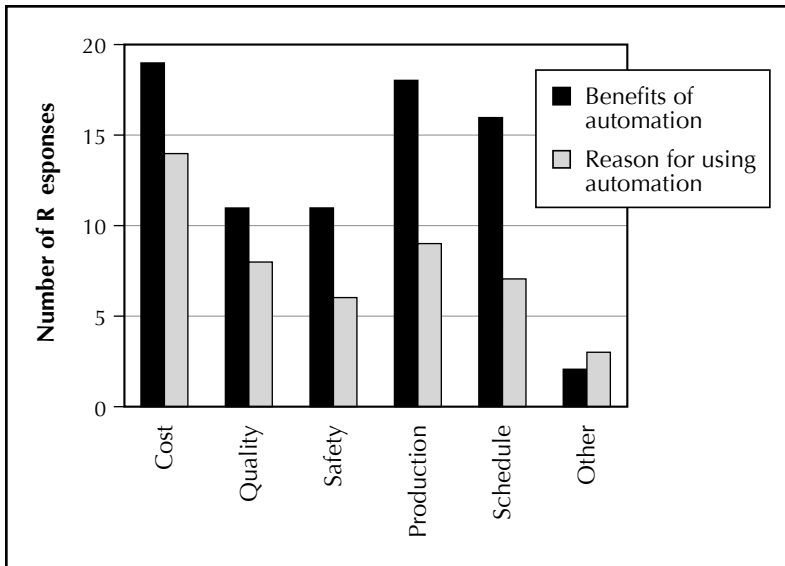


Figure 2. Constructor (Project Manager and Operator) Responses Regarding Automation

The benefits associated with construction automation appear at both the project level and industry-wide. Based on the interview responses, benefits realized at the project level include:

- Lower total project cost
- Increased quality of construction
- Better safety performance
- Improved schedules (both shorter and more reliable)

It should be noted that the actual realization of benefits depends on the project, type of automated technologies used, effectiveness of technology implementation, and other related project characteristics.