

NEEDS ASSESSMENT FOR CONSTRUCTION AUTOMATION

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The University of Texas at Austin

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The purpose of this publication is to make available to industry the results of research conducted by the Construction Industry Institute (CII). The publication does not necessarily represent the views of CII member companies, but is offered as a contribution to the industry.

CII was founded in 1983 to improve the cost effectiveness of the nation's largest industry. The members, who represent a broad cross-section of owners and contractors, believe that many of the problems that limit cost effectiveness are common ones, and that real improvements can be best accomplished in a cooperative environment with the benefits being shared by the construction industry at large.

CII uses the acronym TOPICS to describe the research effort. TOPICS signifies the six research thrust areas: Technology, Organization, People, Information, Controls, and Sigma (meaning others). The task forces for each area are listed below.

Technology

- Advanced Technological Systems
- Computer Integrated Design & Construction Design
- Electronic Data Management
- EPC Flexibility
- Environmental Remediation Technology
- Modularization Technology
- Technology Strategy
- Technology Survey

Organization

- Constructability
- Constructability Implementation
- Contracts
- Project Change Management
- Partnering
- Pre-Project Planning
- Project Organization
- Project Team Building
- Project Team Risk/Reward Allocation

People

- ADA Impacts
- Construction Work Force
- Continuing Supervisory Education
- Drug-Free Workplace
- Education and Training
- Employee Effectiveness
- Safety
- Zero Accidents

Information

- CICE Impact Evaluation
- Industry Data & Statistics
- International Construction
- Owner Engineering Organization

Controls

- Change Order Impacts
- Contracting, Phase II
- Cost/Schedule Controls
- Dispute Prevention and Resolution
- International Standards
- Materials Management
- Overtime
- Productivity Measurement
- Quality Management
- Quality Performance Measurement
- Schedule Reduction
- Total Quality Management

Sigma

- Barriers to Implementation
- Construction 2000
- Insurance
- Piping Function
- Retrofit Projects
- U.S. Navy Demonstration Project
- Workers Compensation

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for
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EXECUTIVE SUMMARY

The construction industry, as a form of manufacturing, is often considered archaic. Basic methods for physically putting work in place have not changed dramatically in the last 30 years. The availability of a large supply of trained construction workers has traditionally been assumed when planning projects. That availability, combined with an emphasis on short-term efficiency, low costs, and a lack of research and development (R&D), has precluded significant attention to automation. As in other industries, productivity and quality in construction have been dependent more upon humans than on machines.

A number of factors indicate that this situation may be changing. Most demographic studies predict a major shortage of skilled construction workers. Many are dissatisfied with construction's ability to predict final project costs, schedules and quality accurately. Increasing attention is given to construction safety; many suggestions for improving construction operations relate to reducing hazards in the construction environment. Recent technological advancements have increased the feasibility of replacing some construction workers with smart tools, robots or other automated devices.

Attention to construction automation is growing. The R&D necessary to create practical construction devices is expensive, however, and resources are expected to be limited for many years. Thus, it is important to identify those construction tasks that have the highest potential for automation and focus immediate efforts on those tasks that have the highest probable payoff.

The purpose of this publication is two-fold. First, it describes a methodology for identifying automation benefits. The methodology can be applied to a variety of construction activities. Second, the methodology is applied to three important areas of industrial construction: piping, electrical and steel erection. The methodology and pilot efforts have identified a total of 12 tasks that promise to benefit from automation.

This research has addressed neither the issue of automation feasibility nor how widely a solution to a particular need might apply across the universe of construction tasks. These issues are left for future R&D activities, as is the matter of opportunities in other construction market segments. Undoubtedly, many useful automated devices will be developed for tasks outside those identified here as ideas and opportunities develop. Nonetheless, this publication provides a methodology and format for addressing automation as interest and activity increase in this important area.

INTRODUCTION

For a sense of automation R&D in construction, refer to the list of applications hardware presented in Appendix A. A device attributed to one corporation or university also may have been developed by others, who are not listed in the interest of brevity. After reviewing this list, a person interested in pursuing automation may understandably ask, "Which of the applications listed (or others that are not) most deserves attention?" or "How does one choose among the alternatives to obtain the greatest benefit?"

The purpose here is to: (1) propose a methodology to assess construction automation needs and (2) assess automation needs using the methodology for more promising areas in the heavy industrial sector. The methodology does not account for technical feasibility or range of application; rather, only needs are addressed.

The Business Roundtable's Construction Industry Cost Effectiveness (CICE) Project examined 17 broad areas for automation potential. The results for the heavy industrial sector are shown in Figure 1 [1].

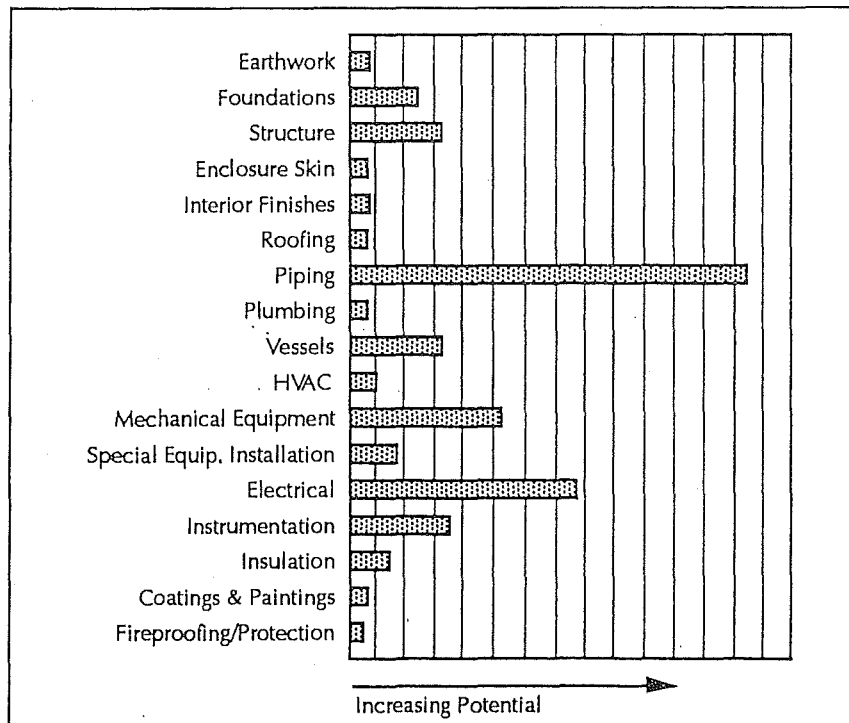


Figure 1. Automation Potential—Heavy Industrial

The report will examine activities within the areas of structural steel, electrical and piping.

The needs assessment methodology cannot make direct use of the broad areas listed in Figure 1. Each must be divided into smaller categories, namely, activities and tasks. A construction activity, such as fabrication or erection, is one component of a broad area, such as piping or electrical. A construction task is a basic unit of an activity that is a readily recognizable component of the activity. Figure 2 depicts the relationship between area, activity and task.

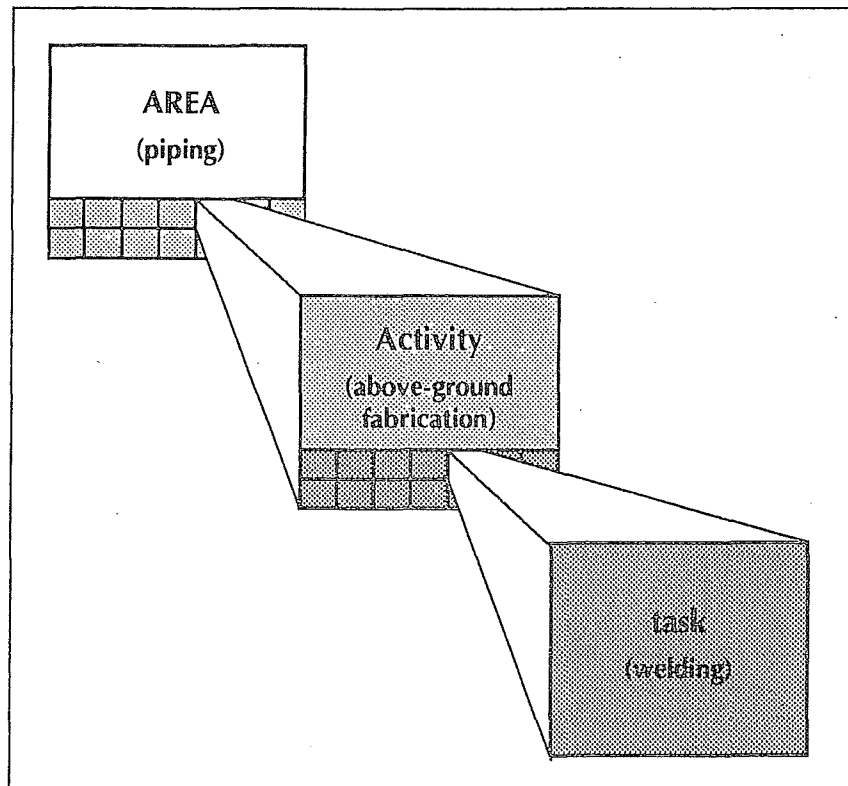


Figure 2. Area-Activity-Task Relationship

For example, welding is a task within the activity of pipe fabrication, which is in the area of piping. Broken down, a task consists of human physical motions. Table 1 gives more examples of related areas, activities and tasks.

Table 1
Area-Activity-Task Examples

AREA	ACTIVITY	TASK(S)
Concrete	Install Rebar	Place Rebar Tie Rebar
	Place Concrete	Place Concrete Vibrate Concrete Finish Concrete
Piping	Fabricate Pipe	Get Materials Assist Welder Weld
	Install Pipe	Get Tools Grind Weld
Structural Steel	Transport Steel	Identify Member Load Transport
	Erect Steel	Rig Steel Align Make Correction

Workers often perform several tasks in a clearly observable and repetitive cycle. One or more cycles for each area—electrical, piping and steel—is described later in this publication. Presence of an inseparable and/or repetitive cycle of tasks may make the need to automate them as a group even more compelling. The methodology does not explicitly force the the investigator to report cycles, although he or she must examine the cyclical aspects of a group of tasks.

NEEDS ASSESSMENT METHODOLOGY

The first and most obvious component of a needs assessment methodology is cost; that is, how much cost does an activity represent on a typical project? The higher the relative cost of a task, the greater the savings its automation can achieve. This component is called *Cost Impact*.

In the final analysis, all benefits from automation can be reduced to cost. In the nearer term, however, such analysis is fraught with uncertainty for factors such as quality and safety. Quantifying future cost impacts of these elements is elusive at best, and any attempt to do so would imply an unwarranted precision for the analysis produced. The methodology presented here avoids that pitfall by judging other important aspects of needs assessment on a qualitative basis. These other, more qualitative aspects, which include quality and safety, are called *Concerns*. The separate qualitative evaluations of each concern are then consolidated to form a *Concern Rating*.

A task's Cost Impact and Concern Rating are combined in a Cost-Concern Matrix. When the several tasks for an activity or a group of activities are plotted together, the relative need to automate a given task is easier to judge.

Figure 3 shows an overview of the needs assessment procedure. Each of the elements shown is described in following sections. For a more detailed explanation of the methodology, the reader can refer to the source document [2].

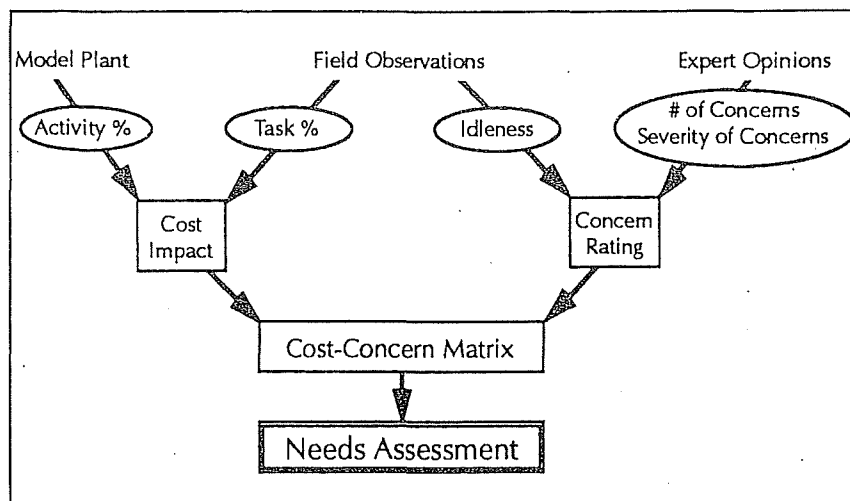


Figure 3. Needs Assessment Process

Cost Impact

The Cost Impact Rating combines information from a previous CII study, the Model Plant Project [3,4,5], with field studies of work crew productivity. The Model Plant is a hypothetical petrochemical facility with a full complement of typical components. It serves as a basis to estimate labor percentages for all project activities from the 17 areas listed in Figure 1. The estimated labor percentage of an activity is inserted into the cell labeled "Model Plant Activity %" that heads each column (see Table 2 below). If the analysis considers tasks from more than one activity, each activity has a separate column.

Table 2
Example Cost Impact Table

[Area Name] TASKS	TASK% Activity (1)	TASK % Activity (2)	...	TASK % Activity (n)	TOTAL % COST IMPACT
Model Plant Activity % =	10.00	1.00		5.00	
Task (1) Description	10	0		0	1.00
Task (2) Description	0	20		10	0.70
Task (3) Description	50	0		0	5.00
.	0	50		0	0.50
.	0	0		30	1.50
.	0	10		0	0.10
Task (m) Description	0	0		10	0.50
Idle Time	40	20		50	6.70

"Task %" is determined from field productivity studies of work crews. These studies summarize minute-by-minute observations of each crew member as he or she performs the tasks comprising an activity. After the observations have been summarized, each task is calculated as percentage of the work activity. This percentage is inserted in the column labeled "Task %" in Table 2 opposite the task description. The sum of all task percentages and idle time should equal 100 percent for each activity.

Task and activity percentages are multiplied and summed to establish each task as a percentage of total project labor (Figure 4). As an example, the Total % Cost Impact for Task (2) (Table 2) is calculated as follows:

$$\begin{array}{rcl}
 10\% \times 0\% & = & 0.00\% \\
 1\% \times 20\% & = & 0.20\% \\
 5\% \times 10\% & = & 0.50\% \\
 \hline
 \text{Total Cost Impact} & = & 0.70\%
 \end{array}$$

$$\text{Total \% Cost Impact (m)} = \sum_{\text{Activity (1)}}^{\text{Activity (n)}} \left[\left(\text{Task (m,n) \%} \right) \times \left(\text{Model Plant Activity (n) \%} \right) \right]$$

Figure 4. Cost Impact Calculation

This procedure effectively lessens "apples and oranges" comparisons among tasks from different activities. For instance, a task comprising 40 percent of an activity representing 2 percent of total project labor ($0.4 \times 0.02 \times 100 = 0.8$ percent) will be rated **lower** than a task comprising 20 percent of an activity representing 12 percent of total project labor ($0.2 \times 0.12 \times 100 = 2.4$ percent).

The total unproductive time observed within each activity is shown in the bar beneath the table labeled "Idle Time."

Concern Rating

Three components—the Concern Analysis, the Concern Severity Factor, and Idleness Rating—are combined in the Concern Rating Table (Figure 5).

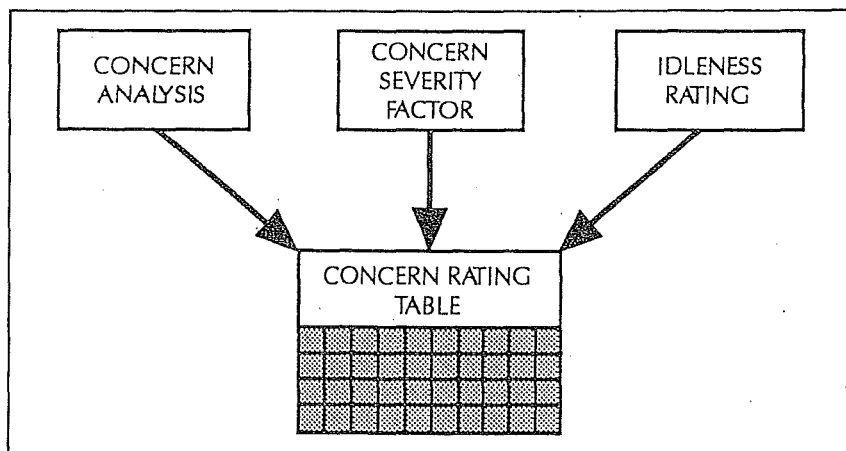


Figure 5. Building the Concern Rating Table

Table 3 is an example Concern Rating Table. The concern analysis and concern severity factor are based on the five concerns and 17 concern factors summarized in Table 4. Briefly, the concerns and their attendant factors represent important aspects of task performance that are difficult to quantify. Appendix B contains a more detailed explanation of each concern and concern factor.