



CONSTRUCTION TECHNOLOGY NEEDS ASSESSMENT UPDATE

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EXECUTIVE SUMMARY

This research report describes the work done during an assessment of future technology needs in the construction industry. The research team conducted a thorough literature review of previous needs assessment for the construction industry, and of topics related to technology in construction, its development, implementation, and relation to the situation of the construction work force. A survey questionnaire was developed as the primary research tool. Three different versions of the questionnaire, customized to the respective respondents, were sent to CII member organizations, craft superintendents, and CII Project Teams. The questionnaires sought the respondents' backgrounds, the respondents' ranking of the potential and impact of various technological areas and of CII Knowledge Areas, an evaluation of technology adoption and work force issues and of attributes of successful technologies, and the respondents' approach to technological innovation and the general prospect for the future of the construction industry.

Among the important findings were that the respondents highlighted the need for integrated systems for planning and execution of construction projects that are geared towards improving the actual field operations and their management, the need for more and better communication between the project participants as well as in the construction industry at large, and the need for a structured approach to the issue of technological innovation. Barriers to technological innovation were acknowledged and the attributes of promising technologies, in particular a proven and clear cost-to-benefit-ratio were highlighted. Based on the knowledge gained in the study, the

researchers developed the Technology Implementation Cycle as a viable way of integrating all parties in the construction industry in a process of continuous evaluation and development of better technologies, having a benefit with regard to cost, time, safety, or quality. Application of this comprehensive Technology Implementation Cycle, which includes the assessment, communication, and solution of technology needs in cooperation of the technology providers and users, will enable the construction industry to become a dynamic entity that sets its own technology R&D agenda and embraces innovation through technology.

CHAPTER 1

1. INTRODUCTION

This chapter describes the challenge that the research topic presents, as well as objectives, scope, and limitations of this study. An overview of the individual chapters of this report in their logical succession is provided.

1.1 The Challenge

While the construction industry is a major user of technology for all of its construction activities [Paulson 1986], it is for the most part a passive user. Prospects for future industrial development point to a growing use of technology in all industrial sectors. Currently, however, technology is predominantly being developed in other industries and may later be adopted and modified by the construction industry without much structure and guidance. In addition, the construction industry currently lacks a clear definition of technologies that are actually needed to achieve excellence in the four target areas of cost, schedule, safety, and quality.

The purpose of this study is therefore to identify and analyze current needs for technologies and present them in a structured framework of what is needed most and how it should be achieved.

The framework will be based on the Knowledge Areas of the Construction Industry Institute (CII) to facilitate implementation and integration of innovative technologies into practice.

Assessing the actual existing technology needs can put the construction industry into a more proactive mode with respect to more efficiently and effectively developing and implementing innovative technologies. It will bring about a shift from merely using available or emerging “products that sell” to facilitating the development of “products that work” and meet real needs [Vorster 2000]. The needs analysis identifies objectives for technology developers and suppliers, who are encouraged to cooperate closely with the construction industry through defined mechanisms. In other words, this study shows how to “move innovation into practice” by considering the path from current needs via R&D to actual industry-wide implementation.

Knowledge about the needs will give companies a competitive advantage in the marketplace. It will make the construction industry as a whole grow more independent of traditional technology providers and will ultimately allow it to set its own technological agenda. The long-term goal of this study thus is to contribute to a major change in the structure of the construction industry that will transform it into a dynamic community with close interaction between developers and suppliers of technology and the users of technology, for the benefit of owners, contractors, and suppliers alike [Vorster 2000].

1.2 Objectives of the Research

The research that is described in this report was undertaken to address the following three basic issues:

- 1) What technologies and technology advancements have potential for improvement as well as impact if actually developed, with respect to safety, cost, schedule, and quality in construction field operations?
- 2) How can these needs best be articulated and disseminated so that the construction industry can be proactive in the development of technologies that support its mission?
- 3) What changes can be made in the interaction between the construction industry, as a user of technology, and the organizations that develop the required advancements to improve the Technology Implementation Cycle?

In order to accomplish these goals of identifying and analyzing technology needs, the research team developed a well-considered list of technology needs and accompanied it with a proposed interface and dissemination mechanism to ensure that the assessed needs will be used in a way that facilitates the desired improvements in safety, cost, schedule, and quality.

1.3 Scope of the Research

The research team was aware that a Construction Technology Needs Assessment Update is an extremely broad field and therefore had to clearly define the scope and direction for the research. The research was supposed to identify industry-wide needs for construction technology advancement in those CII Knowledge Areas where technology can have the highest impact on project safety, cost, schedule, and quality. The overall focus was put on technology *needs* as distinct from technology *availability*.

It was decided to center the research effort on technologies that enable advances in field construction methods, including semi-automated and automated construction and equipment. Opportunities and challenges in Information Technology (IT) should be included in the scope as seen fit, but should clearly not be dominant as other researchers are investigating this topic. The FIATECH (Fully Integrated and Automated Technology Applications) initiative of CII and its objectives were recognized by the research team, and its work was done under consideration of currently ongoing FIATECH activities.

1.4 Limitations of the Research

As mentioned in the preceding section, this research generally deals with technology needs and not with an assessment of existing or possible technologies; thus, it does not seek to develop a

database of currently available or emerging construction technologies [www.new-technologies.org/ECT] as other CII research teams have done.

Very early during the research process, the decision was made to limit the assessment to only technologies with potential to improve field operations. Therefore technologies with potential to improve business management, engineering, procurement, and other commercial or administrative aspects of construction clearly are not within the scope of this research. Technologies related to IT and FIATECH are only briefly mentioned when considered necessary and generally are not included within the actual scope.

1.5 Outline of the Report

This introductory chapter is followed by 10 chapters that are structured as outlined in the following paragraphs. The overall report structure is presented in Figure 1.1.

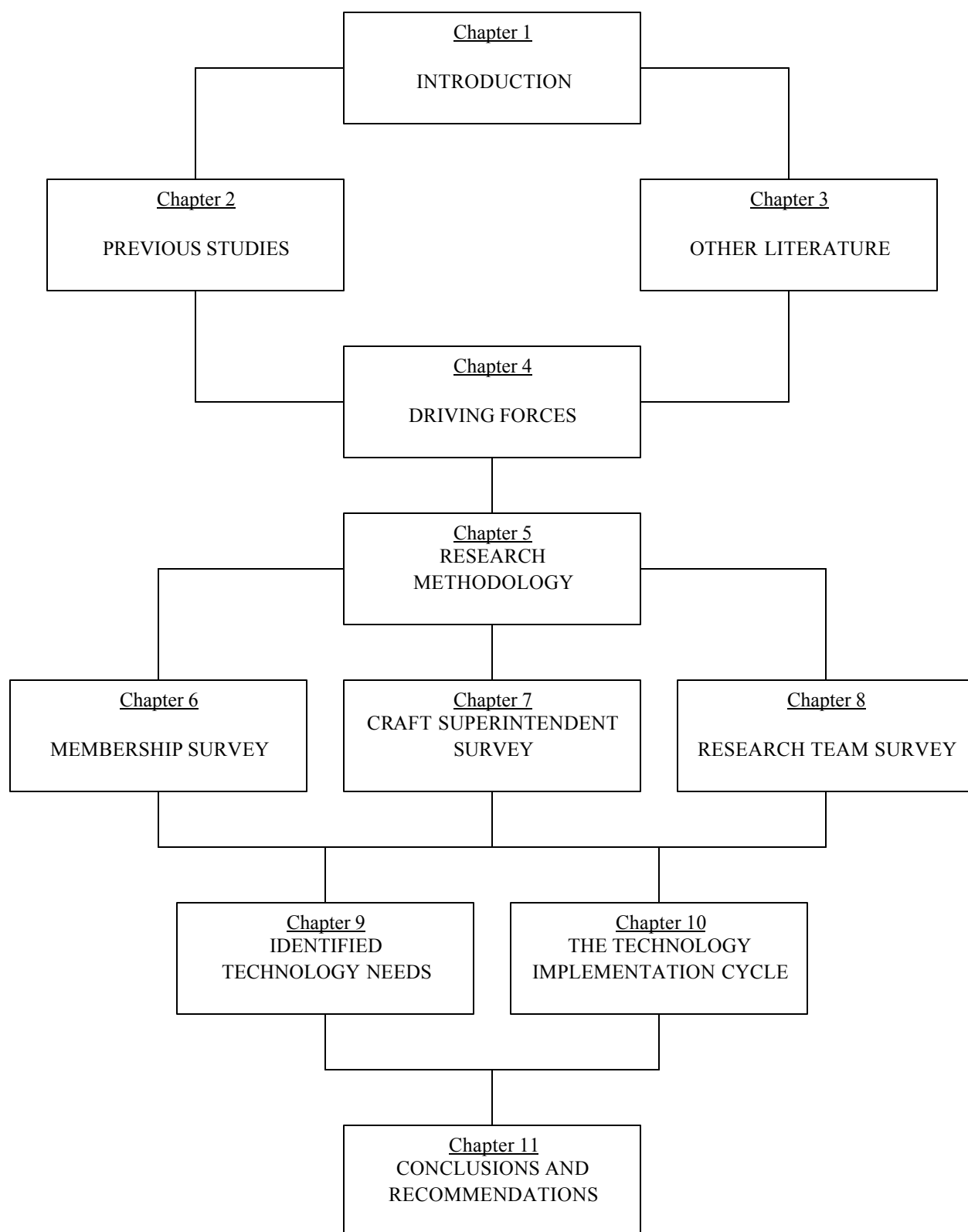


Figure 1.1 Report Structure

Chapter 2: Previous Studies

This chapter reviews studies that had been undertaken previously and dealt with assessments of construction technology needs. It describes the specifics of such needs assessments and highlights the methodology that these studies used to come up with their findings. In particular, the chapter focuses on the widely known report by The Business Roundtable [BRT 1982b], published in 1982, and research done by CII in 1992 [C2K 1992]. This chapter also gives a brief overview of further related research on Emerging Construction Technologies and on literature and summarizes the background information to prepare for Chapter 4.

Chapter 3: Other Literature

This chapter reviews further research that is related to the general topic of technology in construction but was not a direct successor to this construction technology needs assessment. It covers studies on the characteristics and challenges of future construction projects, including a major roadmapping initiative, construction labor issues and the future development of the labor force, including its demographics and education, and studies on technology adoption and implementation processes. Summarizing the conclusions from these studies together with the information from Chapter 2 lays the foundation for Chapter 4.

Chapter 4: Driving Forces

This chapter discusses the main forces that drive the development and implementation of construction technology. These are owners (companies), construction contractors and other providers of service, construction labor, and the technology providers. Each of these parties contributes to the overall success of a technology by preferring it to alternative ways that exist in the marketplace. An innovative technology has to hold benefits that outweigh the resources that are expended by the respective party for the use of the technology.

Chapter 5: Research Methodology

This chapter describes the methodology that the research team used in undertaking the research. The individual phases of the work, including a thorough literature review, preparatory interviews, the questionnaire-based surveying of CII member organizations, construction crafts, and other CII teams, the subsequent data analysis and discussion, and the Technology Implementation Cycle that was developed are described further. The research team meetings with discussions of technology needs based on the team members' expertise throughout the duration of the research project provided further input into the knowledge gained on the subject.

Chapter 6: Membership Survey

This chapter describes the survey that was performed among CII member organizations to identify what technologies are needed from the companies' point of view. Along with the two following chapters and the preceding literature reviews, this chapter contains the data that was assembled for this study. The quantitative and non-quantitative results from the survey are summarized and discussed to provide the basis for Chapters 9 and 10, which are the core of this study.

Chapter 7: Craft Survey

Similarly to Chapter 6, this chapter describes the survey that was performed among construction craft superintendents, again with the intent of identifying what technologies are perceived as needed. Results from this survey also are summarized and discussed to provide for the following chapters.

Chapter 8: Research Team Survey

Finally, this chapter describes the survey of CII research teams to gain their professional expertise on which technologies are needed to enhance the performance in the construction industry, as mentioned in the introduction. The quantitative and non-quantitative results from the survey are also summarized and discussed, similar to the preceding chapters.

Chapter 9: Identified Technology Needs

This chapter, together with Chapter 10, is the core of this research report. While Chapter 10 focuses on the non-quantitative results of the research, developing the dissemination mechanism, this chapter contains the survey results with respect to identified current technology needs in the construction industry. It presents the identified needs in a clear structure and discusses each area briefly. The list of identified current technology needs is broken down further by areas, as developed for the preceding survey.

Chapter 10: The Technology Implementation Cycle

Once the construction technology needs in the current construction industry were identified as summarized in Chapter 9, it will be important to develop mechanisms for dissemination of these insights to developers and suppliers of technology as well as to its users. The construction industry should be supplied with a procedure for continuous improvement through technology. This chapter provides the schematic of the Technology Implementation Cycle that was developed by the researchers as a means of continuous improvement through technology for the construction industry, discusses how an integration of the aforementioned parties may be accomplished through its use, and addresses the topic of barriers to technological innovation.

Chapter 11: Conclusions

This chapter revisits the important findings on technology needs that were made in the previous chapters, gives an overview of the implementation of this knowledge in the construction industry's practice, as well as sketches the path that future studies may take.

The appendices to this report contain the questionnaires used for the surveys and the transcriptions of the results from the survey questionnaires.

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CHAPTER 2

2. PREVIOUS STUDIES

This chapter introduces previous major studies that assessed technology needs for the construction industry. Particularly noteworthy are the studies by The Business Roundtable (BRT), published in 1982, and the research done under the auspices of CII in 1992. For both studies the research approach, methodology, and results are summarized. In addition to this, the chapter also presents further literature related to construction technology needs. Together with Chapter 3, this forms the background information necessary for the understanding of Chapter 4.

2.1 Overview

Previous research has dealt with some needs assessments for construction technologies for selected areas of construction. This chapter therefore contains summary descriptions of these studies, including their motivation and background, scope of assessed technologies, research approach and methodology for data collection and analysis, and their findings. The studies were undertaken by The Business Roundtable (BRT) in 1982 as part of the Construction Industry Cost Effectiveness (CICE) Project and by CII researchers in 1992, who put the focus on automation in

construction. A summary with information on the Emerging Construction Technologies (ECT) Webpage is provided, which represents an initiative by CII to collect and disseminate information on available state-of-the-art construction technologies in a structured way.

It is important to distinguish the *needs* assessment from the technology *availability*. Defining a need is the beginning of any R&D and implementation process. On the contrary, collecting information on available technologies may give a good impression of the variety of know-how that exists in the industry, but some areas may be missed altogether or not sufficiently covered. Beginning with a structured needs assessment and developing technologies based on the findings from such a process ensures that R&D resources are used effectively and efficiently with respect to benefits in project cost, schedule, quality, and safety.

2.2 The Business Roundtable (1982)

The Business Roundtable (BRT) was founded in 1972 with the intent of improving public policies to achieve “sustainable, non-inflationary, long-term growth in the U.S. economy” and is composed “of the chief executive officers of leading U.S. corporations” [www.brtable.org]. Studies and publications on topics of fundamental economic importance, such as education, environmental issues, human resources, and corporate taxation are developed by the BRT through task forces. A widely known report by the BRT, “Construction Technology Needs and Priorities,” was published in 1982 as part of the Construction Industry Cost Effectiveness (CICE) Project. The reasons to conduct this research were the growing awareness of cost-effectiveness,

competitiveness, and the lack of information “about the needs and opportunities for better technology in construction” [BRT 1982b, p5]. The CICE Project had five so-called Study Areas: (A) Project Management, (B) Construction Technology, (C) Labor Effectiveness, (D) Labor Supply and Training, and (E) Regulations and Codes. It was undertaken to identify and describe the major problem areas in the construction industry and help develop solutions.

Prior to this, other studies had been conducted, e.g. by the Associated General Contractors of America in 1975, but suffered from lack of responses to surveys and limitations “in scope and depth” due to time constraints [BRT 1982b, p5]. The “Construction Technology Needs and Priorities” report has subsequently become the background for further studies, e.g. the CII research described in Section 2.3.

2.2.1 Scope of Assessed Technologies

The “Construction Technology Needs and Priorities” study dealt with 17 areas from construction such as earthwork, foundations, and structures from four main sectors of the industry (building construction, light and heavy industrial construction, and power plant) where problems were found to exist. Each of these problem areas was discussed in greater detail in the report, followed by a brief assessment of the potential economic benefit of innovation in the particular area.

2.2.2 Research Methodology

The study that was carried out by the BRT task force included a mail questionnaire survey and face-to-face interviews with construction professionals. The questionnaire was mailed to corporate level managers (from different divisions in large companies) of 53 companies, covering all four aforementioned sectors of the construction industry, of which 36 responded. In total, 128 questionnaires were returned. Questions in the questionnaire were drafted to collect information “on multi-disciplined projects complex enough to involve a variety of crafts and activities” [BRT 1982b, p5].

In particular, the survey questions dealt with project size and characteristics, the composition of the work force, and finally asked the participants to rank “15 separate indicators of inefficiency or construction difficulty on typical projects” on a scale from 1 to 10. Indicators “were chosen for conciseness, ease of understanding and brevity of response” and included ‘difficulty in estimating costs’, ‘sensitivity to problems in materials handling and distribution’, ‘required specialized tools and equipment for construction’, etc. Analyzing the questionnaire responses was done under the assumption that a high value of an indicator pointed at “significant opportunities for technological improvement” [BRT 1982b, p6-8]. An adjustment for the relative amount of activities in the projects was included by multiplying the indicator ratings by the percentage of total project cost of the respective activities.

The interviews were conducted “with 51 craft superintendents and field engineers from 14 job sites in the southwest, midwest and west, and in the mid-Atlantic states” [BRT 1982b, p6]. They

were supposed to identify construction activities that were considered inefficient based on their experience. During the course of the interviews, the participants were asked to rank the construction steps (tasks) “considering complexity, skills required, and dependence on technical information.” Finally, the participants “were asked to estimate the percentage of time required for each step” [BRT 1982b, p6].

2.2.3 Results and Recommendations

The following results were obtained through the BRT study [BRT 1982b]:

- 1) The craft work as well as the distribution of different cost items are highly dependent on the type and individual nature of the particular project. Building construction is particularly labor intensive for civil crafts, whereas heavy industrial construction and power plants have higher percentages in mechanical and electrical trades and overall higher costs.
- 2) Based on the differences found between the reviewed sectors of the Construction Industry, identified activities with “opportunity for technological research” [BRT 1982, pp10ff.] were listed accordingly (in the order of importance):
 - Building Construction
Structure, Enclosure Skin, Interior Finishes, Electrical Work

- Light Industrial Construction
Structure, Piping, Electrical Work
- Heavy Industrial Construction
Piping, Electrical Work, Mechanical Equipment Installation
- Power Plants
Piping, Mechanical Equipment Installation, Electrical Work

- 3) The three areas of piping, mechanical equipment installation, and electrical work were identified to have the most overall economic potential. The five areas of structure, vessels, instrumentation, special equipment installation, and heating-ventilation and air conditioning (HVAC) also were identified to have great potential for benefits from technological advances, according to the indicator values obtained.
- 4) For piping, the following tasks were considered improvable: Alignment of sections, connecting section, and lifting / erecting. For mechanical and special equipment installation, the following tasks were considered improvable: Alignment of elements, and leveling/accuracy. For electrical work, the following tasks were considered improvable: Raceway design and installation, testing, wire pulling, and terminations.

With respect to the potential economical impact of improvements in these areas, the study concluded that a project cost reduction by 2-3% would be possible if the costs for work in these areas could be reduced to the level of other areas. While savings estimates were admittedly approximate only, considerable opportunity to cut overall project costs was seen.

2.3 The Construction Industry Institute (1992)

Based on the initial research done by the BRT task force as described in the preceding section, CII initiated research on a needs assessment for construction automation. The outcome of this research work was described in CII's Source Document 56, "A Methodology for Identifying Automation Opportunities in Industrial Construction" and in CII's Publication 16-1 "Needs Assessment for Construction Automation" [ATS 1992].

2.3.1 Scope of Assessed Technologies

The research was comprised of two main phases, the *development of a methodology* for a needs assessment (see Section 2.3.2) and the *application of this methodology* to three areas that were considered to have potential for automation. These areas were (a) Structural Steel Erection, (b) Electrical Fabrication and Installation, and (c) Piping Fabrication and Erection and had been selected from a list of heavy industrial areas, which had been compiled under the aforementioned CICE Project.

Factors influencing the research focus on automation were the awareness of increasing shortages of skilled laborers in the marketplace, uncertainties in accurately predicting cost, schedule, and quality, the importance of construction safety, and finally the emerging technologies for automation [ATS 1992]. It has to be kept in mind that the research focused on the identification

of needs rather than determining the feasibility of automation and how exactly a task may be automated.

2.3.2 Research Methodology

Part of the methodology was the refinement of the existing breakdown structure of construction areas that were listed under the aforementioned CICE Project. In particular, the construction *areas* (as per the CICE Project list) such as Structural Steel Erection were broken down into general *activities*, e.g., Transport Steel, and these were further broken down into individual *tasks* of repetitive nature, e.g., Identify Member / Load / Transport. The tasks are defined as “readily recognizable component[s] of the activity” and “a task that consists of human physical motions” [ATS 1992]. Sequential tasks within this scheme could be grouped in cycles if applicable.

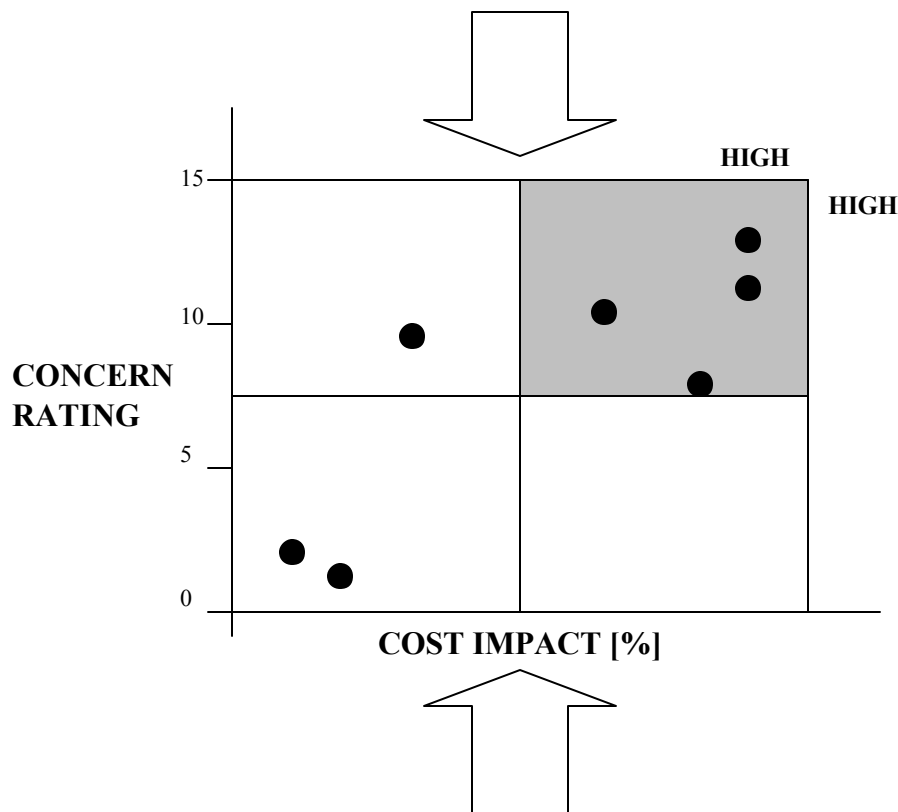
After having established the unit of analysis, the so-called cost impact of the tasks and their concern rating were compiled in tabular format.

Cost impact was defined as the potential savings through automation of a particular task. For this study, data from CII’s Publications 2-1 “Construction Industry Institute Model Plant” and 2-2 “Construction Industry Institute Model Plant Update” [PM 1986, PM 1988] were used to estimate labor percentage for the activities. The percentage of the tasks within the activities was

	Activity 1 % in Task	Activity 2 % in Task	...	Activity n % in Task	Total% Cost Impact
Model Plant Activity	10.00	1.00		5.00	
Task 1 Description	10	0		0	1.0
Task 2 Description	0	20		10	0.7
...					
Task m description	0	10		10	1.5
Idle Time	40	20		50	6.7

All Table Values in Percent

Cost Impact Table



Concern Rating Table

Tasks	# Concerns (out of 5)	# Concern Factors (out of 17)	Safety	Productivity	Quality	Worker Utilization	Superhuman Handling	Idleness Rating	Overall Concern Rating (1 to 15)
Task 1 Description	5	10	H	H	M	H	M	H	15
Task 2 Description	4	7	H	H	-	L	L	M	12
...									

H = High, M = Medium, L = Low

Figure 2.1 CII Study Cost-Concern Matrix [adapted from ATS 1992]

determined “from field productivity studies” [ATS 1992, p5]. Both percentages were multiplied to determine the cost impact for each task.

The *concern rating* was compiled in a spreadsheet format for each task. It included a judgmental rating (high / medium / low) of the severity of a series of concern factors, listed under the headings (a) safety, (b) productivity, (c) quality, (d) worker utilization, and (e) superhuman handling. Some concerns may not apply to certain tasks. A separate column in the spreadsheet was dedicated to a so-called idleness rating. All these pieces of information were combined in the concern rating value to sort the tasks by importance.

Finally, the cost impact and the concern rating were depicted diagrammatically in the *cost-concern-matrix* as shown in Figure 2.1, where each examined task is represented with one point. The higher the cost and/or the concern for a given task, the higher was the identified need for automation of this task. Tasks that fall into the top right sector – high cost impact and high concern rating – require special attention and should be addressed first.

Data for applying the methodology to the three aforementioned construction areas were collected by the researchers through field observations of piping, electrical, and in one case steel erection works on five industrial plant sites. For each of the three areas, a list of the common tasks was developed, the cost impact as well as the concern rating was derived and the results of were presented and discussed.

2.3.3 Results and Recommendations

The following results were obtained through the CII study [ATS 1992] for the three areas that were analyzed:

- 1) The following tasks were identified through their overall high ratings (in the order of importance):
 - Structural Steel Erection
Lift Operations, Align and Bolt Member, Position Member, Get Materials, Rig / Unrig Member
 - Electrical Fabrication / Installation
Measure / Configure / Align, Fabricate Materials, Assemble Materials
 - Piping Fabrication / Erection
Welding, Grind / File / Wirebrush, Align / Measure, Get and Position Materials
- 2) The research developed a practical methodology for comparisons of different works tasks with a common objective measure and ranking of such tasks by priority of improvement needed.
- 3) Further research should include possibilities to evaluate technologies by comparing and rating different technological solution for the same task and should also cover other areas of the construction industry to achieve “development of those devices which demonstrate

the most favorable balance among user need, technical feasibility and range of application” [ATS 1992, p25].

Generally, the researchers cautioned that the results were only intended to be exemplary for the application of the methodology and were not viewed as being representative of the actual technology needs of the construction industry as a whole, nor were they validated with statistical methods.

2.4 Other Studies

While the previously presented studies had been needs assessments, other research initiatives were carried out with different approaches and emphasis as described in the following sections.

2.4.1 Emerging Construction Technologies

Based on research done previously by CII researchers, such as the Technology Study (1990) and the research described in Section 2.3, an initiative was started to assemble and make accessible more practical information on state-of-the-art technologies in the construction industry. The “Emerging Construction Technologies (ECT) Webpage” that was developed under Research Teams 120 and 120a of CII and is administered by the Division of Construction Engineering and Management at Purdue University is the outcome of this research and can be found under:

The ECT Webpage contains so-called Fact Sheets on individual technologies, as well as links to websites of technology suppliers, other sources of literature, and related conferences. Each Fact Sheet contains information on the particular need, the technology, benefits, current status, barriers, contact information, and references. They are grouped under the following headings (not all of which had been used at the time of writing this report):

- Civil:

Building Systems; Composite Materials and Technologies; Concrete Technologies; Construction Equipment and Methods; Demolition; Foundations; Masonry Technologies; Roofing Technologies; Steel Technologies; Structural Connection Technologies; Trenchless Technologies

- Mechanical:

Air Distribution; Basic Mechanical Materials; Building Services, Process, and Fire Protection Piping; Conveying Systems; Heat Generation Equipment; Heating, Ventilating, and Air Conditioning Equipment and Controls; Industrial Equipment; Internal Pipeline Assessment Technologies; Pipe Technologies; Plumbing Fixtures and Equipment; Refrigeration Equipment; Testing, Adjusting, and Balancing; Welding Technologies

- Internet-Based:

e-Marketplace; Information Services; Web-Based Learning Systems; Web-Based Project Management; Web-Enabled Engineering Software

- Electrical:

Basic Electrical Materials and Methods; Communication; Electrical Power; Lighting; Low-Voltage Distribution; Sound and Video; Transmission and Distribution; Wiring Methods

- Other:

Communication; Engineering Software; Equipment Automation; Non-Destructive Evaluation; Remediation; Robotics; Site Positioning and Metrology; Soil Remediation; Water/Waste Systems

In performing the ECT research, an extensive literature review was carried out, including “professional and trade literature, data from the previous studies... and such award competitions as the NOVA award given for outstanding technical developments.” Based on this, experts in the aforementioned areas were interviewed to identify newly arising technologies with potential for beneficial use in the construction industry [www.new-technologies.org/ECT]. Similar to the research thrust chosen for the study described in this report, the ECT researchers decided to “concentrate on technologies related to physical systems” such as “materials, machines, and processes” and include Information Technology (IT) and data manipulation technologies only to the extent that they are related to hardware devices [www.new-technologies.org/ECT].

Using an Internet-based archive was found to be an ideal way of providing concurrent information on a wide range of technological developments. The website assembles the information in a standardized format for free access by construction companies and thus takes on the function of a clearinghouse for state-of-the-art technologies. Regular updates and additions ensure that the information presented is current and make the ECT Webpage a “dynamic and evolving” archive. Technology developers and academia are encouraged to submit information on their new or improved technologies for review and acceptance as an ECT as per certain criteria, including practical use by at least one “Technology Advocate” as a reference for validation of the technology’s usefulness.

2.4.2 Emerging Concrete and Steel Technologies

Another research project initiated by CII in 1992 dealt with how information on emerging technologies for concrete and steel construction could be collected and shared, as these two fields were seen as being disadvantaged with respect to being informed on state-of-the-art technologies. It examined different methodologies with respect to how efficiently and effectively they made such information accessible [Johnston et al. 1992]. Among the methodologies were the classic survey instruments of mail questionnaire, telephone interviews, personal interviews, and the literature review. While all survey instruments generally were found useful, “distinctive characteristics of each make individual methods beneficial for specific stages of the process of accumulating this data” only [Johnston et al. 1992, p56], e.g. using mail questionnaires for an

initial overview, telephone interviews to follow up afterwards, and the literature review for more in-depth information.

The about 180 technologies that were identified through using the survey instruments were in various stages of R&D and were not necessarily already marketable. Technologies that improved construction processes as a whole were relatively scarce. Reference was made to the Advanced Construction Technology (ACTS) electronic database, into which the information collected through the research was entered. Later research funded by CII, however, developed a more feasible database in form of the Emerging Construction Technologies (ECT) Webpage that was described in Section 2.4.1. Overall, it was found that “there is a need for improved means of identifying both new and existing technologies which either may, or are known to be, beneficial to the construction industry” [Johnston et al. 1992, p55].

2.4.3 Emerging Electrical and Instrumentation Technologies

Parallel to the research described in Section 2.4.2, another CII research project dealt with emerging technologies for electrical and instrumentation work. This research took an approach similar to the research on concrete and steel technologies, as it also used the mail questionnaire, telephone interviews, personal interviews, and the literature review, adding site visits to the instruments used. The research results were again recorded in the ACTS database for access by CII member organizations [Chang and DeVoe 1992].

A large variety of technologies were identified to carry potential benefits if implemented in the construction industry. Discussions on software development, optics and opto-electronics, infrared technology, radio frequency, robotics, artificial intelligence and neural systems, virtual reality, “hypermedia” (like the possibilities offered by the Internet), and conducting and other materials show the wide range of possibilities for use of electrical and instrumentation technologies in construction. The researchers concluded that survey instruments should be used under consideration of their particular strengths with telephone interview and mail questionnaires being geared toward a larger surveyed group, while personal interviews and site visits require more effort. It was considered essential that regular updates to the collected information in the database would be performed, as technology is developing rapidly and information may soon be outdated. The database itself would have to be restructured and “be less product- or material-oriented and be more accommodating for methods and procedures” [Chang and DeVoe 1992, p89]. Further research should not be limited to the U.S. only, but should be performed on an International scale. Trends that were identified were “efficiency, both in installation and operation. This is being accomplished through integration, modularization, miniaturization, standardization, automation, and innovation” [Chang and DeVoe 1992, piii].

2.4.4 Classification System for Construction Technologies

The construction industry is composed of several main branches, each with its respective trades that perform a variety of different tasks. Technologies that support one or more of these tasks are usually developed relatively independently from each other. Trying to come up with a system

that classifies the different technologies by various parameters contributes to the effort of defining needs in a clear and structured way. Initial research has been done to develop such a system, which will be briefly described in the following paragraphs.

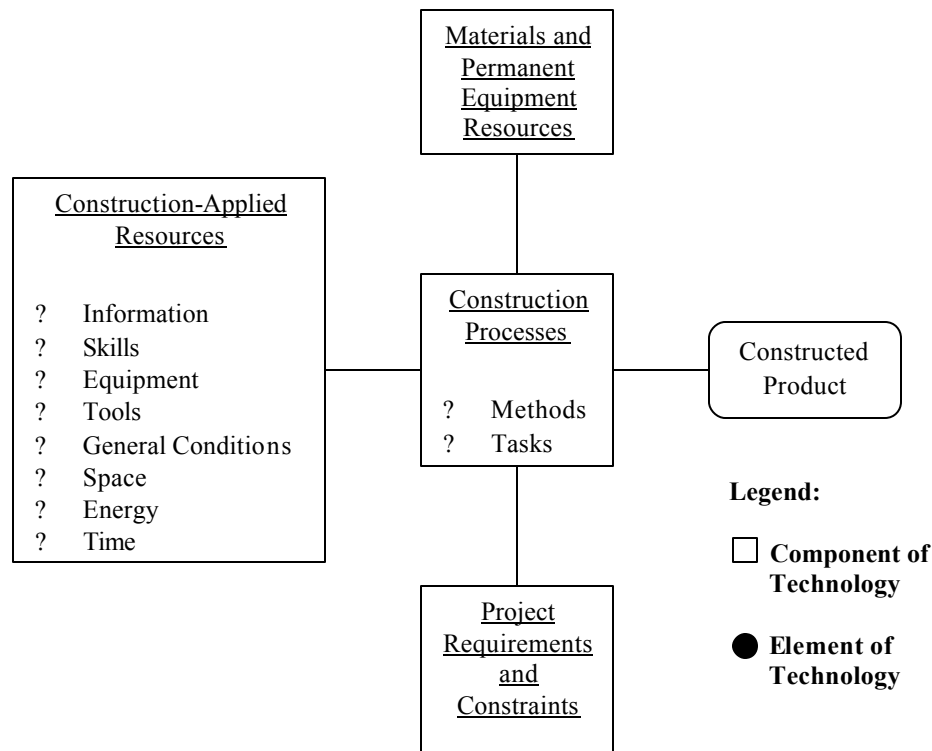


Figure 2.2 Classification System for Construction Technologies [taken from Tatum 1988]

The classification system that was developed has four levels [Tatum 1988]:

- Components: Construction-applied resources, materials and permanent equipment resources (that become part of the finished constructed facility), project requirements and constraints, and construction processes

- Elements: Resources, e.g. information, skills, equipment, tools, general conditions, space, energy, time, methods, tasks
- Attributes: Define each of the elements, characteristics
- Values: For each of the attributes, e.g. rating on a scale, defining class or type, or further description of the element

With this classification system and its indicators, a helpful tool has been created to measure developments in technology and identify areas of potential improvements.

2.5 Summary

In summary, this chapter has presented background information necessary for understanding of Chapter 4, which discusses driving forces for the development and implementation of technology in the construction industry.

Previous needs assessment have been conducted, which focused on selected areas of construction. These needs assessments concentrated on physical systems rather than on IT, as does this study. In particular, a methodology was developed and successfully implemented that allows rating of technology needs in an objective way. Related issues, such as the future development of construction labor were mentioned briefly.

Other studies have dealt with available technologies, as opposed to needs and assembled information on emerging technologies. A system was developed how technologies can be structured in a meaningful way. This structured framework in conjunction with the described methodology to rate needs contributes to the research described in this report.

CHAPTER 3

3. OTHER LITERATURE

This chapter presents research on technology in construction that goes beyond the technology needs assessments that were presented in Chapter 2. Apart from the anticipated features of construction projects of the future, the selected studies deal with forecasts for the skills and availability of the construction work force, as well as with considerations for adoption of new technologies. Studies included in this chapter such as the CII document “Vision 2020,” published in 1999, the FIATECH “Workshop Report and Draft Roadmap” from 2001, and Publications “Projects and Competition of the Future” and “A Strategy to Improve the Construction Industry Through Technology” from 1992 and 1995, respectively, add to the background necessary for the discussion in Chapter 4.

3.1 Overview

When dealing with construction technology needs it has to be kept in mind that this topic relates to several other topics as well; it has to be seen in the framework of factors that influence the particular need for a new construction technology. This chapter provides the necessary background information to gain a better understanding of what those factors are and how they

impact technology needs. Information is assembled from a wider range of CII studies that dealt with future challenges to the construction industry in the widest sense – from “Projects and Competition of the Future,” published in 1992 and “A Strategy to Improve the Construction Industry Through Technology,” published in 1995 to “Vision 2020,” published in 1999.

Other reviewed studies dealt with more specific topics such as High Performance Project Teams in a 1999 study and, particularly important, “Characteristics of the Construction Craft Work Force” in 1992. In assembling knowledge about the projected development trends for construction technology as well as information on the current and future situation of the construction work force – ultimately the users of technology, this chapter in conjunction with Chapter 2 lays the groundwork for understanding Chapter 4.

3.2 Publications Relating to Technology and Its Future Development

The following sections extract key findings from previous CII studies that dealt with technology and its future development in the construction industry.

3.2.1 Projects and Competition of the Future

In 1992, CII set up the Construction 2000 Task Force to perform research on future trends in the construction industry. A wide range of issues was included in the discussion of driving forces on

future projects, including challenges and opportunities of the global marketplace, technological developments in construction and facility operations, and modern project management approaches. Ecological and economical factors were also considered from a sustainability viewpoint. Overall, increasing competitiveness of construction firms and a growing need for innovation can be expected in the global market, which requires flexible solutions that are cost-effective, reduce schedule duration, and guarantee a high quality of the constructed facilities [C2K 1992]. It can be expected that an increasing number of projects dealing with maintenance, rehabilitation, or retrofit will be undertaken as compared with projects of newly built structures.

The report of the task force outlined trends such as the increasing use of advanced IT and the rapidly increasing computer power for design and for project control, furthermore prefabrication, modularization, and automation to facilitate field operations, and advanced materials with customized properties regarding strength, durability, and flexibility in use. With respect to the construction work force the study anticipated a growing need for education and training of personnel due to expected “[s]ignificant resource constraints, such as engineers, skilled craft, and perhaps critical permanent equipment and materials of construction” [C2K 1992, pv] and “[f]ewer engineers and crafts [causing] increased demand for multi-skills” [C2K 1992, p9].

Amongst the actions that were recommended are to “[d]evelop human resources including generalist managers, technical professionals, and skilled crafts... improving the capabilities and effectiveness of the work force, and increase the effective use of new technology... involve all employees by using participative management style” [C2K 1992, p3] as well as an “[i]mproved safety and working environment” [C2K 1992, p8]. Examining and transferring technologies from

other industries such as manufacturing was seen to be carrying great potential benefit for the construction industry.

Finally, another area that was addressed was employees' benefits (including health care) and how they contribute to acquisition and long-term retention of craftspeople, possible initiatives to improve the public image of construction (including career opportunities, safety, the work environment, and support of minorities and women), and improved cooperation between union and nonunion workers.

3.2.2 Vision 2020

In 1999, the CII Strategic Planning Committee developed ideas on the future construction industry, considering the changing global marketplace and project requirements, technological advancements that impact project design and construction, and the development of the construction work force. These concerns were captured in the CII document, "Vision 2020." Its intent was to contribute to a paradigm shift in the construction industry through putting forth innovative ideas and trends.

Of particular interest for the research described in this report are the notions on technological development and on the work force. With respect to technology, the document states that IT and simulation are anticipated to develop towards a fully integrated virtual reality design, construction supervision and equipment automation, and operation of constructed facilities.

Advanced materials with customized properties will allow for even more economic structures with longer service lives, while being able to be reused or recycled [CII 1999].

With respect to the future of the construction work force, “Vision 2020” noted that while the teams working on individual projects may become smaller and less mobile in the future, also due to more automation, they would have to be trained well to become more multi-skilled, like high-performance work teams that are described in Section 3.3.2. “Projects will use a smaller but more broadly competent work force. Craft labor availability will become more critical, and minimizing craft labor content of a project will drive design” [CII 1999, p8]. The skill level and the availability of the work force were clearly seen as key issues for the future of the construction industry.

3.2.3 A Strategy to Improve the Construction Industry Through Technology

CII set up the Technology Strategy Task Force in 1992, which undertook two research projects and surveyed industry parties through interviews. One research project focused on the potential of technology for construction means and methods, which was seen as particularly promising for improving overall project performance. It was found that while a considerable percentage of costs of typical construction projects is caused by labor, limited research funds are dedicated to improving labor productivity [TS 1995].

The second research project focused on the decisionmaking processes of corporate managers who evaluate the potential benefits of a new technology, decide whether it should be adopted or not, describe factors that influence this assessment, and examine barriers to technology adoption. The collected information indicated that incentives for the use of innovative technology by owners contribute to its adoption by contractors and suppliers. Showing measurable benefits of technology versus its costs is important in convincing potential users to implement a technology. In summary, four major interrelated items emerged that are discussed below, including more specific ‘action items’ for all parties in the construction industry [TS 1995]:

- Change Industry Paradigms by Mobilizing Executives:

Owners are important facilitators of introduction of new technologies since it is they who initiate projects and who have influence on the way the design and construction process is executed. They have the power to set requirements demanding the use of specific technology and can give additional incentives. “If the technology issue is to move to the forefront of project decision making, executive involvement and stewardship are critical components. The strongest driver for new technology is for owners to demand its use, and make “track record” and “innovation potential” major factors when hiring designers, construction managers, general contractors, and trade contractors for projects” [TS 1995, p9]. Apart from owners, managers also have a strong influence on the technology development and adoption process and should become more proactive to help tearing down traditional barriers to innovation.