

CONSTRUCTABILITY



IMPLEMENTATION GUIDE

Second Edition

Constructability Implementation Guide

This edition was prepared by

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under the sponsorship of the Construction Industry Institute
Knowledge Management Committee

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Preface to the Second Edition

This second edition is part of the CII Knowledge Management Committee mission to review and update CII research topics. In conformance with the committee's guidelines, enhancements to the original edition have been incorporated, including the following:

- References to the CII web page (<http://www.construction-institute.org/>) have been added throughout to insure that the reader always has access to the latest CII publications.
- The latest data available from CII on project performance through implementation of constructability principles have been provided.
- Material duplicated elsewhere has been omitted and reference has been made to the original source to insure that the most current data are available to the reader.
- References to specific document pages have been omitted to avoid confusion when accessing documents that may have been revised as part of our ongoing efforts to keep all references current.
- The original publication was updated to reflect user feedback relative to readability, presentation, and relevance of material presented. The format now presents the material in a logical and easy-to-follow sequence. Special attention has been given to refocusing Part II, "Roadmap Milestones to Implement a Project Level Constructability Program" and Part III, "Constructability Implementation Tools."
- The original case studies have been replaced with recent robust case studies that reflect in-depth application of constructability principles and significant project benefits.

Reader comments are welcome. Please contact CII at CIIProductFeedback@austin.utexas.edu.

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December 2006

Executive Summary

As demonstrated in the case studies summarized in this publication, when methodically implemented, front-end constructability efforts are an investment that results in a substantial return. Previous CII documentation of constructability efforts showed that owners accrued an average reduction in total project cost and schedule of 4.3 percent and 7.5 percent, respectively. These savings represented a 10 to 1 return on the owner's investment in the constructability effort. Recent CII Benchmarking studies based on project performance reported by contractors indicate that Constructability Implementation is second only to Materials Management in positively impacting project schedules and behind only Change Management and Zero Accident Techniques in positively impacting project cost.

Yet, the need for tools to facilitate constructability implementation continues to exist. This *Constructability Implementation Guide* meets this need by offering a complete set of 17 tools that address both corporate- and project-level constructability programs. For example, Tool 1, the *Constructability Implementation Roadmap*, presents a comprehensive-integrated approach to constructability. Tools containing assessment forms are provided to identify and eliminate barriers in constructability. A procedure for the periodic assessment of program effectiveness is also provided and is helpful in maintaining a commitment to the program and ensuring continuous improvement. The 16 constructability concepts are also summarized in a tool.

The updated *Guide* continues to offer comprehensive guidance and specific insights into how project constructability can be implemented. It is targeted to owners, designers, and construction personnel, with particular emphasis on the owner. Senior executives and entry-level project personnel, and project managers in particular, can benefit from the tools provided in the *Guide*.

Introduction

Who should read this publication? Anyone interested in delivering a higher-quality project for less money and in a shorter time should become familiar with this document. The target audience is quite broad, including owner, designer, and constructor personnel (with particular emphasis on the owner). Virtually everyone from senior executives to entry-level project personnel (project managers in particular) can benefit from this updated publication. Those unfamiliar with the fundamentals of constructability are encouraged to read CII Publication 3-1, *Constructability: A Primer*, prior to undertaking this document.

Why should you read this? Most knowledgeable and effective project managers agree that constructability is key to overall project success. This document offers comprehensive guidance and specific insights into how project constructability can be achieved.

How is this guide structured? The *Guide* is structured in four parts: Part I – A Corporate-Level Constructability Program; Part II – A Project-Level Constructability Program; Part III – Constructability Implementation Tools; and Part IV – Case Studies.

Part I is organized around the Constructability Implementation Roadmap, which is presented as the recommended comprehensive approach to implementing constructability. Accordingly, the information presented in Parts I and II follows the milestones outlined in the roadmap:

- Commit to implementing constructability.
- Establish corporate constructability program.
- Obtain constructability capabilities.
- Plan constructability implementation.
- Implement constructability.
- Update corporate program.

Part III includes 17 different tools for use in implementing a constructability program. These address the roadmap and terminology, program evaluation and assessment, program documentation, and application of constructability concepts.

Part IV describes two recent case studies that demonstrate highly successful constructability initiatives.

Appendix A contains a listing of references.

Appendices B and C contain Constructability Concept Application Matrices that can be used to facilitate constructability implementation.

Constructability: A Mechanism for Success

CII defines constructability as “the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives.”

Why pursue constructability? Constructability efforts can support all project objectives: reduced cost, shortened schedules, improved quality, security, and safety, and enhanced management of risk. In addition, constructability is often viewed as an essential element to any Continuous Improvement Program. Certainly constructability fits well within the context of the other three project “abilities”:

- Maintainability
- Operability
- Reliability

Constructability usually requires that companies, particularly owners, go beyond conventional approaches to project execution by expanding front-end planning and investing additional effort in order to anticipate potential problems. In fact, the full benefits of constructability require a proactive approach, which is generally owner-driven.

Constructability, Payback, and CII Project Performance Benchmarking

Early constructability efforts result in a payback, but how large of a payback is possible? Previous CII research cited cost reductions of between 6 and 23 percent, benefit/cost ratios of up to 10 to 1, and significant schedule reductions. One of the case studies presented in this *Guide* cites total installed project cost savings of 9 percent with a benefit/cost ratio of 13 to 1, and an on-time schedule performance given an extremely aggressive schedule. These benefits establish a significant motive for pursuing constructability.

For many years CII has conducted an aggressive project performance benchmarking program for the purpose of better understanding 1) how the industry is performing, 2) to what extent the industry is advancing, and 3) what factors – or best practices – are having the greatest influence on project performance. Constructability implementation has been one of the practices that have been tracked in CII’s Benchmarking program.

CII’s February 2003 Benchmarking report (BMM2003-4, *Benchmarking and Metrics Value of Best Practices Report*) states that, from the contractors’ perspective for both all sectors and the heavy industrial sector of the industry, Constructability implementation ranks *second* in *schedule reduction* impact, trailing only the Materials Management best practice. Thus, project managers should aggressively implement Constructability on schedule-driven and schedule-critical projects.

For the same groups of all-sector and heavy industrial sector contractors, Constructability implementation ranks *third* in *cost savings* impact, trailing only the Project Change Management and Zero Accident Techniques best practices. The message is clear: if cost performance success is an objective, don’t neglect constructability.

The CII Best Practice impact ranking findings are summarized in the table below:

Table 1.1. Highest Ranking CII Best Practices for Project Cost and Schedule Impact

Impact Type	Project Cost Impact		Project Schedule Impact	
Industry Group	Contractors: All Sectors	Contractors: Heavy Industrial	Contractors: All Sectors	Contractors: Heavy Industrial
Practice Ranking				
1	Project Change Management	Project Change Management	Materials Management	Materials Management
2	Zero Accident Technique	Zero Accident Technique	Constructability Implementation	Constructability Implementation
3	Constructability Implementation	Constructability Implementation	Team Building	Project Change Management
4	Team Building	Team Building	Project Change Management	Team Building

While these benchmarking findings pertain most directly to Contractors, Owners should also heed their guidance, for when Contractors succeed in project cost and schedule performance, so do Owners.

In fact, it is even more important that Owners press for effective constructability efforts, since many contractors are accustomed to focusing on Owners' stated priorities, and may be less informed on the positive impacts that Constructability Implementation can deliver. Thus, both Owners and Contractors need to be well informed on the importance of effective Constructability Implementation.

Constructability vs. Value Engineering

How does constructability differ from value engineering (VE)? Constructability and VE can be similar in effect, but differ in both scope and manner of analysis. VE tends to focus on functional analysis and life-cycle costs, while constructability is achieved by fully exploiting construction experience in a timely and structured fashion. Certainly the two thrusts can coexist and even complement one another.

A Word of Caution: some owners who have ongoing VE programs believe that constructability automatically results from that effort. This is unlikely if discussions and developments do not involve current construction expertise early in the evolution of a project.

CII Constructability-Related Products

CII research teams conducted focused studies on the topic of constructability in both the mid-1980s and the early 1990s. In addition, some more recent CII research teams conducted studies on subjects closely related to constructability or aspects of constructability. Such studies are available online from the CII website: <http://construction-institute.org/know.htm>. Readers are particularly encouraged to review CII Knowledge Areas 1. Front-End Planning and 2. Design.

Constructability Implementation Roadmap

The Constructability Implementation Roadmap, shown in Figure 1.0, has been developed to provide guidance in the planning, development, and implementation of both corporate and project constructability programs. It is around the roadmap that this entire *Guide* is structured.

The Constructability Implementation Roadmap provides an overview of the constructability process by emphasizing six milestones:

- Commit to Implementing Constructability.
- Establish Corporate Constructability Program.
- Obtain Constructability Capabilities.
- Plan Constructability Implementation.
- Implement Constructability.
- Update Corporate Program.

The roadmap is intended to be useful for owners, designers, and contractors. It addresses both corporate constructability programs and project constructability programs. Each of the six milestones is discussed in great detail in separate chapters.

As the roadmap depicts, a company ideally will establish both corporate and project constructability programs. In the early stages of a constructability effort, focus should be placed on those actions listed above the “Commit to Implementing Constructability” milestone in Figure 1.0. Some companies may prefer to initiate constructability efforts with a pilot project and follow up with the development of organizational supports. Such organizations will begin the process by focusing on the actions above the “Obtain Constructability Capabilities” milestone. One should not ignore, however, the requirements for commitment to constructability implementation when beginning at the project level.

Additional Tools Presented in this Document

Constructability program tools are presented in Part III of this *Guide* and include the following items:

- **Tool 2: Summary of Constructability Concepts:** A listing and description of all 16 constructability concepts.
- **Tool 3: Glossary of Terms**
- **Tools 4 and 5: Constructability Program Evaluation Matrices:** A checklist of constructability program parameters useful for evaluating program strengths and weaknesses.
- **Tools 6 through 9: Constructability Barriers Assessment Checklists:** Checklists of commonly found barriers to constructability; useful for identifying barriers.
- **Tool 10: Constructability Barrier Breakers:** A listing of “breakers” useful in combating constructability barriers.

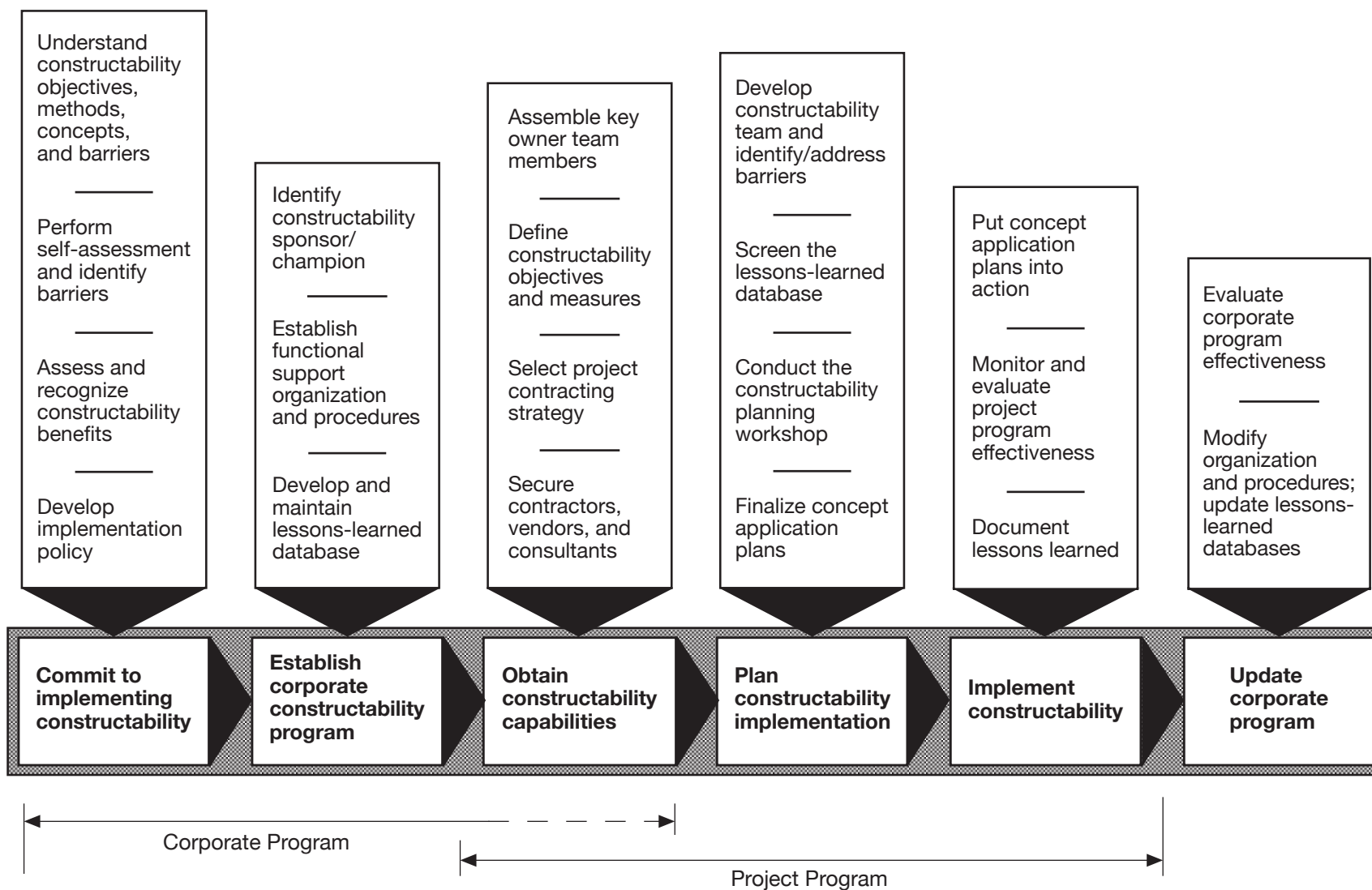


Figure 1.0. Constructability Implementation Roadmap (Tool 1)

- **Tool 11: Program Implementation Policy:** A sample statement communicating management's commitment to project constructability.
- **Tool 12: Constructability Organizational Structure:** A diagram illustrating key constructability positions within both the corporate and project constructability programs.
- **Tool 13: Constructability Planning Workshop Agenda:** A sample agenda for a project team-based workshop for form for soliciting and documenting constructability ideas.
- **Tool 14: Concept Application Plan:** A sample producible for a Constructability Planning Workshop that lays out how a targeted, high-priority concept will be applied or implemented in subsequent efforts.
- **Tool 15: Constructability Suggestion Form:** A form for soliciting and documenting constructability ideas.
- **Tool 16: Constructability Idea Log:** A form for tabulating constructability ideas, their evaluation, and implementation status.
- **Tool 17: Constructability Contract Clauses:** A listing of sample contract clauses useful in acquiring constructability services.

PART I: ROADMAP MILESTONES TO IMPLEMENT A CORPORATE-LEVEL CONSTRUCTABILITY PROGRAM

As stated in the Introduction, it is generally preferred (though not required) to establish a solid corporate constructability program prior to initiating a project-level program. This approach ensures that all supports are in place when needed. The existence of a formal strategy with a constructability “champion” provides the best environment in which a program can flourish.

As the Constructability Implementation Roadmap illustrates, two milestones are involved in developing the corporate program, as shown in Figure 1.1:

- Commit to implementing constructability.
- Establish constructability program.

Each of these is discussed in detail in the following sections.

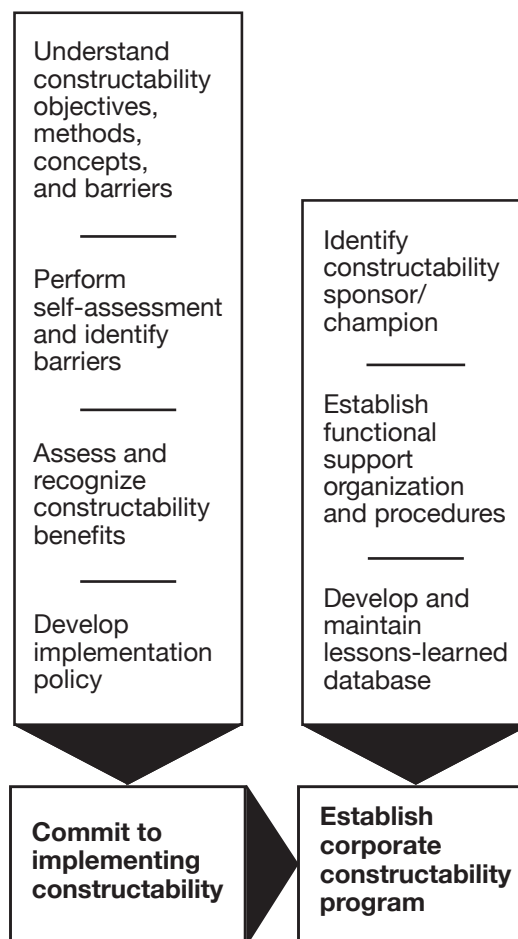


Figure 1.1. Milestones for Corporate Constructability Program Implementation

Roadmap Milestone 1: Commit to Implementing Constructability

The first activity in constructability implementation is to *commit to implementing constructability*. This step is critical to sustaining a successful program. Without a well-developed, widespread, comprehensive commitment to constructability in the organization, implementation efforts will not be effective. The steps involved are shown in Figure 1.2 and are described below.

Step 1: Understand Constructability Objectives, Concepts, and Barriers

To solidify organizational commitment to constructability, personnel at all levels in the company should acquire in-depth familiarization with the objectives, methods, and concepts of constructability. These efforts should define the long-term expectations of the program. Initial efforts should focus on senior management in order to secure high-level understanding and corporate commitment. Company-wide seminars and training courses can then be tailored to spread awareness throughout the company. Periodic refresher courses for all personnel must be part of any ongoing program so that new employees and new projects are included in the constructability program. Awareness and education efforts must cover the following:

- Clear, well-defined organizational goals for the constructability program
- Primary constructability methods that promote discussions on relevant constructability concerns
- Introduction of the constructability concepts and use of Concept Application Plans
- Explanation of the benefits of comprehensive constructability efforts
- Distinction between constructability and traditional procedures (or value engineering)
- Awareness of the differences between corporate and project efforts
- Discussion of the barriers and problems that may be encountered
- Distribution of this *Guide* and other related CII documents.

Constructability is a continuous improvement process. Activities, efforts, and results are continuously evaluated, updated, and improved. The process includes self-assessment, benchmarking against industry standards, barriers identification, goal setting, and progress measurement.

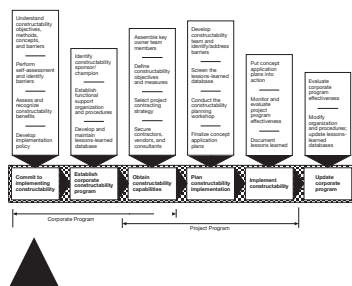
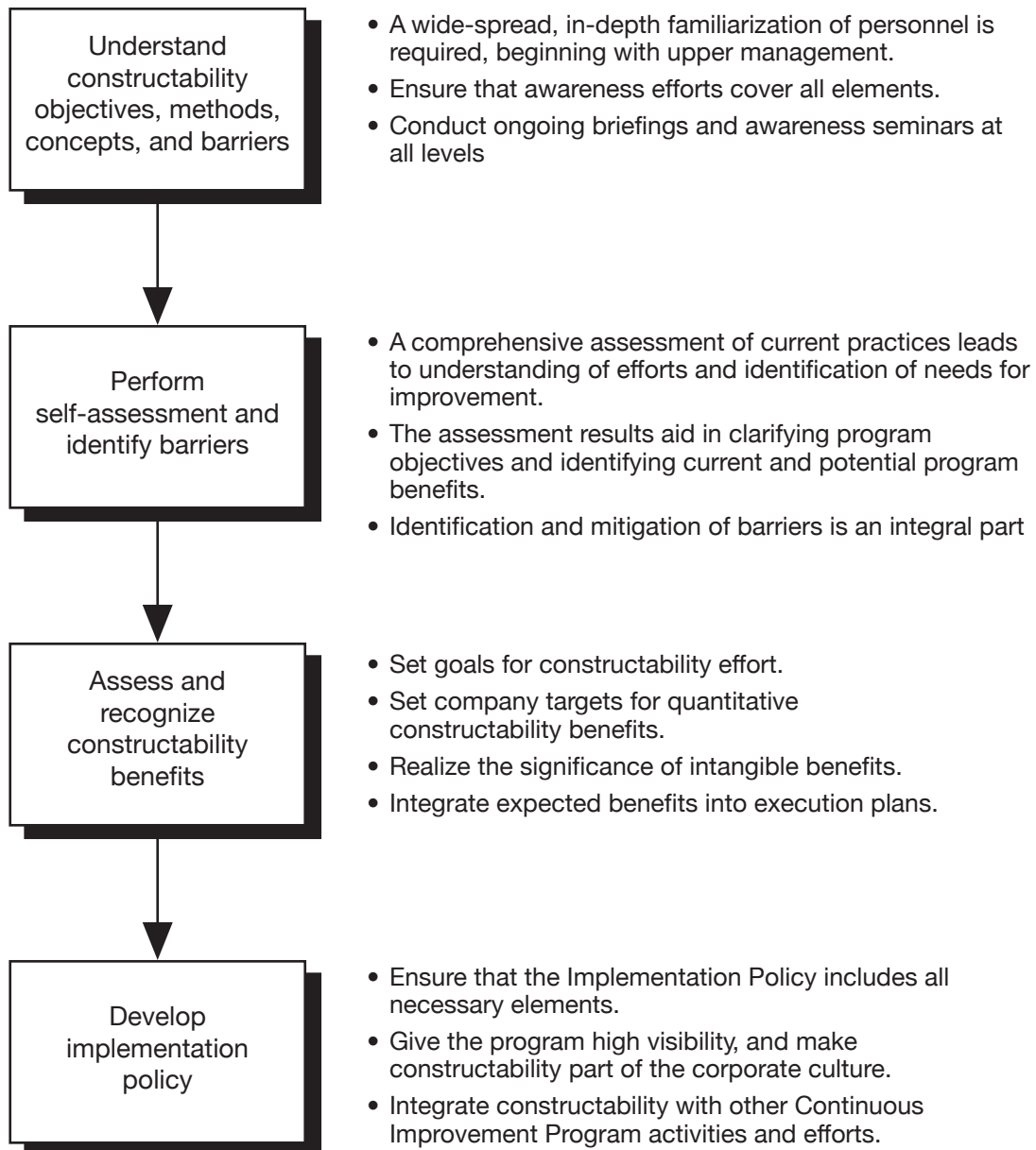


Figure 1.2. Steps to Commit to Implementing Constructability

Step 2: Perform Self-Assessment and Identify Barriers

An assessment of current in-house constructability capabilities and practices should be conducted. This assessment determines the organization's level of current practices and identifies specific needs for improvement. The results of self-assessment procedures are invaluable for:

- Clarifying constructability program objectives.
- Identifying current and future program benefits.
- Defining areas for program improvement.
- Benchmarking current status for future reference.

When performed on a periodic basis, self-assessment provides a vital link with program benchmarking, goal setting, progress measurement, and barrier identification, all of which are bases for continuous improvement.

Approach to Self-Assessment. The goals of constructability self-assessment are to measure the scope of program elements (“inputs”) and their effectiveness using performance parameters (“outputs”). Figure 1.3 shows these constructability inputs and outputs.

“Inputs” encompass all implementation activities at both the corporate and project levels. These efforts include items such as program designation, program documentation, use of constructability concepts and lessons learned, presence of barriers and so on. Some of these input items are directly tied to specific output measures, such as tracking constructability effects. This demonstrates how ongoing feedback and assessment is integral to the constructability process.

“Outputs” offer both quantitative and qualitative measures regarding program performance (i.e., effectiveness of inputs). Most quantitative output parameters assess project-level factors; trending of these items across projects occurs on the corporate level to help track overall program effectiveness.

Constructability Program Inputs	Constructability Program Outputs
Corporate Inputs: • Corporate recognition/designation of the constructability program • Corporate commitment to constructability expressed in a written, widely-distributed policy statement • Management support of constructability efforts/activities • Corporate recognition of the barriers to constructability implementation and identification of barrier breakers • Constructability training of personnel • Designation of an executive sponsor/champion for constructability • Corporate personnel assigned to constructability efforts • Level of constructability program documentation • Corporate efforts to capture and communicate constructability lessons learned • Corporate efforts to promote awareness and implementation of advanced construction technologies • Reference to constructability in contract documents • Corporate efforts to track savings/effects of constructability efforts	Project Outputs: • Number of constructability ideas/suggestions collected, implemented, or added to lessons-learned database • Level of constructability participation from project personnel • Project savings from constructability efforts: – Monetary savings – Schedule savings – Labor reductions • Improved performance due to constructability efforts: – Qualitative assessments of site layout effectiveness – Qualitative assessments of procurement/materials planning – Qualitative assessments of relationships between parties – Reduction of errors/rework – Reduction of change orders – Reduction of claims – Higher quality of finished product • Problems that could have been prevented with proper constructability implementation: – Unrealistic budgets or schedules – Contracting or subcontracting difficulties – Double handling of material or equipment – Specification problems – Delays – Rigging or access problems – Tolerance problems – Problems with physical interferences – Avoidable weather-related problems – Not meeting client expectations • Constructability barriers/resistance encountered – Number/severity of barriers identified – Effectiveness of barrier breakers – Number of barriers broken
Project Inputs: • Project-level recognition/designation of the constructability program • Project-level recognition of the barriers to constructability implementation and identification of barrier breakers • Constructability training of personnel • Project personnel assigned to constructability efforts • Level of constructability program documentation • Project efforts to capture and communicate constructability lessons learned • Reference to constructability in contract documents • Project efforts to track savings/effects of constructability efforts • Nature of project-level efforts and inputs (proactive or reactive) • Implementation of constructability concepts	

Figure 1.3. Constructability Program Inputs and Outputs

Fifteen significant corporate and project parameters for a constructability program are shown in Figure 1.4. These 15 inputs are divided into four major classifications:

- **Corporate Culture:**

- High-level recognition and official designation of constructability efforts
- Existence of a highly visible, widespread, written policy stating the organization's commitment to constructability
- Management awareness of and support for constructability
- Presence of, recognition of, and efforts to overcome barriers and problems inhibiting constructability
- Periodic corporate and project training of personnel to understand and implement constructability

- **Personnel:**

- Designation of and support from an executive sponsor for constructability
- Existence of an effective corporate constructability support organization
- Constructability roles and responsibilities on particular projects

- **Documentation and Tracking:**

- Documentation of constructability procedures and efforts on the corporate and project levels
- Efforts to capture and communicate constructability lessons learned
- Use (and dissemination) of knowledge about advanced construction technologies
- Reference to constructability in contract documents
- Efforts to track the savings or other effects of constructability efforts

- **Implementation:**

- The nature of project-level implementation efforts and constructability inputs
- Project implementation of the CII constructability concepts.

Parameter: C=Corporate P=Project		Program Classification:				
		1 No Program	2 Application of Selected Supports	3 Informal Program	4 Formal Program	5 Comprehensive Formal Program
I: Corporate Culture	A. Program Designation (C/P)	No designation ☐	Part of standard construction management activities ☐	Part of another program, such as Quality, or only identified on a project level ☐	Recognized on a corporate level, but may be part of another program ☐	Stand-alone program on same level as Quality or Safety ☐
	B. Corporate Constructability Policy Statement (C)	None exists; no need seen for such ☐	No corporate policy; may have on project level ☐	Statement exists, but may be part of other policies ☐	Widely distributed corporate policy ☐	Widely distributed corporate policy ☐
	C. Management Attitude toward Constructability (C)	No recognition of need for or benefits of constructability ☐	Limited support within company; some recognition of benefits ☐	Support varies within company; support on a project-by-project basis ☐	Management supports program; constructability understood as a corporate philosophy ☐	Total management support; actively participate in improving program ☐
	D. Recognition of Constructability Barriers/Problems (C/P)	Many barriers exist; no recognition of barriers or problems encountered ☐	Many barriers exist; aware of external limiters; may deny internal factors ☐	Recognize presence of barriers/problems; accept as part of the job ☐	Actively identify, work to document and correct ☐	Most barriers gone; problems caught and corrected quickly ☐
	E. Constructability Training of Personnel (C/P)	None ☐	If any occurs, done as part of on-the-job training ☐	Awareness seminars for specific projects ☐	Part of standard orientation ☐	Part of standard orientation; deeply ingrained in corporate culture ☐
II: Personnel	A. Executive Sponsor for Constructability (C)	No sponsor ☐	No sponsor ☐	Sponsor identified; role of sponsor may be ambiguous or weak ☐	Yes; sponsor actively supports program ☐	Yes; sponsor actively supports program ☐
	B. Assignment of Corporate Constructability Duties (C)	None ☐	No corporate personnel dedicated to constructability ☐	May have corporate duties as part of other responsibilities ☐	Full- or part-time corporate coordinator; corporate support organization for program implementation ☐	Full-time, high-level corporate coordinator; support organization well developed ☐
	C. Role of Project Constructability Coordinator (P)	Not identified ☐	Part-time if identified; very limited responsibility ☐	Full- or part-time position; responsibilities vary by project size, type, participants ☐	Full- or part-time position; responsibilities vary by project size, type, participants ☐	Full-time position; plays major project role ☐
III: Documentation/Tracking	A. Constructability Program Documentation (C/P)	None; CII documents may be available ☐	Limited reference in any manuals; CII documents may be distributed or referenced ☐	Project-level program documents exist; may be included in other corporate documents ☐	Corporate constructability manual is available ☐	Corporate constructability manual is thorough, widely distributed, and periodically updated ☐
	B. Tracking of Constructability Lessons Learned (C/P)	None ☐	Believe that ideas are adequately conveyed via word-of-mouth, personnel interaction ☐	Some individual documentation; primarily post-project reviews and reports ☐	System exists for capture and communication of ☐	Database on lessons learned involves input from all levels ☐
	C. Sharing Advanced Construction Technologies (C)	Not done ☐	New information routed occasionally—journals, word-of-mouth ☐	Library may exist; information routinely routed or seminars held ☐	Formalized routing system; R&D department identifies and promotes ☐	Formalized system with company seminars and pilot applications ☐
	D. Constructability Referenced in Contract Documents (C/P)	No reference ☐	Limited reference, on specific projects; often only at request of other project participants ☐	Level of reference varies by project type, role, or participants ☐	Standard item in all contracts ☐	Standard item in all contracts; actively promoted to other organizations ☐
	E. Tracking Constructability Savings/Effects (C/P)	Not applicable ☐	No tracking or recognition of program results ☐	No tracking, limited recognition of program results on project ☐	Track for particular projects or selected items; may track major ideas across projects ☐	Data kept on all projects; widespread confidence in savings beyond those measured ☐
IV: Implementation	A. Nature of Project-level Efforts and Inputs (P)	None ☐	Reactive approach, constrained by review mentality, lack of understanding of proactive benefits ☐	Aware of major benefits proactive approach; efforts vary project by project ☐	Proactive effort on all projects; routinely consult lessons learned ☐	Aggressive, proactive efforts from beginning of project; routinely consult lessons learned ☐
	B. Implementation of Constructability Concepts (P)	None ☐	Some concepts used periodically; often considered too late to be of use ☐	Selected concepts applied regularly; full use, timeliness of input varies across projects ☐	All concepts consistently considered; timely implementation of feasible concepts ☐	All concepts consistently considered, continuously evaluated, aggressively implemented ☐

Figure 1.4. Constructability Program Evaluation Matrix

Five levels of program maturity as defined by varying levels of implementation of each of the 15 parameters noted above are shown in Figure 1.4. The figure also displays these classification levels. Program descriptions are:

- **Level 1: No Program**

- Lack of awareness or understanding of constructability
- Lack of support for constructability
- No constructability efforts

- **Level 2: Application of Selected Supports**

- Limited awareness or understanding of constructability
- Limited support for constructability
- The need for proactive constructability involvement is poorly understood
- Constructability efforts are on a project-by-project basis with no corporate support and limited transfer of ideas between projects

- **Level 3: Informal Program**

- Awareness of constructability benefits
- Efforts constrained by support within the company and possibly by external limiting factors (i.e., lack of funding)
- Efforts hindered by a perceived lack of benefit from a comprehensive approach to constructability

- **Level 4: Formal Program**

- Comprehensive constructability effort with full-time corporate support
- Some cultural resistance and some barriers to implementation may still exist
- A comprehensive benefits tracking system that may focus overly on quantitative effects

- **Level 5: Comprehensive Formal Program**

- Comprehensive, effective, timely implementation of constructability on all projects
- Widespread confidence in the benefits of the proactive efforts
- Constructability is part of the corporate culture
- A comprehensive benefits tracking system focusing on selected “high-value” program outputs.

Levels 3, 4, and 5 all characterize varied degrees of successful constructability results. Level 5 is obviously the preferred and recommended level of constructability implementation. Only at this stage of effort may the full benefits of constructability efforts be realized. For those programs operating at lower levels, Level 5 implementation may be viewed as a benchmark or “best in class.” Programs at lower levels will still benefit substantially from a program while striving for Level 5.

Table 1.1 shows the research findings from the categorization of 62 companies. These results may be used as a benchmark of the current level of constructability implementation in the industry by those companies that claim to implement constructability.

Table 1.1. Tabulation of Categorization Results from Interviews

Program Categorization	No Program	Application of Selected Concepts	Informal Program	Formal Program	Comprehensive Formal Program	Total
Number of Programs	2	12	33	13	2	62
Percent of Total	3	19	53	21	3	100

Assessment Tools, Procedures, and Level of Effort. Constructability program assessment should involve a variety of personnel from across organizational functions and from different organizational levels. By doing so, the assessment can encompass different perspectives, viewpoints, awareness, and experience, and therefore be truly representative of actual corporate or project implementation practices.

For a comprehensive assessment, organizations should use a variety of methods and procedures, such as interviews, questionnaires, post-project reviews, procedure reviews, and other methods. All methods should be well-defined and properly documented to facilitate consistent evaluation of responses over time.

When first implementing a constructability program, an intensive review of current practices should be undertaken. Constructability program assessment requires two levels of evaluation. Figure 1.5 shows the relationship between Step One and Step Two evaluation. Step One is a broad-level appraisal of all significant parameters identified. Step Two involves selective in-depth evaluation of particular parameters.

The listing of assessment criteria described previously may be used as a tool for Step One assessment. Two separate forms (Tools 1 and 2) are included in this publication to allow for the evaluation of both corporate- and project-level programs. These tools can be used to provide a qualitative assessment of constructability implementation efforts and their effectiveness. These assessment forms should be used in conjunction with other assessment methods as mentioned above.

More in-depth data may be required for particular parameters. Step Two, therefore, involves the significant, quantitative evaluation of selected parameters. Often these items are difficult to measure precisely. While one could attempt to painstakingly document each and every constructability effort and related saving, this approach is neither recommended nor necessary once confidence in the program is achieved. Ideally, tracking efforts should focus only on “high-value” ideas rather than on exhaustive accounting practices. Figure 1.5 (next page) identifies areas where meaningful, in-depth evaluation efforts should be focused. This list is not comprehensive. A critical assessment of this list and of present operations will identify those parameters that possess high value to a particular organization.

Step One:
Primary Evaluation Parameters

Step Two:
Secondary Evaluation Parameters

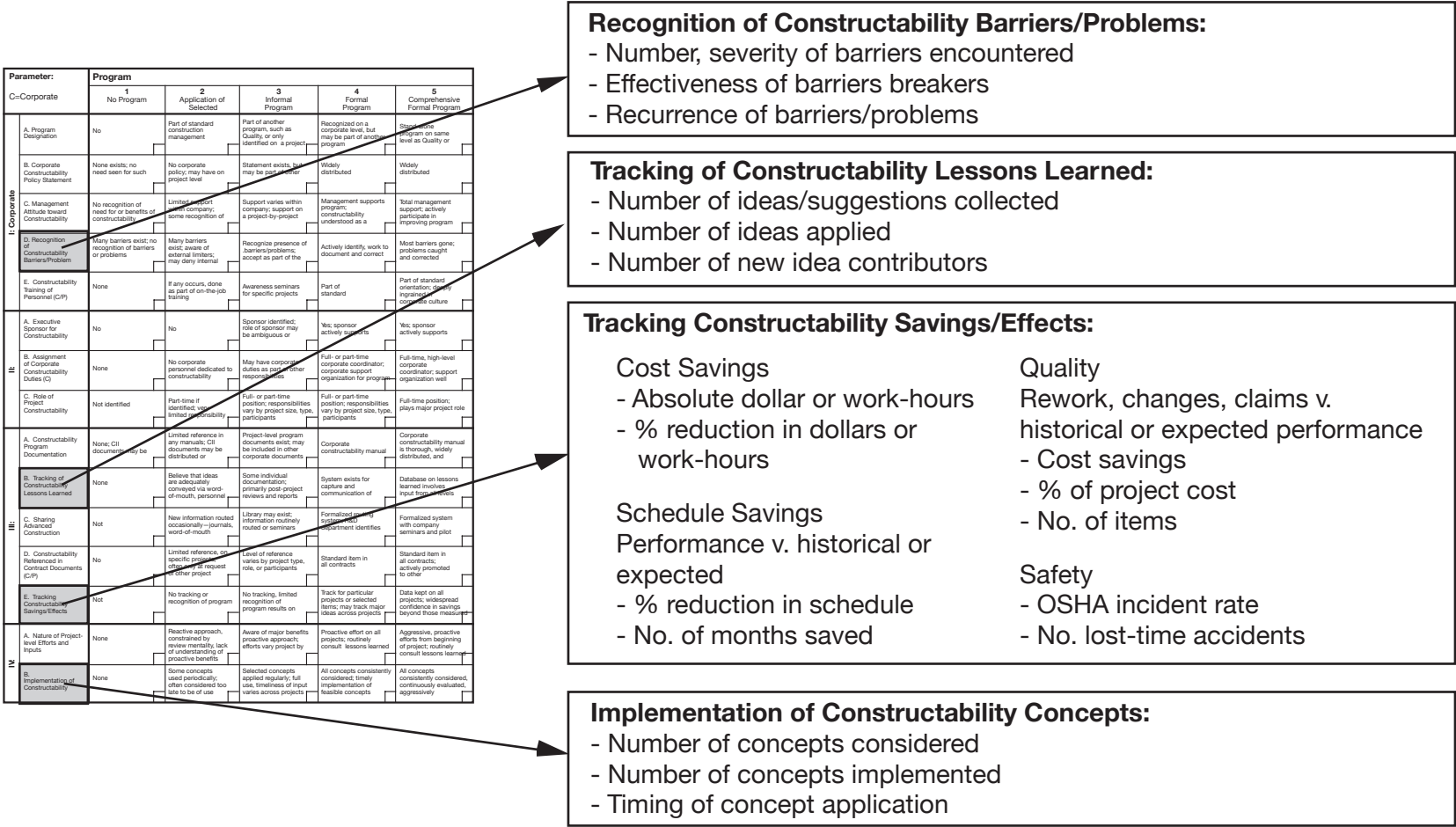


Figure 1.5. Evaluation Parameters Hierarchy

Barriers to Constructability

A “barrier” to constructability is any significant inhibitor that prevents the effective implementation of the constructability program. Participants from 62 companies were asked to identify the five barriers to constructability they believed were most prevalent in their company or on projects with which they were involved. From the initial list of 42 barriers, 18 barriers were consistently identified by participants as significant. These barriers are shown in Table 1.2.

Table 1.2. Most Common Barriers to Constructability

Barrier		Frequency
Rank	Description (n=62)	%
1	Complacency with the status quo.	35
2	Reluctance to invest additional money and effort in early project stages.	35
3	Limitations of lump-sum competitive contracting.	31
4	Lack of construction experience in design organization.	23
5	Designer’s perception that “we do it.”	19
6	Lack of mutual respect between designers and constructors.	19
7	Construction input is requested too late to be of value.	19
8	Belief that there are no proven benefits to constructability.	18
9	Owner’s lack of awareness/understanding of the concepts of constructability.	16
10	Misdirected design objectives and designer performance measures.	15
11	Owner’s perception that “we do it.”	15
12	Lack of genuine commitment to constructability.	15
13	Designer’s lack of awareness/understanding of the concepts of constructability.	15
14	Poor communication skills of constructors.	15
15	Lack of documentation and retrieval of “lessons-learned.”	13
16	Lack of team-building or partnering.	13
17	Poor timeliness of constructor input.	13
18	The right people were/are not available.	11

Barriers to constructability must be identified and removed for successful constructability implementation. The identification of barriers occurs during self-assessment procedures. Part III, Program Tools, contains forms (Tools 6–9) for evaluating the existence of the 18 common barriers identified within particular corporate- and project-level programs.

Table 1.3 (next page) describes the 18 common barriers identified, shows where they occur, and lists symptoms that indicate the barrier is present. Constructability barriers are evident in all organizations, at all levels, within both corporate and project organizations. Four different types of barriers were noted: cultural, procedural, awareness, and incentive.

Table 1.3. Descriptors of Common Barriers to Constructability

Rank	Barrier (18 most common barriers identified from research, listed in decreasing order of frequency)	Organization Affected			Symptoms (Indicators that the Barrier is present)
		Owner	Designer	Constructor	
1	Complacency with the status quo.	X	X	X	• “Oversatisfaction” with performance; lack of interest in new approaches, new ideas; no time for strategic thinking
2	Reluctance to invest additional money and effort in early project stages.	X			• Primary focus on short-term profitability; highly constrained funding procedures
3	Limitations of lump-sum competitive contracting.	X			• Reliance on lump-sum methods; reluctance to investigate/allow other strategies; highly restrictive contracting procedures
4	Lack of construction experience in design organization.		X		• Construction knowledge not considered valuable for design personnel; few opportunities for site visits by A/E
5	Designer’s perception that “we do it.”		X		• Design review procedures considered adequate for constructability
6	Lack of mutual respect between designers and constructors.		X	X	• Adversarial/clannish/disrespectful relationships between personnel; minimal interaction between personnel
7	Construction input is requested too late to be of value.	X	X		• No construction involvement or understanding of such need in early project stages; focus on construction review of completed drawings
8	Belief that there are no proven benefits to constructability.	X	X	X	• Refusal to include constructability efforts in project efforts until cost/benefits proven
9	Owner’s lack of awareness/understanding of the concepts of constructability.	X			• No comprehension of the breadth of constructability efforts and issues

Table 1.3. Descriptors of Common Barriers to Constructability (continued)

Rank	Barrier (18 most common barriers identified from research, listed in decreasing order of frequency)	Organization Affected			Symptoms (Indicators that the Barrier is present)
		Owner	Designer	Constructor	
10	Misdirected design objectives and designer performance measures.		X		• Promotion of goals to minimize design costs at project expense
11	Owner's perception that "we do it."	X			• Satisfaction with current efforts, no desire to improve or increase effectiveness; no benchmarking of performance
12	Lack of genuine commitment to constructability.	X	X	X	• Use of constructability as a buzzword; constructability outside the corporate culture
13	Designer's lack of awareness/understanding of the concepts of constructability.		X		• No comprehension of the breadth of constructability efforts and issues
14	Poor communication skills of constructors.			X	• Failure to present ideas to project members in a usable, non-adversarial fashion
15	Lack of documentation and retrieval of "lessons-learned."	X	X	X	• No system for documenting or ineffective methods for documenting lessons; quick to "close the file" on a project
16	Lack of team-building or partnering.	X	X	X	• No reference to the team approach
17	Poor timeliness of constructor input.			X	• Lack of proactive efforts; focus on construction review of completed drawings
18	The right people were/are not available.	X	X	X	• Casual or non-deliberate assignment of constructability personnel

Once barriers are identified, they may be mitigated or overcome with specific tactics. Barrier “breakers” have been evaluated for the seven most common barriers. Table 1.4 shows the breakers recommended, including at least one tactic for each barrier. The table also describes where the barrier is effective, and lists the type of breaker, corresponding with the four barrier classifications (cultural, procedural, awareness, incentive). Finally, the table outlines where these techniques should be integrated with the Constructability Implementation Roadmap. This should assist the user in integrating these breakers into formal implementation plans. This table is also included in Part III as Tool 10.

In addition to being relatively easy to implement, these tactics are considered to have a high impact on the barrier. This list is not absolute; other tactics should be developed and assessed for potential application. A listing of the recommended barrier breakers is included in Part III (Tool 10) for distribution as an implementation tool.

Table 1.4. Summary of High-Impact, Easily-Implementable Barrier Breakers (Tool 10)

Barrier	Recommended Barriers	Where Effective		Type of Breaker				Roadmap Activities
		Corporate	Project	Cultural	Procedural	Awareness	Incentive	
1. Complacency with status quo.	Designate a strong program champion.	X		X		X		“Identify constructability sponsor/champion”
2. Reluctance to invest additional money and effort in early project stages.	Promote the attitude that constructability should be viewed as an investment opportunity with corresponding downstream payoff.	X	X				X	“Assess and recognize constructability benefits” “Define constructability objectives and measures”
	Include constructability as part of a standard bid response and in cost tracking/control efforts.		X		X	X		“Select project contracting strategy”
3. Limitations of lump-sum competitive contracting.	Owner/designer acquire in-house construction expertise for input during design.		X		X	X		“Assemble key owner team members” “Develop the constructability team”
	Develop a short list of contractors who offer constructability input in return for the opportunity to be on the short list of bidders.		X		X			“Select project contracting strategy” “Secure contractors, vendors, and consultants”
4. Lack of construction experience in design organization.	Communicate construction issues from field engineers to office engineers/designers.		X	X	X			“Consult applications matrix and lessons learned”
	Close the “project loop” by getting feedback from the field and by tracking lessons learned.		X	X	X			“Document lessons learned”
	Modify design management practices to elevate the visibility of constructability issues.	X		X		X		“Develop implementation policy” “Define constructability objectives and measures”

Table 1.4. Summary of High-Impact, Easily-Implementable Barrier Breakers (Tool 10) (continued)

Barrier	Recommended Barriers	Where Effective		Type of Breaker				Roadmap Activities
		Corporate	Project	Cultural	Procedural	Awareness	Incentive	
5. Designer's perception that "we do it."	Secure comprehensive understanding of what constructability is prior to assessing adequacy of efforts.	X				X		"Understand constructability objectives, methods, concepts, and barriers"
6. Lack of mutual respect between designers and constructors.	Aggressively promote effective team-building among project personnel.		X	X				"Develop the constructability team"
	Establish constructor presence in design process before pride of authorship develops.		X	X	X			"Develop constructability procedures and integrate into project activities" "Select project contracting strategy"
	Keep the project team focused on common objectives and accepted procedures rather than personalities.		X	X				"Orient project constructability team/perform team-building"
7. Construction input is requested too late to be of value.	Increase awareness of the necessity for early construction involvement.	X				X		"Understand constructability objectives, methods, concepts, and barriers"
	Include constructability as an early activity in a formal project activity flow plan or roadmap.	X	X		X			All Roadmap Activities
	Include individuals with significant construction experience in the project team from the outset.	X	X		X			"Assemble key owner team members" "Select project contracting strategy"
Sum of effective breakers in each category:		7	11	7	8	6	1	

Step 3: Assess and Recognize Constructability Benefits

Before the implementation strategy for a constructability program may be developed, goals for the effort should be set. Such goals are intended to:

- Promote a unified vision for the company program.
- Evoke enthusiasm within the organization.
- Act as a source of motivation for constructability efforts.

Company targets should be identified for quantitative program benefits. Such targets are usually project-specific, high-value items such as percent cost savings, percent work-hour savings, straight dollar savings, percent reduction of rework, and elimination of delays caused by procurement problems. These same measures can then be tracked on a corporate level in order to monitor constructability program effectiveness and overall achievement of program goals over time.

The intangible benefits from constructability are as important as the quantitative benefits, and must be recognized accordingly. These include more accurate budgets and schedules, improved site layouts, improved project team relationships, more repeat work, improved security, and many others.

All of the constructability outputs listed in Figure 1.3 are benefits of effective constructability implementation, and this list is by no means complete. The benefits of effective constructability implementation can be significant provided that efforts start early in the project. The remainder of this document discusses particular implementation needs.

As described in CII Publication 3-1, quantitative benefits of effective constructability include:

- Reduction of total project cost ranging from 1 to 11 percent
- Reduction in total project schedule ranging from 5 to 10 percent
- Consistent, documented, quantified benefit/cost ratios of 10:1.

As many constructability benefits were not tracked on these projects, savings went beyond those items that were documented. Therefore, the documented numbers may underestimate the true benefits of constructability. Additional qualitative benefits recognized on these projects included constructability-produced improvements to such items as safety, security, schedule, cost, and quality. Further discussion of these case studies may be found elsewhere in this publication.

Once identified, methods to achieve all expected constructability benefits are integrated into the constructability execution plans. Tracking of these benefits, as mentioned above, may then be incorporated into assessment procedures as discussed under Step 2 above.

Step 4: Develop Implementation Policy

The corporate constructability implementation policy raises the visibility of the constructability program, communicates commitment at a high level, and defines the level of program efforts. The policy document must contain several key items:

- A statement of program goals for the organization
- Indication of the level of management and corporate commitment
- Identification of the corporate executive sponsor
- Ties to project-level implementation.

Figure 1.6 shows a sample implementation policy statement, also included in Section III as Tool 11. This example may be used as a guideline for developing a company-specific policy.

Constructability Implementation Policy The Construction Industry Institute has endorsed the cost savings potential of constructability efforts, “the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives.” The CII publications <i>Constructability Implementation Guide</i> and <i>Constructability: A Primer</i> are useful reference guides to Constructability. In view of our continuing efforts to provide the highest degree of quality and cost effectiveness to our projects, it is our corporate policy to implement Constructability to the fullest degree possible. This applies to all phases of project planning, design, and construction. We will ensure that we take full advantage of the high potential of Constructability to achieve savings during the earliest phases of project planning and prior to the start of design. _____ is hereby designated as the Executive Sponsor for Constructability, and will oversee the constructability program, ensure consistency with other continuous improvement processes, implement changes, and regularly report to me on its effectiveness. President _____ Date _____
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Figure 1.6. Sample Constructability Implementation Policy (Tool 11)

The constructability program requires a high corporate profile to maximize effective implementation. Constructability ideally should become part of the corporate culture and be integrated into everyday procedures. To achieve this goal, the implementation policy should be disseminated to all levels of the organization. This policy should accompany the initial awareness seminars and training courses as discussed at the beginning of this chapter. Constructability efforts should be integrated with other continuous improvement programs. In the final analysis, constructability implementation activities should be consistent and compatible with other activities, and energize the overall improvement process.

Roadmap Milestone 2: Establish Corporate Constructability Program

This chapter addresses the steps necessary in establishing a corporate-level constructability program for either owner, designer, or contractor organizations. Figure 2.1 illustrates the three activities that comprise this milestone on the Constructability Implementation Roadmap. Program roles and information support systems are discussed in detail.

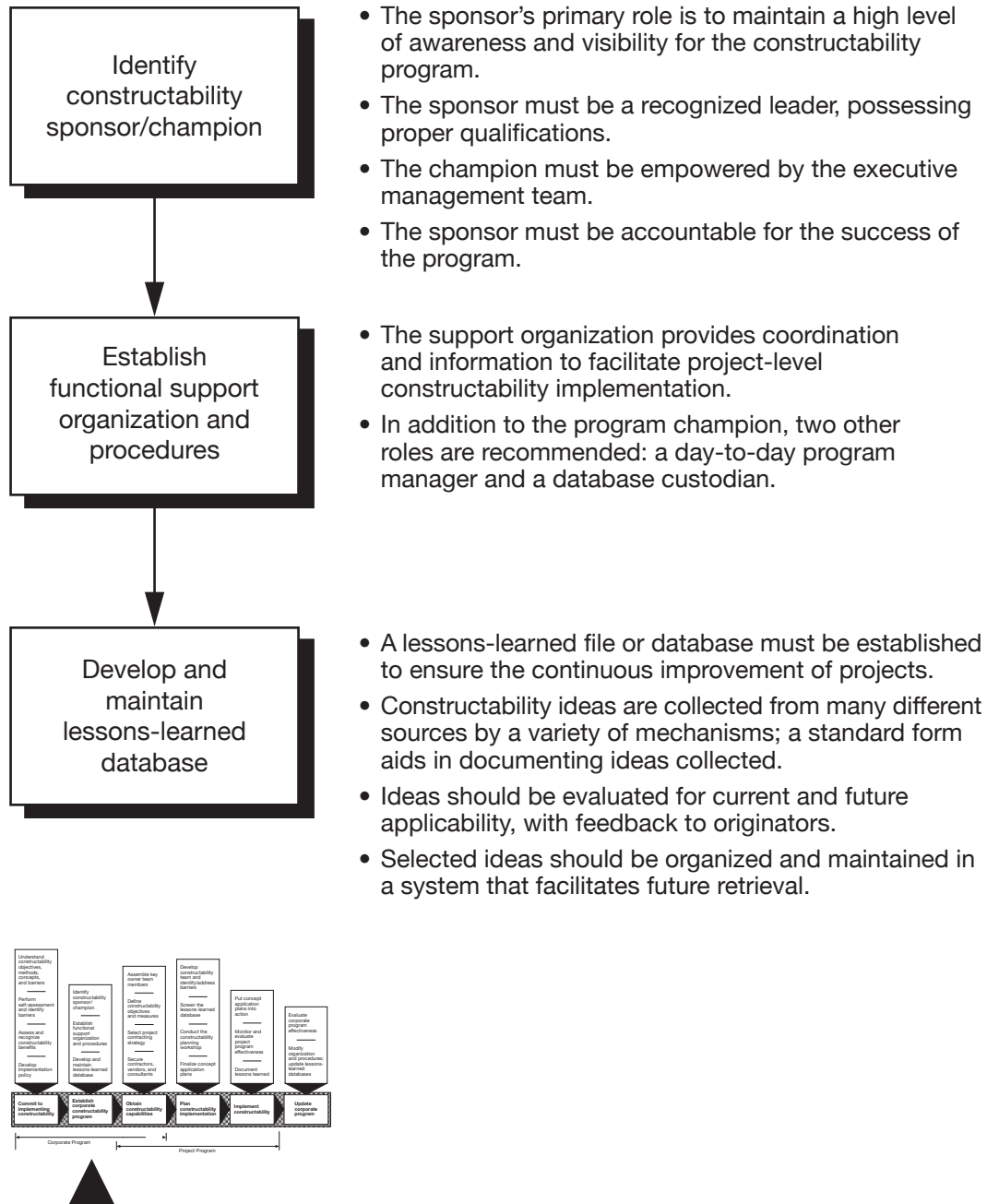


Figure 2.1. Steps to Establish Corporate Constructability Program

Step 1: Identify Constructability Sponsor/Champion

Successful constructability programs require the active support of a designated sponsor or champion whose primary role is to maintain a high level of awareness and visibility of the constructability program. Beyond promoting the constructability cause, this “champion” also should be the catalyst for change by supporting selective trial-and-error implementation efforts at lower levels within the organization.

The program sponsor or champion should be a recognized leader within the organization, possessing a breadth of project management experience and being capable of ensuring that adequate resources are applied to the effort. The sponsor must be directly accountable for the success of the constructability program. In identifying and designating the champion, it is important to understand the desired qualifications of the position:

- High level of authority and influence
- Dedicated to the cause of constructability
- Time available to provide leadership
- Sensitive to feedback and possessing effective interpersonal skills
- Proper technical and managerial experience for the position.

Once selected, the champion must be empowered with the full support of the corporate executive management team.

Step 2: Establish Functional Support Organization and Procedures

The purpose of other program personnel and support elements is to facilitate implementation of constructability at the project level. Coordination from project to project must be ensured. Effective linkage to needed information and expertise must be provided. To accomplish this, two other important roles are recommended as the program evolves:

- **A program manager responsible for:**
 - Day-to-day coordination of company-wide constructability efforts
 - Selection and briefing of Project Constructability Coordinators
 - Program training
 - Assessment and continual monitoring of corporate barriers
 - Set-up of the lessons-learned database
 - Identification and removal of program barriers
 - Tracking of corporate program goals
 - Ensuring communication of good ideas and success stories across projects
 - General assistance to Project Constructability Coordinators.

This program manager, like the program sponsor and project-based constructability coordinators, should have extensive construction and project management experience, a working knowledge of design needs and requirements, and strong communication skills. In smaller organizations or for smaller projects, the program manager also may serve as project constructability coordinator.

- **A database custodian** who is responsible for the documentation, tracking, and distribution of constructability ideas and lessons learned. The database custodian may also assist project coordinators and the program manager (along with other technical specialists) in the screening or evaluation of constructability ideas. In addition to construction and project management experience, this individual should possess strong communication skills and have a working knowledge of computerized data handling, storage, and retrieval.

Figure 2.2 (Tool 12, next page) illustrates the organization chart for the constructability organization. Although the corporate constructability team is distinct from project-level constructability teams (one for each project), the two teams should be closely linked.

For small- to medium-sized organizations, a single individual may serve all three roles of champion, corporate program manager, and database custodian. These positions also may be split between two or more individuals. For such organizations, it is unlikely that each of the three roles will require a full-time position. The constructability program support organization need not be large, burdensome, or costly—but it must exist formally.

A constructability orientation program for employees also should be a part of corporate program functional support. CII is developing a Constructability Education Module available for both regional seminars and in-company training purposes. This module should be offered to key project employees annually and at the start of every large project.

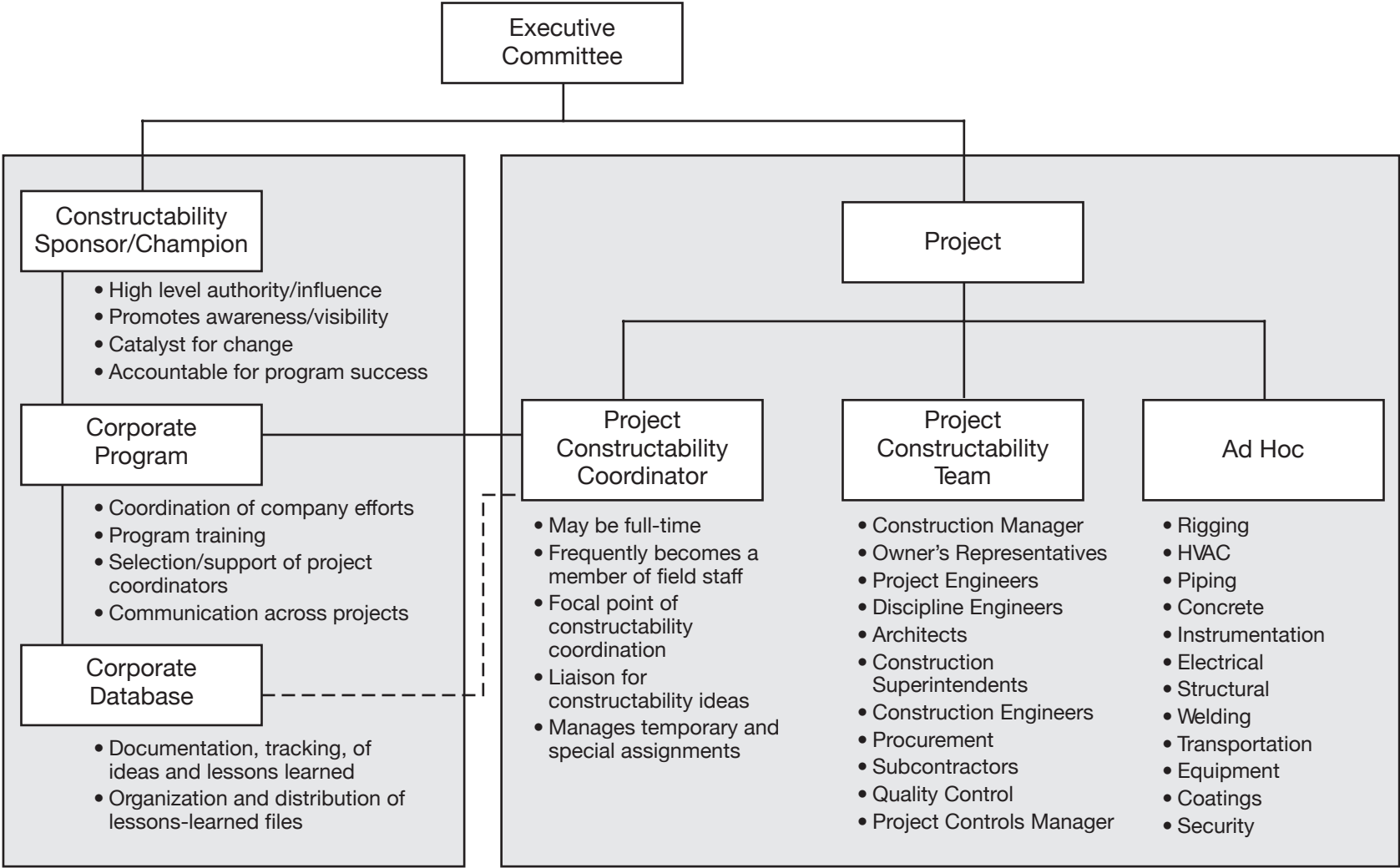


Figure 2.2. Constructability Organizational Structure

Step 3: Develop and Maintain a Lessons-Learned Database

As illustrated in Figure 2.3, the constructability lessons-learned database is one of three mechanisms for eliciting and documenting constructability ideas. Ideas also may come from project discussions of constructability concept applications and from a constructability suggestion program (either corporate- or project-based).

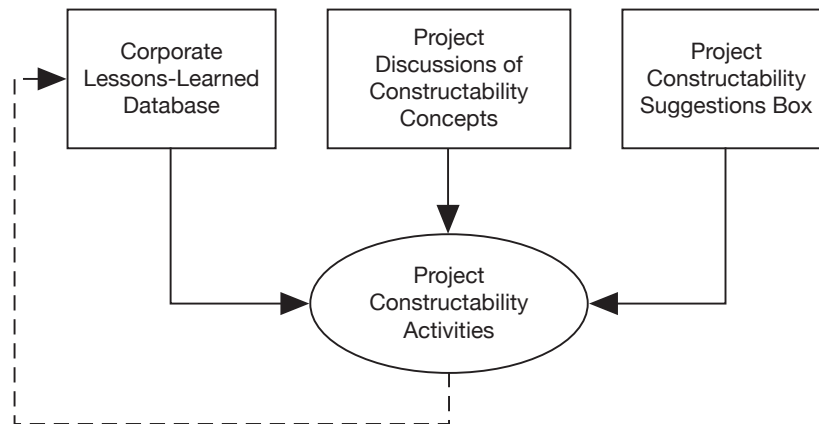


Figure 2.3. Sources for Improving Project Constructability

The necessity of a lessons-learned database cannot be overemphasized. With such a database, past failures and successes can be recorded for the benefit of future projects, thereby reinforcing continuous project improvement.

Constructability ideas can and should be collected from many different sources by a variety of mechanisms. Potential sources include lead engineers, discipline engineers, procurement personnel, superintendents, foremen, craftsmen, vendors, inspectors, area coordinators, owner field personnel, A/E field personnel, and others from all phases of the project cycle. The mechanisms for collecting constructability ideas include project monthly progress reports, final (closeout) project reports, personal interviews, job site suggestion box programs, and minutes or notes from project planning meetings. Personal interviews have been found to be particularly effective.

The recommended form contains information “fields” for evaluation and tracking of the implementation of ideas. Such information should be documented for each idea or suggestion. Idea evaluation criteria should be established and should include estimates of impacts on cost, schedule, quality, and safety. Information pertaining to design or construction work-hours, required management effort, or effects on risk/uncertainty also may be of value in deciding whether or not to implement a particular idea.

Program participants might suggest an alternative approach to design or construction which, while not improving on the original approach, may identify a shortcoming in the approach. In such a case, significant benefits may result from simply identifying a problematic situation. In addition, ideas with low evaluations or applicability on one project may be beneficial or significant on other projects. For these reasons it is important not to prejudge ideas, since this may have the effect of discouraging future contributions to the database.

Previous constructability program efforts underscore the importance of timely and responsive feedback to idea originators, those people who have taken the initiative to “find a better way.” They need constructive feedback on the merits or value of their proposed alternative solutions. It may be desirable to establish a highly visible award or recognition system: incentives such as cash awards, lunch programs, hard hat stickers, parking privileges; even brief, publicized recognition can be effective in encouraging the submittal of good ideas and in maintaining awareness of the constructability program.

Once ideas are collected and documented, they should be organized or maintained in a system that facilitates ready retrieval on future projects. This normally will involve a computerized database of the ideas categorized by work area or discipline (e.g., civil, piping, instrumentation) and by project phase (e.g., conceptual planning, detailed design, procurement, construction, and start-up). Suggested information fields for each record in the database include the following:

- Short descriptive title of the idea
- Detailed idea description
- Discipline/work area category and subcategory (e.g., piping: fabrication, or electrical; conduit, etc.)
- Pertinent project phase (e.g., detailed design, procurement, field construction, etc.)
- Primary effects on project (e.g., cut cost, shorten duration, reduce work-hours, improve safety, improve security, eliminate materials, etc.)
- Needs for updating/modifying corporate standard specifications
- Projects using this idea
- Personal contacts for more information
- Referenced manufacturer’s literature.

The database should be available in both hard copy and computer file formats. The hard copy format should contain a complete, detailed, and accurate table of contents.

PART II: ROADMAP MILESTONES TO IMPLEMENT A PROJECT-LEVEL CONSTRUCTABILITY PROGRAM

Overview

The constructability process at the project-level consists of three critical milestones: (1) Obtain constructability capabilities, (2) Plan constructability implementation, and (3) Implement constructability. These milestones, as well as steps describing each milestones, are presented in Figure 3.1 (next page) and further described below.

The constructability process should begin shortly after the owner's conception of the project and continue through project planning, design, procurement, construction, and start-up. The earlier in the facility delivery process that the constructability program begins, the higher the potential savings. In addition, project constructability plays a role in securing contractors, vendors, and consultants.

The following three sections describe each of the steps included in a model project-level constructability program. Note that the same program applies to all participants on a project (although some portions are more relevant to specific project participants than others). Information is presented as a sequential process to provide owners with a starting point in the development and implementation of a constructability program. Relevant portions of the program may be adopted into an organization's constructability program.

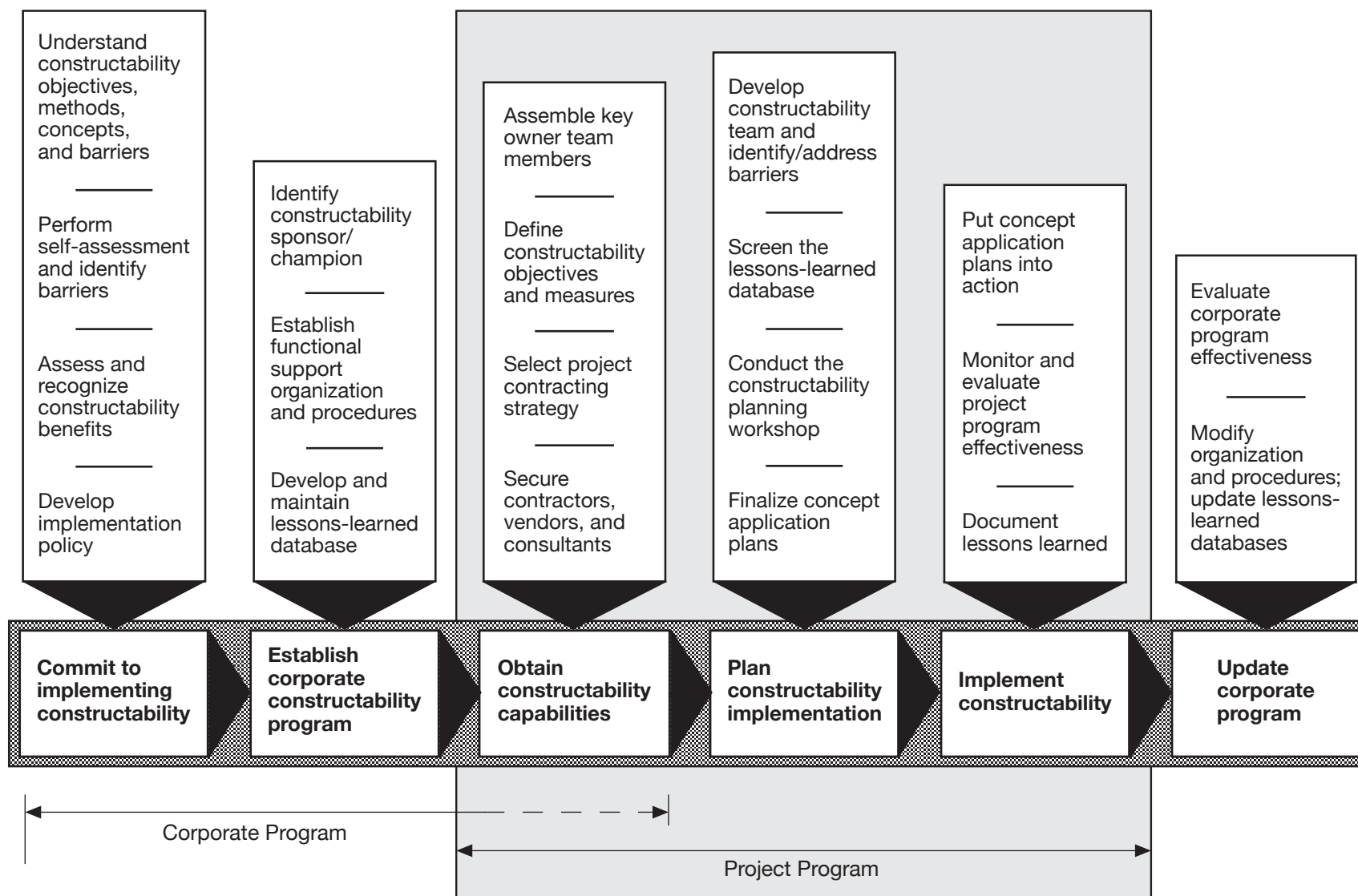


Figure 3.1. Overview of Steps in Project-Level Constructability Program

Roadmap Milestone 3: Obtain Constructability Capabilities

To obtain constructability capabilities for the project, the owner should assess available in-house expertise and consider the procurement of external design and construction constructability expertise. As shown in Figure 3.2 (next page), four general steps lead to obtaining constructability capabilities: (1) Assemble key owner team members, (2) Define constructability objectives and measures, (3) Select project contracting strategy, and (4) Secure contractors, vendors, and consultants. Each of these steps is described below.

Step 1: Assemble Key Owner Team Members

The owner's project manager and team members have a critical influence on the success of the project's constructability. Only when the owner's team is fully committed to planning for and implementing a constructability program will such a program be of maximum benefit. To enhance the constructability efforts, the owner should: (1) select a project manager committed to constructability and (2) establish criteria for selection of other key owner team members. Considerations which must be addressed during these two activities are described below.

Select owner project manager committed to constructability. The project manager (PM) from the owner's organization plays a vital role in the decision to implement a project-level constructability program. In addition, the emphasis the PM places on the program impacts its effectiveness. Without the PM's commitment, making constructability a positive influence will be extremely difficult. The project manager must be able to lead the team in the following areas:

- *Establish a supportive project environment.* The roles, responsibilities, actions, and lines of communication for the project's team need to provide for early and meaningful construction knowledge and experience.
- *Make a commitment to increased cost effectiveness.* Constructability will be enhanced if the project manager emphasizes the influence that project decisions have on the project's cost. The project manager can insist that construction input be provided for in the project's major decisions.
- *Use constructability to meet other project objectives.* Constructability should support the traditional project objectives of cost, schedule, quality, security and safety. Constructability also can be used to provide trade-offs between conflicting objectives.
- *Involve construction.* The project team should actively obtain and retain construction personnel involved in major management and technical decisions for the project. The owner's project manager should provide an objective balance between both design and construction needs.

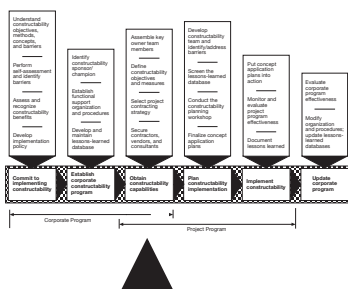
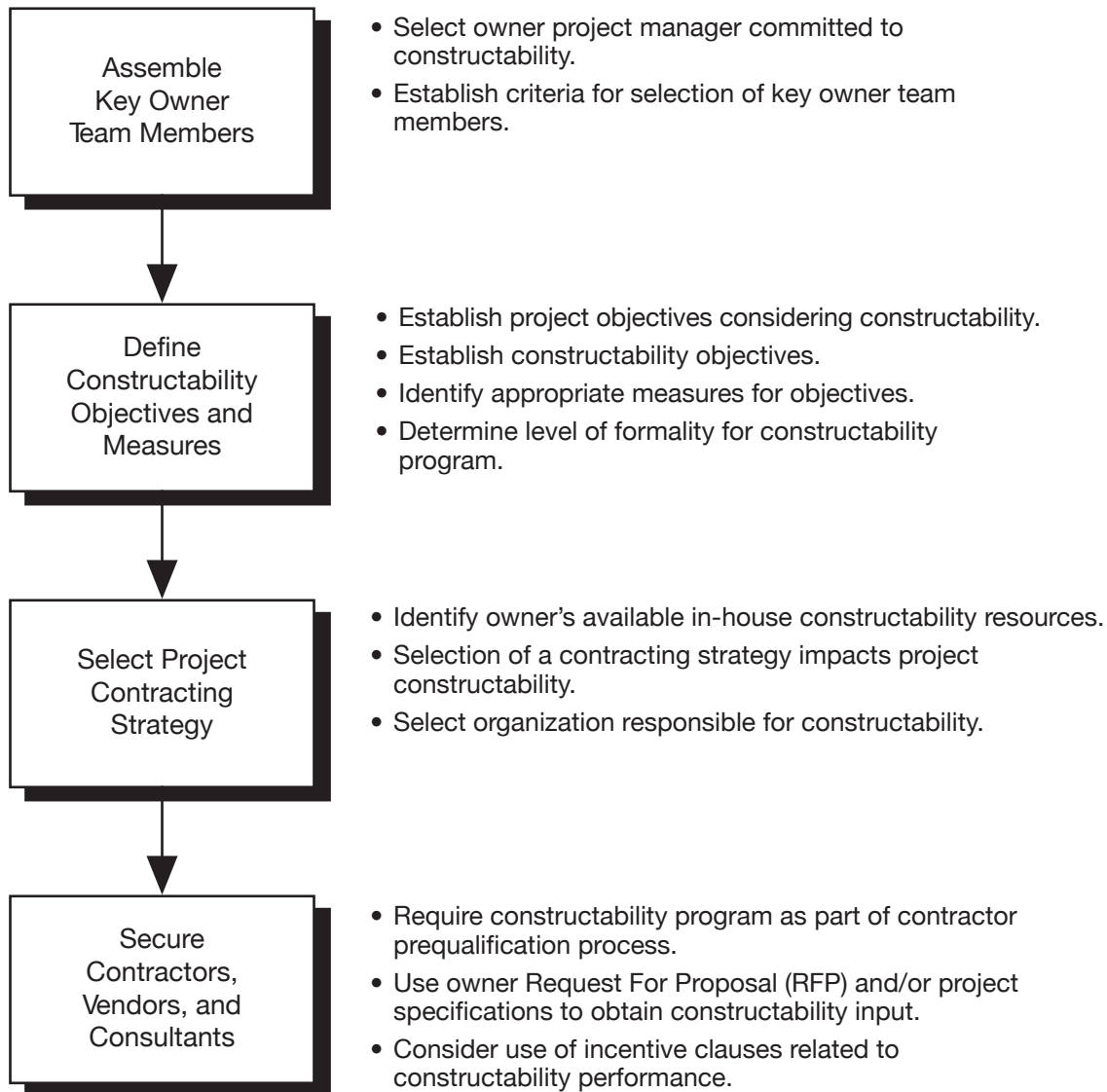


Figure 3.2. Steps to Obtain Constructability Capabilities

Establish criteria for selection of key owner team members. Similar to the project manager, the key team members from the owner's organization should be committed to constructability. If certain team members are unfamiliar with the constructability philosophy, they should be educated on the potential benefits. Their level of involvement in the constructability program depends on the contracting strategy and expertise of the other participants. A clear set of criteria should be developed for selection of key owner team members. Selection criteria should include the individual's:

- Work experience
- Construction knowledge
- Communication skills
- Teamwork skills
- Skill to objectively evaluate design and construction trade-offs
- Receptiveness to new ideas.

Step 2: Define Constructability Objectives and Measures

Once the owner's key team members are selected, the team can then define its constructability objectives and measures. This step includes the following four activities: (1) establish project objectives considering constructability, (2) establish constructability objectives, (3) identify appropriate measures for objectives, and (4) determine level of formality for constructability program.

Establish project objectives considering constructability. Constructability plays an important role in fulfilling established project objectives. Developing a clear understanding of the project's objectives and priorities is the first responsibility of the owner's team in constructability improvement. The project objectives typically include cost, schedule, quality, security, and safety. Other objectives for various projects include: reliability, aesthetics, lease-ability, public image, operability, and maintainability. As illustrated in the case studies presented in the appendix, constructability programs can reduce maintenance costs, increase operability, and increase safety.

Traditional project objectives are shown in Figure 3.3 (next page). Each participant should be aware of the project objectives and attempt to achieve them rather than solely focus on their individual sub-objectives. For example, a designer that attempts to minimize design effort only may actually cause an increase in construction effort, which in turn increases the project's overall life-cycle cost.

The owner's team should develop a detailed list of project objectives and prioritize each one. Assigning priorities based on qualitative criteria is as equally important as those based on cost and schedule. It is important to evaluate the design and construction implications when prioritizing the objectives. These objectives should be used later in the project to analyze trade-offs between alternatives influencing both design and construction. As various participants become involved in the project, these objectives can be mutually agreed upon.

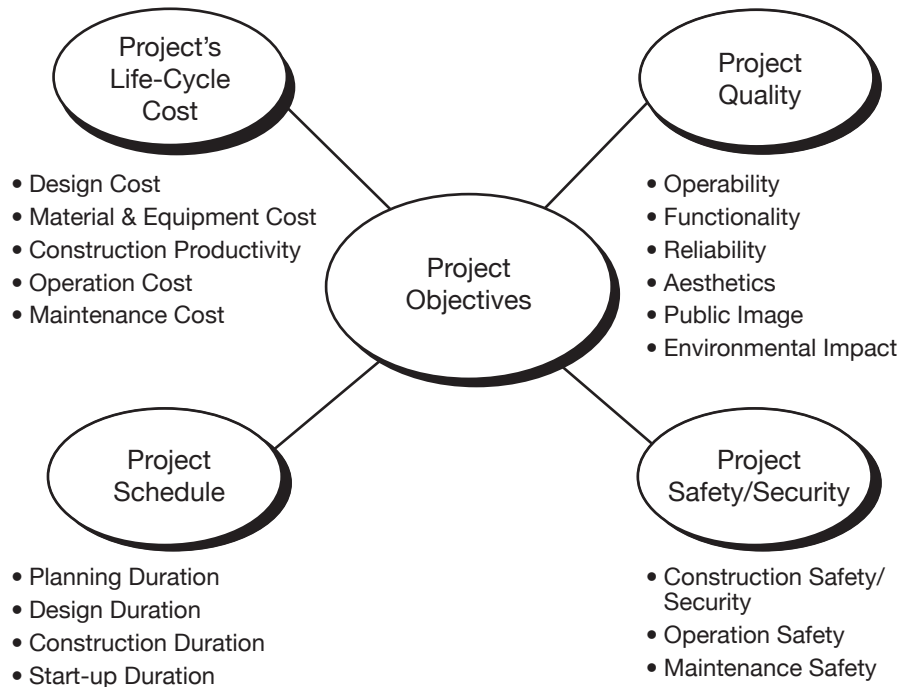


Figure 3.3. Traditional Project Objectives

Establish constructability objectives. Once the design and construction participants are involved, a specific set of constructability objectives can be developed. This set of objectives can be used to enable trade-off analysis between constructability and other project considerations, such as security. A list of constructability-specific objectives may include optimizing:

- Use of standardized elements
- Use of modules/preassembly
- Use of lift equipment
- Material lay-down areas
- Ease of fabrication and erection
- Use of physical models or three-dimensional CAD
- Number of field welds
- Jobsite accessibility
- Develop construction-friendly specifications
- Improve constructor/engineer communications
- Minimizing construction rework
- Minimizing design rework
- Minimizing jobsite congestion
- Minimizing occurrence of labor disputes.

In developing constructability objectives, consideration should be given to how the objectives can be objectively measured by diverse levels of personnel.

Identify appropriate measures for objectives. Often more difficult than establishing objectives is the development of appropriate performance measures. Cost and schedule performance usually is the most easily measured. Cost and savings estimates are commonly made for design alternatives and trade-off analysis. Safety can be measured by comparing lost-time accident rates to similar projects or national averages. Some sample performance measures for projects are:

- Capital dollars
- Construction dollars
- Direct field labor hours
- Labor productivity (work-hours/unit)
- Number of items nonconforming with owner's specifications
- Design rework work-hours
- Amount of scope change orders (dollars)
- Lost-time incident rate
- Shut-down duration (hours)
- Personnel and material jobsite accessibility (feet/hour/unit).

Several ways exist to formalize a constructability program. These methods include:

- Provide a budget.
- Develop a constructability manual.
- Prepare procedures for major constructability tasks.
- Issue progress and status reports.
- Track constructability suggestions.

Determine level of formality for constructability program. Several considerations affect the level of formality of the constructability program. These considerations predominantly consist of owner and project characteristics. Owner characteristics include owner type, objectives, expertise, and resources. Project characteristics include construction type, contract type, project size, technical difficulty, site location, and peculiarities. Project size need not be the only consideration in determining the formality of the constructability program. Even if a project is relatively small for an owner, a formal program may still be feasible. One industrial owner has formally tracked constructability suggestions across projects in the \$750,000 range. Many of the constructability lessons learned on such projects were applicable to other projects.

Step 3: Select Project Contracting Strategy

The selection of the contract strategy has a profound impact on the timing and application of constructability input. A contract strategy consists of two parts: (1) contract arrangement and (2) contract type. Contract arrangements examples include traditional design-build and design-manage. These arrangements influence the parties involved and their relationships. Conversely, contract type dictates the commercial terms in which the parties are contractually bound and paid. Examples of contract type are fixed price or reimbursable. Contracting strategy also affects the level of formality of the constructability program. In selecting a strategy, an owner must (1) assess the available in-house constructability expertise that can either lead or enhance the project constructability effort, (2) recognize how the selection of a contracting strategy impacts project constructability, and, most importantly, (3) select the contract organization best suited to be responsible for constructability during the initial stages of project definition.

Identify owner's available in-house constructability resources. The owner's project team should identify and assess existing in-house resources available to either lead or enhance constructability. Performing a self-assessment can assist in determining what constructability expertise is available. If formalized constructability approaches have been previously taken, the project team should obtain first-hand knowledge of the success of the constructability program and lessons learned. Owners should seek out and use pre-existing, in-house constructability expertise to the fullest extent possible.

Selection of contracting strategy impacts project constructability. CII Source Document 4, "Constructability Improvement During Conceptual Planning," states that "the contractual relationship between the owner, the designer, and the contractor strongly influences the means and extent of early construction involvement." Each owner selects a specific contracting strategy for each project based on those parameters that are perceived to best meet the project goals. This contracting strategy, consisting of a contractual approach used for selecting the engineer and construction contractor and the contract type used for each of these services, takes a variety of forms.

In the traditional contracting arrangement, the owner first selects an engineering or architectural firm and then selects a single general contractor to be responsible for the construction. The general contractor can self-perform a portion of the construction and award multiple subcontracts to accomplish the balance of the work. Generally the contract type used for the selection of the engineering or architectural firm is of a professional fee type. The contract type with the general contractor is a fixed price. Under a fixed-price contract type, the constructor is unable to participate early in the planning and design phases. Hence, the owner must lead the constructability effort. A variation of this approach occurs when the general contractor is selected early in the project process to act as the owner's construction manager (CM). For purposes of identification, this is referred to as the general contractor. The contract used varies from a reimbursable, professional fee for the CM services to a guaranteed maximum price for the cost of construction, which is established once the project scope is defined.

In the design-build contracting arrangement, the owner selects a single firm to be responsible for the engineering/design as well as the construction. A number of variations of the contract types are used in

this approach. Many are fixed price based on an owner's performance or turnkey specification. In this contract strategy, constructability is best implemented by the design-build contractor. The benefits of constructability accrue to the design-build contractor, possibly creating substantial cost savings. This encourages the design-build contractor to utilize constructability tools to the fullest extent possible. Some owners award a design-build contract with a guaranteed maximum price that is established after project scope has been determined. Design-construct, a form of the design-build approach, is usually performed on a cost reimbursable basis with performance-based incentives.

In the design-manage contract arrangement, the owner selects a single firm to be responsible for the engineering/design and the construction management of the project. The selected firm also is responsible for implementing constructability. Construction is performed through the utilization of multiple contract packages, which generally are competitively bid. The contract type may be fixed price for professional services, containing a ceiling with some type of fee structure, or cost reimbursable with an incentive program related to performance. A variation of this approach occurs when the owner awards a separate contract for construction management. This is referred to as the construction management contract arrangement, and the CM is responsible for implementing constructability. The contract types under the CM approach are similar to that of the design-manage arrangement.

Each of these contracting arrangements will have different results due to the timing of contractor construction expertise availability to the project. The traditional approach does not call for selecting a general contractor until the design package is complete, whereas the design-manage and design-construct strategies can provide for early construction participation. The other strategies may allow for early construction participation, depending on how the owner establishes the strategy.

Select organization responsible for constructability. Once a contracting strategy is selected, the owner should decide which organization (owner, constructor, or design/construction manager) is responsible for implementing and monitoring the constructability program. Owner-implemented programs usually maintain their own lessons-learned files that benefit constructability communication between projects. Such communication can be particularly useful if the owner frequently constructs similar facility types. Considerations to potential barriers created by assigning constructability responsibilities to a constructor may need to be addressed. This may occur when a design engineer is not familiar with participating as part of a team.

Step 4: Secure Contractors, Vendors, and Consultants

Once the owner has selected the contracting strategy to be used on the project, the next step is to determine how to facilitate early implementation of the constructability process. When the construction contractor or construction manager has not been selected early enough to contribute to the high cost impact decisions made during the conceptual planning phase of a project, a surrogate construction contractor or construction manager may be required to provide the necessary construction knowledge and experience input. The surrogate may come from the owner, the design organization, a constructor, a construction manager, or a consultant.

Require constructability program as part of contractor prequalification process. When the contract strategy involves early selection of the constructor or requires the utilization of other resources, the owner should include in their contractor prequalification process criteria that includes utilization and effectiveness of the contractors constructability program. Factors to consider are:

- Corporate-level program — Assessment of corporate philosophy and recognition of program.
- Program documentation — Evaluation of existing manuals, methods used to track progress, and incorporation of lessons learned.
- Breadth of experience implementing program — Assessment of previous application of their program and the personnel responsible for its implementation.
- Project-level program supports — Evaluation of tools to assist in implementing constructability including how they incorporate new technology.

A process to prequalify and evaluate sources of constructability input can be found in the references under Gugel (1992).

Use owner request for proposal (RFP) and/or project specifications to obtain constructability input. When owners include constructability requirements in their bid documents, a wide variation in their level of detail can occur. The constructability requirements may appear in the owner's "Standard Terms and Conditions" or "Specification within the Scope of Services" sections. Several excerpts of inquiry documents for engineering and construction services are provided below.

1. Engineering Inquiry Document for Engineering Services:

- "Constructability – advise how bidder would integrate constructability into the front end of this project and outline any previous experience the bidder has with such integration."
- "Prepare a construction plan, including constructability, contract strategy, etc. for each of the work divisions. This plan will be developed by your construction management organization."
- "You shall provide constructability analysis."
- "Eight general contractors will be invited to review the planning material during the course of project development. Inclusion of the contractors would occur during the project initiation meeting, schematic design and design development presentations. Contractors will be requested to evaluate information offered and respond with value engineering and constructability suggestions."

2. Construction Inquiry Document for Construction Services:

- "Furnish experienced construction personnel in the engineering contractor's home office to provide constructability and scheduling input."

One owner included in the RFP a document that described the desired relationship between the owner and construction contractors. Included within this document is a paragraph that states:

- “We normally expect an earlier involvement of some of the contractor’s key personnel than is customary. For example, in advance of the general job mobilization certain personnel may be assigned for training on the specific methods to be employed, to prepare procedures manuals, participate in team development and early planning, and to provide effective input on constructability of specific details as the engineering design and schedule are developing.”

One owner included in their Scope Specifications a three-page section titled, Constructability, that defines:

- “the minimum constructability requirements that shall be implemented on the project.”

The specification requires that a complete constructability program be developed and approved by the owner early in the design phase.

Tools 17a through 17d in Part III provide sample documents that owners can use as a basis for defining the project constructability program requirements. Tools 17a and 17b can be used when the contracting strategy facilitates early construction participation. By including the appropriate tool in the owner’s RFP (as modified to meet the owner’s specific project needs), the owner can proactively ensure that personnel with construction knowledge and experience are active participants throughout the project process. Tool 17c can be used when the contracting strategy requires the use of third party constructability services. The owner can use this tool to place the constructability responsibility with the engineer or obtain these services from a contractor, construction manager, or a constructability consultant. Tool 17d is a clause to be included in the architect’s or engineer’s contract when the owner places responsibility for managing the project constructability program with a construction contractor, construction manager, or constructability consultant.

Consider use of incentive clauses related to constructability performance. Well-conceived incentive clauses can effectively enhance a project’s constructability. On a petrochemical facility expansion project, an owner effectively integrated incentive programs between the on-site designer and constructor (see Case Studies). The designer’s and constructor’s incentive programs both included incentives for milestones, quality, and final completion. The designer also had home office effort-hour incentives. The constructor had field productivity and safety incentives in addition to other incentives. To benefit from the incentives, the two organizations (designer and constructor) were dependent upon one another and had to work jointly to coordinate their efforts. On this project, common goals were established between the designer and the constructor. These goals encouraged the implementation of constructability as a means to ensure that common objectives were met. Creating the common goals also acted as one of the means to provide team building for the project.