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IMPLEMENTING PROJECT CONSTRUCTABILITY

TCM Framework: 11.5 – Value Management and Value Improving Practices (VIPs)

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PURPOSE

This recommended practice for "Implementing Project Constructability" is intended to provide a guideline, not to establish a standard. As a recommended practice (RP) of AACE International, "Implementing Project Constructability" provides guidelines for developing and implementing constructability programs in all the phases of a project's life cycle.

Constructability is the integration of construction expertise into *all* phases of the project to benefit cost, schedule, quality, and overall project objectives. The successful use of construction knowledge and expertise increases the probability of project success. Constructability reviews (CRs) should be conducted at key points in the project life cycle: in the planning phase, early in the design phase, prior to the procurement phase and again prior to the mobilization phase for construction. CRs should hold true to the designer's intent, and the design concept is easiest molded to good constructability early in the design phase.

Constructability, as addressed in this RP, is applicable to projects in any industry in any location (e.g., architectural, process plant, transportation, utilities, offshore, etc.) that include construction work of any scope. In total cost management (TCM), constructability is one of many value improving practices (VIPs) such as manufacturability analysis; reliability, availability and maintainability (RAM) analysis; and so on.[9] Constructability is also useful as a risk management practice that supports risk mitigation. However, these other VIPs and risk management practices are not directly included in this RP.

AACE is not the sole or even primary steward of recommended constructability practice; there are several leading organizations included in the reference section. However, constructability is a skill and knowledge area of cost engineering because, as a VIP, constructability practices require the assessment of cost, schedule, risks and other project attributes for which AACE *is* the leading organization. This RP highlights the role of cost engineering in the practice.

This RP will discuss how to implement a constructability program in order to maximize the positive impact on the project. It also provides project examples illustrating the success of those properly implemented efforts. Integrating constructability into project plans can result in better safety, lower costs, better productivity, earlier completion and start-ups for ultimately better projects.

RECOMMENDED PRACTICE

Constructability is a term of art which has come to encompass a detailed review of design drawings, models, specifications, and construction processes by one or more highly experienced construction engineers or specialists, working with the project team (including cost engineering) before a project is put out for bids and also prior to construction mobilization. It is defined as "the use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives."[4] The purpose of the constructability review is to identify the following five items:

- Design errors, in either material selection or dimensions.
- Ambiguous specifications.
- Project features that will be difficult or exceedingly costly to construct as designed.
- Project features that exceed the capability of industry to properly build.
- Project features that are difficult to interpret and will be hard to accurately bid.

Project "features" include both physical characteristics and planning attributes (e.g., execution strategy, schedule logic, etc.).

Constructability reviews add value to the project planning and development process through the following methods:

1. Strategies by which to implement improved constructability include these:
   - Use improved construction systems.
   - Simplify the design or combine elements.
   - Standardize the design and repeat elements.
   - Improve information availability and clarity.
   - Improve the construction sequence.
   - Improve the use of equipment and tools.
   - Improve constructor-designer communication.

2. Cost savings derive from:
   - Fewer delays.
   - Reduced direct construction effort.
   - Shortened duration of activities.
   - Less work at higher elevations.
   - Less material required.
   - Decreased likelihood of labor conflicts.

3. One must initially invest to earn the cost savings from better constructability:
   - More effort for design and procurement.
   - More communication among builder, designer, and vendors.

4. Improve constructability and reduce costs by:
   - Mitigating the effects of adverse site conditions.
   - Implementing better design, building, or process technologies.
   - Offering assembly-line conditions.
   - Accelerating the schedule by decoupling sequential workface activities.
   - Reducing the number of workers and costlier skills.

5. Better constructability methods can include:
   - Prefabrication. Economies and quality via manufacturing process.
   - Preassembly. Join components into subunit at remote, better-controlled location.
   - Modularization. Assembly operations create the largest unit logistically possible; contains all components of final state.

The application of constructability to architectural and process plant projects has been around for decades. However, its use on transportation projects is relatively new.[8] A comprehensive study in this field is presented in National Cooperative Highway Research Program (NCHRP) Reports 390 and 391.[1,2] In this study, constructability is thought to be an integral part of the project development process where a project is divided into three phases: planning, design, and construction. Its authors drew this process from the study of the implementation of constructability in the non-transportation sectors. So constructability as presented in this RP represents not only the current thinking on this subject, but also a synthesis of the latest research making it generally applicable to any type of project.

Project-Oriented Constructability Review Process

The constructability review is incorporated into the project development process by defining parallel constructability phases such as constructability in planning, design, and construction. These three phases of constructability review are further divided into features of work based on the needs of the project in question. This format can be used to guide both the constructability reviewers and the designers in

ensuring that the entire project scope of work is included in the review process and that the resultant construction documents are of the best quality possible.

As a study by Yates and Battersby[15] validated, the implementation of a constructability review cannot be conceived separately from experience in the field. Therefore, past experience and best practices are invaluable contributions to the constructability process. With the implementation of the information learned during similar projects, potential areas of difficulty can be identified prior to construction. Analyses and constructability reviews during planning, design and construction phases only improve the quality of the final product. In doing the analyses and constructability reviews, the constructability team tries to establish some connections with similar past projects. The factors that created success in a past project can be replicated in the new project, and the reasons that led to the failure of the project can be avoided in the future. One practical problem towards using past experience in organizations that are new to constructability is the lack of documentation regarding experience and knowledge gained during each previous project. Acquisition of this past experience information can be either realized within the organization of the project, or it can be shared with other similar project organizations. As a key process step of TCM in general, and specifically for constructability, accumulated knowledge within the organization should be stored in a database and retrieved as required.

Organizations that are new to implementing constructability can draw from the successful experience of the U.S. Army Corps of Engineers (USACE) who in the early 1980's instituted a program of conducting formal constructability reviews on all projects before they are released for bids.[13] Experience in USACE showed that virtually every review catches some factor that if it were left unchanged would have necessitated a potentially costly construction change order during that project.

For those in the process industries, quantitative, empirical research by Independent Project Analysis, Inc. has demonstrated that VIP programs (which almost always include constructability) improve project cost performance when combined with well defined project scope prior to full funds authorization.

The USACE concept can easily be applied to other public and private projects. Essentially, it is a review of the capability of the industry to determine if the required level of tools, methods, techniques, and technology are available to permit a competent and qualified construction contractor to build the project feature in question to the level of quality required by the contract documents (i.e. drawings and specifications). The constructability review also entails an evaluation of the ability of the industry to understand the required level of quality and accurately estimate the cost and schedule of providing it. Thus, the level of project risk due to misinterpretation that is inherent to a set of specifications or a project feature is reduced. When a formal constructability review is combined with a thorough economic analysis, the final design is greatly enhanced. And the project is therefore less susceptible to cost and time growth resulting from change orders and claims. The benefits of a constructability review are listed below.[7]

- Reduced cost
- Shorter schedules
- Improved quality
- Enhanced safety
- Better control of risk
- Fewer change orders
- Fewer claims

A survey taken in Canada confirmed many of the above-cited constructability benefits.[10] Additionally, this study found that "the areas that survey respondents indicated have the greatest potential to yield the benefits are achieved by implementing the following:

- Up-front (early) involvement of construction personnel.
- Use of construction-sensitive schedules.
- Use of designs that facilitate construction efficiency."[10]

Thus, the study reinforces that the opportunity for design and construction organizations to use this powerful constructability review as a tool to improve their projects. Unfortunately, some studies do not highlight the key role of cost engineering in constructability. Poorly done assessment of the cost, schedule, risks, and economics of constructability alternatives will diminish if not negate the results of the practice. Therefore, cost and schedule specialists should be a part of the constructability review team. This leads the discussion to an example where the details of how to apply constructability to every phase of the project can be used to illustrate to the reader the benefits of implementing a constructability program.

IMPLEMENTING CONSTRUCTABILITY

For this recommended practice, the concept of accruing the benefits of implementing constructability is detailed throughout every phase of a construction project — feasibility studies, conceptual planning, design, procurement, and construction as well as after construction. During these phases, the methods by which to implement constructability might involve changes to:

- Field supervision and operational planning.
- Location of direct effort, from workface to shop.
- Equipment and tool application.
- Design effort and material selection.
- Communication between designer and builder.

Note on competencies: the following implementation-by-phase discussions describe typical roles of owners, contractors, consultants, and others in constructability reviews. Other than the need to bring the best available construction competency to bear in the practice, this RP's discussion of typical situations is not recommending specific roles except under the circumstances noted. The project team should first assess the required and available competency (i.e., between owner, contractor, consultant, etc.) in consideration of project strategies. For example, the Construction Industry Institute (CII) has developed a core competency assessment toolkit that includes constructability competency assessment.[11]

Feasibility Phase: Often owners of projects do not have any "in-house" capability for construction services, so they procure the services of a consulting firm to perform the initial "feasibility phase" constructability review. The consulting firm works from the preliminary design documents and provides useful suggestions that are incorporated into the design package. The results of the constructability review can literally make or break a project's viability.

Constructability input as a service provided by either a consultant or construction management firm during project activities prior to the start of construction is referred to as constructability services. This constructability services approach during the conceptual or feasibility phase of the project provides the owner with a facility that meets all its project objectives. This approach often combines the benefits and costs of constructability with other services provided such as value engineering, risk management, and project planning. The services are primarily to supplement an owner's limited resources for early planning and design evaluation. Constructability improvements obtained through the use of constructability services "is more a byproduct of early construction involvement rather than an intentional attempt to avoid unnecessary construction difficulties. As a result, this approach tends to be informal."[5] Additionally, an owner that is exploring the potential feasibility of a given project will want to limit its costs to the minimum necessary to determine economic feasibility. Thus, the focus of a feasibility phase constructability review will be to generate alternatives that can be expanded by conceptual design decisions in a manner that permits the necessary financial and schedule considerations for each alternative to be determined with the requisite degree of certainty by cost engineering specialists or equivalent. Essentially, the constructability reviewer/consultant will furnish the owner with options that were not contemplated by the designer.

Early Design Phase: As the architects/engineers develop the project design; the owner typically retains a second team of specialists who specialize in providing construction management (CM) services. The constructability review takes place as the construction documents are being developed. This CM team will perform a detailed constructability review (CR) of the proposed project documents: design drawings, technical specifications including specified construction materials, the proposed site layout and if available; the construction cost estimate and project milestone schedule. This review effort will focus on whether the project can be built as designed and must be conducted at a point in time were design effort is not lost by incorporating CR recommendations. For large projects or those with a complex work breakdown structure and/or execution strategy, multiple reviews may be appropriate. As with other VIPs, it is best practice that the constructability effort at this phase be a formally planned, with an assigned team, working in special session or sessions, with documented findings. This CM/CR team effort will provide suggestions on ways to improve the project: such as a more efficient site layout, alternate construction materials, and identifies possibly detrimental design specifications that could result in long lead time procurements or exotic construction techniques. All of this constructability review information is provided to the owner (who has optimally been a participant throughout) along with their expert construction opinion about the probability for the construction success of the project.

These construction management specialists can also assist the owner in establishing the philosophy, procedures, and tracking systems during pre-detailed design activities for the project. Although typically an informal aspect of the constructability program, the application of this approach to provide construction input is typically limited to specialized projects. Formal corporate-level tracking of lessons-learned and cost/benefit data resulting from constructability implementation is a best practice but is not routinely performed.

Procurement Phase: When the overall project design is approximately 60 to 90 percent complete, the owner retains a construction management firm to prepare the project for the procurement phase: the preparation of subcontracts and procurement bid packages, pre-qualification of vendors, suppliers and trade contractors. These procurement bid packages must be complete design packages in order to provide the qualified bidders with the information necessary to make intelligent cost proposals for the overall success of the project. For example: During a CM review of preliminary draft bid packages; a subcontract for several self-contained semi-trailer mounted air filtration/monitoring units had been specified by the mechanical engineer for subcontractor fabrication in the field. The craft labor effort and cost for this on-site fabrication would be enormous. By rewriting this bid package from a subcontract into a special vendor procurement to fabricate and deliver those as fully assembled semi-trailer units, the owner was able to avoid a significant cost to the project.

During the subcontractor procurement process, after receipt of the request for proposal (RFP), the various bidding contractors will normally conduct their own constructability reviews prior to bidding. Constructability clarification questions are frequently transmitted to the owner's representative who provides additional information about site conditions, ambiguous or missing construction details, and often the bidding contractors may propose alternate construction methods for consideration. Although typically not a formalized aspect of the constructability process, these are also important elements of constructability and this request for information (RFI) process during the request for bids must be established in a manner that allows it to capture unexpected constructability input from subcontractors during the procurement phase.

Construction Phase: Constructability continues to be a viable tool for the success of the project after the award of the major contracts and purchase orders. For example, a mechanical contractor, employing formal or informal constructability reviews for their scope, may determine that certain piping components could be fabricated in their shop and economically transported by truck to the project site, thereby improving both labor productivity and reduce the field costs for that large component of the work on a project. The owner, the engineer, and the CM must remember that trade subcontractors are the technical experts in their field and must include construction contract language that encourages constructability improvement suggestions as well as requests for material and means substitutions. The submittal review

process must be established to identify potential constructability improvements and then analyze the impact of implementing them on both project budget and schedule.

An example of this process occurred on a project where approximately 2,000 linear feet of large bore piping was eliminated from the scope of work for the mechanical contractor by relocating the designed liquid holding tank location to a place adjacent to an existing (and unused) pipe tee connector point. The holding tank was also redesigned to take advantage of readily available "off the shelf" top and bottom components that expedited the fabrication and delivery of that unit, thereby improving the schedule by several weeks. By eliminating a function (pipe conveyance), this construction decision combined constructability and value engineering approaches.

Constructability and value engineering are often confused as synonymous terms that should be separately differentiated. Constructability does not include value engineering, nor does it infringe on the designer's responsibilities for the project. A recent survey conducted by the Construction Management Association of America (CMAA) concluded, "Architects need to be held more responsible for completing a quality design that can be built without numerous change orders or requests for information."[6] A common definition for value engineering is "a practice function targeted at the design itself, which has as its objective the development of design of a facility or item that will yield least life-cycle cost or provide greatest value while satisfying all performance and other criteria established for (the facility or item)."[3] Value analysis and engineering is focused on evaluating and optimizing functions of the process or facility [9] whereas, constructability is the integration of construction expertise into *all* phases of the project design to benefit cost, schedule, quality, and overall project objectives.

After Action Reviews: Constructability does not end when the project is completed. Often the project participants are in a hurry to close out the project and move on to another assignment. Either there is elation over the success of the project, or there is a strong desire to put their bad experiences behind them and move on. In either case, there should be a formal review to capture the constructability lessons-learned on the project. The corporation should establish a constructability database. "Implementing that approach, it is believed that the constructability review program will initially experience large incremental increases in total-annual documented savings. However, as the program matures, and the design and construction processes are optimized, the program's incremental increase in total annual documented savings reach a steady-state condition. In the "mature" state, additional documented constructability savings are realized through application of new construction methods and technologies."[5]

Constructability Implementation Plan: The literature clearly shows that the involvement of constructors early in a project's life cycle greatly enhances the possibility of accruing quantifiable benefits through reduced change order costs, compressed delivery schedules, and state-of-the-art construction means and methods being integrated into the design process. Next, it also shows that it is difficult for design professionals alone to develop the requisite field expertise to be able to recognize potential construction issues improvement opportunities and risks during the design process.

The successful use of construction knowledge and expertise will optimize the opportunities for project success. Constructability reviews should be conducted at key points in the project: in the planning phase, early in the design phase, prior to the procurement phase, and again prior to mobilization phase for construction. Constructability integration can result in lower costs, better productivity, earlier completion and start-ups for ultimately better projects.

A constructability implementation plan should include the process and procedures for conducting CR in each project phase. It is best practice that during the early design phase, constructability, as with other VIPs, be a planned, formal, documented process with specialized resources assigned. The plan should recognize that the assessment of the cost, schedule, risks, and economics of constructability alternatives will be improved by including cost and schedule specialists as part of the constructability review team. The following are some other key elements to be included in a constructability implementation plan:

- **Procedures for incorporating CR in the feasibility phase.** These should identify the method by which the owner will either utilize internal resources or outsource the requirement to a qualified CM or similar consultant.
- **Procedures for incorporating CR in the early design phase.** These should identify the method by which the owner will ensure that the architect/engineer will develop early design documents that can be submitted for CR to a qualified CM or equivalent consultant or appropriate CR team. They should also contain the appropriate contract language that will be inserted in both the design and CM contracts regarding the administration of CRs during this phase.
- **Procedures for incorporating CR in the procurement phase.** These should identify the method by which the owner will ensure that the architect/engineer will develop detailed design documents that can be submitted for CR to a qualified CM or equivalent consultant or appropriate CR team. These procedures must be developed with the idea that CR must minimize lost design effort in order to be effective. They should also contain the appropriate contract language that will be inserted in both the design and CM contracts regarding the administration of CRs during this phase. They should also contain specific instructions for identifying constructability input from RFIs and a methodology for evaluating and implementing that input during this phase.
- **Procedures for incorporating CR in the construction phase.** These should identify the appropriate contract language that will be inserted in both the design and CM contracts regarding the administration of submittals during this phase. They should also contain specific instructions for identifying constructability input from construction submittals and a methodology for evaluating and implementing that input during this phase. They should differentiate between contractor-initiated value engineering proposals and contractor-initiated constructability suggestions.
- **Procedures for CR after action reviews.** These should establish a systematic program to evaluate project performance and capture both best practices for future implementation and problem areas that must be addressed for starting the next project.

The implementation of formal constructability reviews as early as possible in a project's life cycle is of benefit to the designers and well as the constructors and owners in the reduction of lost design effort due to required changes identified during construction and the better coordination of cross-disciplinary issues. Constructability is a powerful tool that works to the benefit of all parties in the capital construction project delivery process. The major conclusion can be best summed up by the following statement from CII:[5]

> "Constructability can mean better projects — lower costs, better productivity, earlier project completions, and earlier start-ups." Owners, designers, and builders who belong to the Construction Industry Institute (CII) believe this statement and their message is: "Be sure that construction considerations are incorporated into every phase of a project — feasibility studies, conceptual planning, design, procurement, as well as construction."

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