Integrating Constructability into Project Development: A Process Approach

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Abstract: The National Cooperative Highway Research Program initiated a research project to develop a constructability review process (CRP) for transportation facilities. The basic objective of this research was to develop a systematic approach and methodology for constructability reviews. This paper describes the development of a CRP that meets the National Cooperative Highway Research Program's research objectives. A process approach is followed to integrate constructability improvements into project development for transportation projects. A function modeling tool is used to portray the interface between the CRP and the project development process. The function modeling tool captures constructability functions and information necessary to perform these functions. The research method to develop the CRP is presented. The CRP has three phases corresponding to planning, design, and construction of a transportation project. Seven constructability functions are performed in each phase. The model was tested using two transportation projects of different complexity.

INTRODUCTION

The National Cooperative Highway Research Program (NCHRP) initiated a research project to develop a constructability review process (CRP) for transportation facilities. This research resulted from the need for contract documents to ensure rational bids and minimize problems during construction. State transportation agencies (STAs) recognized that a significant aspect of developing high-quality contract documents is to incorporate a review process in project planning and design to assess a project's constructability. This process must include input from professionals involved in planning, design, construction, operation, and maintenance of transportation facilities.

A successful CRP for an STA should follow an established methodology similar to value engineering. The process must be flexible for application to all types of STA projects. Furthermore, the process must address critical issues impacting transportation construction such as environmental factors, construction phasing and sequencing, project safety, and accommodation of future operations and maintenance. To obtain the maximum benefit from a constructability review, it must be initiated early in the project planning phase and continue through design and construction.

The basic objective of the NCHRP research was to develop a systematic approach and methodology for a CRP. This methodology must incorporate constructability concepts, existing analytical tools to support constructability reviews, and functions needed to apply both concepts and tools. Also, the methodology must be designed to fit different project characteristics and requirements. Finally, it must be adaptable to different STA approaches to project development.

The purpose of this paper is to describe the development of a CRP that meets the objectives of the NCHRP research. Once this is accomplished, the paper presents the CRP model. A process approach is used to integrate constructability reviews into a project development process (PDP) for transportation projects. This paper focuses primarily on the methodology used to identify the functions of a CRP and how these functions are related to each other. A companion paper discusses how constructability functions are performed using specific constructability tools (Fisher et al. 2000).

BACKGROUND

Constructability has been defined in a number of ways. Constructability is the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives (''Constructability'' 1986). Constructability is also defined as a measure of the ease or expediency with which a facility can be constructed (Hugo et al. 1990). Finally, constructability is often portrayed as integrating construction knowledge, resources, technology, and experience into the engineering and design of a project (Anderson et al. 1995).

A major challenge of implementing constructability is how to effectively integrate construction knowledge and experience into each phase of the PDP. Anderson et al. (1995) proposed a process-oriented framework to portray when, where, and how integration of construction knowledge and experience should occur with respect to project development. Further, they recommended the use of the IDEF0 (Integrated computer aided manufacturing DEFinition) function modeling technique to describe the CRP and its interface with project development.

IDEF0 function modeling was used to successfully model the design process (Sanvido and Norton 1994) and the preproject planning process (Gibson et al. 1995). IDEF0 modeling has not been used to model the interface between two distinctly different but interrelated processes, such as project development (planning, design, and construction) and constructability. Modeling the interface between project development and constructability reviews identifies information, such as draft plans from the PDP, that is received from one process as input. This input is transformed into output from the second process, such as constructability improvements from the CRP. When constructability improvements are incorporated into design documents, the project should benefit by minimizing the number and magnitude of changes, disputes, cost overruns, and delays during construction. In effect, this will improve the project development process for STAs and other public agencies who want to implement constructability.

The IDEF0 modeling technique is used to design and layout a process. It captures functions and key information supporting the performance of these functions. Relationships between

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Note. Discussion open until September 1, 2000. Separate discussions should be submitted for the individual papers in this symposium. To extend the closing date one month, a written request must be filed with the ASCE Manager of Journals. The manuscript for this paper was submitted for review and possible publication on June 25, 1998. This paper is part of the ***Journal of Construction Engineering and Management***, Vol. 126, No. 2, March/April, 2000. ©ASCE, ISSN 0733-9634/00/0002-0081–0088/$8.00 + $.50 per page. Paper No. 18638.

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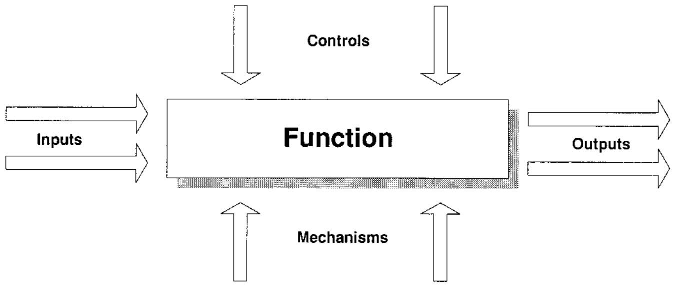

FIG. 1. Cell Modeling Technique

functions can be modeled through IDEF0 (Mayer 1992). IDEF0 uses cell modeling graphic representation as shown in Fig. 1 (Mayer 1992). Fig. 1 shows a function (the box) and the interfaces to or from the function as arrows entering or leaving the box. The input (information needed to perform the function) is transformed by the function to provide output (information produced by the function). Controls (arrows coming into the top of the function box) are information that governs the accomplishment of the function. Mechanisms (arrows coming into the bottom of the box) are tools that are used to perform the function.

IDEF0 was selected to develop and portray the CRP. The result of using IDEF0 was a validated, generic model that describes a systematic approach to incorporating construction knowledge and experience into the STA project environment. This environment is typically characterized by the design-bid-build approach, where construction is competitively bid using a fixed unit price basis. The CRP model and approach is adaptable for use in other construction industry sectors.

METHODOLOGY

Current Practice

A survey was used to determine the extent that formal constructability programs were being used in STAs (including Puerto Rico and the District of Columbia). A one page questionnaire was sent to each transportation agency. Each agency was asked to respond to this questionnaire and also send a similar one page questionnaire to three design firms and three construction firms. The purpose of these questionnaires was to capture information regarding the formality of current constructability practices, level of constructability input during major project development phases, and critical issues impacting implementation. Table 1 indicates participation in the survey.

Of the 40 STAs responding to the questionnaire, 23% have formal constructability processes. Of those agencies that had a formal constructability program, five provided documentation of their programs. However, the level of formality of these programs varied. Several programs were very formal as they incorporated concepts suggested in the literature, such as specifying constructability objectives, forming a constructability team, and identifying means to obtain constructability input. Several programs incorporated constructability only through standard design procedures. These programs often used checklists and defined points in the design process where reviews occur. In general, all formal programs appeared to lack distinct functions or steps that lead the user through constructability implementation. They were also heavily focused on the project design phase.

Most STAs that practice constructability did so informally depending on project complexity and the degree of involvement of the agency with in-house design. In these agencies, constructability was accomplished through a series of design reviews at various stages in design (e.g., 60 or 90% design). These reviews often occurred at final design, just prior to bid.

TABLE 1. Distribution and Receipt of Questionnaires

Group (1)	Sent out (2)	Received (3)	Response rate (%) (4)
Agency	52	40	77
Design firm	156	73	47
Construction firm	156	50	32

Seventy-three responses were received from design firms of which 16% stated they had a formal constructability program. Similar to state agencies, the degree of formality varied from extremely well documented with flowcharts and definitive steps, to checklists that ensure design standards are met and construction issues are considered when reviewing plans. However, most design firms that practiced constructability did so informally through standard design reviews. Interaction with agency personnel occurred at major predetermined milestones.

Fifty responses were received from construction firms. None of these firms had a formal program for constructability. Most indicated that they pursue constructability as part of preconstruction planning and bid preparation.

Literature Review

Research conducted by the Construction Industry Institute (CII, University of Texas at Austin) has been the driving force behind the formalization of constructability. Initial CII research identified many specific constructability ideas (''Constructability'' 1987). A second major constructability research thrust by CII produced a comprehensive constructability implementation guide (''Constructability'' 1993). The guide provided a methodology for implementation in the form of a roadmap with steps and tool applications.

Although constructability has been studied in the transportation industry, its exposure has not been as widespread as in the industrial and building construction industries. A constructability approach was documented in a highway constructability guide, developed for the Texas Department of Transportation (Hugo et al. 1990). This guide described constructability in some detail, with respect to its definition, its relationship to other programs such as value engineering, why and when to pursue constructability, and factors affecting highway constructability. The guide offered a constructability enhancement program. Another constructability study was conducted for the Florida Department of Transportation (FDOT) (Ellis et al. 1992). The constructability review system developed for FDOT consisted of two parts: (1) Constructability reviews; and (2) postconstruction review. The FDOT system suggested that constructability reviews should be performed at 30, 60, 90, and 100% completion of design. A constructability guide was developed for the Arizona Department of Transportation (ADOT) (Wright 1994) that provided an overview of constructability and identified current practices. In the area of implementation, goals and objectives were defined and a general philosophy was provided to aid ADOT in incorporating constructability into their project development process. A major contribution of the guide was the identification of numerous constructability concepts directly applicable to highway construction. Finally, Russell and Swiggum (1994) developed a highway constructability work process for the Wisconsin Department of Transportation (WDOT). The process was divided into two phases: (1) Precontract award constructability; and (2) postcontract award constructability. Each phase has a number of specific steps that are described in detail.

The models reviewed varied in terms of depth and breadth of information presented. The CII roadmap and the WDOT models provided the most detail in terms of steps and the

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sequencing of steps in a process formulation. Both suggested tools to aid in implementation.

Research Advisory Team

Because the proper implementation of constructability requires input from many different professionals, the research approach incorporated a similar spectrum of different viewpoints. A research advisory team was formed to provide practical input. Table 2 shows the type of expertise that was represented on this advisory team. This team provided input through review of various IDEF0 models and other documents as the CRP was developed.

Process Modeling

IDEF0 function modeling is systematic and very structured. The research followed the modeling approach suggested by Mayer (1992). First, it is important to determine the model's orientation. This includes the context, viewpoint, and purpose of the model. The purpose of the CRP model was to document an integrated process for applying constructability reviews to the planning, design, and construction of transportation facilities. The context of the model was the project life-cycle phases; planning, design, construction, and operation and maintenance. The viewpoint was that of an STA, and more precisely, the group(s) responsible for project development of transportation facilities within STAs.

The model is hierarchical in nature, that is, lower-level diagrams are decompositions of the upper-level diagrams immediately proceeding them. The process is represented at the first level by one general box called a context diagram. The context diagram represents the whole process as a simple unit-box with arrow interfaces to functions outside the system. Because the context diagram represents the process as a whole, the descriptive name written in the box is general. In the CRP, this name is ''apply constructability to transportation projects.'' The next level is more specific, and the functions at this level include ''apply constructability during the planning, design, and construction phases'' of the PDP. The third level is a decomposition of planning, design, and construction into yet more specific subphases that occur during each of these major project development phases. Finally, the fourth level represents the actual constructability functions performed during each project development phase.

At each level, diagrams are created that describe the information needed to perform the function. As shown in Fig. 1, the input (information needed to perform the function) is transformed by the function to provide output (information produced by the function). Controls are information that govern the accomplishment of the function. Mechanisms are people or tools that help perform the function (Mayer 1992).

At each level of decomposition, information in the form of input, output, controls, and mechanisms are attached to each model function. Functions are then linked to one another according to the inputs required to perform the function. Output from one function may be the input required for a subsequent function. This process is iterative until a complete model of the general process is developed. This model consists of diagrams, narrative descriptions of all functions and information, and a glossary of terms presented in the model.

The research team followed this IDEF0 approach to develop a preliminary CRP (Anderson and Fisher 1997a). The details of the preliminary model were derived from several sources such as the CII and WDOT models, documents received from several STAs, and input from the research advisory team. The preliminary model was then reviewed and approved by the NCRHP panel overseeing the research.

The preliminary model was refined to incorporate more specific comments from detailed reviews with the research advisory team. The major focus of these reviews was to analyze each function in the model to confirm that the function was required, to clarify the description of each function, and to confirm the proper location of every constructability function within the overall CRP framework. At the same time, the model framework and details were reviewed with several STAs. Each of these review sessions contained a discussion of the general concept of integrating the CRP with the PDP, a detailed review of the constructability functions represented in the model including their sequence, and the applicability of the constructability functions and their timing in terms of the PDP.

TABLE 2. Composition of Research Advisory Team

Number of participants (1)	Type of organization (2)	Job position (3)
4	STAs	Chief, claims research branch; director of operations; construction engineer; constructability engineer
3	Design/consulting firms	Manager, special projects; engineering manager, highway and bridges; vice president, data technology
1	Contractors	Vice president, heavy/highway division
1	Federal agency	Chief, advanced research team
3	University	Research academics

PROCESS MODEL PRESENTATION

The concept of linking constructability functions to the PDP is achieved by connecting both processes (i.e., PDP and CRP) through key inputs and outputs. Fig. 2 shows this relationship in three dimensions. The boundary represents the context of the system, and the two parallel planes represent the PDP and the CRP. Both processes span through the entire project life cycle. The two processes transfer inputs and outputs to each other in a specific sequence. Key PDP inputs to the CRP reflect different project deliverables and information as illustrated in Fig. 2. These inputs tie into the CRP at different points in the project. In turn, the constructability improvements are generated as outputs of the CRP and become inputs to the PDP. This exchange of information is iterative until each project phase is completed. Finally, as shown in Fig. 2, updated lessons learned, benefit/costs, feedback from operations and maintenance, and feedback to designers is output of the CRP that becomes input for future projects. This type of information flow leads to continuous improvement of the CRP and PDP.

CRP Framework

The framework that describes both the PDP and CRP are shown in Fig. 2. The IDEF0 hierarchical approach was used to visually represent the framework for both processes. Figs. 3 and 4 show the PDP and CRP framework, respectively, using the IDEF0 hierarchical representation. Notice that the first two levels of decomposition are essentially the same. The context diagram or summary level represents the project development process (A0P), Fig. 3, and the application of the CRP to transportation projects (A0) in Fig. 4. The first decomposition shows the three phases of a project: planning, design, and construction. These phases are denoted as A1P, A2P, and A3P, respectively, for the PDP and A1, A2, and A3, respectively, for the CRP. The second decomposition reflects subphases

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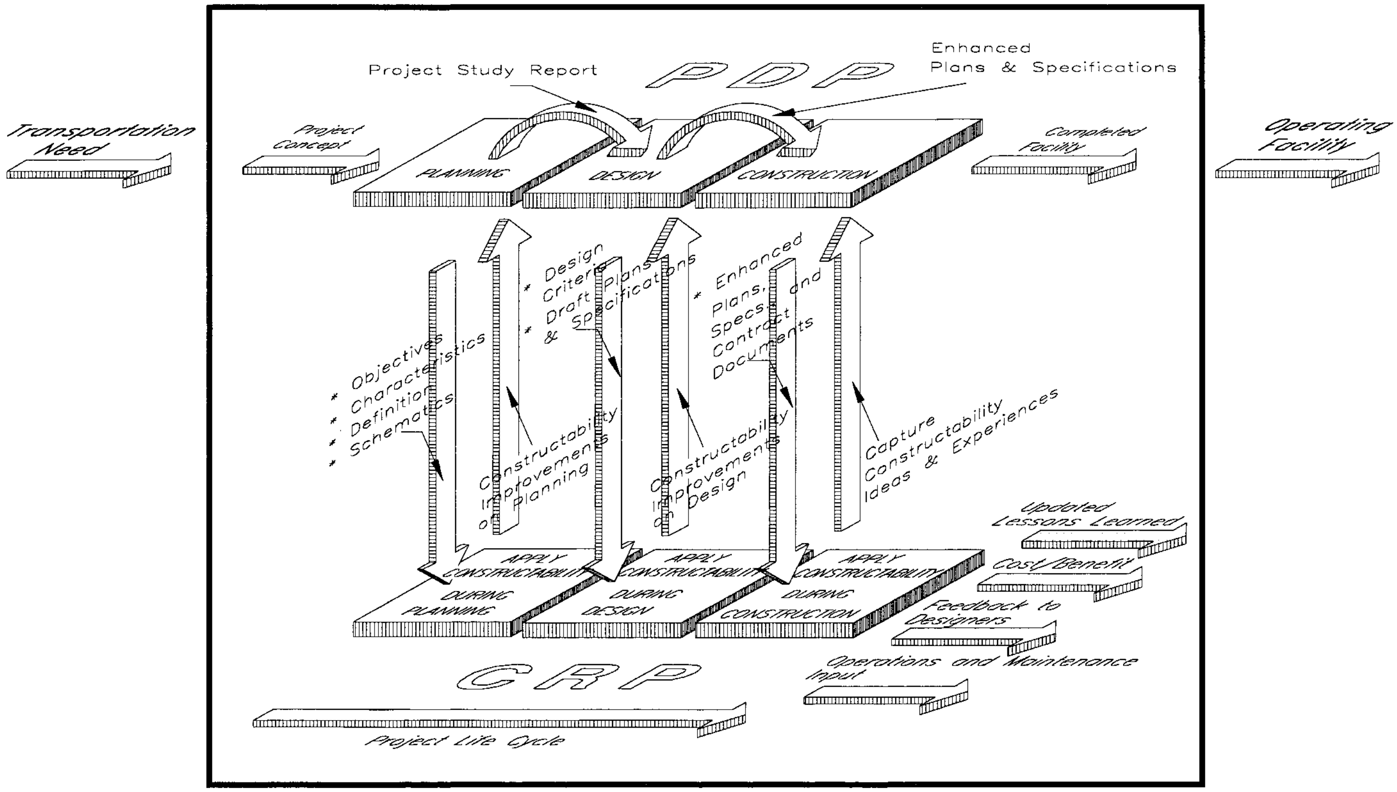

FIG. 2. Total Constructability Management: Integration of CRP and PDP

within each major project development phase (A11P, A12P, etc.) and the application of constructability during these subphases (A11, A12, etc.). The final decomposition represents the specific activities performed during each subphase of the PDP as shown in Fig. 3. The same decomposition for the CRP in Fig. 4 shows the constructability functions performed during the application of constructability during each subphase. Since the interest of the NCHRP research was to develop a CRP, the IDEF0 symbology was retained at the function level for the CRP framework (A111, A112, A113, etc.). Thus, the CRP is comprised of 21 functions: 7 in planning, 7 in design, and 7 in construction. This configuration of constructability functions was considered adequate to describe the process without being too complex.

As shown in Fig. 2, a continuous exchange of information occurs between the PDP and the CRP. During the project development phase, information exchange is initiated through PDP activities and then is followed by specific applications of constructability functions. As a typical example, Fig. 5 shows this iterative process in schematic form as it happens during the project definition subphase. The actual IDEF0 diagram for the project definition phase of the CRP is shown in Fig. 6.

The project scope study or scoping report is the major output of the PDP planning phase. During the project definition subphase of planning, a preliminary project scope study is prepared. This document is completed as a final scoping report during concept plan development. The focus of constructability, during the project definition stage, is to establish a constructability plan for the project (functions A111, A112, A113, and A114 in Fig. 6). This includes determining how constructability strategies can help achieve project objectives. The level of formality of the program is also determined. How to acquire constructability expertise is addressed, particularly in the context of in-house or outsourced design. Finally, the constructability team is created. This constructability plan would be included in the scoping report submitted for approval and incorporation into a STA multiyear plan. Since constructability requires monetary expenditures and commitment of other resources, incorporating such a plan for project constructability ensures the proper availability of these resources once the project proceeds to the design phase.

The CRP was designed to be flexible to adapt it to specific project characteristics and requirements. A key driver behind the flexible nature of the CRP is project complexity. Typically, total project cost and total work hour effort reflect a level of complexity. Also, the type of project has a relationship to complexity. Projects located in an urban setting and those involving reconstruction and/or grade separation are often more complex. Projects that involve many interfaces with other government agencies, the public, consultants, designers and contractors, may indicate a higher level of complexity. A classification scheme for transportation projects was adopted to reflect the level of project complexity (Anderson and Fisher 1997b). Using this scheme, the CRP model can fit specific project characteristics and requirements. Similarly, the CRP can be modified to be consistent with an STA approach to project development, policies, and resource availability.

Major Subphases of CRP

''Apply constructability during project definition'' is the first major subphase of the CRP. It is initiated as project definition provides inputs such as project objectives, project characteristics, and scope definition. Using this information, a constructability plan is formulated by performing four functions. The first function establishes the constructability strategies (A111) to meet project objectives. Based on these strategies and project characteristics, the level of formality of the constructability program (A112) can then be determined. Standard or small projects will require a less formal program than a large complex project. Next, agency personnel must determine how constructability expertise will be obtained (A113) for the project. This is influenced by the formality of the program and certain strategies such as the use of outside consultants. Fi-

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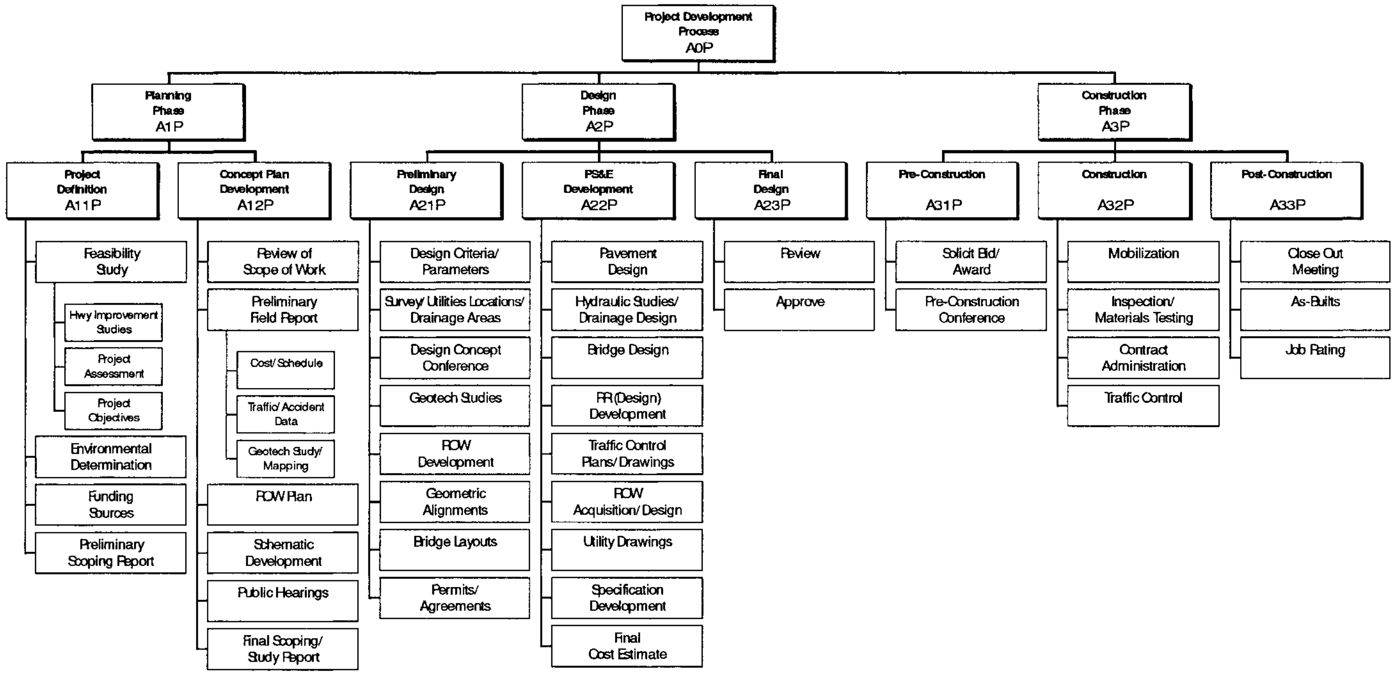

FIG. 3. PDP Framework (ROW = Right of Way; PS&E = Plans, Specifications and Estimate)

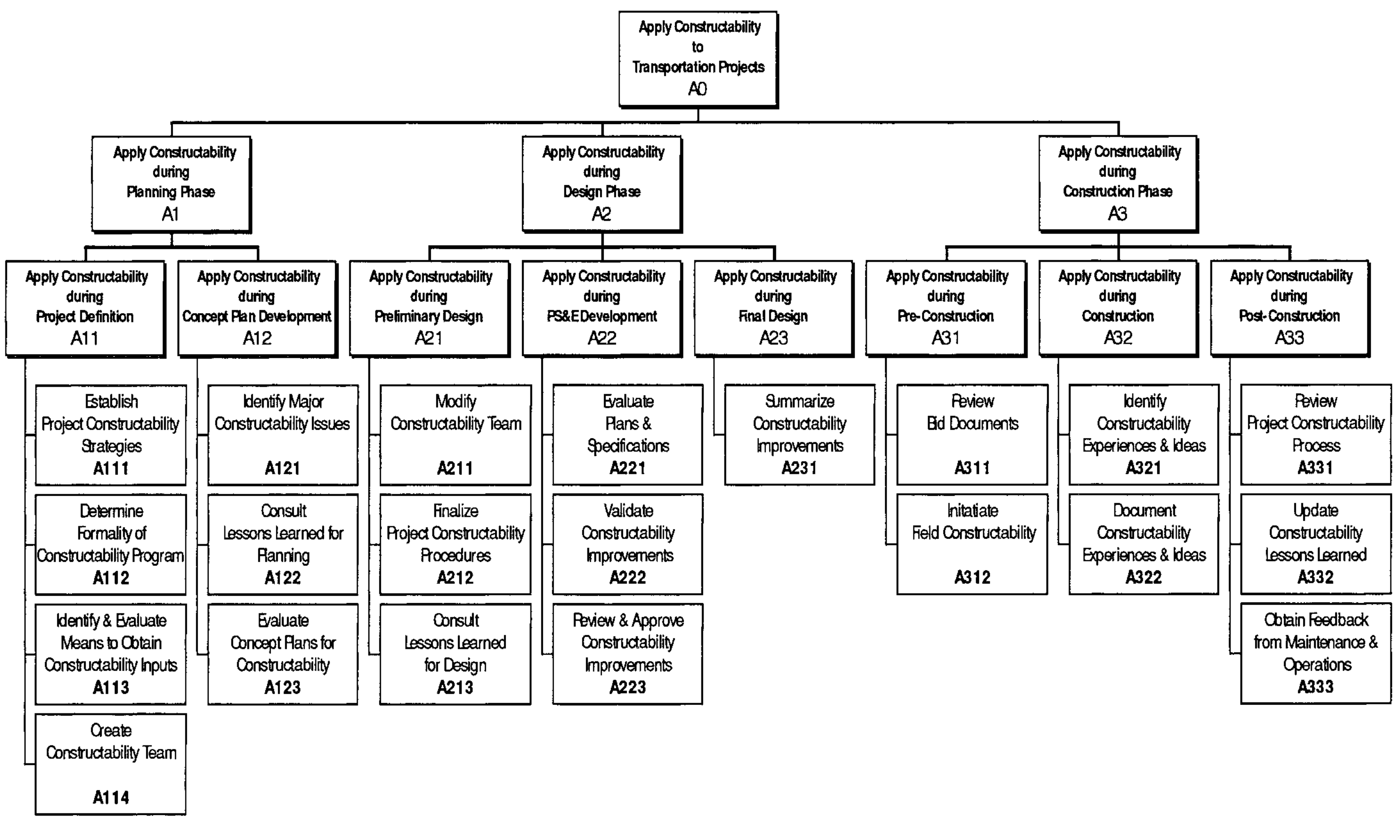

FIG. 4. CRP Framework (PS&E = Plans, Specifications and Estimate)

nally, a constructability team is created (A114) that is congruent with program formality and the expertise required. The combination of constructability strategies, formality of program, expertise needed, and team make-up describes the plan for constructability implementation. This plan will be incorporated into a preliminary scoping report (see Fig. 5).

''Apply constructability during concept plan development'' is the next major subphase of the CRP. It is initiated once the preliminary scoping report is complete and accepted. The constructability team identifies major constructability issues (A121) based on information contained in the scoping report such as constructability strategies and project characteristics. These issues, for example, may be related to site access particularly when right-of-way (ROW) is restricted or maintaining traffic during construction is critical. Once major constructability issues are listed, the team should consult lessons learned (A122) for previous experiences with respect to these issues from other projects or through expertise of the team. This experience, if applicable to the current project, is then used as a basis for evaluating concept plans for constructability

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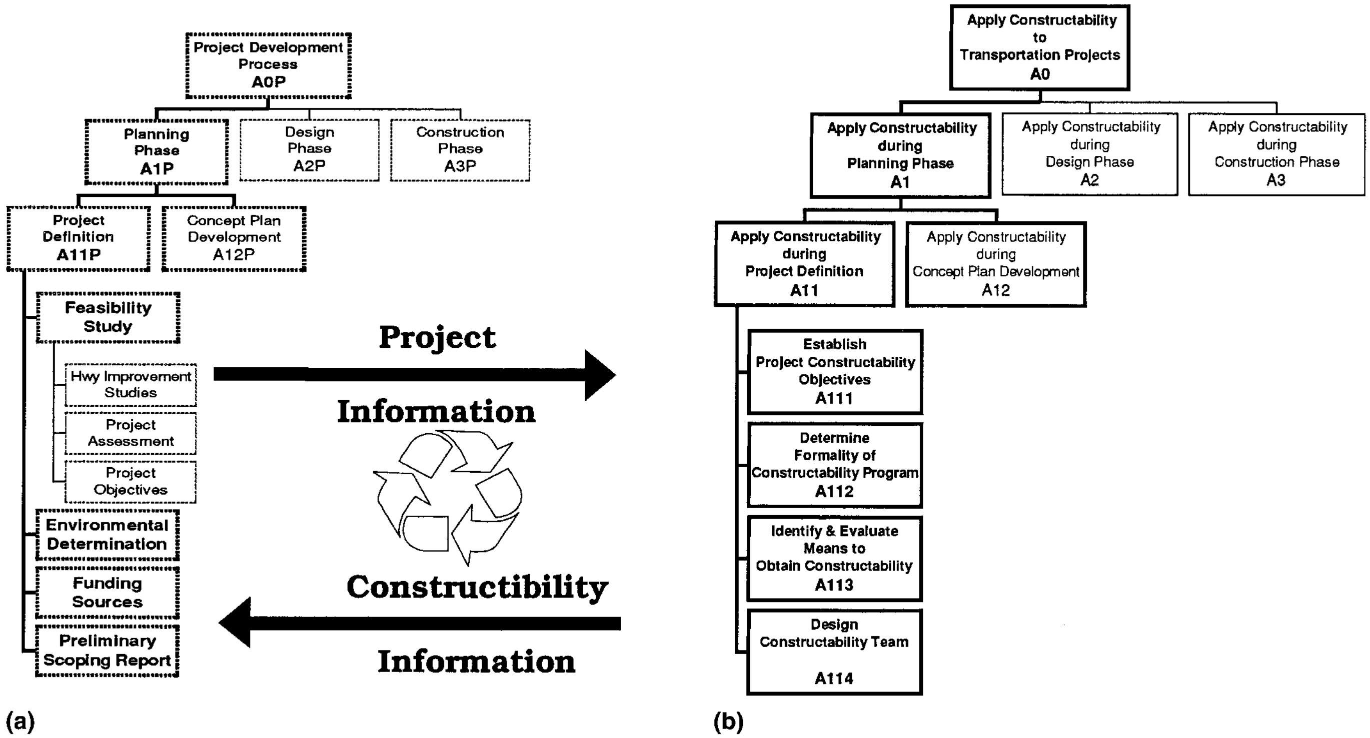

FIG. 5. Interaction during Project Definition Phase of: (a) PDP; (b) CRP

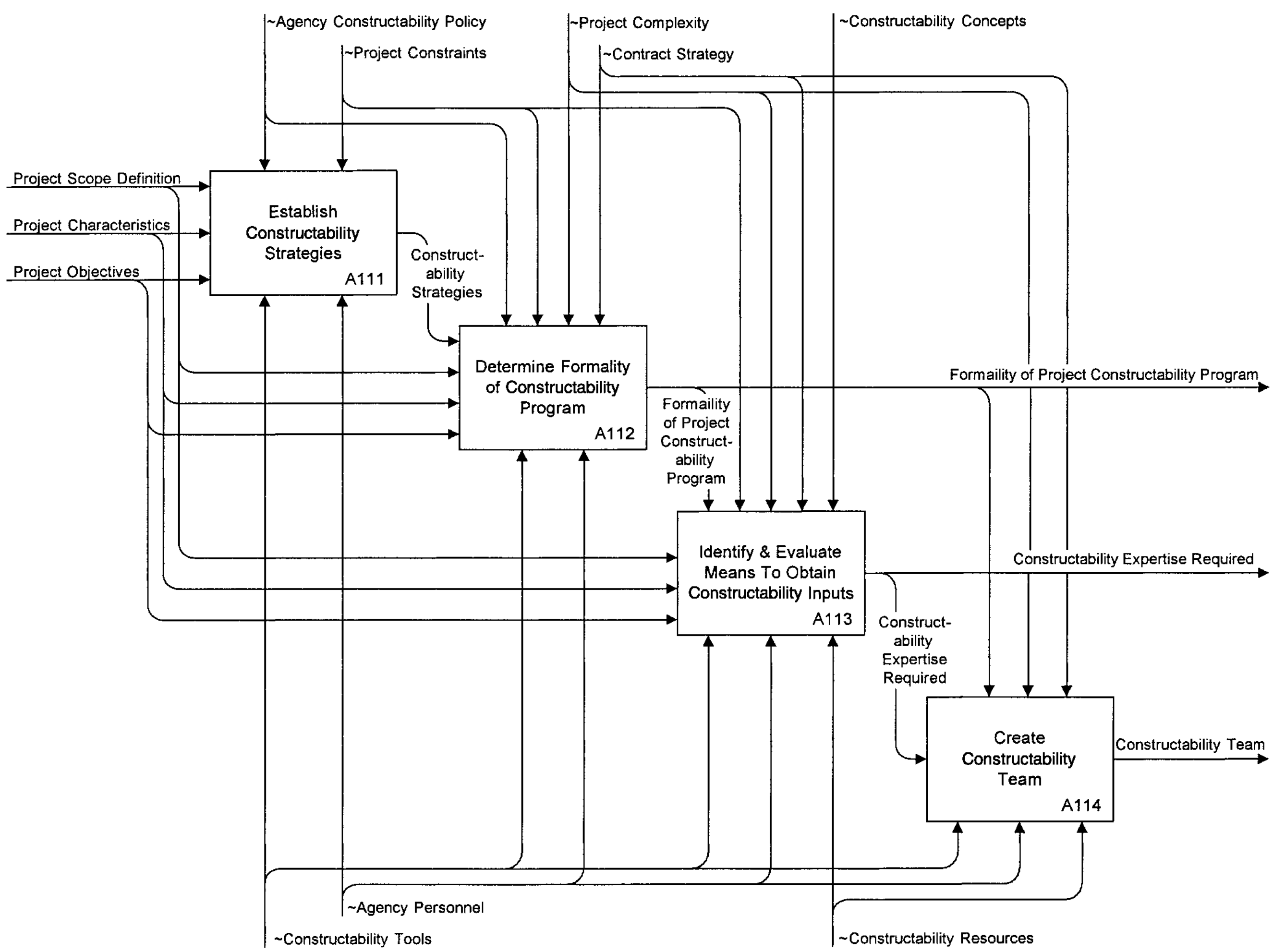

FIG. 6. IDEF0 Model for CRP during Project Definition

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(A123). Concept plans include schematics, right-of-way plans, field data, and other documents and information from concept plan development. Constructability ideas and suggestions are identified, documented, and evaluated for potential use as a constructability improvement. If accepted, the improvement is passed onto the planning team for incorporation into concept plans and the final scoping report. This document provides the basis for project approval and inclusion in the multiyear budget plan. The planning phase of project development is concluded.

After funds are released to design a project, ''applying constructability during preliminary design'' commences. An initial input of this subphase is the final scoping report from planning. This report contains the constructability plan that defines a proposed composition of the constructability team. The first function performed modifies the constructability team (A211). Actions taken include evaluating the project scope for technical requirements to ensure the appropriate construction expertise and knowledge is available. Team size is determined and the composition of the team is changed to fit the current needs of the project. Finally, the team is assembled. The constructability team must finalize project constructability procedures (A212). Constructability strategies and proposed program formalities are reviewed as a basis for determining team organization structures, roles and responsibilities, communication channels, and levels of documentation required. The team structure and constructability procedures may be modified as preliminary design information becomes available that more specifically describes project details. After the team is operating and procedures are finalized, the team consults lessons learned (A213). This function begins as design criteria are set and preliminary layout drawings and field data become available. The team can examine this preliminary design information and investigate previous experiences with projects that had similar characteristics. The intent is to identify and select the best ideas, procedures, and/or techniques applied on projects with similar conditions to the project being designed. If these ''lessons learned'' are applicable then they are recorded for later evaluation as the design develops.

''Apply constructability during plans, specifications and estimate (PS&E) development'' is the next subphase. This phase can overlap with preliminary design. At this stage, draft design documents (e.g., plans and specifications) are available for constructability analysis. The first function, evaluate plans and specifications (A221), is initiated by the constructability team according to project procedures. Key inputs include the current design data, draft plans and specifications, and any applicable lessons learned. The team tests the lessons learned to determine if they are truly applicable to the design. Simultaneously, the team analyzes plans and specifications, and then documents possible ideas and suggestions to improve the constructability of the design. Potential constructability improvements are identified. These improvements are then validated (A222) from a technical as well as a benefit/cost perspective to test their feasibility, and are then recorded. The final function is to review and approve documented constructability improvements (A223). The net impact of implementing the improvement is considered, and those with the highest benefit to the project are approved. These constructability improvements will then be incorporated into design documents. This subphase is iterative as determined by procedures until the design documents are complete.

The last subphase of design is to ''apply constructability during final design.'' The only function performed is to summarize all constructability improvements (A231). This function simply complies all approved constructability improvements included in the design. The team also verifies that they have been incorporated into design documents as recommended. Further, the team compiles those improvements not included in the design as possible lessons learned for future projects. The design phase of the project is complete at this stage.

The construction phase begins after the PS&Es are approved and the project bidding process has commenced. The first major subphase under construction is ''apply constructability during preconstruction.'' Two functions are performed: review bid documents (A311) and initiate field constructability (A312). The purpose of reviewing bid documents is to ascertain if bidders are interpreting design documents differently. This may indicate possible lack of clarity, conflicting information, and missing constructability information. Contractual deficiencies may also be uncovered. The constructability team may document potential constructability issues for a later discussion with the successful bidder. Once the contractor is awarded the project, field constructability can be initiated. Some steps that are recommended include reorganize the constructability team, review and modify the constructability procedures for construction, review the plans and specifications, and recommend field changes from a preconstruction review. A key aspect of this effort is to convey the design intent and objectives to the contractor and provide an opportunity for contractor input. This may be facilitated by the use of partnering and/or value engineering.

''Applying constructability during construction'' in the next major subphase. The focus of this phase is to identify constructability experiences and ideas (A321) and document these experiences and ideas (A322). This would include both good and bad experiences. Input for these functions would include field changes, as built drawings, and discussions with field personnel. Ideas, suggestions, and/or problems are identified, and each is sorted and categorized. The best ideas or suggestions are documented with backup information and submitted for future consideration as lessons learned. These two functions are performed continuously and as needed throughout construction.

The final subphase of the CRP is ''applying constructability during postconstruction.'' The first function performed is to review the project constructability process (A311). The constructability team would evaluate the costs and benefits of implementing the project constructability process. This would include soliciting comments from project participants. The results of this review would then be documented. Senior policy makers would be apprised of the success of the process. Project designers would receive feedback on how their designs performed in the field. Finally, specific lessons learned would be forwarded for possible incorporation into a lessons learned database. At the agency level, agency personnel would update constructability lessons learned (A332). This includes compiling and organizing new lessons learned and documenting those that will be added to the agency knowledge base. The last function performed is to obtain feedback from maintenance and operations (A333). These agency personnel have to work with the operating facility. Their input with respect to constructability issues is invaluable. Suggested steps to obtain their input include establishing roles and responsibility for feedback; establishing a methodology to gather feedback; organizing comments, ideas, and suggestions; and documenting constructability issues that result from their assessment of the operating facility.

A complete description of the CRP is documented in the form of guidelines. These guidelines were developed to assist STAs in implementing formal constructability reviews on their projects (Anderson and Fisher 1997b).

TEST APPLICATION BY CASE STUDY

Although model development was extensive and the CRP was reviewed in detail by a variety of industry professionals,

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test applications of the CRP were deemed necessary. Two highway projects were used to test the applicability of the CRP. One project was small and would require minimal constructability analysis, whereas the second project was moderately complex with an increased level of constructability analysis being necessary. Both projects were recently completed.

Each project test was conducted by performing the functions of the CRP in the sequence in which they occur. Information about project scope was derived from plans, specifications, and other related project documents. Personnel knowledgeable about these two projects participated as constructability experts. As each constructability function was performed, likely outcomes were documented. Other changes related to each constructability function were noted.

The small project was an intersection improvement in Abilene, Tex., described as the Buffalo Gap Intersection. This project cost about $1,600,000 and had a project life of approximately 20 months from planning to completion of construction. The project consisted of complete intersection reconstruction under an existing overpass and modifications to a frontage road.

Using the Buffalo Gap Intersection project, the CRP was applied beginning with the planning phase, then design, and finally to construction. Each constructability function step was reviewed in detail, including actions and the use of relevant tools. Issues to consider were confirmed, and specific outputs relevant to each function were developed for this project. Each function was scrutinized in detail. Changes in steps of functions and tool applications were recommended. Final assessment indicated that the CRP can be successfully applied to small projects.

After this project application, the CRP was modified slightly. Based on results from the first project test evaluation, the CRP was then applied using a moderately complex project to assess its flexibility as a generic model. The Loop 322 Interchange project was selected. This $16,000,000 project included construction of a series of two level overpasses connecting US 83 and US 322 near Abilene, Tex. Overall, project time from start of planning through construction completion was about 7 years. A full day was spent applying the CRP to this project. Each constructability function was performed with likely outcomes documented. Suggested modifications to the model were identified.

Based on test applications of the CRP to these two projects and the resulting modifications, the final assessment indicated that the CRP could be successfully applied to a range of projects. It is believed that the generic model, with some degree of adaptation, could also be effectively applied to very large and complex projects.

CONCLUSIONS

STAs need to improve contract documents to ensure rational bids and minimize problems during construction. A formal CRP can help improve contract documents. However, most STAs do not formally apply constructability during their PDP. The CRP described in this paper can aid STAs in the implementation of constructability. The process was developed based on the key concept that integrating the CRP into the PDP is necessary to ensure that constructability improvements are incorporated into planning and design documents. The CRP model presented is flexible and can be adapted to fit different project types and organizational approaches unique to each STA in terms of their PDP. The CRP can be adapted with some modifications by companies in other construction industry sectors. These modifications should fit a company's type of project delivery and contractual approach. The complete formal CRP with integrated tools and case study applications is now available in an easy-to-use workbook (Anderson and Fisher 1997b).

ACKNOWLEDGMENTS

The writers express their appreciation to the NCHRP, Transportation Research Board, under the National Academy of Sciences for sponsoring this research. Also, publication of this article does not necessarily indicate acceptance by the academy of its contents, either inferred or specially expressed herein. The writers would also like to thank the NCHRP 10-42 Project Panel for their excellent comments and direction during the research process. Finally, the writers would like to thank a remarkable group of highway industry practitioners who gave freely of their time and talents in support of this research. Specifically, the writers would like to recognize Lauren Garduno of the Texas Department of Transportation, Dick Wright of ADOT, Roy Mendelsohn of Parsons Brinckerhoff, Hugh Thomas and Jay Steele of Caltrans, Leonard Vincik of Brown & Root, Travis Cannon of H. B. Zachry, and Jim Wentworth of the Federal Highway Administration.

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