Interdependence between Structural Engineering and Construction Management
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# ANALYSIS OF IMPEDIMENTS TO A SUCCESSFUL CONSTRUCTABILITY PROCESS IN HIGHWAY CONSTRUCTION

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The US Federal Highway Administration (FHWA) Every Day Counts Program (EDC) has resulted in state Departments of Transportation (DOTs) putting evermore emphasis on speeding up the delivery of highway and bridge construction projects for use by the driving public. This has resulted in an increase in the use of integrated project delivery methods and adding alternative technical concepts (ATCs) to traditional design-bid-build (DBB) contracts. ATCs have exhibited great potential for delivering substantial benefits like cost savings, increased constructability, and quicker project delivery. Previous research has found that knowledge of project constructability was lacking in state DOT planning, programming, and environmental staffs. At the same time, the permitting process for several government agencies has become increasingly restrictive. The intent of this paper is to report on the research team's progress in an ongoing effort to furnish the US government with a uniform set of guidelines for the application of the constructability process during all phases of project development and delivery. The research uses surveys, focus groups and interviews to determine which states have implemented formal programs to ensure that the constructor is furnished with a set of contract documents that affords said constructor with the best possible opportunity to successfully construct the project with the highest quality standards, within the contract duration and without exceeding the construction budget.

*Keywords*: Project management, Alternative technical concepts, Project planning and design, Highway and road design, NCHRP10-99.

## 1 INTRODUCTION

The concept of constructability was introduced into the construction industry in the 1980s. The research directed by the Construction Industry Institute (CII) was the driving force behind applying and implementing constructability. CII defines constructability as "the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve [the] overall project objective" (CII 1986). In the highway sector, several state Departments of Transportation (DOTs) applied constructability to their projects in the early

1990s. During this period, Constructability Review (CR) systems were developed for Florida DOT (Ellis *et al.* 1992) and Wisconsin DOT (Russell *et al.* 1994). The Wisconsin constructability work process enables construction input in design, creation of constructability teams, continuity and communication between design and construction, and continuous improvement of highway projects.

The intent of CRs is to identify unclear specifications, refine project design, increase project construction efficiency, and potentially reduce disputes, cost overruns, and delays. Research has documented several key benefits of conducting CRs, including reduced cost, shorter schedules, improved quality, better risk-control, fewer claims, and fewer change orders. NCHRP Reports 390 and 391 are considered key references for implementing CRs for DOTs because of their systematic approach to integrating constructability into the project development process (Anderson and Fisher 1997).

DOTs across the nation are constantly dealing with ever-increasing technical complexities, increasing regulatory restrictions, and pressures to deliver quality products on time and within budget. This can create a schedule-driven environment during the project development process that can lead to errors, omissions, and constructability problems. To overcome such issues, DOTs are increasingly using alternative contracting methods, including design-build (D-B) and construction-manager-as-general-contractor (CM/GC), along with applying alternative technical concepts (ATCs) to procurement in several project delivery systems.

The Federal Highway Administration (FHWA) Every Day Counts Program (EDC) brought national visibility to implementing ATCs for incorporation into transportation projects. ATCs have well-documented potential to accrue sizable benefits in cost savings, increased constructability, and schedule reduction. Among the many documented benefits of alternative contracting is early construction input during project development and design. In fact, some practitioners believe that CM/GC inherently builds constructability into project delivery, eliminating the need for a separate constructability process.

DOTs often seek contributions from industry representatives to identify constructability issues and improve their environmental, design, construction, and maintenance processes. The objective of the NCHRP 10-99 research is to develop a decision-making Framework scalable to all contract delivery methods that complies with all environmental statutory requirements, in order to assist DOTs in evaluating savings from using CRs and industry input during planning, design, and permitting.

## 2 LITERATURE REVIEW

Although constructability is an important concept in construction projects, it was rarely applied to construction projects until relatively recently. In 1989, the Texas DOT sponsored a project named “Investigation of Highway Project Constructability Improvement” implemented by Hugo *et al.* (1989). In this project, constructability concerns related to highway specifications were studied. The results of the analysis show that information and communication, project scoping, and processes and methods are the major constructability problems. The resistance by owner, contractor, and designers hinders the integration between design and construction, as well as other factors like contractual limitations and time shortage.

Fischer and Tatum (1997) studied the design-relevant characteristics of constructability knowledge. They demonstrated that lack of formal constructability knowledge is the primary reason for lack of constructability inputs. Availability and level of detail are two concerns of designers. Access to sufficient knowledge at the proper time was known as one of the factors that play an enormous role in understanding constructability issues. The other element was the level

of detail of CRs, which provide designers with feasible alternatives that would lead them to constructible designs. Fischer and Tatum showed that an appropriate level of detail at the right time will enable companies to improve their performance.

Anderson *et al.* (1997) studied the CR process for transportation facilities through the NCHRP 390 research project. As stated in this study, State Transportation Agencies (STAs) are interested in initiating the CRs in early stages of projects to maximize their benefits and according to them, lack of feedback to the design team, lack of input from construction team, low clarity of the specifications and plans, and lack of available reviewers are the main issues in conducting CR processes. In addition, the authors stated that paradigm shifts in both project-level and agency-level are necessary to implement the constructability process. While strategies like a team approach and pilot projects benefit the STAs at the project level, organizing for constructability and a systematic lessons-learned process help them improve the CR processes at the agency-level.

Delay in delivering highway projects is a great source of conflict. Ford *et al.* (2004) studied this issue and recommended formal CRs as a potential solution to reduce construction project delays. The effects of these reviews were studied at the design and construction phases to determine the optimal amount of constructability to achieve the greatest effect on projects. For this purpose, a model was designed to relate CRs to project duration as a management tool. Their study showed that there is a positive correlation between the time put into CRs and the design phase duration, and a negative correlation between the time invested in CRs and construction duration. Based on these results, the authors illustrated that an intermediate-sized CR is the most efficient solution to reduce delays in comparison to small or large reviews.

The design phase has been targeted through different studies on constructability because it is known as the most obvious phase within which to implement CRs. Lam *et al.* (2006) gathered the major factors affecting constructability of the designed projects. Those authors demonstrate that three major factors of through-site and ground investigation before the actual design process starts, coordinating the design documents and sequences, and standardized and safe designs are the most critical factors. By considering these factors, it is possible to improve the efficiency of projects and save time and cost while delivering a high-quality project.

Tauriainen *et al.* (2014) studied constructability through assessing Building Information Modeling (BIM). After discussing the system used in Finland as a constructability appraisal model, those authors developed an experimental constructability assessment method (ECAM) as a constructability information source, using BIM. By applying ECAM, constructability scores of the building and building elements were calculated. These scores could forecast the potential constructability issues of the projects in the future and support decision making on them.

One of the latest research studies reviewing the past, present and anticipated future practices of constructability was conducted by Kifokeris and Xenidis (2017). Their study presented research regarding constructability implementation, tools, and current trends, to evaluate its applications. The success performance parameters for any project considered within this article are cost, time, quality, and client satisfaction.

## 3 RESEARCH METHODOLOGY

The research is broken into two phases. These phases are named “Benchmark the Current State of Practice” and “Decision-Making Framework”. The main objective of the first phase is to define the state of the practice regarding the use of CRs. For this purpose, designing a rigorous Research Plan is required to ensure the collection of high-quality data that can yield meaningful

trends and the detection of any gaps and barriers in the current state of CRs. Special attention will be given to impacts on NEPA and the environmental permitting process.

In Phase I, "Benchmark the Current State of Practice," five tasks are defined as: literature review, define the current state of practice, develop conceptual Framework, prepare interim report, and face-to-face meeting. Task 1 is literature review, through which a comprehensive content analysis will be conducted to cover both historic and contemporary writings, covering the current environmental requirements for public transportation agencies, use of BIM in the CR process, and the codes that impact the CRs. All tasks related to defining the current state of the practice are covered under Task 2. Every effort is being made to include a clear description of the best practices discovered in Phase I, and then to utilize what is learned in Phase II of the project. Gathering data on the current state of practice is done utilizing a survey, focus groups, case studies, and a workshop. Task 3 is focused on developing a conceptual Framework to provide transportation agencies with sound constructability practices that will help in evaluating cost and time savings, project quality, and other metrics across the entire project development process. The decision-making Framework that is finally recommended by the team is apt to resemble the Conceptual Framework shown in Figure 1. Task 4 is preparing the interim report, which will be started toward the end of completion of Tasks 1 and 2 and will include the following: the findings of the state of practice review; a preliminary design of the proposed decision-making Framework; and a Work Plan for Phase II. The last task of the first phase is a face-to-face-meeting between project team, which will include the Work Plan for Phase II, the preliminary proposed decision-making Framework, and plans for the Workshop.

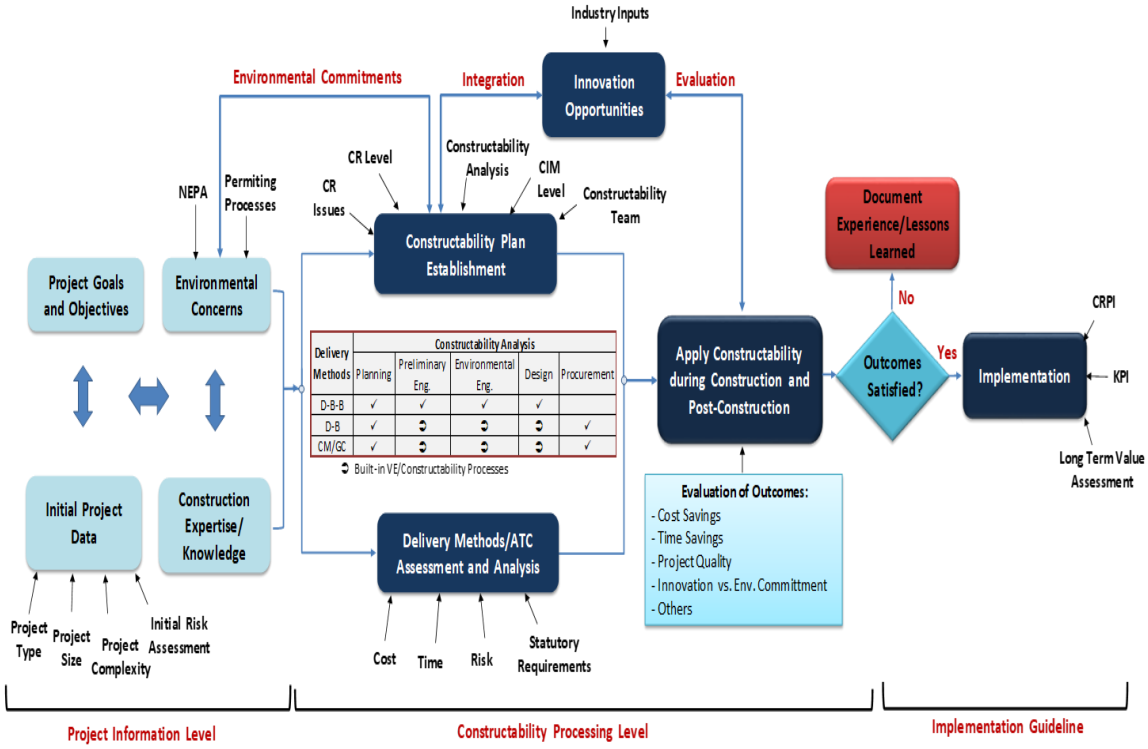


Figure 1. Decision-making framework.

In Phase II, "Decision-Making Framework," the following tasks will be performed: develop Framework, workshop, develop training materials, develop an electronic presentation, final report, and prepare final deliverables. Task 1 is assigned to Developing a Decision-Making Framework. This new Framework will result from changes made to the Conceptual Framework (Figure 1), based on information obtained from the data analysis and the comments of the NCHRP 10-99 Panel in the face-to-face Meeting. Under Task 2, a Workshop will be developed and convened with representatives from DOTs, panel members, and the research team to demonstrate the proposed decision-making Framework and gather feedback. The next step is Developing Training Materials for the use of DOTs in training their personnel in the implementation of CRs and industry input during project development. This will be done as Task 3. In conjunction with Task 3, Task 4 is to Develop an electronic presentation to be used as part of the training effort. Once Tasks 3 and 4 are completed, a final report will be prepared as an outcome for Task 5.

## 4 RESEARCH PROGRESS

Tasks 1 and 2 were worked on for the time period spanning from the last week of May 2018 to the end of August 2018. The literature review (Task 1) began during proposal preparation and has been completed. Through this task, over 60 writings, consisting of papers, National Cooperative Highway Research Program (NCHRP) projects, and guidelines were reviewed. Several areas such as the definition of constructability, CR implementation and issues, integrating constructability into the project development process, design-relevant constructability knowledge, risk management for addressing constructability issues, incorporating maintainability in the CR process, the role of CRs in conflict resolution, the relationship between total quality management and CR, lessons-learned systems for constructability, and the benefits of BIM / virtual reality in constructability are covered by Task 1.

A data gathering process is underway under Task 2, contacting the Central Design and Central Construction Offices of each of the 52 State DOTs have been contacted separately and key personnel from each office interviewed. This task is 99% completed. The team has successfully interviewed 103 offices (of the 104) with the purpose of identifying the DOTs which have formal constructability processes. Besides, this task was focused on gathering data on whether the DOTs include contractor/industry input during their process. Interviewees have provided the names/contacts of consultants and contractor who are experienced in conducting CRs, and the team has successfully interviewed 25 out of the 49 additional contacts.

## 5 RESULTS AND SUMMARY

The next step after gathering data is the data analysis. Table 1 has the results of the questions asked of 103 Construction and Design employees from 52 DOTs. This initial telephone survey consists of three main questions and two follow-up questions. The questions and the results are in Table 1

Each state is ranked using its Design and Construction Offices' answers to the basic questions of the survey. Using this ranking criterion, a number ranging from 1 to 5 is assigned to each state. States ranking higher than 4.0 are the selected states. Through the telephone interview process, the team has recognized ten DOTs as most knowledgeable and experienced in conducting CRs. These state DOTs are Arizona, California, Colorado, Maryland, New Mexico, New York, Oregon, Pennsylvania, and Virginia.

The research team plans to interview the 1 remaining DOT office and 20 referred additional contacts in the coming month. The data gathering process will last through the end of 2018.

With the completion of data gathering, data analysis and conceptual Framework development will start at the beginning of 2019.

Table 1. Answers to questions in initial telephone interview.

| No. | Question | YES | Participants | Percentage |
|---|---|---|---|---|
| 1 | Do you have a formal constructability process? | 73 | 98 | 74% |
| 1a | Does your formal constructability process change when you use alternative delivery? | 36 | 73 | 49% |
| 1b | Does your agency's effort to improve constructability involve / include industry input? | 60 | 73 | 82% |
| 2 | Does your agency have established processes that allow contractor input into the design? | 49 | 98 | 50% |
| 3 | Has contractor input to the design ever been hampered by a fear on the part of the parties involved of having to re-open the NEPA process, environmental permitting process, or any other pre-construction process? | 23 | 98 | 23% |

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