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A SYNTHESIS OF CONSTRUCTABILITY IN TRANSPORTATION CONSTRUCTION

R. EDWARD MINCHIN JR.[1], MACKIE MYERS[1], DAN TRAN[2], and YIFENG TIAN[1]

[1]*School of Construction Management, University of Florida, Gainesville, USA*
[2]*Dept of Civil, Environmental and Architectural Engineering, University of Kansas, Lawrence, USA*

The problem of "constructability" was successfully addressed by leading researchers in the early 1990s, and was considered a problem in remission for over a decade afterward. Constructability, at that time, was seen as the level of difficulty faced by a constructor (usually a contractor) in building a structure in the field as drawn by the designer. Many contractors in those days found it impossible to build the project as drawn and directed. Researchers then devised what became known as the Constructability Review Process, and state Departments of Transportation (DOTs) took up their recommendations as each agency saw fit. This review process drastically reduced obstacles to the point that constructability was no longer viewed as a problem. Then, however, came the proliferation of fast-track, integrated construction delivery systems in the transportation construction industry, with early contractor involvement in the design inherent in these delivery methods. About the same time, DOTs were inundated with new requirements for procuring environmental permits prior to construction, as well as an additional process required by the National Environmental Protection Act. Constructability, with these new requirements, has returned as a problem. This paper reports on a survey conducted as part of a research project funded by the National Cooperative Research Program to determine how each of the 52 DOTs in the US are confronting this problem.

Keywords: NEPA, Environmental permitting, Integrated project delivery, Highway, Bridge.

1 INTRODUCTION

In the current era of specialization, the level of ease with which a contractor can build a project using the project documents provided is known as "constructability." This term became popular in the early 1990s when levels of constructability had sunk to the point that the National Cooperative Highway Research Program, the Construction Industry Institute, and other industry research sponsors funded research on the subject that all but resolved the problem. The Constructability Review Process (CRP) emerged from that collection of research projects, and enough Departments of Transportation (DOTs) embraced the concept to greatly mitigate the problem. However, as the industry evolved, two major facets of the evolution conspired to threaten the new higher level of constructability: 1) Integrated Project Delivery; and 2) an expanded and more stringent environmental permitting process.

DOTs are required to procure permits from a multitude of affected environmental agencies—mostly federal— such as the US Coast Guard, the US Army Corps of Engineers, the US Fish and Wildlife Service, as well as other agencies. In addition to all these permits, the project design is

scrutinized using a process contained in the 1970 law known as NEPA, the National Environmental Policy Act. Though NEPA has been around for decades, its enforcement has become more stringent over time and it is now considered by DOTs to be a major milestone in the life of any highway or bridge project. The collision of the NEPA and expanded environmental permitting processes with integrated project delivery has resulted in a nation-wide problem that has caused DOTs to largely lose the former advantages of integrated project delivery. There have been many reports of contractors submitting excellent ideas that would have improved quality, lowered cost, or shortened the duration of the design-construction process of highway and bridge projects, only to have the ideas rejected out of hand. The two factors collide in the most detrimental way when a DOT has completed the NEPA process and procured all its environmental permits, only to have a contractor or a design-build firm subsequently submit an idea for the design of the project that would markedly improve some major aspect of the project e.g., time, cost or quality. Sometimes the implementation of these commendable ideas would change the footprint or other design aspect of the project to the extent that a NEPA Re-evaluation or a replication of the environmental permitting process would be required. The DOT often then hesitates, or even refuses, to consider the idea simply because they know that implementing the idea will probably require a NEPA Re-evaluation and/or a repeat of the process of procuring one or more environmental permits.

2 LITERATURE REVIEW

The American Society of Civil Engineers (ASCE) presented the main concepts and definitions of constructability current in the year of publication (Construction Management Committee of the ASCE Construction Division 1991). Constructability implementation and cost/benefits of implementing constructability are highlighted in the research. ASCE argues that constructability optimizes the project plan, the planning and design phases, the reliable cost and schedule estimates, and construction methods used. They advised that the most suitable time to consider constructability issues is at the early planning stage of project development. The constructability program should then extend over the duration of project development.

Anderson *et al.* (1999) conducted a survey to identify constructability issues. The target population of this survey included construction contractors, state transportation agencies (STAs), and design firms. By analyzing the results of the survey, the authors suggested that to implement a successful constructability program, STAs must first oversee as many as 11 paradigm shifts. The publication indicates that the research problem is associated with constructability practices, related mostly to buildings and concurrent delivery methods. The challenge is to adopt a constructability concept that is applicable to the Design-Bid-Build (DBB) environment, the dominant delivery method for highway construction projects.

Anderson *et al.* (2000) viewed the primary challenge to successfully implementing constructability as the ability to achieve the desired level of integration. Previous integration tools, such as the Integrated Computer Aided Manufacturing DEFinition (IDEF0) modeling tool, are discussed. IDEF0 was used to model the CRP, which produced an integrated model able to involve construction knowledge within the development of STA projects. However, the writers state that IDEF0 is only suitable for DBB projects, where fixed-unit pricing is the basis for bidding. A CRP was modeled using the IDEF0 to consider a systematic CRP over the lifecycle of the project, from planning, design, construction, operation and maintenance phases, allowing for the model to be hierarchical in nature and composed of four levels. The first of the four levels as defined by those authors represents the context, the second represents the main phases of the

plans development process, the third represents sub-phases, and the fourth level represents actual constructability conducted during the major and sub-phases.

Eriksson and Westerberg (2011) designed a conceptual framework for analyzing the effect of cooperative procurement on the performance of construction projects. Their main purpose was to provide a procurement framework to evaluate the impact of different procurement factors on project performance. They identified six factors that most contribute to project performance success: time, cost, quality, environmental impact, work environment, and innovation.

The potential role of constructability has been studied by Ogburn and El-Adaway (2013). Those authors evaluate the contribution of biddability, constructability, and operability. They include an environmental checklist created by the US Army Corp of Engineers concerning the reduction of claims and disputes of vertical construction projects. The checklist is database-supported, and the database is regularly updated with all current practices and methods of construction world-wide.

The level of awareness and knowledge of constructability concepts and principles among construction professionals, reached by identifying and ranking conditions that constrain the overall constructability of projects, was investigated by Akpan *et al.* (2014). Two hypotheses were presented: first, that there is no agreement between the opinion of different respondent groups on constructability principles and degree of importance; second, that there is no strong agreement between the opinions of different respondent groups on conditions restricting constructability.

Amade (2016) concentrated on identifying constructability tools and techniques deployed by professionals within the industry, intending to improve the performance of construction projects in Nigeria. Of the 50 questionnaires sent out to the public, 42 private construction and contracting organizations in Port-Harcourt, Rivers State, Nigeria, had complete responses and were used for the analyses. The responses were analyzed using both descriptive and inferential statistical tools. A majority of the respondents had little familiarity with the term "constructability," while a handful were conversant with it. From a practical standpoint, this implies that on average there is generally a low level of awareness and understanding of the concept and the application of constructability tools and techniques among the various professionals. The technique of "corporate lessons-learned log/file" was used most frequently, ranking first.

One of the latest research studies reviewing the past, present and anticipated future practices of constructability, conducted by Kifokeris and Xenidis (2017), 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. The research regarding the evolution of constructability concepts and principles is presented, with a discussion of the relationship between the two attributes. Further discussion ensued regarding the main tools used to implement constructability. Based on the literature, the barriers were then combined and categorized collectively, based on the literature, into six main groups: general barriers, owner-based barriers, designer barriers, contractor barriers, waste management and recycling barriers, and project-specific barriers. Regarding the project delivery method, those authors asserted that the proper selection of a constructability program depends mainly on the selected strategy for delivering the project.

3 METHODOLOGY

3.1 Research Design

The data gathering process to research the state of practice of CRPs included two phases of surveys: telephone interviews and questionnaires. The purpose of these surveys was to investigate how DOTs handle CRPs in relation to the NEPA and environmental permitting processes. The goal of the telephone interview instrument was to screen DOTs in an effort to discover who was using CRPs and whether or not they found issue with NEPA and/or the environmental permitting process. The interviews were comprised of four questions, which asked about CRPs, delivery methods used, industry input, and problems with NEPA or the environmental permitting process. These interviews targeted one person from the construction division of a state's DOT and one from the design division. All 50 states, plus Puerto Rico and the District of Columbia, were included in the study, for a total of 104 initial participants. From these interviews, 46 additional contacts were acquired, such as other suggested DOT members and non-DOT members, e.g., local consultants or contractors. Non-DOT members were included in the study in order to gain additional perspectives outside of the DOTs. These additional contacts were given the same interview as original DOT members.

After the phone interviews were completed, the data were analyzed, and participants for the next phase of the research were chosen based on their responses. This second research phase included an in-depth questionnaire tailored to the part the participant plays in the project development process. Participants for the second survey were chosen based on their knowledge of and experience with CRPs and NEPA or the environmental permitting process. DOT questionnaires contained 30 questions and non-DOT questionnaires contained 24 questions. These questionnaires investigated CRP programs, CRP teams, CRP evaluation, and the perceived impact of NEPA and the environmental permitting process. There were 92 participants selected for the questionnaire: 25 non-DOT and 67 DOT.

3.2 Survey Process

3.2.1 *Phone interview*

Of the 104 pre-identified participants for phone interviews, all were interviewed. Of the 46 contacted referrals, 29 participated, yielding a 63% interview completion rate.

3.2.2 *Questionnaire*

Of the 92 total questionnaires distributed, 47% were completed. Of the completed questionnaires, 30% were non-DOT participants and 70% were DOT participants. The 27 non-DOT participants included nine consultants and 18 contractors.

3.3 Survey Findings

It was found that 69% of DOTs did conduct some form of CRPs. Additionally, 59% included industry input, and 50% had processes that allow contractor input into the design. The majority of DOT personnel responded that the fear of re-entering the NEPA process did not keep them from implementing changes after the design was complete.

The two main problems identified involving the early entrance of contractors into the process were disqualification from bid and lack of cooperation. For a traditional delivery system, contractors privy to contract documents and participation in CRPs prior to bid during the design

phase are unable to bid on the project due to their advantage over others. Further, it was determined by DOT personnel that contractors able to review plans were often tight-lipped and hesitant to give feedback for fear of another contractor gaining an advantage.

The most common approaches used to address constructability included CRP activities, construction personnel involvement in the design, post-construction review activities, checklists, and design reviews. The least utilized methods of those listed were augmented reality and virtual reality applications; only one response indicated the use of these technologies. The most common factors used to determine whether or not a project would undergo CRPs included project complexity, size, and delivery method; contract type and construction method were the least common factors considered. The greatest issues identified with conducting CRPs included designers' lack of construction experience, limitations of a traditional delivery system, lack of a formal process, inadequate review time, and lack of experienced construction personnel.

The timing of CRPs in relation to NEPA was also investigated, with 47% of participants indicating that CRPs commenced after the completion of NEPA, 30% indicating that CRPs commenced during the NEPA process, and 23% indicating that CRPs started before NEPA. Regarding aid with the NEPA process, 36% of DOTs had policies in place to streamline the process, 28% had no streamlining process, and 36% were unsure or did not indicate either way. It is worth noting that some states have been granted authority over their own NEPA process by the Federal Highway Administration.

A key finding of the surveys is that Virginia DOT (VDOT) has developed a process that can serve as a model for how DOTs can exploit the advantages of integrated project delivery and avoid losing time, money or quality because of conflicts between input to the design from outside sources (the contractor or design-builder) and the NEPA and environmental permitting processes. VDOT bases its system on equal parts "Expanded Limit of Disturbance" and something they call "The Merged Process."

The surveys reveal that CRPs are taking place, and that there does exist a complicated relationship with the NEPA and environmental permitting processes. The discovery that CRP activities and construction involvement in the design are the most common ways to address constructability, show that these are both valid and valuable ways to identify problems. After the initial phone interview revealed a lack of resistance to change from DOT personnel, it was further investigated and discovered that often the risk associated with NEPA and/or the environmental permitting process (mostly the threat of delay) would fall to the contractor. For this reason, the possibility of a NEPA Re-evaluation or a re-execution of the environmental permitting process was often of minimal concern to the DOT. In many cases, if a contractor finds a potential constructability improvement, and it requires a NEPA Re-evaluation, the DOT will allow the change, but it is up to the contractor to prepare new documents with which to undergo the process again. This is how a lot of potential improvements are left on the table. Although the survey did not show a concern from DOTs, NEPA and the environmental permitting process are often underlying causes for not incorporating contractor input into a design; but, contrary to previous belief, the choice not to pursue a NEPA Re-evaluation or a re-execution of the environmental permitting process is made by contractors. In the end, the potential schedule delays often deter contractors from undergoing these extra processes. The consensus from the surveys is the importance of starting CRPs early, before the NEPA process when possible; the need for a formal process that outlines procedures; and the importance of including construction personnel in the design process.

4 CONCLUSION

In order to apply CRPs most efficiently, DOTs should start the process as early as possible. Experts from multiple states had the same bottom line regarding CRs: one does not need a set of plans in order to perform a constructability review, so the CRP could start prior to the commencement of the NEPA process. Those interviewed from the most progressive constructability states believed that CRPs should start no later than the same time as the NEPA and environmental permitting processes. By having early involvement, contractors can give recommendations and the DOT can make changes to the design prior to entering and completing the NEPA process.

DOTs should get "buy in" from state, and especially from federal permitting agencies, as early as possible. Some states are meeting with these agencies before they begin the NEPA and environmental permitting processes, to familiarize these agencies with the scope and geographic limits of the project. They sometimes have "10-15%" plans to show the agencies, and sometimes have no plans at all. After explaining the scope and showing agencies the project footprint, DOTs ask for advice on any facet or portion of the project, as explained, that these agencies would have problems with when it comes time for permit application. This early "buy-in" from the agencies seems to make the permitting process proceed smoothly.

While NEPA has proven detrimental to innovation and constructability improvements, it will remain a required process. Therefore, it is important to identify how to best navigate this process while also being able to incorporate CRP feedback and changes to projects. Some ways that DOTs are effectively implementing CRPs, while also respecting the NEPA and environmental permitting processes, include conducting CRPs early; getting construction involvement, whether from DOT or non-DOT entities; and having open discussions with permitting agencies prior to beginning the environmental permitting process. It is suggested that more formal processes and procedures be provided to, or developed by, DOTs to ensure the success, understanding, and implementation of their CRPs, while also providing timelines for appropriate timing of CRPs in regard to undergoing NEPA processes and getting "buy-in" from agencies prior to permitting.

References

Akpan, E., Amade, B., Okangba, S., and Ekweozor, C., *Constructability Practice and Project Delivery Processes in The Nigerian Construction Industry,* Journal of Building Performance, 5(1), 10-21, March, 2014.

Amade, B., *Constructability Tools and Techniques in Use in The Nigerian Construction Industry*, PM World Journal, 5(2), 1-19, March, 2016.

Anderson, S. D., Fisher, D. J., and Rahman, S. P., *Constructability Issues for Highway Projects,* Journal of Management in Engineering, 15(3), 60-68, May, 1999.

Anderson, S. D., Fisher, D. J., and Rahman, S. P., *Integrating Constructability into Project Development: A Process Approach,* Journal of Construction Engineering and Management, 126(2), 81-88, March, 2000.

Construction Management Committee of the ASCE Construction Division, *Constructability and Constructability Programs: White Paper,* Journal of Construction Engineering and Management, 117(1), 67-89, March, 1991.

Eriksson, P. E., and Westerberg, M., *Effects of Cooperative Procurement Procedures On Construction Project Performance: A Conceptual Framework*, International Journal of Project Management, 29(2), 197-208, February, 2011.

Kifokeris, D., and Xenidis, Y., *Constructability: Outline of Past, Present, and Future Research,* Journal of Construction Engineering and Management, 143(8), 04017035, August, 2017.

Ogburn, M., and El-adaway I., *Biddability, Constructability, Operability, and Environmental Checklist: Potential Role in Reducing Conflicts, Claims, and Disputes*, Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, 6(1), 05013001, February, 2013.