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Discussing the Development of a Constructability Review Process (CRP) Approach Selection Framework for Transportation Projects

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Abstract
A constructability review process (CRP) is a systematic approach to reducing design errors, disputes and claims, and cost and schedule escalations throughout the project development process (PDP). Current approaches to constructability implementation vary among state departments of transportation (DOTs). Some state DOTs, such as California, Indiana, and Washington DOTs, utilize formal constructability approaches that utilize special teams, resources, and lessons learned to implement their CRP. Other state DOTs employ informal approaches that incorporate partial constructability considerations as part of other programs or processes. Consistent approaches for selecting, evaluating, and implementing CRPs across state transportation agencies are essential to reduce cost and schedule overruns. This paper introduces a CRP selection framework to assist state DOTs in effectively and efficiently perform constructability reviews throughout PDP. The framework utilizes a combination of project and owner related characteristics to select an appropriate CRP approach for a given project. The outcome of this study will help decision makers determine the appropriate means to incorporate constructability and construction knowledge into management and delivery of their transportation projects.

1 INTRODUCTION

Design and construction integration is still a significant challenge in the construction industry. Traditionally, designers and constructors do not cooperate in the early project phases. Designers often have limited inputs from constructors. This limitation sometimes leads to incomplete and ambiguous design documents. As a result, design revisions, claims and disputes, and change orders often happen during construction that extend the anticipated cost and duration of the project. Griffith and Sidwell (1997) indicated that most of construction related problems are traced back to the design process.

Traditionally, owners used to procure separate professionals for both design and construction. This method of project delivery is commonly known as the Design-Bid-Build (DBB). Using the DBB delivery method, the owner separates the design and construction, and contractors usually involve into the project after design completion. Tran and Molenaar (2015) concluded that the DBB is the dominant delivery method across transportation agencies in the U.S. One of the main criticisms of DBB involves contributing to latent adversarial relationships between designers and contractors and lack of innovative solutions. Integrated approaches for projects delivery are essential to overcome the shortcomings of the traditional DBB delivery method.

In an effort to overcome DBB shortcomings, state departments of transportations (DOTs) across the U.S. increasingly utilize alternative contracting methods (ACMs) in addition to the traditional DBB to deliver their transportation projects (Tran et al. 2018). One of the main advantages of using ACMs is to reduce the gap between design and construction. Design-Build (DB) and Construction Manager/General Contractor (CM/GC) are among the primary ACMs utilized by state DOTs (Tran et al. 2018). Utilizing an ACM ensures that construction knowledge is incorporated early during the design phase, and thus reduce design deficiencies. In the absence of proper construction knowledge support during the design, agencies used to utilize constructability as an approach to bringing contractors' perspectives into the design phase.

Constructability is defined by the Construction Industry Institute (CII) as “the optimum use of construction knowledge and experience in planning, designing, and procurement and field operations to achieve the overall project objectives” (CII, 1986). It implies that integrating construction knowledge early into the project development process (PDP) enhances the overall project performance. Gransberg and Douglas (2005) and Stamatiadis et al. (2014) agreed that considerable amount of savings could be achieved by bringing contractors to the design process. Dunston et al. (2005) indicated that constructability benefits construction projects in reducing the total construction cost and duration, the amount of rework and change orders, and improving site safety.

Constructability advances slowly across the industry and lacks consistent standard processes (CII 1993). Anderson and Fisher (1997) concluded that transportation agencies lack a proper guidance for implementing constructability across their projects. Additionally, state DOTs mostly consider constructability informally as part of the PDP, and only small percentage of DOTs implemented formal CRPs. CRPs are designed to consider constructability systematically in the planning and design phases through a chain of structured reviews (Dunston et al. 2005). Several models are available in the literature to guide agencies in selecting a constructability review approach based on an evaluation of the project requirements. However, those models often failed to comprehensively consider owner capabilities while evaluating project needs. Additionally, most of these models focused on the traditional DBB delivery method. There are limited studies, if any, focusing on examining constructability review approaches to ACMs’ projects. This paper describes the development of a CRP selection framework to help state DOTs implement constructability review for highway construction projects. The framework enables state DOTs to select a CRP approach early in the planning phase based on an assessment of project and owner related characteristics associated with different project delivery methods.

2 LITERATURE REVIEW AND BACKGROUND

CII (1986) indicated that constructability reviews (CRs) provide a considerable amount of cost and time savings if applied early in the project development. Various studies have been conducted to incorporate constructability into the PDP. One of the earliest efforts in this topic indicated that the appropriate constructability approach must be allocated for each individual project based on an assessment of the type and size of the project (Radtke and Russell 1993). Specifically, eight constructability approaches were introduced by Radtke and Russell (1993) with different degrees of formality in application, including: (1) construction management historical practice, (2) constructability contract documents, (3) constructability services, (4) constructability design review, (5) quality improvement program, (6) specialized formal constructability programs, (7) standard constructability guidelines, and (8) comprehensive tracking. Each approach is uniquely different than another. Various constructability attributes were assigned for each approach, including: the use of lessons learned, owner involvement, the use of standards and guidelines to guide constructability implementation, team formations, and efforts tracking and benefits assessment (Radtke and Russell 1993).

Russell et al. (1994) and Gugel and Russell (1994) analyzed a range of techniques utilized for constructability and divided them into formal and informal approaches. The main difference between both approaches is related to efforts, benefits, and lessons learned from constructability reviews. For instance, the formal approach incorporates construction experts into the design team, evaluates the efficiency of the constructability program, and utilizes the use of lessons learned under a standard pre-defined process. On the other hand, the informal approach limits construction inputs to a reactive review role that is limited to design checklists. The informal approach focuses mainly on the completeness and conformity of contract documents.

Selecting an approach depends on a combination of owner and project related factors (Gugel and Russell 1994). Owner related factors include: project type and objectives, availability of internal staff, and the amount of resources available for constructability. Project related factors include: contract type and strategy, project size and cost, technical difficulty, location, and site-specific factors. However, most of the constructability review approaches in previous studies is descriptive in nature and lacks for consistent practical considerations that summarizes the amount and frequency of constructability reviews. Additionally, these approaches did not address the requirements of ACMs, that is being used increasingly by state DOTs.

Building from the literature, this paper discusses the development of a comprehensive framework for selecting a CRP approach based on an assessment of project and owner characteristics, as well as, consideration of project delivery methods. The framework is proposed to facilitate the decision making process in allocating reliable constructability review efforts at the early planning phase of transportation projects to meet the project needs and owner capabilities. The following section provides a detailed description of the research methodology followed by the decision making framework.

3 RESEARCH APPROACH

The proposed research is composing of two main phases. Phase 1 analyzes main CRP approaches and the main factors contributed to selecting an approach. This phase mainly involves conducting a literature review to summarize the key findings concluded by researchers and industry practitioners. Phase 2 evaluates the interaction between those factors and proposes the decision making framework. This phase mainly incorporates an assessment of the relation between CRP approaches and selection factors to structure the recommended CRPs.

The first phase of the research project involved reviewing and collecting all constructability related literature. In total, 191 constructability related documents were analyzed. The analysis of the literature review resulted in forming the need to the current research. Phase2 mainly focused on the development of the CRP decision making framework. Future research is necessary to evaluate the proposed approaches and selection factors, and to verify the applicability of the framework by collecting projects data from various state DOTs across the U.S. Phase 1 results were discussed briefly in the literature review section. The following sections present a brief summary of the framework development process conducted in Phase 2 of this study.

3.1 Framework Development

The framework mainly contains three main levels: (1) Input Level; (2) CRP Approach Selection; and (3) Developing of CRP Parameters. A leveled decision making process is adopted to facilitate constructability approach selection. A CRP approach involves a number of reviews at consequent stages of the PDP. Each review involves an evaluation of constructability related issues related to the stage of development. The optimum number of reviews is determined based on an assessment of two groups of factors; project and owner related characteristics. An assessment of project characteristics ensures selecting an approach consistent with the anticipated project development level and phases' interface. Assessing owner characteristics optimizes the selected approach to fit owner's capabilities. The CRP includes a maximum number of six reviews; four during preconstruction (project initiation package, 30%, 60%, and 90% PS&E reviews) and two during construction and post construction (construction closeout and M&OP reviews). All six reviews are proposed to be conducted for large and complex projects. This number of reviews will be optimized based on each individual project case. Figure 1 presents the proposed constructability approach selection framework.

The input level compromises an individual assessment of project and owner related characteristics. This level also serves as a main input to subdivide the decision into intermediate decision points. The second level in the framework interacts both group of characteristics. The outputs of this level is a recommended approach and formality level to implement constructability: (1) CRP 1, 2, or 3; (2) formal, semi-formal, or informal. The third level mainly determines the attributes of the desired CRP approach. If a formal approach is desired, then three possible outcomes are feasible; (1) Constructability Design Review – CRP 1A; or (2) Project Level CRP – CRP 2A; or (3) Comprehensive Tracking CRP – CRP 3A. If an informal approach is desired, then another three possible outcomes are feasible; (1) Historical Practice – CRP 1B; or (2) Quality Improvement Program – CRP 2B; or (3) Constructability Guidelines – CRP 3B.

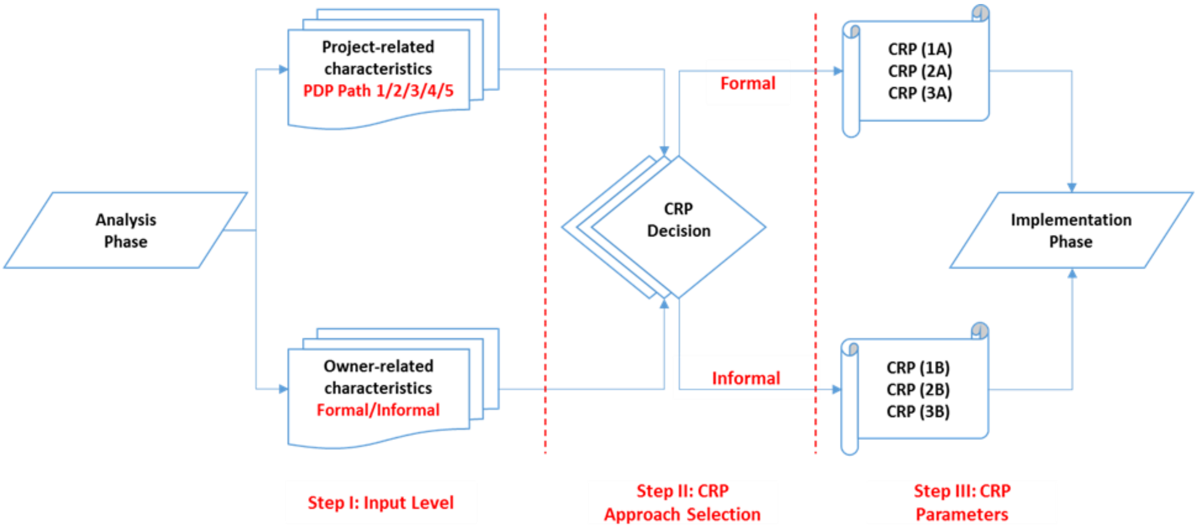

Figure 1: A framework for CRP approach selection

Level 1: Input level

Owner Characteristics

Owner related characteristics are shown in Figure 2, and include: (1) owner objectives; (2) staff requirements; and (3) resources. The owner objectives parameter plays a substantial role in determining the formality of a constructability approach. Owner's objectives vary based upon the selected project, and a project often possesses multiple objectives. Most transportation projects found to have one or more of four main objectives: minimize cost, minimize duration, maximize quality, and maximize safety. Those objectives represent the main measures followed to track the performance of construction projects. Owner objectives were considered to reflect the owner's needs at every singular project. A formal CRP approach is desired if an owner is requiring a combination of two or more objectives. For instance, if the owner objectives are to minimize cost and duration of the total project, then a formal coordination among all project disciplines is required to achieve the targeted objectives.

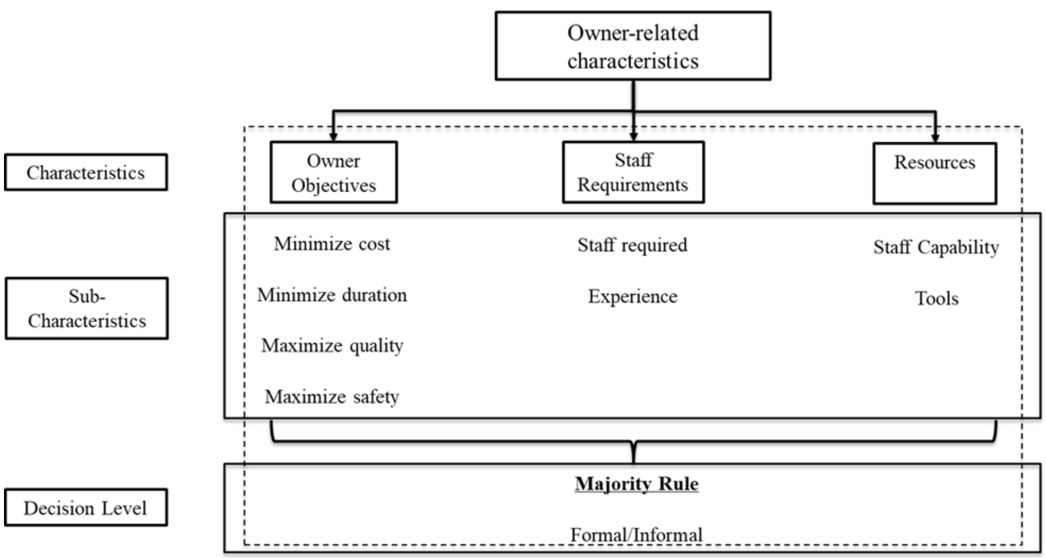

Figure 2: Owner related characteristics

The staff requirements contain two main factors: (1) the number of staff required; and (2) the experience required to successfully implement constructability. The number of staff required is related to the project size, and it mainly considers the number of staff required to conduct major project activities, including, planning, design, management, procurement, and construction. As the number of staff required to deliver the project increases, the level of formality associated with constructability implementation increases. In relation to the project size, all transportation projects are categorized into three main staffing levels as follow:

1. Small size projects: low staffing level is required, thus an informal CRP is desired;
2. Medium size projects: medium staffing level is required, thus a semi-formal CRP is desired;
3. Large size projects: high staffing level is required, thus a formal CRP is desired;

The second factor, the required staff experience, is a function of the project complexity. An evaluation of the complexity of design and construction (D/C) techniques and communication difficulty is essential to determine project complexity. Project complexity is a function of project related characteristics and it is further discussed in the next section. In total, three main levels of complexities are considered: non-complex, moderate, and complex projects. Based on complexity's category, three levels of staff's experiences are required; low experience (non-complex projects), medium experience (moderately complex projects), and highly experienced (highly complex projects). As the staff experience required increases, the level of formality of constructability implementation increases.

The constructability resources consist of two main factors; (1) Owner staff capability; and (2) tools available to support constructability implementation (Figure 2). Owner staff capability is a measure of the number of staff available at owner's facility as well as their experience. Owner's ability to conduct CRPs over transportation projects is assessed by comparing the experience and number of available staff versus the required. If the number of available staff is more than the required number, then an assessment of their experience with constructability implementation on similar projects is essential. However, if the number of staff available is less than the required then the owner needs to outsource constructability knowledge and incorporate it into the review process. If an assessment of owner staff experience is desired, then an assessment is conducted based on the staff experience with conducting constructability in previous similar projects. As the staff experience with conducting constructability on similar projects increases, the level of formality associated with constructability implementation decreases.

The tools parameter considers the tools available at the owner facility to support constructability implementation. Tools include, constructability guidelines and policies, lessons learned databases, B/C databases, advanced technologies (3D models, Building Information Modeling, or Virtual Reality applications), and CR checklists. The more tools the owner has, the more the ability to support formal constructability review programs. The current research concludes that if the owner has three or more such tools, then a formal approach is applicable.

In summary, the owner characteristics' decision is made by combining the recommended formality resulted from the three variables; objectives, staff requirements, and resources available. To prevent conflicts while assessing the formality of a CRP, the majority role is followed. For example, if the result of assessing owner objectives concluded a formal approach, while staff requirements and resources available concluded an informal approach, then an informal approach is recommended for constructability implementation.

Project Characteristics

Figure 3 summarizes project related characteristics that include: (1) site specific variables; (2) contract strategy; (3) project size; and (4) project complexity. The contract strategy parameter considers three main delivery methods that are utilized by state DOTs: DBB, DB, and CM/GC. The project delivery method forms the basis for the desired constructability reviews milestones as it determines the structure of the project development phases and the interaction between those phases. For instance, DB and CM/GC delivery methods have opportunities to integrate design and construction phases that promote incorporating construction knowledge in a consistent manner into the design process. The project size parameter divides projects into three typical sizes based on the project cost: (1) small projects (less than $30M); (2) medium projects ($30M - $100M); and (3) large projects (more than $100M). The larger the project the more formal constructability approach is required. Three main formality levels are feasible: informal CRP (for small projects), semi-formal CRP (for medium projects), and formal CRP (for large projects). For safety purposes, a semi-formal approach is upgraded automatically within the selection framework to a formal approach at the decision level.

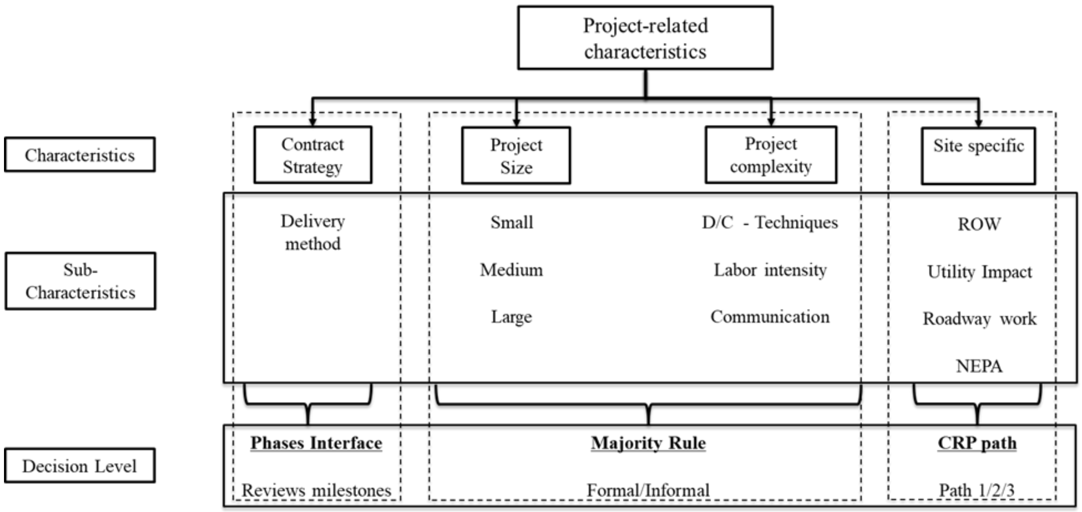

Figure 3: Project related characteristics

The project complexity parameter consists of assessing three main variables: (1) design/construction (D/C) techniques; (2) labor intensity; and (3) communication difficulty. D/C techniques variable represents an evaluation of the level of new techniques required for the project development, as well as, the complexity associated with using D/C techniques. D/C techniques are proposed to be divided into three main categories: complex, moderately complex, and non-complex techniques. The level of formality of CRPs associated with those complexities is of three tiers as well; formal, semi-formal, and informal.
The labor intensity variable evaluates the risk associated with the project and its impact on labors. A labor intense project represents more interaction on site with construction, as compared with a machine intense project, thus requires a higher degree of formality. The communication difficulty variable mainly assesses the complexity of communication between design and construction teams. The core principle of constructability is to reduce the gap between design and construction by bringing contractors to work parallel with designers at the early phases of the project development (Dunston et al. 2005). This parameter therefore is related to the selected project delivery method. The selected project delivery method either hinders D/C communication (such as DBB), or facilitates it (such as DB and CM/GC). The more the D/C communication is difficult, the more formal the CRP approach.

The site specific parameter considers four main variables: (1) National Environmental Policy Act (NEPA) requirements of the project; (2) amount of Right of Way (ROW) acquisitions and utility impacts; (3) alignment status; and (4) the amount of structure and roadwork required. Those variables were utilized by several state DOTs to select a constructability approach, including: Caltrans, Connecticut, Idaho, Indiana, Ohio, Oregon, Pennsylvania, and Virginia DOTs. The main purpose of considering those factors is to broaden the framework's applicability by assessing site related issues. The outcome of this assessment is a tiered project development category and an associated CRP category. In order to facilitate the assessment process, a selection matrix was developed. This matrix will provide with the amount of constructability investigations required associated with the main tasks involved in the PDP. Figure 4 presents the proposed selection matrix.

Project Development Path Selection Matrix						
		ROW Acquistions/Utility Impact				
		No or minor ROW, with minor utlility.	Major ROW w mod Utility relocation	Substantial ROW and Utility relocation		
Alignment	New	Path3	Path4	Path5	Level 4, EA, EIS	**NEPA Level**
	Existing	Path 2	Path 3	Path 4	Level 2 & 3	
	No	Path1	Path2	Path3	No, Level 1	
		No or Minor Impact	Moderate	Significant		
		Structure and Roadway work (Impact on Public access, LOS, traffic flow, mobility patterns, and sharing modes)				

LEGEND

CRP Path (1)
CRP Path (2)
CR path (3)

Figure 4: A selection matrix to allocate a PDP and CRP category

The selection matrix considers five possible PDP categories (e.g., project paths) and three possible CRP categories. A project development category determines the set of tasks, sequence, required coordination and communication, and the required management efforts to successfully develop the targeted project. The CRP category determines the set of concepts, tools, and practices that need to be adopted to reduce design errors and to ensure that the design is constructible. A brief description of each category is provided below:

1. PDP category 1 – CRP category 1: includes projects such as, bridge deck overlay, superstructure maintenance, and General highway maintenance (ex., traffic signals, signs, guardrails, pavement, etc.).
2. PDP category 2 – CRP category 1: includes projects such as, bridge replacement, bridge rehabilitation, culverts replacement, resurfacing, and pavement widening.
3. PDP category 3 – CRP category 2: includes projects with moderate roadway improvements such as, bridge replacement, bridge rehabilitation, pavement rehabilitation, pavement widening, geometric realignment, and Intersection/Interchange upgrades.
4. PDP category 4 – CRP category 3: includes projects such as, new interchange construction, and major modifications to existing interchange.
5. PDP category 5 – CRP category 3: includes projects with significant alteration to existing highway such as, relocation of major portion of highway, construction of new interchange, significant modification to existing interchange, interstate widening.

A project path is assigned based on an evaluation of the matrix's main variables (ROW and utility impact, NEPA required level, structural and roadwork impact, and alignment status). The PDP categories divide transportation projects into three main types: small non-complex projects (categories 1 and 2), medium complex projects (category 3) and large highly complex projects (categories 4 and 5). A CRP is then assigned for each type, resulting in a total of three CRPs; (1) CRP category 1; (2) CRP category 2; and (3) CRP category 3. Below is a comprehensive illustration of each variable and its impact over the desired PDP category:

1. ROW acquisitions and utility impact: Mainly, transportation projects have one of the following three types of impacts:
   a) *No ROW acquisition without or with simple utility impact:* most projects within this group are from category 1 and 2 projects;
   b) *Moderate ROW acquisition without or with simple utility relocation:* most projects within this group are of categories 2 (without relocation) and 3 (with relocation) projects;
   c) *Substantial ROW acquisition and utility relocations*: some complex category 3 projects, and all category 4 and 5 projects fall within this group;

2. NEPA and Environmental Impact: Mainly three NEPA levels are available as follow:

a) *No categorical exclusion (CE) or Level 1 CE*: includes projects of categories 1 and 2, and some category 3 projects;
b) *Level 2 or 3 CE:* includes most category 3 projects, and some category 4 projects;
c) *Level 4 CE, environmental impact statement (EIS), and/or environmental assessment (EA):* contains projects with considerable environmental impact (most category 4 and 5 projects). Projects within this category have to conduct an analysis to identify the environmental impact's intensity and context.

3. Structure and Roadway work: three main impacts are feasible:
   a) *No or minor roadway impact:* this includes projects of categories 1 and 2 that do not require noticeable changes to the structure and roadway geometry;
   b) *Moderate roadway impact:* mostly contains projects of category 3, and some category 4 projects;
   c) *Significant roadway impact:* this group contains most category 4 and all category 5 projects. Projects of this category have the highest design complexity with significant impact on the road's level of service (LOS), traffic flow, mobility patterns, sharing modes, and public access. This category of projects involve an assessment of multiple design alternatives;

4. Alignment status: highway construction projects typically fall in one of the following alignment statuses:
   a) *No alignment:* this group mainly includes projects of category 1 and some category 2 projects;
   b) *Existing alignment:* This group of projects involve widening works and includes the majority of category 3 and some category 4 projects;
   c) *New Alignment:* this group includes the majority of category 4 and 5 projects that require adding new alignments to existing alignment or realigning existing alignment;

The project characteristics' decision is made by combining the recommended formality resulted from assessing project size and complexity with the selected CRP category and the proposed project delivery method. In terms of formality, project complexity outweighs the decision of project size, as it considers communication, D/C techniques, and labor intensity. For example, if the result of assessing project size concluded a formal approach, while project complexity concluded an informal approach, then an informal approach is recommended for constructability implementation. Consequently, the general form for the recommended constructability approach out of this phase can be expressed in a generic form: CRP (n) – Delivery Method – Formality (ex., CRP (1) – DBB – Formal). The notation "n" represents the category of the CRP resulted from using the selection matrix presented in Figure 4 while evaluating site specific factors.

Level 2: CRP Approach Selection

Once a decision is made for each owner and project related characteristics independently, a final decision is taken during this decision level. At this level, six possible decisions regarding a CRP approach are feasible. Those approach decisions are divided into two main groups: formal and informal approaches. The proposed formal decisions are as follow: (1) CRP 1A – Constructability Design Review; (2) CRP 2A – Project Level CRP; and (3) CRP 3A – Comprehensive Tracking CRP. The feasible informal CRP approaches are: (1) CRP 1B – Historical Practices; (2) CRP 2B – Quality Improvement Program; and (3) CRP 3B – Semi-formal Constructability Guidelines. It is noted that if project characteristics recommend an approach different than the owner characteristics recommendation, then the priority is given for the project related decision. The selected approach will then be implemented according to its related attributes. The CRP approach attributes are discussed and shown in details in the level three of the framework.

Level 3: CRP Parameters

Gugel and Russell (1994) suggested six main attributes to differentiate a constructability approach from the other. Those attributes, along with the attributes suggested by the AASHTO (2000), were used mainly to differentiate the proposed CRP approaches in this paper. In total, eight main attributes were concluded to have a direct relation to the six proposed CRP approaches. The interrelation between constructability approaches and attributes was guided by the attributed constructability approaches suggested by Radtke and Russell (1993). The attributes are: (1) formalized constructability procedures and guidelines; (2) construction input source; (3) constructability review milestones; (4) B/C tracking and documentation; (5)

lesson learned tracking and databases; (6) constructability tools; (7) constructability coordinator/champion; and (8) constructability reviews team. Table 1 summarizes the attributes associated with each of these six CRP approaches.

Table 1: Attributes of CRP Feasible Approaches

CRP Approach **Attributes**	Historical Practices **CRP 1B**	Quality Impr. Program **CRP 2B**	Constructability Guidelines **CRP 3B**	Constructability Design Review **CRP 1A**	Project Level CRP **CRP 2A**	Comprehensive Tracking CRP **CRP 3A**
Formal Procedures	NO	NO	PARTIALLY	PARTIALLY	YES	YES
Construction Inputs	In-House	In-House	In-House	In-House	In-House/On-Call Consultant	Industry Inputs/ ATCs
CR Milestones	30% design	30%, 90% PS&E	PIP, 30%, 60%, 90% PS&E	PIP, 90% PS&E	PIP, 30%, 90% PS&E, CC*	PIP, 30%, 60%, 90% PS&E, CC*, PC**
B/C Documentation	NO	Qualitative	Qualitative & Quantitative	Qualitative	Qualitative & Quantitative	B/C database & Tracking
Lessons Learned Database/Tracking	NO	NO	NO	NO	NO	YES
CR Utilized Tools	Design Team Experience	Design Review Checklists	CR Checklists, 2D/3D Analysis	Design Review Checklists	CR Checklists, 2D/3D Analysis	CR Checklists, nD Modelling, VR, Databases
CR Coordinator (Champion)	NO	Project Manager	1 Part Time	Project Manager	1 Part Time	1 Full Time
CR Responsible Team	NO	Design Team	QA/QC Team & VE	Design Team	QA/QC Team & VE	Special Multi disciplinary team

*Construction Close-out Review **Post-Construction Review

The attributes shown in Table 2 represent the requirements associate with the traditional DBB delivery method. It is noted that design and construction are performed independently in DBB projects. However, when an ACM is employed, a single entity represents the owner and take the responsibility of both design and construction combined. Therefore, design phase interfaces with the construction phase to deliver a more collaborative project. This adjustment requires combining some of the structured CR milestones. Table 2 represents the CR adjusted structure for ACMs. An arrow in the table represents a combined review. The arrow direction represents the combination direction and thus leads to the final combined review.

Table 2: Adjusted CR milestones for ACMs

CRP Approach	CRP Level	PIP	30% design	60% PS&E	90% PS&E	Construction Closeout	Post construction (M&OP)
Constructability Design Review	CRP (1A) – Formal	√			√	←	
Historical Practice	CRP (1B) – Informal		→		√		
Project Level CRP	CRP (2A) Formal	√	√	√	←	←	
Quality Improvement Program	CRP (2B) Informal		√		←		
Comprehensive Tracking CRP	CRP (3A) – Formal	√	√	√	←	→	√
Constructability Guidelines	CRP (3B) – Semi-formal	√	√	√	←		

4 RESEARCH LIMITATIONS

The proposed framework is based on an extensive analysis of the CRP models presented in the literature. Future research needs to collect data to validate the proposed approaches and the selection factors.. One of effective methods to verify and validate the proposed framework may include conducting case studies from completed transportation projects that utilized CRs into their design processes. The case studies are expected to provide a deeper insight into the practicalities and accuracy of the framework, and thus make adjustments as required.

5 CONCLUSION

This paper proposed a framework for selecting a CRP approach. The framework enables the decision makers in state DOTs of selecting the most suitable CRP approach for each individual project, based on an assessment of project and owner characteristics. Project characteristics include: contract strategy, project size, project complexity, and site-specific factors. Owner characteristics include: owner objectives, staff requirements, and owner resources. A CRP approach decision is determined by a hierarchy of decision levels. The hierarchy follows three main levels; (1) an individual assessment of project and owner characteristics which determine the desired CRP level and formality; (2) interacting the recommendation of both characteristics to determine the final formality desired for the project (A represents a formal approach and B represents an informal approach); and (3) selecting a CRP approach based on the combined formality decision. In total, six main CRP approaches are feasible: Historical Practice (CRP 1B), Quality Improvement Program (CRP 2B), Semi-formal Constructability Guidelines (CRP 3B), Constructability Design Review (CRP 1A), Project Level CRP (CRP 2A), and Comprehensive Tracking CRP (CRP 3A). With successful verifying the proposed framework, it may help state DOTs in allocating a CRP approach suitable for the project at hand while considering the agency's internal capabilities. This allocation would help agencies in determining the proper means of incorporating construction knowledge early into the design phase.

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