**Technical Memorandum**

This Technical Memorandum discusses key research findings and recommendations for both future research, and implementation of the Constructability Decision-Making Framework. Additional details of the research in summary form, can be found in this Final Report in the Executive Summary, and the Conclusions.

**Key Research Findings**

Outside of the Decision-Making Framework most of the interesting and probably enduring findings from this research project were discovered in Phase I, and during the Workshop early in Phase II. The Case Studies and the Workshop were especially enlightening. The Framework model was developed to produce findings in its application, more than through its development. Still, there were a few notable findings during its development, notably that participants (users) have various interpretations of questions, answer options, and specific terms in the electronic framework.

* Virginia DOT (VDOT) has a process that can serve as a model for how DOTs can exploit the advantages of integrated project delivery and not lose time, money, or quality because of conflicts between input to the design from outside sources (the contractor or design-builder). VDOT bases its system on equal parts “Optimized Limits of Disturbance” and “The Merged Process.” A detailed description of this two-pronged system, and recommendations as to how it can help every DOT with their CRP, will be a highlight of this report. Details of this system can be found in the Hampton Roads Bridge Tunnel (HRBT) / VDOT Case Study, and Appendices B and C.
* During the time of the research, the President signed an Executive Order that forces all DOTs to follow most of VDOT’s model. While there will be the inevitable initial pain from change, this is a long-term positive development for agencies.
* DOTs should start their CRPs as early as possible. In state after state, researchers heard “one doesn’t need a set of plans in order to perform a constructability review.” Those interviewed from the states most progressive in this area said they thought the CRP should start at the same time as the NEPA and environmental-permitting processes, or earlier.
* DOTs should get “buy in” from state and (especially) 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 project scope and geographic limits. They sometimes have “10-15%” plans to show the agencies, and sometimes have no plans at all. After explaining the scope and showing them the project geometric footprint, they ask the agencies to advise them of any facet or portion of the project, as explained, that these agencies would have problems with when it came time for permit application. This early “buy-in” from the agencies seems to make the permitting process go much more smoothly.
* Submitting an oversized project footprint to the Federal Highway Administration (FHWA) for the NEPA process has two important and distinct advantages: (1) Instead of exceeding the submitted Limits of Disturbance (bad news), causing a NEPA Re-evaluation, there is almost always less land required to build the project. This means a lesser environmental impact and smaller need for eminent domain land seizures than had been feared (good news) and (2) It improves the relationship between the DOT and the FHWA. The FHWA was impressed after a while that the state was being liberal in its estimate, and not trying to see just how small a piece of land it could claim in its NEPA proposal. This seems to have resulted in the FHWA overlooking small overruns. In other words, if the final design ends up requiring a small piece of land outside the footprint in the NEPA proposal, they don’t force a NEPA Re-evaluation (see Appendix B.3, HRBT Case Study).
  + Seventy-four percent of survey respondents said their DOT has a formal CRP.
  + Forty-nine percent of respondents said their agency’s formal CRP changes when the delivery system changes.
  + Eighty-two percent of respondents said their agency’s effort to improve constructability involved/included industry input.
  + Fifty percent of respondents said their agency has established processes allowing contractor input into the design.
  + Twenty-three percent said they had witnessed contractor input to the design hampered due to a fear on the part of the parties involved of having to endure a NEPA Re-evaluation, or re-open the environmental-permitting process.
* Minnesota DOT has generated guidelines for their CRP, in which they have inserted a 12-step process for gaining contractor input into the design they have labelled the “Industry Constructability Review Process” (see Appendix B.3, HRBT Case Study for details and the 12 steps). The process involves inviting contractors into the DOT office to view and analyze contract documents of upcoming projects early – before the projects are advertised. In exchange for the privilege of reviewing the plans and specifications early, the contractor agrees to meet with DOT Construction and Design personnel for one hour to discuss constructability issues.
* Of those interviewed in various states, several called for a formalized cross-training program. One claimed such a program would “help constructability more than just about anything we can do.”
* District Design Offices in the Florida and Connecticut DOTs have implemented a “Plans in Hand” Review somewhere between the 60% and 90% plans stage on all D-B-B jobs. This sometimes includes a field walk. They report having identified major problems at this meeting. Other DOTs have a similar procedure.
* Over the course of developing the electronic model, the team considered various forms of delivery. For example, as a standalone application run from the desktop, or hosted from a web server. It was determined that hosting the application on a website would be the most accessible and convenient, as software downloads would not be required. The only requirement would be a modern web browser. It was observed that the installation of the standalone application added a layer of complication that negatively affected the user's experience.
* During the virtual workshop, the team faced issues with concurrency and internet connection while the participants were submitting their AHP forms. Changes were made to the database system to handle multiple submissions at the same time, and an automatic retry function was added on the client (user) side to handle cases where the initial submission attempt is unsuccessful.
* It was observed that when participants (users) have interpretations of the questions, answer options, and specific terms within the electronic framework that are different from those of the research team, invariably, the performance of the model is negatively affected. To mitigate this problem, short popup modals were added to questions and content to provide explanation or guidance for completing the data entry process of the electronic framework. This reduces confusion among participants while maintaining the simplicity of the interface.

**Recommendations**

Recommendations are separated into two categories - “Recommendations for Implementation,” and “Recommendations for Future Research.”

**Recommendations for Implementation**

The limitations of this research (see “Recommendations for Future Research”) indicate the need for additional research and development, and strategic, purposeful implementation

procedures. The NCHRP 10-99 Panel was wise to include specific required tasks for the development of Training Materials and an Electronic Presentation as part of this research. These tasks have been successfully completed. These elements stand ready for operation, but they, and the model, need testing and fine-tuning. The Research Team presented a prototype of the model to the delegates to the Workshop in March 2021, but there have been countless changes to the model since then. So many changes, in fact, that the current status of the model would be that of a prototype that is much more potent, robust, and comprehensive than the one presented last March, but a prototype just the same. The model needs assessment under field conditions.

The research also revealed the need to develop methods to measure the performance, not only for the model, but for an agency’s CRP. These are needed to allow continuous improvement. Topics recommended for immediate consideration by NCHRP and FHWA for implementation include:

**1. Test, and deploy Training Materials**. All Training Materials developed as part of this research were developed post-Workshop. Therefore, none of these materials have ever been tested by practitioners. Unfortunately, the scope, funding, and time for the research did not include testing or implementation. Much of the Training Materials are imbedded in the model, so a thorough testing of the model would test these Training Materials. However, many of the Training Materials are outside the model, and need testing separately. The Research Team strongly recommends a systematic and comprehensive approach to testing the effectiveness of these Training Materials as the Decision-Making Framework model is implemented on real projects owned by DOTs in selected states. Five or six states should be chosen from agencies that participated in the research effort. These states should be visited, and the Training Materials should be tested there. It will also prepare the Training Materials for use by all PTAs with limited-to-no help needed from a central source.

2. **Test Decision-making Framework implementation on pilot projects**. Use of the Decision-making Framework is available to all PTAs. However, it is doubtful that more than a very few know how to use it. Testing of the model on pilot projects and publishing the results as case studies would aid in the speed and effectiveness of model implementation. Since some of the Training Materials are embedded in the model, the testing of the model could largely be accomplished at the same time as the testing of the Training Materials. The testing of the e-guidebook for the purposes of customization could be accomplished consecutively by the same researchers, right before, or right after. This approach will allow refinement, and prepare the model to be used by all PTAs.

**3. Create, test, disseminate, and employ CRP performance measures.** The research revealed a lack any semblance of a standardized approach to measuring the competence of an agency’s CRP. What is needed is a standardized, comprehensive framework, performance measures, and targets for measuring CRP performance. Such a system, though standardized, would not be a “one-size-fits-all” proposition. An e-model is envisioned. As with the Decision-making Framework, there should be mechanisms developed and provided, to allow agencies to customize the model to their own needs. Some data to aid in the development of a model to measure the effectiveness of a CRP were gathered in the Decision-making Framework research. More should be gathered and amalgamated with the current data for use in developing the model.

Besides offering improvement of the CRP for all PTAs, national research to develop a common set of CRP performance measures and targets will expedite and improve implementation of the Decision-making Framework.

4. **Develop more electronic models similar to the Decision-making Framework, where agencies have needs**. During this research, the research team has hit on a marvelous procedure for developing electronic models (developing software) to help mitigate, or even solve, problems faced by today’s PTAs. As in Number 3 just above, a process similar to that followed to develop the Decision-making Framework can be followed to fill gaps where there is a lack of tools to help with any number of processes. Some areas to consider include measuring the effectiveness of the CRP, the project closeout process (including punchlist protocol), project bundling strategy, risk management, how best to deploy alternative contracting methods, quality management, optimization of Limits of Disturbance, and work packaging. Researchers could work with agencies to develop practical tools for any of these issues to meet felt needs of agencies.

In good faith, the research team suggests strongly that NCHRP—possibly in collaboration with FHWA—execute these four recommendations as soon as possible. The research team can assist with implementation, and DOTs willing to participate are easily distinguishable from the early tasks and Workshop in this research study. These recommendations constitute four distinct opportunities to accelerate the diffusion of knowledge, and the standardization of practice.

**Recommendations for Future Research**

These recommendations are a combination of discoveries made as part of the research, but made too late to include in the Decision-Making Framework, and limitations in the research.

1. Recommendations for future research include a research effort that focuses on the reason for the project. Many experts in the Focus Groups, Case Studies, and Workshop, said that they found it difficult to use the Framework unless they understood the reason that the project is being built in the first place. It is not enough, they say, to know facts and statistics such as project size, project cost, and project duration. They need to know the core purpose for the project. How the purpose of the project impacts the CPR should be integrated into this Framework.
2. The current Framework is insufficiently responsive to the delivery system being used, or considered for the project. Therefore, the Framework should be revised to be more sensitive to the delivery systems being used or proposed. Newer delivery systems, such as Integrated Project Delivery, and Progressive Design-Build should be included in the Framework.
3. Much like the problems faced by PTAs when dealing with the railroads when projects cross or run adjacent to railroad ROW, contractors are also having problems when the highway or bridge they are building cross, or run adjacent to, a military installation. Research into how this situation impacts the CRP, and integrating the knowledge procured into the Framework would be helpful.
4. The current Framework addresses availability of skilled and unskilled labor in the vicinity around the project site. There should be research toward similarly handling the issue of availability of equipment and materials (especially concrete) in the vicinity around the project site.
5. It would also strengthen the Framework to document the relationship between CRP and Partnering, and integrate that into the Framework.
6. Finally, though the current Framework includes the utilization on contractors into the CRP, more research is needed in this area, in order to make the practice more widespread, and more easily integrated into the Framework.
7. The Case Studies afforded the team the deepest understanding of the current state of the practice in the US. In the Case Study schedule for this project, no DOT from a state in the Southwest or Midwest was studied.