Arizona Department of Transportation

Digital Delivery Program Guidance Document

Prepared by HDR

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Executive Summary

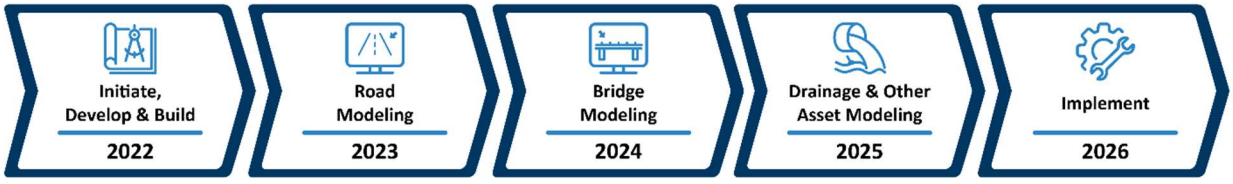
What is Digital Delivery?

Digital Delivery refers to a modernized process for the design and delivery of digital data such as 3D models. For years, transportation agencies have relied heavily on printed 2D plans for roadway and bridge projects. However, an ongoing shift towards digital delivery is changing the way projects are delivered and constructed, leaving 2D plans behind. Overall, digital delivery is becoming increasingly essential for transportation agencies as it offers a more efficient, accurate, and cost-effective way of delivering construction projects.

Overview

The adoption of digital delivery in the transportation construction industry has been steadily increasing. As advancements in digital technology continue to progress at a rapid pace, ADOT is working towards a phased systematic approach for a statewide digital delivery adoption and implementation plan. This paperless delivery system has quickly become a “must-have” as it offers numerous advantages over traditional paper-based delivery methods. The Digital Delivery Program (DDP) will streamline processes from inception through project delivery and will proactively establish guidelines to help ADOT achieve their goals and continue adapting to evolving technology.

The DDP is guided by a Digital Delivery Roadmap (DDR) that includes a series of activities to be completed by the end of 2025 and long-term recommendations to sustain the program into the future. The first step was to assemble a team to oversee the project that will ultimately launch ADOT further into the future as digital delivery becomes a primary business practice. It is expected that ADOT will be positioned for implementation by calendar year 2026 and will begin working on a framework for the collection of digital as-build records to support operations and maintenance activities.



The value of digital delivery lies in its ability to improve collaboration, increase efficiency and sustainability, and enhance visualization, so that projects can be completed on time, within budget, and to the highest level of quality.

Approach

A vast group comprised of executive team members, representatives from each ADOT functional group and multiple agency committees, and a consulting team were tasked with developing and directing the DDP that highlights the foundational activities needed to move towards a digital transformation.

- The Digital Delivery Governance Committee (DDGC) is responsible for setting strategic direction for the overall program.

- The Digital Delivery Steering Committee (DDSC) is responsible for executing the strategic direction to align with business needs.
- The Digital Delivery Technical Committee (DDTC) is responsible for executing activities related to technology implementation.

The team conducted a benchmark study of 10 state DOTs, a review of national efforts, and a Digital Delivery Readiness Assessment and Gap Analysis to provide guidance on best practices and successful elements that ADOT can incorporate into its digital delivery program.

The State DOT Benchmark Study showed that ADOT should expect some challenges and growing pains due to the lack of the necessary expertise to implement digital tools, inadequate funding and workforce capacity to handle additional tasks, and legal concerns around product liability, which all must be addressed before a full adoption occurs.

Fortunately, the research shed light on best practices and tasks necessary for successful implementation including adopting a strategic and phased approach, engaging stakeholders early, managing change effectively, piloting hybrid projects, leveraging consultant support, establishing dedicated digital delivery leads, developing clear modeling standards, and partnering with technology providers to facilitate success. Collaboration and communication, both internally and externally, have been deemed critical to success. Research shows that a holistic approach is key, with a focus on risk mitigation, change management, and continuous improvement through pilot projects.

National efforts were also reviewed to provide a baseline of best practices from the Federal Highway Administration (FHWA), the American Association of State and Highway Transportation Officials (AASHTO), and the National Cooperative Highway Research Program (NCHRP). These agencies are at the forefront of advancing the maturity of digital delivery in transportation. Federal Highway Administration (FHWA) initiatives include the Every Day Counts (EDC) Program, the Turner-Fairbanks Highway Research Center, and discretionary funds, such as the Accelerated Innovation Demonstration (AID) and Advanced Digital Construction Management Systems.

The EDC program encourages the use of underutilized innovations in highway projects, enhancing safety and environmental protection. The Turner-Fairbanks Highway Research Center, a national research facility, conducts advanced research in digital delivery and Building Information Modeling (BIM). Discretionary funds provide financial assistance enabling agencies at state and local levels to deploy new technology. NCHRP has successfully documented the state of practice for digital delivery through synthesis and project reports, providing guidance and information to assist ADOT with its implementation of digital delivery. By leveraging these national efforts, ADOT can advance its digital delivery program, enhance efficiency, and improve transportation infrastructure.

The gap assessment performed utilized data collected from a variety of methods including a primary review of manuals and documents, Project Delivery Academy videos, communication between stakeholders, software documentation, and interviews with ADOT subject matter experts.

The FHWA Organization Digital Delivery Assessment tool offers a simple yet comprehensive approach to implementing digital delivery. The team deemed it the most effective and utilized it to assess ADOT's readiness score that identifies areas of improvement and provides a path for achieving digital maturity. The following areas were evaluated and recommendations for each category have been provided for consideration and should be evaluated by ADOT's leadership based on priority.

- Strategy
- Digital Delivery Uses Cases

- People
- Processes
- Data
- Technology

Digital Delivery is here to stay and will enable project teams to share information in real-time, collaborate remotely, and avoid the costs and delays associated with paper-based document handling. By using digital tools such as BIM, Global Navigation Satellite Systems (GNSS), and automated machine guidance (AMG), construction projects can be completed more efficiently and with greater precision that will not only meet but exceed expectations. Digital delivery also enables stakeholders to visualize and simulate the project before construction, reducing the likelihood of design errors and construction delays.

By adopting a phased approach, engaging stakeholders, and leveraging state and national efforts, the recommendations outlined will streamline processes, help manage data integrity, and facilitate a paperless delivery system that will put ADOT ahead of the curve for a successful digital transformation.

Gap Analysis: Summary of Key Observations and Recommendations

An assessment of ADOT processes highlights key observations and areas of improvement in four planning elements: **People, Processes, Data**, and **Technology**.

People: ADOT personnel are eager for digital delivery implementation, but have concerns about training, costs, and resource allocation. They need clarity on digital delivery's impact on various business groups and stakeholders, as well as software, hardware, training, and information management policies.

Recommendation: Establish multi-disciplinary committees, identify dedicated staff, prioritize ADOT needs, create communication and training plans, and establish technology business leads. Collaboration and engagement with internal staff and external stakeholders will also be vital.

Processes: Staff from different groups focus on specific processes for their tasks. Current processes for delivering plan-based products must be adapted for digital delivery. Real-time collaboration is in its infancy, with Workfront aiding collaboration, but lacking integration with ADOT's modeling platforms.

Recommendation: Develop guidelines and support documentation to enable digital delivery. Establish processes for leveraging multiple types of digital data, model-based design, digital-model review, and standardized collaboration. Update process maps for digital workflows and focus on digital data exchanges.

Data: ADOT lacks a strategic data business plan, with groups operating independently. Data management is inconsistent and there is no managed common data environment. Data standards for model-based design are inconsistent and various systems storing data are not effectively connected.

Recommendation: Develop strategic, business, and action plans for data management to prioritize project development. Establish consistent data storage locations, standards, and guidelines for file naming conventions, model development requirements, and information requirements for data collection of as-built records. Coordinate with Transportation Systems Management and Operations (TSMO) and other asset inventory data owners to enhance data management.

Technology: ADOT is working on initiatives including deploying 3D modeling technologies including the implementation of OpenRoad Designer, OpenBridge Designer and evaluating OpenGround as an enterprise geotechnical information database; replacing the legacy FAST system; and migrating from ArcGIS-to-ArcGIS Pro. ADOT has access to various data acquisition technologies and software but faces challenges in connecting systems and sharing information.

Recommendation: Assess current technology, work with ITG to create a technology plan for the use of Bentley products currently available under the ADOT licensing agreement and collaborate with the team leading the software replacement for FAST. Also, the DDP leads should collaborate with the GIS group in defining desired attributes from 3D model data. Also, consider asset management solutions and pilot tools for digital construction inspection.

Introduction

Overview

As advancements in digital technology continue to progress within the transportation industry, the Arizona Department of Transportation (ADOT) is changing the way projects are designed, delivered, and constructed, and assets are managed through digital systems. ADOT has initiated a project to develop and implement a multi-year Digital Delivery Program (DDP) that will establish how to best leverage digital workflows including 2D and 3D model-based products and other types of digital files.

Digital delivery is defined as "modernized approach to project delivery processes and contract media that incorporates digital data. Simply stated, construction projects have the ability to be bid using 3D technology and no longer only be delivered in a traditional 2D construction plan format". (Pennsylvania Department of Transportation, 2023)

This guidance document provides critical information to enable ADOT to help prioritize foundational activities to complete this digital transformation.

There are four key sections in this guidance document:

Introduction. This section provides a description of the ADOT Digital Delivery Program, including the vision and mission established by ADOT, as well as the specific goals for achieving that vision. In addition, this section describes a high-level roadmap that uses a phased approach to reach these goals by the end of calendar year 2025. ADOT recognizes the complexity of implementing Digital Delivery across the entire agency, thus the full implementation may continue well into 2026. Lastly, this section defines the interim structural organization to oversee the development and partial execution of an implementation plan, as well as a potential long-term structural organization to manage the program once in place.

Digital Delivery State of the Practice. This section summarizes national efforts by the Federal Highway Administration (FHWA) and the American Association of State and Highway Transportation Officials (AASHTO) advancing the maturity of digital delivery, as well as best practices from other State Departments of Transportation (DOTs).

ADOT Digital Delivery Readiness Assessment and Gap Analysis. This section provides an overview of digital delivery readiness assessment methodology for measuring ADOT digital delivery maturity based on the information collected through the interviews with ADOT subject matter experts (SMEs), and review of ADOT publications. The section ends with a summary of the ADOT digital delivery readiness assessment results. A gap analysis highlighting the steps to achieve higher digital delivery maturity is also provided in this section.

Conclusions and Recommendations. This section summarizes conclusions and recommendations based on the input received by ADOT staff and best practices shared by peer State DOTs.

In addition to the four key sections described above, the report also includes references for information sources and several appendices.

Vision and Mission

ADOT'S VISION for digital delivery is that by December 31, 2025, construction projects will be designed and bid using 2D and 3D modeling technology with digital delivery of design documentation, and no longer deliver projects in a traditional construction plan format.

THE MISSION OF THE DIGITAL DELIVERY PROGRAM is to enable continued modernization of the project delivery process to improve design quality, reduce risk, improve design and construction efficiencies, while managing data integrity of deliverables. A secondary desired outcome is to enhance the management of asset information post construction.

Goals for Achieving the Vision

DEVELOP STANDARDIZED AND ACCESSIBLE digital delivery standards and processes, guidance documents, training, and tools to support all project development functions by all stakeholders.

USE 2D AND 3D DIGITAL TECHNOLOGIES to create high quality, data-rich models of our projects and system, by capturing historical, present, and future data through our project deliverables.

DEVELOP AND IMPLEMENT new information management processes that capture asset information from projects and use it to improve construction inspections and asset management.

Multi-Year Roadmap

The implementation of digital delivery is a complex process that requires the deployment of new technology, incorporation of new methods and processes, and managing the pace of change and people's expectations. Thus, ADOT has set a phased approach to take incremental steps to achieve a statewide digital delivery adoption. Figure 1 illustrates this year-by-year phased approach of activities to achieve proficiency in the various aspects of 3D modeling and digital delivery. The ADOT Digital Delivery Multi-Year Roadmap plan began in December 2022. The first activity was to assemble an ADOT team to oversee the program and hire a consultant to assist with the development of a comprehensive implementation plan. The implementation plan will include a series of short-term activities to be completed by end of calendar year 2025, and long-term considerations. By the end of calendar year 2025, ADOT will have the pieces necessary for successful implementation of a standardized approach to digital delivery to enable model-based design methods for project development, construction administration, and digital construction practices. Starting in 2026, ADOT will start working on a framework for the collection of intelligent digital as-built records to hand over to support operations and maintenance activities.

Structural Organization

Interim Structural Organization

An interim team has been established to oversee the ADOT Digital Delivery Program composed of executive team and champion, two co-leads, three committees, and the consulting team working with ADOT on the development and implementation strategy for the Digital Delivery Program. This section provides definitions for each of the roles and responsibilities, and overall composition for each of the three committees illustrated in Figure 2.

Figure 1. ADOT's Multi-Year Roadmap – A Phased Plan Approach

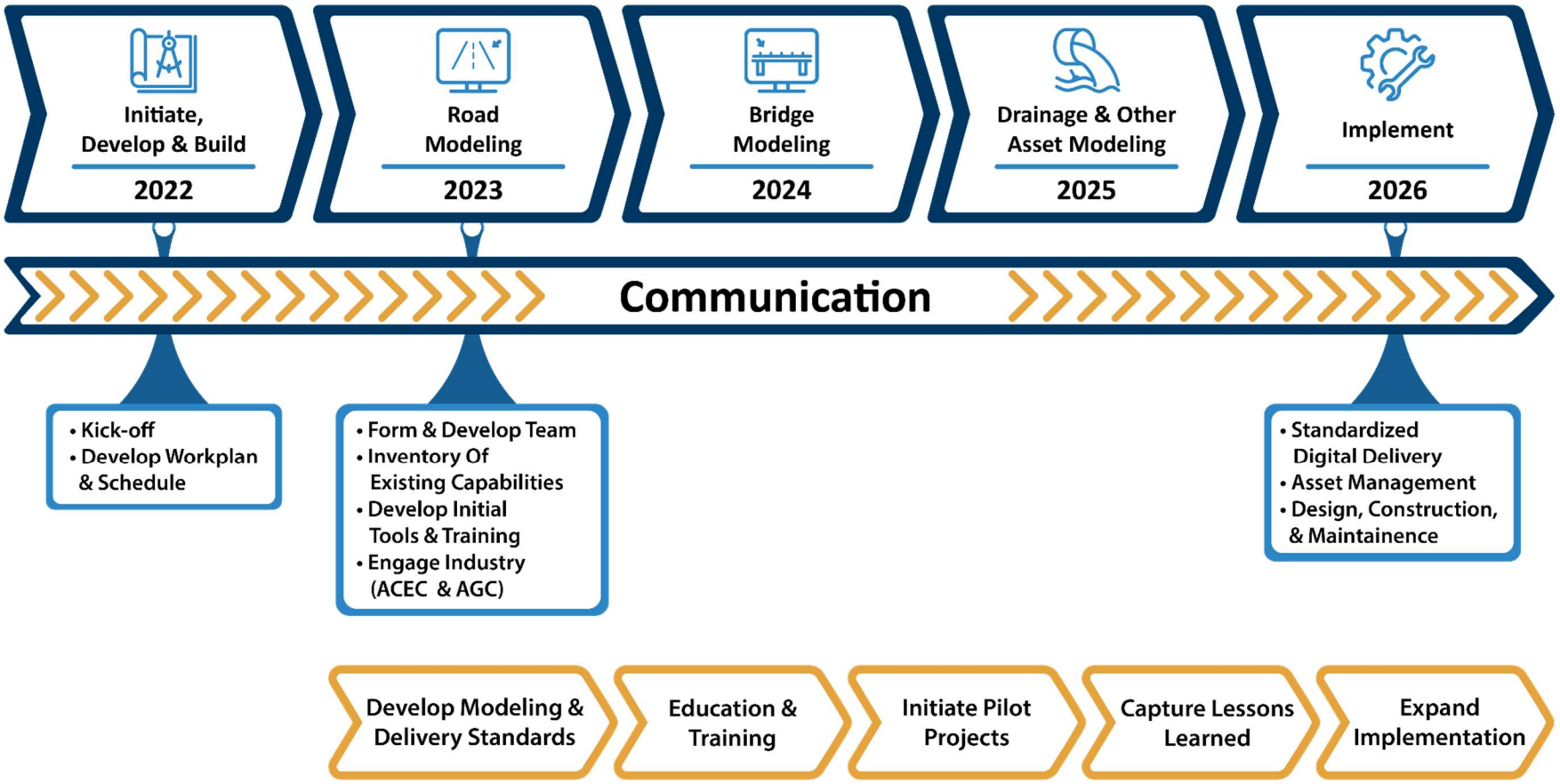
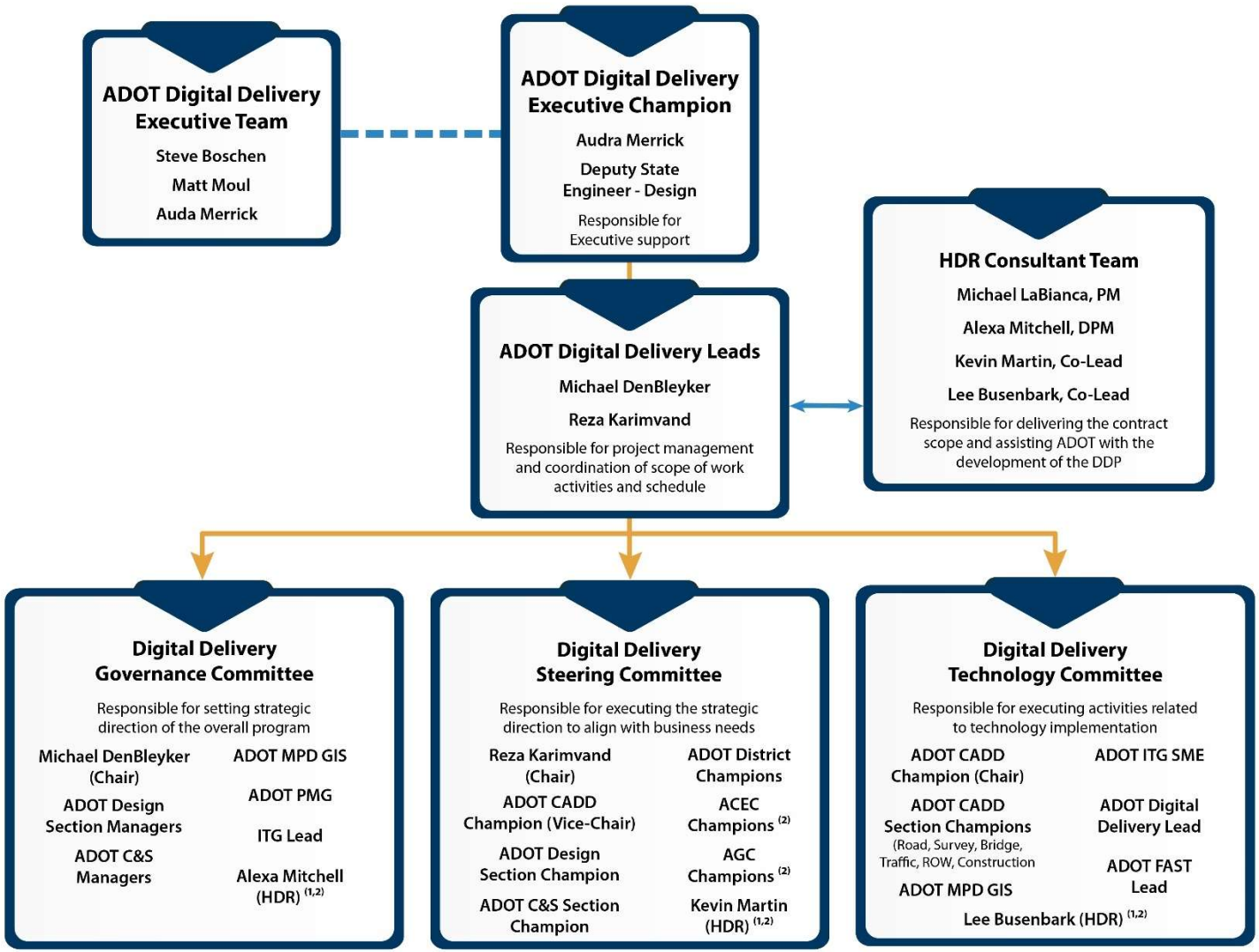


Figure 2. Interim Digital Delivery Program Structural Organization



Roles and Responsibilities

Digital Delivery Leads: The role of the Digital Delivery (DD) Leads is to manage the contract scope of work and schedule, lead, facilitate, coordinate, and move the ADOT Digital Delivery Roadmap forward.

Digital Delivery Governance Committee: The Digital Delivery Governance Committee's (DDGC) primary responsibility is directing the overall Digital Delivery Program, specifically

1. Set the vision, for the Digital Delivery Program.
2. Oversee progress of the program, discuss risks and mitigation strategies, and review the resource needs for executing the Digital Delivery Program.
3. Secure funds (including federal funds) and approve budget to support initiatives.

Digital Delivery Steering Committee: The Digital Delivery Steering Committee's (DDSC) primary responsibility is directing the business needs to be supported by the Digital Delivery Program.

1. Develop strategies, and make decisions about the activities and timelines for achieving the Digital Delivery Program objectives, specifically,
    a. Provide business requirements for the development of the Digital Delivery Program framework.
    b. Define goals, strategies, and desired outcomes for achieving the vision established by the DD Governance Committee.
2. Research and participate in national efforts to learn and share best practices for Digital Delivery of projects/programs, such as Pooled Fund Program, etc.
3. Communicate progress of the Digital Delivery Roadmap and implement requirements.

Digital Delivery Technology Committee: The Digital Delivery Technology Committee's (DDTC) primary responsibility is to execute activities related to technology implementation, such as development, testing, implementation of ADOT's DD systems and programs through existing and new technologies. Specifically,

1. Investigate and test technologies of interest that support ADOT's DD initiative.
2. Develop and manage ADOT digital delivery standards, procedures, and guidance documents, including:
    a. Computer Aided Design (CAD) platforms, workspace, and related standards, such as pay items, etc. (e.g., Bentley products).
    b. Survey data collection hardware and software (e.g., Trimble products).
    c. Traffic modeling and simulation software (e.g., Vissim).
    d. Project management, letting and bidding software (e.g., AASHTOWare, custom).
    e. Construction administration and inspection software (e.g., FAST and PEN 5).
    f. 3D Real-time review software (ProjectWise iTwin Design Review).

g. Geographic Information Systems (GIS) and Linear Referencing Systems (LRS).

h. Common data environment (e.g., ProjectWise).

i. Technology hardware and software planning, budgeting, inventory, and updates, including software and tool testing, vendor coordination, assess and plan hardware needs and updates.

3. Manage technology and Digital Delivery Training Program.
4. Communication of technology and Digital Delivery technical support.
5. Complete activities related DD Roadmap actions (strategies, planning, actions), including:
    a. Close coordination with the DD Task Force and Steering Committees, and
    b. Carrying out DD implementation decisions/actions.
6. Develop, manage, and update ADOT's Digital Delivery Program website.

Consulting Team: The Consulting Team is HDR. The primary responsibility for HDR is to serve as ADOT's SME consultant providing guidance, expertise, and recommendations in the development and successful deployment/implementation of ADOT's Digital Delivery program. Specifically,

1. Submit project progress reports and invoicing as required per task order contract.
2. Submit an email with a bullet list of the progress of technical activities on the second Tuesday of every month (by mid-day) to Reza Karimvand.
3. Attend and serve as ADOT's SME consultant during Governance, Steering and Technology committee meetings, including providing guidance, recommendations and expertise into the discussions and decisions.
4. Develop ADOT's Digital Delivery Guidance Document, including a summary of digital delivery efforts and best practices, assessment of ADOT and its partners digital maturity, discovered challenges and limitations and recommendations with an action plan to address them.
5. Develop ADOT's Digital Delivery Implementation Plan, including:
    a. An executive summary of ADOT's vision, objectives, and description of the Digital Delivery Roadmap.
    b. Introduction section summarizing the desired outcomes of the ADOT Digital Delivery Program, focus areas, key success factors, risk management strategies and suggested schedule of activities and strategies for implementation.
    c. Activities and details to conduct as part of the planning phase.
    d. Activities, strategies, and details to conduct as part of the implementation phase for project delivery.
    e. Activities and details to conduct as part of the implementation phase for asset management.

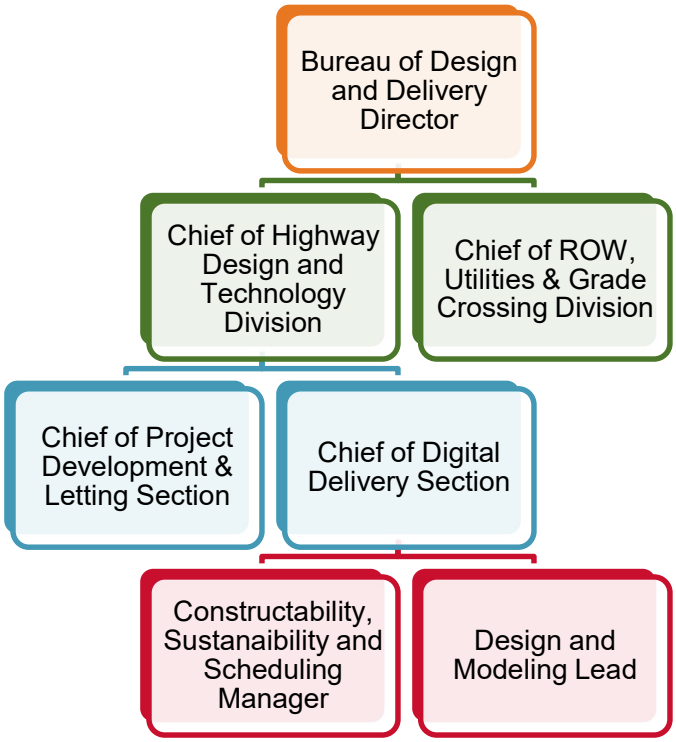
6. Develop an annotated outline with recommendations and strategies for producing ADOT's Digital Delivery Training and Tool Development Plan.
7. Develop a Communication and Education Plan for Digital Delivery. This plan will provide recommendations and strategies for activities and strategies for communicating with internal and external partners and customers.

Recommendations for Long-Term Structural Organization

While ADOT has an interim structural organization to oversee the success of the Digital Delivery Multi-Year Roadmap activities, it is important to recognize that the program will not end on December 31, 2025, when the initial program activities reach their objectives. It may be advantageous for the ADOT Digital Delivery Program to establish a long-term organizational structure to govern the growth and the priorities of the program moving forward. Similar to the establishment of any other Statewide Department Program, the Digital Delivery Program will require dedicated resources to oversee long-term digital delivery policy, technology deployment and training, and overall technical support of standards, procedures and updates to guidance documents, and communication with internal and external stakeholders as the program matures. With the ambitious timeline to establish the ADOT Digital Delivery Program by end of calendar year 2025, it is recommended for ADOT to identify dedicated resources to start transitioning to a long-term organizational structure as soon as possible.

Other states are recognizing that the continued success of statewide digital delivery program and the return on the initial investment to establish such a program heavily depends on a strong and dedicated digital delivery team. Figure 3 is an example of a Digital Delivery Structural Organization recently adopted by the Pennsylvania Department of Transportation (PennDOT).

Figure 3. PennDOT Digital Delivery Program Structural Organization



PennDOT added a Digital Delivery Section to the Highway Design and Technology under the Bureau of Design and Delivery. The Chief of Digital Delivery is responsible the Digital Delivery Directive 2025 (3D2025), a five-year program to implement digital delivery as a standard practice by the end of 2025. While the section is not large, it has three full-time equivalent (FTE) employees assisting the Chief of Digital Delivery with specific roles. As the program grows, PennDOT may evaluate the need for additional FTEs. The Design and Modeling Lead is responsible for providing technical support to users within PennDOT and for managing the roadway modeling software and all related technical support. The Constructability, Sustainability and Scheduling Manager's main responsibility is to assist in developing the use cases and supporting the technology for digital construction. A unique partnership exists between other Division and Section Chiefs under the Highway Design and Technology Division in sharing the responsibilities for advising on digital delivery practices. For example, the Right-of-Way and Grade Crossing Division Chief leads all digital delivery items related to right-of-way, utilities, and railroads, while the Project Development and Lettings Section Chief is responsible for assisting with digital delivery use cases piloted on projects within their purview. The Digital Delivery Section also coordinates with internal partners, such as PennDOT's liaison for Information Technology support at the Pennsylvania Office of Administration (OA), Engineering Applications, and the pilot project sponsors within the Districts. (Pennsylvania Department of Transportation, 2023)

Digital Delivery State of the Practice

Background

The transportation construction industry has been using 3D modeling technology and Global Navigation Satellite Systems (GNSS) guided equipment for several decades. Yet State Departments of Transportation (DOTs) continue to struggle with full adoption of digital delivery.

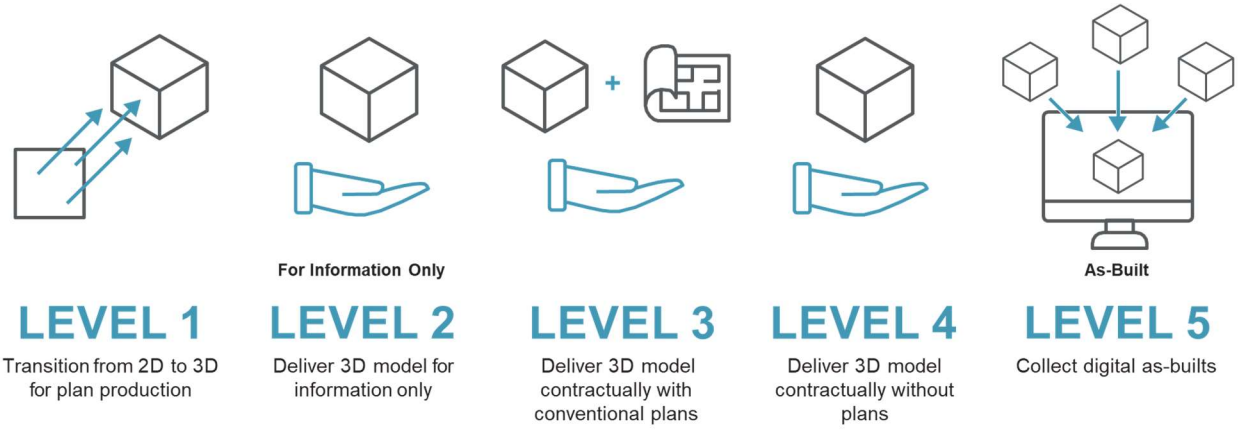
State DOTs have investigated the use of digital information for construction activities since the early 2000's. Contractors in the heavy civil and transportation construction industry began to invest in GNSS equipment and software to outfit their machinery and provide a more efficient method for grading and paving activities. During this time, contractors specializing in earthworks were leading the use of Automated Machine Guidance (AMG) and started lobbying State DOTs to move towards digital delivery. In a few years, the use of AMG expanded to paving operations, and later to material fabrication.

To accommodate contractors leveraging AMG technology, a few State DOTs started providing earthwork 3D models during the pre-bid period or after award. However, this practice did not become the standard in the United States (U.S.) until the mid to late 2010's. These 3D models were still not considered contractual, but rather supplemental to the traditional printed (or vellum) contract plans. While the practice of State DOTs sharing earthwork 3D models as supplemental information or for information only (FIO) was quickly becoming the state of the practice, the contractual deliverable for most DOTs remained as traditional 2D contract plans in the form of printed paper, vellum plans, or electronic plans in the form of portable document format (PDF). Starting in the mid 2010's, several DOTs started exploring and piloting elevating earthwork 3D models to become contractual deliverables, now commonly known as Model as the Legal Document (MALD).

"Model as the Legal Document is a form of digital delivery in which a model(s) comprises the primary construction contract document, preeminent in importance as defined by the Specifications or Special Provisions. This definition elevates the project design models, both 2D and 3D along with any related details and accompanying data further defining the project's design intent, to primary authority for construction." (Pennsylvania Department of Transportation, 2023)

The move towards MALD is partly due to the success of the Federal Highway Administration (FHWA) Every Day Counts program that started in 2013. Figure 4 provides a high-level illustration of the Joint Technical Committee on Electronic Engineering Standards (JTCEES) digital delivery maturity framework. (Joint Technical Committee on Electronic Engineering Standards, 2023). The JTCEES digital delivery maturity framework does not define which of the levels is considered to have reached MALD implementation, leaving each State DOT to define what it means for their organizations.

Figure 4. JTCEES Digital Delivery Maturity Framework



However, as of today, many State DOTs continue to experience significant challenges to make MALD a standard practice. Many of these challenges have been documented over the last several years through many research projects. Some of the most common challenges identified by various studies include:

- Culture change and attachment to the known environment.
- Obtaining leadership support and appropriate funding for implementation.
- Cost of implementation and lack of evidence of quantifiable benefits.
- Availability of adequate training resources.
- Lack of national standards defining modeling standards, such as classification systems, level of development (LOD), and level of information need (LOIN).
- Legal uncertainty, specifically the absence of a legality framework for contractual agreements, ownership and intellectual property, and product liability risks.

A significant number of studies and technology transfer activities have been conducted to-date to understand digital delivery state-of-the-practice and how to advance it. Appendix A illustrates a timeline of these efforts.

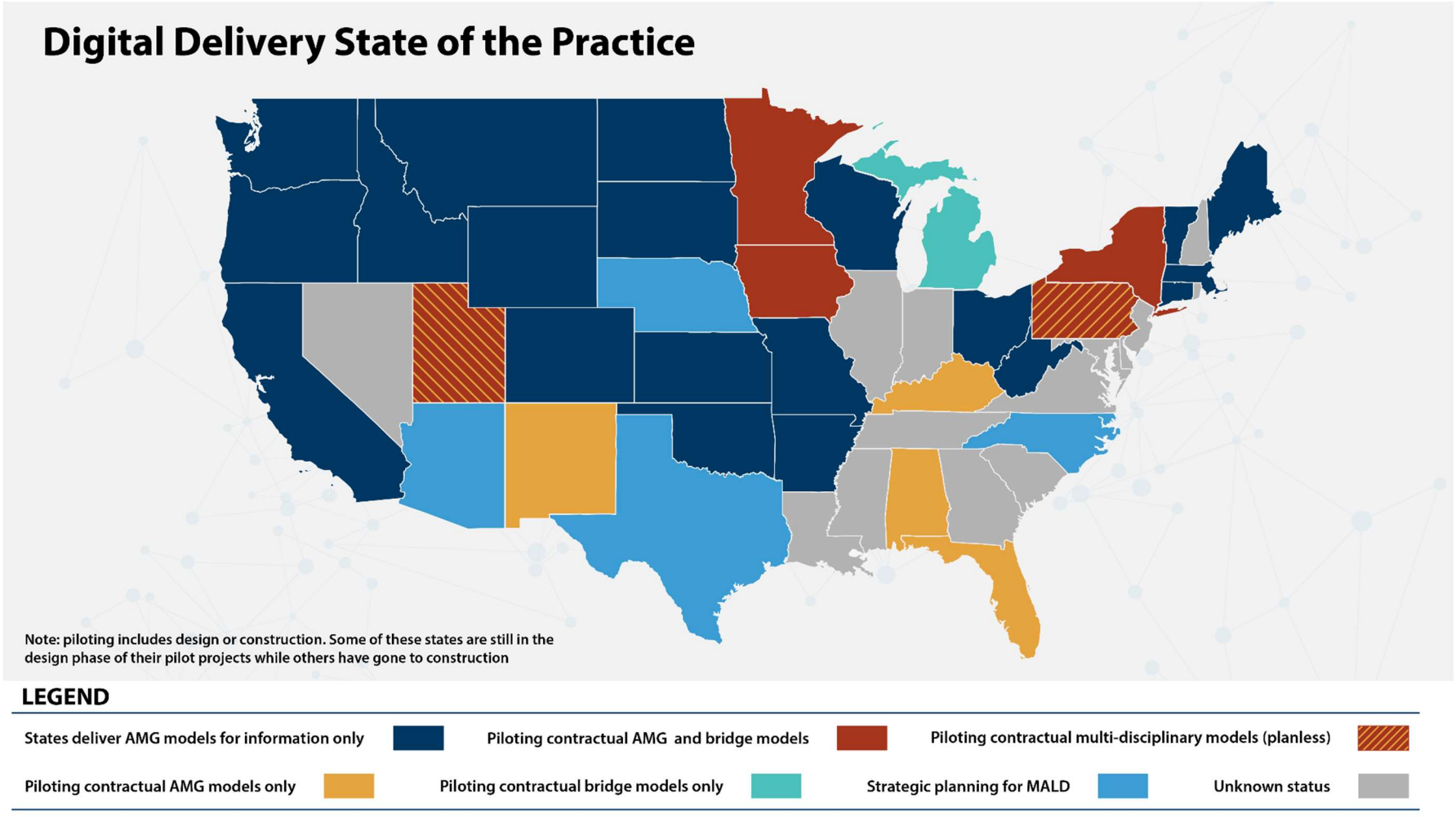
State Digital Delivery Efforts

Overview

Many State DOTs and Highway Authorities continue to advance their own digital delivery efforts, but the level of maturity and approach for implementing digital delivery varies greatly. Nevertheless, State DOTs have come to an agreement on defining the various levels of digital maturity. This section summarizes the digital delivery maturity of states, and best practices collected by the HDR team over the last several years. Figure 5 illustrates the national digital delivery state of the practice.[1]

[1] Information illustrated in figures 5 is based on current knowledge of the HDR team.

Figure 5. Map Showing Digital Delivery State of the Practice



Summary of Best Practices

Based on a review of other DOT efforts and lessons learned, Table 1 summarizes digital delivery planning methodology and state of the practices for the 10 State DOTs HDR is the most familiar.

Table 1. Digital Delivery State of the Practice from State DOTs.

Name of Agency	Digital Delivery Planning Methodology	State of the Practice and Lessons Learned
Florida Department of Transportation (FDOT)	• Ad-hoc approach[2] • Limited consultant support • No strategic plan being considered	• Started piloting MALD in 2017, and has conducted approximately 12 pilot projects. • Beginning July 2022, all earthwork was delivered contractually via the design model. • Developed modeling standards and best practices. • Updated current CADD manual with well-defined digital deliverables and requirements for project teams that clearly define the standards. A link to the FDOT updated manual: FDOT CADD Manual. • FDOT recommends partnering with technology providers for piloting different hardware and software, especially for construction field activities. FDOT partnered with Trimble to test SiteVision and Quadri.
Illinois State Tollway Highway Authority (ISTHA)	• Ad-hoc approach[2] • Relies heavily on consultant support for development and management of digital delivery program through a GEC contract	• It is important not to rush implementation and work with stakeholders on incremental approach to digital delivery. The ISTHA issued its first “for information only” model in 2015. • Formed a digital delivery advisory group composed of ISTHA staff, Illinois DOT, and industry representatives, and working together to get input for developing a Building Information modeling (BIM) Manual. Highly recommend piloting hybrid projects in which only a portion of the project uses MALD approach. (model and plan sets).

[2] Ad-hoc approach is defined as a methodology to implement a technology using a project-by-project exploration style instead of defining a strategic direction. Often, it takes longer to implement a technology using an ad-hoc approach, but it is a method that works well for many organizations.

Name of Agency	Digital Delivery Planning Methodology	State of the Practice and Lessons Learned
Iowa Department of Transportation (Iowa DOT)	• Initial ad-hoc approach[2] • Issued strategic plan in 2022 • Some consultant support for strategic planning and pilot projects	• Conducted both roadway and bridge MALD pilot projects. • Started with hybrid projects for bridge modeling. The first bridge modeling project delivered models for all bridges, but only one section was MALD. Plans were provided as contractual documents for all the other bridge sections in the project. • Created a strategic plan to guide future direction, and a detailed implementation plan to prioritize your activities. • Looked at digital delivery holistically, not just model delivery to construction. • Established Digital Delivery Leads. • Created a readiness matrix and prioritized growth in digital maturity by staggering pilot project goals. • Engaged the industry early and often. • Created a risk registry with mitigation strategies. • Created modeling standards and provided clear requirements to design staff for developing digital deliverables.
Kentucky Transportation Cabinet (KYTC)	• Ad-hoc approach[2] • Pilot projects identified on a volunteer basis • Combination of internal and consultant led pilot projects	• KYTC has 16 pilot projects of varying status and schedule (three have gone to construction), which has made it easier to manage change. • Worked with technology providers to pilot different tools for construction inspection KYTC is piloting Bentley SYNCHRO for construction management and inspection. • Not having dedicated staff to oversee the digital delivery program has slowed down or halted progress. • KYTC Digital Delivery Program Website
Michigan Department of Transportation (MDOT)	• Commissioned planning documents for ROI • Consultant led pilot projects	• Modeled a bridge from a previous project that had already been constructed as proof of concept to assess the level of effort and functionality of the software as a risk mitigation strategy. • To better manage change, consider piloting only one portion of a project, for example if a project has two major bridges, select one to deliver a contractual model and the other with traditional 2D plan sheets. • Communication internally and with the contracting industry was critical to building support and promoting transparency. • Outreaching to field staff who are often overlooked and will be leveraging the models to inspect daily. • Strategic selection of pilots based on staff likely to adjust to innovation easier.

Name of Agency	Digital Delivery Planning Methodology	State of the Practice and Lessons Learned
Minnesota Department of Transportation (MnDOT)	• Ad-hoc approach[2] • Consultant led pilot projects	• Establish a statewide BIM coordinator position with authority to make decisions and guide the program. • Leverage Construction Management at Risk (CMAR) delivery method to pilot the first project. • Be flexible in working with consultants to test different technology. Investing in new software pays off. The consultant was paid to do a 3D, 4D and 5D model using Bentley software (OpenRoads Designer and Synchro) and was able to find significant savings on the projects resulting in a positive ROI. • Focus on establishing a digital as-built that feeds geospatial and attribute-rich information to the Asset Management group. CAD development is ongoing to accommodate asset collection.
New Mexico Department of Transportation (NMDOT)	• Ad-hoc approach[2] • Pilot project led in-house	• NMDOT completed its first pilot project using Autodesk Civil 3D. • Work with survey and contractor to establish appropriate survey setup using nearby CORS stations and perform a geodetic survey. • Plan ahead on using specialized equipment during construction as various contractors use a variety of technologies, including Leica, Trimble, Topcon, etc.) • Define the level of detail for 3D models. • Work with construction to use special provisions that will not conflict with standard construction specifications. The contract specifications required the contractor to use cross-sections to measure actual earthwork quantities even though they had a model. A special provision overruling that specification would have been helpful. • Define clear requirements for digital as-builts. NMDOT required a digital as-built without additional information delivery requirements and received an electronically marked up PDFs.
New York State Department of Transportation (NYSDOT)	• Ad-hoc approach[2] • Bridge digital delivery lead • Road digital delivery lead • Combination of in-house and consultant led pilot projects	• Conducted several pilot projects with BIM requirements, some MALD and some traditional deliverables. • Has used Design-Build and Design-Bid-Build delivery methods for pilot projects. • Pilot projects in rural Upstate New York and urban New York City Metropolitan area. • Define what MALD means to the organization. When other State DOTs talked about MALD, they were referring to earthwork models. NYSDOT thought everyone was creating 3D solids of all disciplines and realized peer agencies were doing something much simpler than what they were trying to implement. • Work with the contractor to understand what they need, in specific fabricators, as they prefer spreadsheets over 3D models. Bridge contractors prefer different file types than earthwork contractors. It is important to understand bridge contractors do not use AMG. • Do not overcomplicate solutions. NYSDOT's signing and sealing requirements dictate that an engineer must sign contract plans. To get the pilot project underway, NYSDOT officially redefined contract plans to include digital files in their specifications.

Name of Agency	Digital Delivery Planning Methodology	State of the Practice and Lessons Learned
Pennsylvania Department of Transportation (PennDOT)	• Strategic planning approach from the start of program • Only state with dedicated resource to oversee the digital delivery program	• Initiated pilot projects starting in 2022, and most pilot projects are still in the design phase. The first MALD project for roadway to go to construction in 2023. • Established a Digital Delivery Section, and assigned a dedicated digital delivery lead with the authority and the resources to oversee the statewide implementation of digital delivery. • Created a strategic plan before jumping into full implementation, and clearly defined goals and objectives. • Leveraged consulting partners to add resources to perform specific activities in the strategic and implementation plan. • Pay close attention to change management. Managing the pace of change is important to get buy-in from all people affected by digital delivery. Recommend a phased approach to piloting and providing technical support and just in-time training to pilot project teams. Assign a technical support team to meet weekly with pilot project teams to answer questions and help them with technical issues related to modeling or other aspects of the project.

Utah Department of Transportation (UDOT)	• Ad-hoc approach at first, but has issued a strategic plan
	• Used AID grants for funding digital delivery initiative
	• Significant support from consultant services to develop strategic plan, standards and guidance documents and training
		• Has conducted over 15 projects with MALD requirements and have applied lessons learned from each iteration of pilot projects. Pilot projects have been a combination of roadway and bridge projects. UDOT offers the following lessons learned:
		  ○ Used CMAR delivery method for first pilots to manage risk.
		  ○ Created a digital delivery advisory board composed of DOT staff, consultants, and contractors to work collaborative in finding solutions for implementing digital delivery.
		  ○ Leveraged consultants to assist with pilot projects and activities to advance digital delivery.
		  ○ Provided a repeatable and reproducible process through the use of clear modeling standards and technical guidance. UDOT was the first state to issue modeling standards with extensive library of resources for users through their digital delivery website: https://digitaldelivery.udot.utah.gov/

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National Efforts for Advancing Digital Delivery

This section provides a summary of national efforts by the Federal Highway Administration (FHWA) and the American Association of State and Highway Transportation Officials (AASHTO) advancing the maturity of digital delivery, as well as a list of resources currently available as useful references.

Efforts by FHWA

Over the years, the FHWA has spurred State DOTs to adopt newer, more efficient, and innovating practices through federal initiatives and programs, such as Every Day Counts (EDC), the research conducted through the Turner-Fairbanks Highway Research Center (TFHRC), and discretionary funds for assisting with technology deployment at the state and local levels. In fact, according to a 2019 presentation, FHWA has invested over $24 million. (Federal Highway Administration, 2019)

Every Day Counts

This program is designed to help State DOTs, local governments and tribes accelerate the deployment of proven but underutilized innovations, and thus considered a technology transfer type of program. (Federal Highway Adminstration, 2011)

The EDC program does not provide direct financial assistance for specific projects, but rather offers funding opportunities to help organizations learn from each other, case studies and technical briefs. The innovations under the program aim at reducing the time it takes to deliver highway projects, enhance safety, and protect the environment. The program has been around since 2011, and the seventh round (EDC-7) is currently underway.

The EDC program provided a mechanism to encourage the use of 3D models for construction and the advancement of digital delivery during EDC-2 through EDC-6. It was during EDC-2 that 3D Engineered Models for Construction were first introduced as one of the technologies being promoted under the program and was carried onto EDC-3 with the addition of e-Construction as a second technology related to the advancement of digital delivery. The innovation of 3D Engineered Models for Construction was graduated from the Every Day Program and is no longer considered an underutilized technology. Innovation of e-Construction continued to EDC-4 before being graduated as an underutilized technology. The Collaborative Hydraulics – Advancing the Next Generation of Engineering (CHANGE) was also introduced in EDC-4. During EDC-5, two other digital delivery related innovations were promoted including the continuation of CHANGE, and the addition of Unmanned Aerial Systems (UAS). The last two digital delivery innovations during EDC-6 included e-ticketing and Digital As-Builts as a combined effort. The current EDC-7 program does not have any innovations related to digital delivery.

Turner-Fairbanks Highway Research Center

A federally owned and operated national research facility managed by FHWA conducts applied and exploratory advanced research in many categories including digital delivery and BIM. Table 2 provides a list of publications by FHWA related to the advancement of digital delivery including links to the original documents. (Federal Highway Administration, 2022)

Table 2. FHWA Research Projects Related to Digital Delivery

Name of Study	Description	URL	Applicability to ADOT
Advancing BIM for Infrastructure Strategic Roadmap (2021).	The roadmap helps State departments of transportation (DOTs) strategically develop a uniform, nationwide policy framework related to BIM for infrastructure, open data—exchange standards and methods for adopting those standards, BIM tools, and a robust personnel training and upskilling program. These actions can then become the basis for planning and implementing BIM for infrastructure to better deliver projects and transportation services at the State DOT level.	https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/21064/index.cfm	A resource for ADOT to consider when aligning its DDP with national vision for digital delivery adoption including: • Establishing policies and processes • Identifying and execute capacity building activities (increasing competencies) • Implementing change management strategies • Deploying standards-based data management tools and techniques
BIM for Infrastructure Global Benchmarking Study (2019)	This study was conducted on behalf of FHWA's Global Benchmark Plan to document evolving trends in BIM implementations in BIM-mature nations and their public highway infrastructure agencies, with a focus on understanding how other countries are using BIM for infrastructure to better deliver transportation projects, manage assets, and provide related services with a view to benchmark and advance U.S. practice.	https://international.fhwa.dot.gov/pubs/pl21024/fhwa_pl21024.pdf	A resource for ADOT to consider best practices from Europe, including: • Actions for digital delivery awareness, leadership, preparation, and collaboration. • Actions for implementing building blocks of digital delivery organizational structures, data modeling, data exchanges and management of platforms.
Lifecycle BIM for Infrastructure: A Business Case for Project Delivery and Asset Management (2022)	This study explores the costs and benefits of BIM adoption within the context of transportation agencies by analyzing a baseline to a desired level of maturity for various BIM use cases across the asset data lifecycle. The products of this research include a final report describing the details of the study, educational materials presented via a multi-media toolkit, and a ROI calculator with a user guide.	https://nap.nationalacademies.org/catalog/26731/lifecycle-building-information-modeling-for-infrastructure-a-business-case-for-project-delivery-and-asset-management#resources	A resource for ADOT to consider if interested in quantifying return on investment for implementing digital delivery.

Name of Study	Description	URL	Applicability to ADOT
Automation in Highway Construction: Design Guide and Guide Specification Manual (2015)	This report provides the accuracies needed for both survey control and topographic survey. It describes how construction specifications can incorporate practices to manage the use of automation technology in a manner to adapt to project characteristics and evolving technologies. It also describes how consistency in 3D data and survey methods provides for automated inspection tasks, especially acceptance and measurement processes, can enhance transparency, make inspectors available to observe construction, and enhance project safety. State transportation departments interested in developing 3D digital design for use in automation in highway construction would benefit from reading this volume.	https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/16031/index.cfm	While this study is quite old, is perhaps one of the most underutilized resources for developing standards, specifications, and best practices for managing and deploying automation technology for construction and should be explored. The manual: • Identifies capital and human resources investments. • Offers implementation strategies and formulating implementation plans. • Describes enabling technologies and policies for MALD specific to AMG use case. • Introduces automation technology applications and guidelines. • Provides best practices for survey in a digital delivery world and much more.
Utilizing 3D Digital Data in Highway Construction (2015)	A comprehensive case study of how 3D digital design data was used successfully by both the owner agency and the construction contractor during six specific highway construction projects.	https://www.fhwa.dot.gov/construction/3d/hif17027.pdf	Another older resource that provides insights on successful case studies showcasing successful use of 3D digital design data. ADOT should consider becoming familiar with these case studies as they provide many of the lessons learned still not being leveraged today.

Name of Study	Description	URL	Applicability to ADOT
Determination of Improved Pavement Smoothness when Using 3D Modeling and Automatic Machine Guidance (AMG) (2017)	This report documents case studies and data analysis undertaken to assess the impact of using 3D models and AMG on achievement of pavement smoothness during construction. The studies evaluated how the use of design models combined with construction equipment automation affected initial pavement smoothness and ride quality. Smoothness acceptance data from companion projects with and without the use of AMG were compared in five documented case studies. The results provide an enhanced understanding of how the technology can be used as a contractor tool for quality control and how State agencies can work with contractors to mitigate risks and optimize pavement smoothness.	https://highways.dot.gov/research/research-programs/infrastructure/building-information-modeling-bim-infrastructure-publications	Maybe not as significant of a resource for digital delivery deployment, but an interesting case of understanding how the use of 3D digital design data and AMG technology may improve pavement smoothness outcomes for construction.
Construction Inspection for Digital Project Delivery (2018)	This study explored the use of digital data and paperless workflows for digital construction methods. The study documented how inspectors use digital data and field survey technology in daily construction inspection activities and to highlight best practices for managing, disseminating, and integrating such digital data in those inspection activities. Final Report still under publication by FHWA. A webinar recording is available.	Not yet available	This study was intended to provide State DOTs guidance on how to develop core competencies skills for construction inspection staff to be able to work with 3D digital design data in the field. Unfortunately, the study has not yet been published, but HDR has a draft copy of the document as a co-author of the study. While ADOT may not directly need to explore this study, the HDR team will leverage the findings of this study in the development of ADOT's implementation plan.

Name of Study	Description	URL	Applicability to ADOT
Effective Use of Geospatial Tools in Highway Construction (2018)	This research investigates effective uses of geospatial technology for a wide variety of highway construction and maintenance applications; identifies a number of tools and their related accuracies; offers recommendations for tool selection, workflows, and strategies for conducting BCA; and analyzes future directions of these technologies in highway project and service delivery applications. The research explores several case studies using these technologies to document their benefits and limitations. In particular, the research determines the ROI associated with using these technologies in several of those case studies.	https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/19089/19089.pdf	Another older study that provides a lot of good information for ADOT to consider for comparing suggested workflows and opportunities for streamlining and improving data collection using geospatial technologies, such as drones and LiDAR.
Use of Unmanned Aerial Systems for Bridge Inspections (2020)	This report documents research undertaken to explore the use of unmanned aerial systems (UAS) to support bridge inspection. It addresses UAS platforms and sensors used to assist or augment inspections, the data-collection needs to which UAS can contribute, and means and methods for managing the tremendous amount of data that can be collected by UAS-mounted sensors. The report also presents case studies that illustrate real-world applications of UAS for bridge inspections and the results of both field and laboratory testing geared toward establishing standards and requirements for UAS sensors that will ensure quality inspection products.	Index - Collection of Data With Unmanned Aerial Systems (UAS) for Bridge Inspection and Construction Inspection, September 2021 - FHWA-HRT-21-086 (dot.gov)	A study that provides good information related to the use of drones for bridge inspections that ADOT may want to consider in the future.

Discretionary Funds

The FHWA provides financial assistance through a variety of discretionary funds under the following programs:

Accelerated Innovation Demonstration (AID) - ADOT has a long history of successfully obtaining AID grants for piloting emerging technologies. We recommend applying for this grant to help execute the Implementation Plan delivered as part of this project. (Federal Highway Administration, 2022)

Advanced Digital Construction Management Systems (ADCMS) - This program was introduced as a discretionary grant under the Infrastructure Investment and Jobs Act (IIJA's) highway and transit titles. (Thibault, 2022) Our FHWA sources tell us that details for the program will be available in Summer 2023. The funds may be used for projects that fit the following categories:

- Maximize Interoperability with Other Systems, Products, Tools, or Applications - Funds could be used to develop software routines to export information from Bentley products using the IFC schema and file format and import these IFC files in more contractor traditional products, such as Trimble Business Center.
- Boost Productivity Using Technology Solutions - Funds could be used to automate title block integration and quantity takeoffs using item types in ORD. Also, could be used to develop information delivery specifications such as a tool being tried in Europe, a machine readable type application that serves as a review checklist of model-based deliverables. This type of software application would require specialized software developers familiar with IFC.

Efforts by AASHTO and the National State DOT Community

In the U.S. there has been significant movement to advance digital delivery and open data standards. A few notable key milestones include:

The creation of TPF-5(372) BIM for Bridges and Structures Pooled Fund in 2017: This pooled fund was sponsored by the AASHTO Committee on Bridges and Structures, and has a total of 25 funding sponsors, including FHWA and 24 separate State DOTs. Iowa DOT is the lead agency, but ADOT is not participating. HDR is leading the consultant team delivering the work. The cooperative effort has an overarching goal of creating a national open data standard for bridge design, construction, and fabrication. At the end of this process, design and construction software packages will have a streamlined and reliable open data exchange, much like a 2D document can be shared using a non-proprietary PDF, for designers to pass detailed 3D model information with attributes to contractors or fabricators. This will allow each entity to work in their chosen BIM program but still efficiently share robust digital data. It will set the stage for more automation during construction and fabrication as well as open the door to better asset management. The information delivery manual was developed by bridge engineers and BIM experts across the United States and shared with state DOTs for feedback to ensure it met the needs of each state. A second BIM for Bridges and Structures is currently under solicitation to continue advancing the work accomplished in the first effort. (Rivera, 2023). ADOT should consider joining the Phase 2 pooled fund.

AASHTO's Administrative Resolution in 2019 (AR-1-19): This resolution officially establishes the adoption the Industry Foundation Classes (IFC) as the national standard for model-based data; and the Joint Subcommittee on Data Standardization (JSTAN), multi-disciplinary governing body to oversee the development, management and adoption of IFC and other open data standards for digital delivery. Lastly, AASHTO joined buildingSMART international as a principal member. buildingSMART

is a non-profit organization that shepherds a variety of openBIM Standards. (American Association of State Highway and Transportation Officials, 2019). ADOT should consider aligning modeling standards with the IFC 4.3 schema, which organizes model objects in a way that computer software can export and import consistently.

The creation of TPF-5(480) BIM for Infrastructure Pooled Fund in 2022: This pooled fund was sponsored by the AASHTO Joint Technical Committee on Electronic Engineering Standards (JTCEES) and has a total of 20 separate State DOTs as funding sponsors including ADOT. The ADOT representative is Sage Donaldson. Iowa DOT is the lead agency, and a joint venture team composed of WSP, and Michael Baker will perform the work. The project just kicked off and a contract with the consulting team has recently been signed and executed. The objective of this pooled fund is to provide a mechanism for State DOTs and their stakeholders to work collaborative to advance BIM for Infrastructure. The scope of work is heavily influenced by the activities established by the FHWA National Strategic Work Plan, with emphasis on coordinating and raising awareness of BIM technologies and activities. There is no overlap with the scope of work for the BIM for Bridges and Structures. The BIM for Infrastructure pooled fund has a totally of 34 deliverables being described as white papers and guidance documents. On the other hand, the BIM for Bridges and Structures pooled fund is developing a national data exchange standard that will enable State DOTs to solve the problems with interoperability of files between proprietary systems. (Transportation Pooled Fund, 2022). ADOT should consider sending a second person that represents project development to pooled fund meetings.

JTCEES: This committee, under the parent AASHTO Committee on Design, has been actively working over the last several years to create a community of sharing and learning. ADOT has been involved in this effort. The most notable work they have conducted to-date includes a series of guidance documents that are now published on the committee website Electronic Engineering Standards – Transportation.org and the Digital Delivery Maturity Framework illustrated in Figure 6. (Joint Technical Committee on Electronic Engineering Standards, 2023). ADOT may benefit from reviewing these guidance documents to extract what may be applicable to its digital delivery program, such as using the model element breakdown structure (MEBS) as a starting point for defining ADOT modeling standards.

Figure 6. JTCEES Recommendations for Steps to Follow to Achieve Digital Delivery Maturity

	PHASE 1	PHASE 2	PHASE 3	PHASE 4	PHASE 5
GOALS	Transition from 2D to 3D for plan production	Deliver 3D model for information only	Deliver 3D model contractually with conventional plans	Deliver 3D model contractually without plans	Collect digital as-builts
ASSESS	• Department and stakeholders' readiness • Resources and technology • Projects that fit use case criteria and timeline	• Software suitability (design, bridge, review, construction) • Files to be delivered • File exchange mechanism	• Modeling standards • 3D review process • Stakeholder readiness for contractual models	• Tools available to replace all plan sets	• Tools/systems to harvest information • Priority asset data collection methods
DEVELOP	• Identify digital delivery lead and champions • Draft multi-year plan and schedule • Plan stakeholder engagement • Procure software and create user training	• Develop standards and information requirements • Update/streamline processes • Create procedures for 3D reviews • Create training • Determine which projects will be model-based	• Update department manuals with new digital methodology • Update contractual language – consultant agreements construction specs and general provisions	• Procure software for viewing 3D models during construction	• Develop information and modeling requirements for digital as-builts
IMPLEMENT	Collaborate with project teams, stakeholders (contractors/consultants/sister agencies) and partners (software vendors)				
	• Start exploring signing and sealing approach • Work with state board of registration • Implement 3D modeling software	• Select and conduct pilot projects (e.g., roadway, bridge, drainage) • Deliver just-in-time training and assist pilot project teams • Collect feedback and refine process • Report outcomes of pilot projects		• Report progress and outcomes • Institutionalize practices	• Select and conduct pilot projects for digital as-builts • Institutionalize practices

Source: HDR (Developed for JTCEES)

Efforts by NCHRP

There have been many efforts by the National Cooperative Highway Research Program (NCHRP) over the years documenting the state of the practice for digital delivery through synthesis and project reports. (BIM for Bridges and Structures Pooled Fund, 2023). Table 3 provides a summary of published NCHRP synthesis and project reports, which content is applicable to ADOT's Digital Delivery Program. Table 4provides a list of NCHRP synthesis and projects to track as these will produce much needed guidance and information to assist ADOT with its implementation of digital delivery.

Table 3. NCHRP Synthesis and Reports Related to Digital Delivery and Technology Implementation (Published)

Name of Study	Overview	Applicability to ADOT's Digital Delivery Efforts
NCHRP Synthesis 582 Highway Infrastructure Inspection Practices for the Digital Age (2022)	Documents the state of the practice by State DOTs for using various technologies for inspecting highway assets either during construction or maintenance. The study revealed that most state DOTs are using geospatial technologies, such as GPS and GIS to perform activities related to construction inspection (and asset inventory collection during maintenance inspections)	Best practices identified during this study: • The need for creating guidance on how inspection technologies can be effectively used to augment inspections. • Buy-in from users and leadership, as well as proper effective training influence the success of implementing inspection technologies.

Name of Study	Overview	Applicability to ADOT's Digital Delivery Efforts
NCHRP Synthesis 593 3D Digital Models as Highway Construction Contract Documents (2022)	Documents state of the practice for delivering 3D digital models to highway contractors and the use of these models as part of the legal construction document	This study highlights the challenges and reasons to why state DOTs do not provide 3D digital models as legal construction documents. These challenges should be considered during the development of the implementation guide to assess applicability to ADOT and create risk mitigation strategies: • Need for more education and training of field staff. • There is variability in the quality of the models, with roadway models having the highest quality. • 60% of States require models to be signed and sealed. • Lack of quality management procedures and checklists. • IT infrastructure to support 3D digital models. • Impact on subcontractors and specialty contractors.
NCHRP Synthesis Topic 52-02 Bridge Element Data and Use (2022)	Documents state of the practice for collecting and ensuring accuracy of element-level data for bridges and what data is being used from inspection reports	This study provides a list of needs or use cases for data-driven bridge asset management. ADOT should review these use cases for applicability and work with bridge asset managers to determine what is the best time of information to collect during construction to support these use cases: • Improving deterioration models, cost models, life-cycle cost models, performance measures, and treatment efficiency models for bridge elements. • Using bridge element data used in asset decision-making for selection of projects and scoping work type for each structure.

Name of Study	Overview	Applicability to ADOT's Digital Delivery Efforts
NCHRP Synthesis 594 Technological Capabilities of Departments of Transportation for Digital Project Management and Delivery (2022)	Documents state of the practice for using advanced digital construction systems to deliver highway projects	This study highlights the challenges when implementing technology to support digital project management and delivery. These challenges should be considered during the development of the implementation guide to assess applicability to ADOT and create risk mitigation strategies: • Some technologies have numerous vendors to manage. • Lack of training and IT background of staff. • Decision paralysis from too many alternatives. • Prioritization implementation efforts. • Organizational structure to facilitate technology implementation. • Funding limitations. • Inability to update models in the field. • Lack of transfer of data to asset management. • Connectivity with field technologies. • Legal hurdles and lack of specifications can be roadblocks. This study also highlights lessons learned shared by various State DOTs. These best practices should be considered when developing ADOT's implementation plan: • Learn from other DOTs and ask questions. • Failure happens but need to keep trying. • Seek to find solutions that work with existing systems and software. • Have utilized project management training for different staff positions to develop. implementation skill sets. • Changing direction takes time, technology change increase complexity and need to build confidence. • Setting long-term benchmarks on implementation.

Name of Study	Overview	Applicability to ADOT's Digital Delivery Efforts
NCHRP Synthesis 548 Development and Use of As-built Plans by State DOTs (2020)	Documents the state of the practice for procedures for collection and approval of as-built records during construction. The method for documenting as-built records varies, but most state DOTs as-built collection process is to redline markups on PDFs using Adobe or Bluebeam software, and only three DOTs are using 3D modeling techniques. However, the study did not identify the three states	ADOT was one of the six case studies in this study, which highlights the following current state of the practice: • Procedures for collecting as-built records using the web through the ROAD portal. • As-built data is not currently incorporated into asset management. • ADOT has well defined procedures for collecting the information that is required for as-built records and has a data warehouse where this information is stored. ADOT also has well defined information requirements for asset data to be managed in FIS. These current practices were also identified during the SME interviews and will be considered for developing the implementation plan.
NCHRP Synthesis 545 Electronic Ticketing of Materials for Construction Management (2020)	Documents and identified state DOTs with experience in using e-ticketing; and provides a summary of implementation, lessons learned, success factors and challenges encountered by these DOTs	This study highlights lessons learned shared by various State DOTs. If ADOT is considering implementing e-ticketing as part of the digital delivery program, these best practices should be considered: • E-ticketing is its infancy but is gaining traction and acceptance by industry and provide an efficient way for tracking materials. • There is a cost component to the DOT and technology investment cost to the suppliers. • Suppliers in rural areas or smaller markets might not be able to invest and maintain the technology.

Name of Study	Overview	Applicability to ADOT's Digital Delivery Efforts
NCHRP Synthesis 534 Emerging Technologies for Construction Delivery (2019)	Documents technologies being used by state DOTs, barriers of implementation, strengths and weaknesses of these emerging technologies, opportunities to improve construction delivery and lessons learned	This study highlights lessons learned shared by various State DOTs when implementing emerging technologies for construction delivery. ADOT should consider these lessons learned when developing the digital delivery implementation plan: • Encourage contractors to use technologies that are cost-effective and do not create a financial burden. • Look at adopting technology to help you solve a current problem or inefficiency rather than looking for a technology looking to solve a problem. • Internal champion is necessary to promote and educate DOT staff. • Collaboration with other DOTs is encouraged. • There is more than one tool in the toolbox, meaning that one technology does not replace another. Rather each technology is just another tool that is effective for a specific purpose. • Challenges exist with incompatibilities in hardware and software between DOT and contractor. • It is essential to develop skills and knowledge to use a technology to its full potential.

Name of Study	Overview	Applicability to ADOT's Digital Delivery Efforts
UDOT Report No. UT-20.14 Model Development Standards in the Construction Industry and Beyond (2019)	Summarizes the findings to determine if Utah DOT digital delivery approach aligns with national and international direction.	Five elements were identified to successfully implement digital delivery, which should be considered when developing the implementation plan: • Need for organizational information requirements, which are specific to each state DOT. • Object-oriented data requirements that adequately describe data quality (i.e., LOD and LOIN). • Process management and documentation guidelines. • Consideration for open data standards such as LandXML and IFC. • Container-based data management, which is a strategy for organizing information into specific files (or containers) and common data environments such as ProjectWise to manage all file containers.
NCHRP Research Report 956 Guidebook for Data and Information Systems for Transportation Asset Management (2021)	Guidebook provides a comprehensive approach to defining data needs and uses for asset management	This guidebook is a great reference for creating information requirements for supporting ADOT's Transportation Asset Management Plan (TAMP), and should be considered for when ADOT's Digital Delivery Program expands to the use of digital workflows for asset management.

Name of Study	Overview	Applicability to ADOT's Digital Delivery Efforts
NCHRP Synthesis 508. Data Management and Governance Practices (2017)	Documents current practices in data governance, quality assurance, integration and sharing, and warehousing at state DOTs	This report provides best practices shared by various state DOTs when setting up a statewide data management and governance plan, and should be considered in combination with the NCHRP Report 956 noted above for future development of digital workflows for asset management: • Current data governance approach seems to be "bottom-up". A top-down approach could help recognize and leverage the value of data as an asset. • Major factors in limiting progress include lack of staffing, other mission-related issues are more pressing, and lack of resources. • There is a link between having designated data stewards and the use of data warehousing systems. State DOTs with designated data stewards manage data in warehouses and those who don't have mostly disparate files and databases. • State DOTs use multiple types of location referencing methods which is roadblock for data integration. • Digital as-builts is an identified opportunity to reduce duplication of data, however integrating this data with legacy systems is a problem. • Strategies that improve data sharing and access include increased use of web-based data storage and access, and improved database management systems.

Table 4. Ongoing NCHRP Synthesis and Reports Related to Digital Delivery and Technology Implementation

Name of Study	Overview	Applicability to ADOT's Digital Delivery Efforts
NCHRP Synthesis Topic 53-04 Practices for the Collection, Use and Management of Utility As-Built Information	Will document current state of the practice related to utility as-built data collection, use, and management for both as-built utility data for subsurface and above ground utilities	• HDR is a technical advisor for this study and had access to an early draft copy of the report. This document points out that most state DOTs are not aware of the new American Society of Civil Engineers (ASCE) 75-22 Standard Guideline for Recording and Exchanging Utility Infrastructure Data, which has comprehensive list of data requirements for digital as-builts. • HDR recommends ADOT consider implementing the ASCE 75-22 guidelines as the standard to setup the ORD workspace with applicable attributes for utility as-built records, as well as the reference for ADOT's information delivery requirements for digital as-builts at the end of construction.
NCHRP 10-110 3D Modeling Guide for Construction Inspection	Will identify 3D model information required to support construction inspection, verification, and contract administration. Also, the research will produce a list of core competencies needed for construction inspectors to transition to a 3D model-based environment for construction activities	• The research report is scheduled to be completed by end of summer 2023, but it will likely not be published at that time. • HDR recommends requesting an unofficial copy from NCHRP to assist with development of training for construction field staff.

Name of Study	Overview	Applicability to ADOT's Digital Delivery Efforts
NCHRP 10-113 Quality Management for 3D Model-Based Project Development and Delivery	To provide a guidebook that will assist state DOTs with implementing standardized methods for performing quality management reviews of 3D model-based deliverables.	• HDR is the prime consultant on this study and has entered the second phase of the project and will be developing the methodology for performing quality management reviews. • The NCHRP research team (HDR) will be able to share early drafts of the methodology with ADOT. It is anticipated to have a draft version of the methodology at the end of summer 2023. • HDR recommends testing the early drafts of the methodology on pilot projects. • Once the official guidebook is published, ADOT should consider using it as standard reference instead of creating procedures and best practices from scratch.
NCHRP 10-111 Guide for 3D Model Viewers for Construction Inspection	Will produce a guide to assist state DOTs in the evaluation of technical requirements for selecting 3D model viewers specifically designed for construction inspection	• The timing of this project unfortunately does not align with ADOT's effort to procure a new construction management system. Nevertheless, ADOT should follow the progress of this study for developing long-term technical requirements that are software agnostic. • HDR is a technical advisor for this study and will have access to updates throughout the project. Our team will relay any pertinent information to the digital delivery directive. One of the 3D model viewers to be evaluated is the Bentley Synchro platform, which is the product that HDR has identified in the stack of ADOT technology portfolio that should be piloted for digital delivery.
NCHRP 08-174 Development of a Surveying and Mapping Guide for Transportation Projects (for BIM)	Will produce a national surveying and mapping guide that will specify practices that are consistent with the National Spatial Reference System (NSRS)	• This project has been approved for NCHRP funds. • Scope of work has not been determined and it may be a couple of years before there is a product shared with state DOTs, but ADOT should nominate a survey SME to participate as a project panel member to help oversee the project and provide input that may be beneficial for ADOT. • At a minimum, it is recommended for ADOT to consider becoming active in the TRB AKD70 – Geospatial and Data Acquisition Technologies Committee.

Name of Study	Overview	Applicability to ADOT's Digital Delivery Efforts
NCHRP 03-140 Guidelines for Applications of RFID and Wireless Technologies in Highway Construction and Asset Management	To provide a guidebook that state DOTs can use to assess their digital maturity of wireless technologies and strategies for implementing these technologies to achieve desired target digital maturity	• ADOT may want to consider reviewing this guidebook to assess which technologies are already in place and which should be identified for implementation as part of future construction and asset management activities to include in the long-term digital delivery implementation plan.
NCHRP Project 23-29 Enterprise Data Warehouse Implementation Guide	Will produce a guide for enterprise data warehouse development, implementation, and best practices to support DOT business needs	• The research team for this study has been selected, but the contract is pending. • This guide may assist ADOT for long-term activities for managing enterprise data. • HDR recommends ADOT to follow the progress of this study.

ADOT Digital Delivery Readiness Assessment and Gap Analysis

Introduction

This section summarizes the information needed to assess ADOT's readiness for implementing digital delivery at the enterprise level. In specific, this section provides an overview on the methodology used to:

- Collect information to use in the readiness assessment.
- Select a readiness assessment framework for digital delivery.
- Explain the implementation factors for successful implementation of digital delivery.
- Define the categories for each of the implementation factors.
- Score ADOT digital delivery readiness assessment.

The readiness assessment and gap analysis will provide a high-level overview of ADOT's digital delivery maturity level and recommendations to successfully implement the Digital Delivery Program.

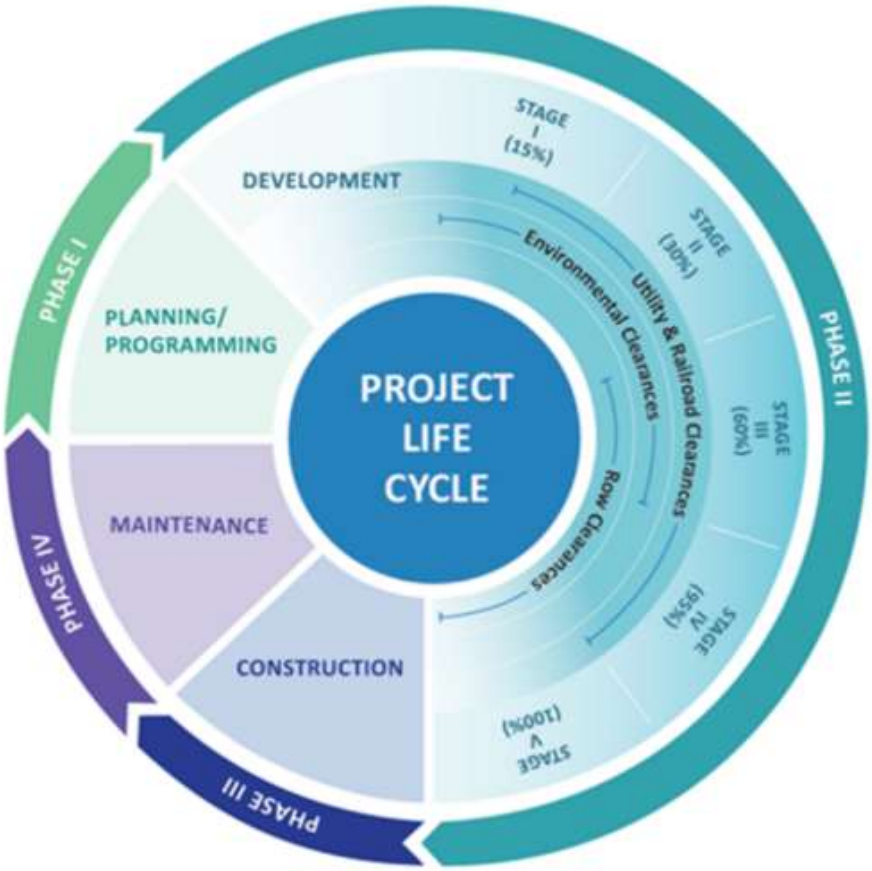
Data Collection Methodology

Approach

The data collection methodology was based on:

- A cursory review of manuals, checklists, and guidance documents available on the ADOT website.
- Project Delivery Academy videos.
- Documentation of information exchanges between various stakeholders during the planning, project development, and construction delivery of ADOT projects.
- Interviews with subject matter experts from 17 of ADOT's technical and project delivery teams from Infrastructure Delivery and Operations (IDO), Transportation Systems Management and Operations (TSMO), and Multimodal Planning Division (MPD) Divisions, as well as the Information Technology Group (ITG) .
- Documentation of engineering and analytical software, and asset management systems used during the lifecycle, as depicted in Figure 8, ADOT's Project Lifecycle. (Arizona Department of Transportation, 2023)
- Results from the data gathering were organized into four major categories: people, processes, data, and technology.
- Key takeaways were documented, and areas of improvement were created for the DDP initiative.

Figure 7. ADOT Project Lifecycle



Source: ADOT

HDR conducted interviews with 18 ADOT technical groups and teams:

Engineering Survey Section: provides survey and data acquisition for design activities and construction inspection, as needed.

Roadway Engineering & Roadside Design Sections: provides design services specific to road corridors (pavement and earthwork modeling, etc.) and aesthetic treatments, landscaping, etc.

Bridge Group: provides bridge and large structural analysis and design, as well as management of existing bridge inventory.

Drainage Section: provides drainage and hydraulic analysis of roadway and bridge systems.

Traffic Group: provides analysis and design of traffic control facilities (signals, lighting, capacity analysis, simulations, signing, and striping).

Environmental Planning Group: provides services related to NEPA clearances and documentation.

Right of Way Group: provides survey, documentation, and plans for the establishment of existing rights of way and for the acquisition of real property for ADOT construction projects.

Utility and Railroad Engineering Group: provides coordination and oversight of utility relocations and conflict determination for ADOT projects, as well as coordination with rail crossings and impacts to rail rights of way.

Pavement Design Section: provides pavement structure designs and analysis. Also manages pavement inventory.

Materials Group: oversees material specifications and certifications for ADOT construction projects.

Project Resource Office: manages the ROAD Portal, ADOT's as-built (record plans) repository.

Construction Group: provides support to ADOT Districts for the management and administration of construction contracts, as well as managing ADOT's Partnering Program for contractor engagement and collaboration.

Resident Engineers: District field staff that oversee construction projects and provide inspection services.

Contracts and Specifications Group: provides procurement services for ADOT projects, such as advertisement for bids, solicitation of bids, and management of electronic deliverables provided pre-bid.

Project Management Group: monitors scope, schedule, and budget of ADOT project development activities.

Traffic Systems Management & Operations (TSMO): provides operational services of various traffic systems, such as dynamic message boards, signals, etc., along with housing the Feature Inventory System (FIS) a collection of asset data received via record plans of post-construction GPS location.

Technology Support Team: mixed group that provides GIS and CAD support for ADOT.

Information Technology Group: manages software licensing such as Bentley.

Summary of Findings

Based on the assessment of ADOT processes through SME interviews and literature review, the following observations were made for the four planning elements identified in the maturity matrix, People, Processes, Data, and Technology:

People

Overall, ADOT personnel are looking forward to the implementation of digital delivery, although there are many questions and concerns that will need to be overcome. Key observations include:

- Interviewees have a varied definition of digital delivery and other key terminology yet understand the need for digital information and identifying how that fits the needs of the customer.
- There are many technical issues regarding the deployment of Bentley's OpenX technology. Initial training was provided to design staff, but there is no long-term plan for future training and the content was not tailored for ADOT. OpenX refers to the various model-based platforms that Bentley supplies for engineering services (OpenRoads, OpenBridge, OpenGround, etc.).
- There is concern regarding the cost of training and implementation and whether ADOT has resources to invest.
- There is concern regarding the challenge of allocating human resources and funding to properly set up systems and provide adequate technical support for digital delivery projects. Specifically, concerns with having the capacity to take on work given that each group does not have a CAD manager or technical support lead and growing the skill sets needed to support digital delivery long term.

- There is a need for additional knowledge or understanding on how the integrity of data models being shared with contractors will be managed. How will engineers sign and seal digital files?
- Non-CAD users are concerned about performing tasks currently dependent on plan sets. For example, internal and external stakeholders conducting reviews will need tools, processes, and appropriate training to review project data in a digital environment. While concessions can be made for some stakeholders using a hybrid approach, ADOT should make that the exception to the norm.
- There are several initiatives and innovations taking place at ADOT, such as replacing the antiquated Field Office Automation System (FAST) for construction management and inspection, harvesting data from various business groups for ease of access within a GIS platform, and collecting post-construction asset information for FIS, among others. However, there does not appear to be streamlined and effective communication or sharing of information regarding those efforts between various business groups, sections or divisions.
- Progress to leverage project development digital data is being inhibited by the need for technical resources to establish modeling standards, configure modeling software, developing technical guidance and best practices, and providing training and technical support to all users.
- There are many questions and uncertainty about how digital delivery will affect each business group and stakeholders. While the interviews educated participants on the initiative, there will be many others within ADOT, as well as industry partners, that will need to be engaged.
- Various interviewees posed questions about necessary software, hardware, training, and file/information management policies, as well as validating and managing the integrity of digital information.

Processes

Overall, people recognize that different business functions need specific processes to accomplish their daily tasks. Key observations include:

- Project Development staff are focusing on establishing design data workflows and developing processes for using model-based design.
- Construction staff need a variety of information to administer contracts and document inspection and verification observations. Most of their data is document-based or entered in electronic forms using legacy systems, such as FAST and PEN5. It is important to note that there is an ADOT initiative investigating a replacement for the aging construction management (FAST) and inspection (PEN5) systems.
- Maintenance staff are focusing on developing processes for collecting and maintaining asset inventory information (location of specific assets within the ADOT transportation network). TSMO has an asset information dictionary to aid in the collection of detailed information post-construction.
- Operations staff are focusing on developing processes to access information to understand the condition and operational state of the roadway assets.
- A connection between these three major efforts (ORD workspace development, FAST replacement, and asset collection and management) to the broader lifecycle digital thread is currently missing.
- The as-built condition is documented in an electronic format (redline PDF plans) and stored in a central location, along with the as-designed CAD files. However, this is a static data format that is not easily absorbed into other systems, such as those for asset management.
- Much of the information exchanges at ADOT consist of manual entry or additional data acquisition post-construction.
- Current processes for delivering plan-based products have not been adapted to enable a transition to digital delivery.

- Processes for real-time collaboration are currently in their infancy. The implementation of Workfront is assisting in increasing collaboration, but specific processes for multi-disciplinary collaboration and coordination in a model-based environment will be needed for digital delivery. Currently, Workfront cannot provide collaboration within the DOT's modeling platforms, Bentley OpenX.
- Except for the Engineering Survey group, ADOT workflows are mostly document-based. Although many of the engineering design groups are CAD savvy, data is still being shared and/or captured using analog methods such as electronic plans, forms, and documents (PDF).

Data

Overall, there is a large amount of data being produced that needs to be governed. ADOT does not have a strategic data business plan today to govern data throughout the organization. Key observations include:

- ADOT does not have data management goals. All business groups work independently of each other.
- ADOT recently adopted Adobe Workfront, which is being used as a collaboration tool to deliver milestone deliverables and make redline comments. However, it does not manage work-in-progress or data files such as CAD (DGN/DWG) or other exchange language for transportation delivery (IFC/XML)
- There is no managed common data environment. ADOT has improved their data management in the last several years by creating guidelines on project folder organization for project development teams, but it is not ideal.
- The Data Analytics business group tries to collect information that can be visualized in GIS. While this section does not own any data, they enable the visualization and access to data.
- Engineering Survey is leveraging multiple technologies that result in large data files and data processing challenges. There are no data management protocols currently in place for Survey and the transference and storage of this large-format data is cumbersome and inefficient.
- ADOT is working to reduce "electronic paper" (i.e., PDF files) during the letting and construction phases and moving to digital, model-based information (e.g., DGN, .IFC, .XML).
- ADOT has a public-facing open data portal that reports information about the roadway network.
- There are no consistent data standards for model-based design. For example, ADOT is using out of the box Bentley product configuration with minimal documented data standards for level and feature naming conventions (except survey feature codes), as well as standards for template and point naming conventions.
- ADOT creates a lot of data that is stored in various systems. However, these systems are not effectively connected to each other and suffer from limitations of file management and storage.
- The TSMO group does have data dictionaries for the assets they wish to collect post-construction. However, this information isn't shared nor connected with project development activities that could set the stage for more streamlined asset information collection and ensure consistency across all disciplines.

Technology

- ADOT is working on a variety of uncoordinated initiatives, specifically:
  - Implementation and deployment of modern 3D modeling technologies, i.e., Bentley OpenRoads Designer (ORD) and OpenBridge Designer (OBD) products.
  - Investigating the replacement of the legacy statewide construction management system FAST. A request for information (RFI) is currently out, and there are plans to move forward with issuing a request for proposal (RFP).
  - Implementation of low-projection NGS zones.

    - Migration from ArcGIS to ArcGIS Pro.
- There is a plethora of data acquisition technologies available to ADOT, including UAV, total stations, lidar scanners, digital levels, statewide RTK network, etc.
- ADOT has an extensive list of software available to each discipline to perform calculations and analytical models, especially in the bridge, drainage, and traffic engineering groups.
- ADOT has various relational databases for storing and retrieving information related to projects. Specifically;
    - FIS - a linear referencing system to keep track of inventory of network features including bridges, pavements, etc.
    - FAST - a construction management system with many modules including PEN5 for daily work reporting, among other inspection forms.
    - Various databases (some GIS-enabled).
    - BidX - reviewing contractor bids electronically.
    - 3-GIS - fiberoptic inventory management.
    - PECOS - maintenance cost modeling and tracking.
    - PIRT (Project Information Retrieval Tool) - accessing various project-related information such as schedule, budget, project authorizations, etc.
    - BrM/BrR - bridge rating and management.
    - Pavement ME - analyzing pavement designs.
    - Historical Geotechnical logs - accessing previous project boring information.
    - Utility Permit Logs - conceptual-level utility conflict determination.
- ADOT has access to many modern 3D modeling software via the Bentley contract.

Overview of Readiness Assessment Framework

Readiness Assessment Background

Over the years, several digital delivery readiness assessment tools have been developed. According to a 2022 study (Mitchell, Williges, Messner, & Henly-Thomas, 2022), a total of 11 organizational digital delivery readiness assessment tools have been introduced to date. Our team evaluated these readiness assessment tools described in the study and concluded that only one – the Organizational BIM Assessment tool developed by the Pennsylvania State University was appropriate for measuring digital delivery readiness for a State DOT. (John Messner, 2020) The Pennsylvania State University readiness assessment tool was used as the foundation for developing the FHWA Organizational Digital Delivery Assessment Tool (being referred from now on as the assessment tool) as part of the EDC-2 efforts. The assessment tool was shared with State DOTs through workshops conducted in the mid 2010's. Our team chose the FHWA Organizational Digital Delivery Assessment Tool to assess ADOT's digital delivery readiness score.

Readiness Assessment Overview

The FHWA assessment tool uses a simplistic, but holistic view of the considerations for implementing digital delivery at the organizational level. The tool also provides a diagnostic assessment to highlight the areas of improvements and offers a path for achieving desired digital delivery maturity.

Digital delivery implementation consists of three essential steps including assessing current readiness and capabilities, identifying target readiness, and considering key success factors for successful implementation. The assessment tool uses a total of six planning elements. These planning elements are used to critically compare ADOT's established practices against the desired target goal. Our team assumed optimal maturity for key planning elements that can be achieved during the ADOT Digital Delivery Multi-Year Roadmap. This target is considered short term and will be reevaluated periodically and adjusted to target long term goals in the future.

Each of the planning elements also has specific subcategories to be measured using a score scale from zero to five, where zero is the least mature of all levels. The score scale is defined in Table 5 on the next page.

Table 5. Description of Scoring Scale

Level Number	Level Name	Score Description
Level 0	Non-Existent	The least mature of all levels. It is assumed that no efforts have started to meet the planning element category.
Level 1	Initial	This level is considered to represent the stage at which point the DOT is initiating the planning element category being measured.
Level 2	Developing	This level represents a slightly higher readiness than the first level, and it indicates the stage at which the DOT is developing the requirements for piloting planning element category being measured.
Level 3	Defined	This level represents the stage at which the DOT is defining the planning element category being measured based on piloting projects
Level 4	Managed	This level represents the stage at which the DOT is managing the full planning element category being measured (after pilots projects have been successful)
Level 5	Optimizing	The most mature of all levels. This represents the stage at which the DOT is optimizing to the institutionalizing the planning element being measured by revisiting the growth and needs for updates since full implementation.

Readiness Assessment Planning Elements

The planning elements in the assessment tool are defined as follows:

Strategy: Refers to the enterprise strategy of the organization as a success factor. Does ADOT have a vision, mission, goals and objectives for implementing digital delivery at the agency level, along with management support? Have digital delivery champion(s), and digital delivery steering and technology committees been identified and established their memberships?

Digital Delivery Use Cases: Refers to the complexity of use cases ADOT may want to implement. What are the specific digital delivery uses that ADOT wishes to implement? For example, if the desire is to only create 3D models to be used for automated machine guidance construction activities, that is a very narrow view of digital delivery use cases, and the benefit for such a large implementation effort may not outweigh the level of effort and expense required to establish a program.

Process: Refers to the amount of preparation to define processes to support the digital delivery use cases ADOT wants to implement. What processes does ADOT have established to-date to support the staff in implementing specific use cases?

Data: Refers to the data requirements to support use cases previously defined. What data requirements have been established as standard for various use cases? How many data requirements are needed to fully support the federation[3] of 3D model data to convey information accurately and effectively between phases and stakeholders using standardized digital formats?

Technology: Refers to the portfolio of technologies available to ADOT to support the modeling, storing, managing, consumption, reviewing, and approving milestone deliverables and data requirements necessary throughout the project development, construction delivery, and handoff of digital files?

People: Refers to the change management, training, competencies, and number of staff needed to perform each of the digital delivery tasks for the organizational implementation of digital delivery to be successful. and human resources of an organization necessary to successfully.

Planning Element #1: Strategy

The first planning element is “Strategy”, which has five categories to be scored, and are defined as follows:

Organizational Mission and Goals: A mission is the fundamental purpose for existence of an organization. Goals are specific aims which the organization wishes to accomplish.

Digital Delivery Vision and Objectives: A vision is a picture of what an organization is striving to become. Objectives are specific tasks or steps that when accomplished move the organization toward their goals.

Management Support: To what level does management support the Digital Delivery Program short and long-term?

Digital Delivery Champion: A digital delivery Champion is a person who is technically skilled and motivated to guide an organization to improve their processes by pushing adoption, managing resistance to change, and ensuring implementation of digital delivery.

Digital Delivery Committees: Digital delivery committees are responsible for setting the overall direction of the program, coordinating with the business needs of the DOT, and executing activities related to technological implementation.

[3] The term “federated” refers to grouping multiple 3D models into a single file showing the entire or “federated” model.

Planning Element #2: Digital Delivery Uses Cases

The second planning element is “Digital Delivery Use Cases”, which has two categories to be scored, and are defined as follows:

Project Uses Cases: The specific methods of implementing digital delivery on projects as defined in guidance or policy.

Operational Use Cases: The specific methods of implementing digital delivery within the organization's standard operations.

Planning Element #3: Process

The third planning element is “Process”, which has two categories to be scored, and are defined as follows:

Project Processes: The documentation of processes through a digital delivery execution plan on a project-by project basis.

Organizational Processes: The documentation of organizational digital delivery processes established as adopted policies for all digital delivery projects.

Planning Element #4: Data

The fourth planning element is “Data”, which has three categories to be scored, and are defined as follows:

Model Element Breakdown Structure (MEBS): Model Element Breakdown Structure contains identifiers assigned to each physical or functional element in the breakdown of the facility model.

Level of Development (LOD): The Level of Development (LOD) describes the level of completeness to which a Model Element is developed.

Level of Information (LOI): The Level of Information (LOI) describes the level of completeness to which a Model Element is attributed.

Planning Element #5: Technology

The fifth planning element is “Technology”, which has two categories to be scored, and are defined as follows:

Software: The programs and other operating information used by a computer to implement digital delivery.

Hardware: Physical interconnections and devices required to store and execute (or run) digital delivery software.

Planning Element #6: People

The sixth planning element is “People”, which has six categories to be scored, and are defined as follows:

Roles and Responsibilities: Roles are the primary function assumed by a person within the organization and Responsibilities are the tasks or obligations that one is required to do as part of that role.

Organizational Hierarchy: An arrangement of personnel and grouped into functional groups within the organization.

Education: Education is to formally instruct about a subject.

Training: Training is to teach so as to make fit, qualified, or proficient in a specific task or process.

Industry Receptiveness: The willingness and capacity of the business partners to receive planless contract documents.

Change Readiness: The willingness and state preparedness of an organization to integrate digital delivery.

ADOT Digital Readiness Assessment Score Card

Our team used the data collected during the SME interviews to determine the current state of the practice and assign a score. These scores can be discussed further, but a consensus will need to be reached prior to the prioritization workshop with ADOT's leadership. While the most digital mature target level on the tool is defined as *Level 5 Optimizing,* HDR has made recommendations for short term goals for achieving digital maturity. However, this is just a recommendation and may be updated as best determined by Digital Delivery Governance Committee working with ADOT Leadership.

Planning Element: Strategy

Legend Current Level Target Level

Planning Element	Description	Level of Maturity						Current Level	Target Level	Total Possible
Strategy	The Mission, Vision, Goals, and Objectives, along with management support, Digital Delivery Champions, and Digital Delivery	**0 Non-Existent**	**1 Initial**	**2 Developing**	**3 Defined**	**4 Managed**	**5 Optimizing**	**15**	**25**	**25**
Organizational Mission and Goals	A **mission** is the fundamental purpose for existence of an organization. **Goals** are specific aims which the organization wishes to accomplish.	No organizational mission or goals	Basic organizational mission established	Basic organizational mission and some goals established	Organization mission which addresses purpose, services, values (at a minimum)	Goals are specific, measurable, attainable, relevant, and timely	Mission and goals are regularly revisited, maintained and updated (as necessary)	5	5	5
Digital Delivery Vision and Objectives	A **vision** is a picture of what an organization is striving to become. **Objectives** are specific tasks or steps that when accomplished move the organization toward their goals.	No digital delivery vision or objectives defined	Basic digital delivery vision is established	Basic digital delivery vision and some objectives established	Digital delivery vision addresses mission, strategy, and culture	Digital delivery objectives are specific, measurable, attainable, relevant, and timely	Digital delivery vision and objectives are regularly revisited, maintained and updated (as necessary)	2	5	5
Management Support	To what level does management support the Digital Delivery planning process.	No management support	Limited support for feasibility study	Full support for digital delivery implementation with some resource commitment	Full support for digital delivery implementation with appropriate resource commitment	Limited support for continuing efforts with a limited budget	Full support of continuing efforts	2	5	5
Digital Delivery Champion	A digital delivery Champion is a person who is technically skilled and motivated to guide an organization to improve their processes by pushing adoption, managing resistance to change and ensuring implementation of digital delivery.	No Digital Delivery Champion(s)	Digital Delivery Champion(s) identified but limited time committed to digital delivery initiative	digital delivery Champion(s) with adequate time commitment	Multiple Digital Delivery Champions within each working group	Executive-level Digital Delivery Champion with limited time commitment	Executive-level Digital Delivery Champion working closely with working group champions	4	5	5
Digital Delivery Committees	Digital delivery committees are responsible for setting the overall direction of the program, coordinating with the business needs of the DOT, and executing activities related to technological implementation.	No digital delivery Committees established	Small Ad-hoc Committees with only those interested in digital delivery	Digital Delivery Committees are formalized but not inclusive of all operating units	Multi-disciplinary Digital Delivery Committees established with members from all operative units	Digital Delivery Committees include members for all levels of the organization, including executives	Digital Delivery planning decisions are integrated with organizational Strategic Planning	2	5	5

Planning Element: Digital Delivery Use Cases

Legend Current Level Target Level

Planning Element	Description	Level of Maturity						Current Level	2025 Target Level	Total Possible
Digital Delivery Use Cases	The specific methods of implementing digital delivery.	**0 Non-Existent**	**1 Initial**	**2 Developing**	**3 Defined**	**4 Managed**	**5 Optimizing**	**0**	**4**	**10**
Project Uses Cases	The specific methods of implementing digital delivery on projects as defined in guidance or policy.	No digital delivery use cases for projects identified	Minimal owner requirements for digital delivery	Minimal digital delivery uses required	Extensive use cases of digital delivery with limited sharing between parties	Extensive use cases of digital delivery with sharing between parties within project phase	Open sharing of digital delivery data across all parties and project phases	**0**	**3**	**5**
Operational Use Cases	The specific methods of implementing digital delivery within the organization's standard operations.	No digital delivery use cases for operations identified	Record (As-Built) digital delivery model received by operations	Record digital delivery data imported or referenced for operational uses	Digital delivery data manually maintained for operational uses	Digital delivery data is directly integrated with operational systems	Digital delivery data maintained with operational systems in real-time	**0**	**1**	**5**

Planning Element: Processes

Legend Current Level Target Level

Planning Element	Description	Level of Maturity						Current Level	Target Level	Total Possible
Processes	The means by which the digital delivery Uses are accomplished	**0 Non-Existent**	**1 Initial**	**2 Developing**	**3 Defined**	**4 Managed**	**5 Optimizing**	**0**	**4**	**10**
Project Processes	The documentation of project digital delivery processes.	No external project digital delivery processes documented	High-level digital delivery process documented for each party	Integrated high-level digital delivery process documented	Detailed digital delivery process documented for primary digital delivery uses	Detailed digital delivery process documented for all digital delivery uses	Detailed digital delivery process documented and regularly maintained and updated	**0**	**3**	**5**
Organizational Processes	The documentation of organizational digital delivery processes.	No internal organizational digital delivery processes documented	High-Level digital delivery process documented for each operating unit	Integrated high-level organizational process documented	Detailed digital delivery process documented for primary organizational uses	Detailed digital delivery process documented for all digital delivery uses	Detailed digital delivery process documented and regularly maintained and updated	**0**	**1**	**5**

Planning Element: Data

Legend Current Level Target Level

Planning Element	Description	Level of Maturity						Current Level	Target Level	Total Possible
Data	Data Needs refer to the federation of data to convey information efficiently and effectively to stakeholders in a digital format.	**0 Non-Existent**	**1 Initial**	**2 Developing**	**3 Defined**	**4 Managed**	**5 Optimizing**	**0**	**8**	**15**
Model Element Breakdown Structure (MEBS)	Model Element Breakdown Structure contains identifiers assigned to each physical or functional element in the breakdown of the facility model.	No consistent Organizational Model Element Breakdown	Organizational Model Element Breakdown defined but not uniform within entire organization	Organizational Model Element Breakdown is uniform within the organization	Organizational Model Element Breakdown aligned with industry standards	Organizational Model Element Breakdown updated along with industry standards	Organizational modifications to industry standard model element breakdown are balloted for inclusion in industry standards	**0**	**3**	**5**
Level of Development (LOD)	The Level of Development (LOD) describes the level of completeness to which a Model Element is developed.	No consistent Level of Development	LOD defined but not standardized witin the entire organization	LOD standardized within the organization	Organizational LOD standards aligned with industry standards	Model View Definitions & Information Delivery Manuals are used to define LOD	Organizational modification to MVDs and IDMs are balloted for inclusion in industry standards	**0**	**2**	**5**
Level of Information (LOI)	The Level of Information (LOI) describes the level of completeness to which a Model Element is attributed.	No consistent Level of Information	LOI defined but not standardized witin the entire organization	LOI standardized within the organization	Organizational LOI standards aligned with industry standards	Model View Definitions & Information Delivery Manuals are used to define LOI	Organizational modification to MVDs and IDMs are balloted for inclusion in industry standards	**0**	**3**	**5**

Planning Element: Technology

Legend Current Level Target Level

Planning Element	Description	Level of Maturity						Current Level	2025 Target Level	Total Possible
Technology	Technological and physical systems needed for the operation of digital delivery within the organization.	**0 Non-Existent**	**1 Initial**	**2 Developing**	**3 Defined**	**4 Managed**	**5 Optimizing**	**4**	**6**	**10**
Software	The programs and other operating information used by a computer to implement digital delivery.	No digital delivery Software	Software capable of accepting digital delivery data	Basic digital delivery Software Systems	Advanced digital delivery software systems	All software systems available to all personnel	Program established for continous updating of digital delivery software systems	**2**	**3**	**5**
Hardware	Physical interconnections and devices required to store and execute (or run) digital delivery software.	No Hardware capable of running digital delivery software	Some hardware capable of running basic digital delivery software	All hardware capableof running basic digital delivery software	Some advanced hardware systems with the organzation	All organization hardware is capable of running advanced digital delivery software	Program established for continous updating of digital delivery hardware systems	**2**	**3**	**5**

Planning Element: People

Legend Current Level Target Level

Planning Element	Description	Level of Maturity						Current Level	2025 Target Level	Total Possible
People	Human resources of an organization necessary to implement digital delivery.	**0 Non-Existent**	**1 Initial**	**2 Developing**	**3 Defined**	**4 Managed**	**5 Optimizing**	**7**	**27**	**30**
Roles and Responsibilities	Roles are the primary function assumed by a person within the organization and Responsibilities are the tasks or obligations that one is required to do as part of that role.	No roles and responsibilities documented	Digital delivery is the responsibility of the Digital Delivery Champion(s)	Digital delivery is the responsibility of the interdisciplinary Digital Delivery Group	Digital delivery responsibility lies with each operating unit	Digital delivery responsibility lies with each person	Digital delivery Responsiblities are regularly reviewed to ensure they are properly distributed	1	5	5
Organizational Hierarchy	An arrangement of personnel and group into functional groups within the organization.	Organizational Hierarchy does not address digital delivery	Digital Delivery Champion(s) outside of typical organizational hierarchy	Small Digital Delivery Implementation Team outside the typical organization hierarchy	Large interdisciplinary digital delivery Implementation Team outside the typical organization hierarchy	Digital Delivery Champion(s) defined within each operating unit	Digital Delivery Implemenation Team supports digital delivery use within operating units	1	5	5
Education	Education is to formally instruct about a subject.	No education program	Ad hoc education as needed	Formal Presentations on what is digital delivery and the benefits is has for the organization	Regularly conducted employee education sessions	On-Demand education program established for the organization	Education is seemlessly improved through lessons learned within the organizartion	0	3	5
Training	Train is to teach so as to make fit, qualified, or proficient in a specific task or process.	No training program	Training program run by vendors - only for necessary personnel	Internal Training program for all personnel that may interact with digital delivery	Regularly conducted and routine training programs	On-Demand training program established for the organization	Training is seemlessly improved through lessons learned within the organization	1	4	5
Industry Receptiveness	The willingness and capacity of the business partners to receive planless contract documents.	Industry is not capable of producing or using digital information	Industry is capable, but limited in its use	Industry is capable and producing/using digital information, but there is no requirement to do so	Industry is capable and producing/using digital information even if not contractual	Industry operates in a digital environment as contractually obligated by ADOT	Industry operates in a fully digital environment across all disciplines	2	5	5
Change Readiness	The willingness and state preparedness of an organization to integrate digital delivery.	No Change Readiness Awareness	Established need for digital delivery	Upper management buy-in	Operating unit buy-in	All individuals buy-in	Willingness to change is part of the culture of the organization	2	5	5

Summary of ADOT Digital Delivery Readiness Assessment for Achieving Short-Term Goals

Digital Delivery Planning Element	Current Level	2025 Target Level	2027 Target Level	2030 Target Level	Total Possible Score
Strategy	15	25	25	25	25
Organizational Mission and Goals	5	5	5	5	5
Digital Delivery Vision and Objectives	2	5	5	5	5
Management Support	2	5	5	5	5
Digital Delivery Champion	4	5	5	5	5
Digital Delivery Committees	2	5	5	5	5
Digital Delivery Use Cases	0	4	7	10	10
Project Uses Cases	0	3	4	5	5
Operational Use Cases	0	1	3	5	5
Processes	0	4	7	10	10
Project Processes	0	3	4	5	5
Organizational Processes	0	1	3	5	5
Data/Information	0	8	12	15	15
Model Element Breakdown Structure (MEBS)	0	3	4	5	5
Level of Development (LOD)	0	2	4	5	5
Level of Information (LOI)	0	3	4	5	5
Technology	4	6	8	10	10
Software	2	3	4	5	5
Hardware	2	3	4	5	5
People	7	27	30	30	30
Roles and Responsibilities	1	5	5	5	5
Organizational Hierarchy	1	5	5	5	5
Education	0	3	5	5	5
Training	1	4	5	5	5
Industry Receptiveness	2	5	5	5	5
Change Readiness	2	5	5	5	5
Totals	26	74	89	100	100

Conclusions and Recommendations

This section of the guidance document provides recommendations for ADOT to consider when planning for its Digital Delivery Program implementation. This section is divided into two sections, (1) national state of the practice recommendations, and (2) digital delivery score card recommendations.

National State of the Practice Recommendations

Our team has reviewed information listed in Tables 1-4 to provide overall assessment of ADOT compared to its peer State DOTs; and had many discussions with ADOT staff. This data collection exercise was helpful in providing general recommendations for ADOT's consideration. A full list of SME Interview Recommendations are provided in Appendix A This section summarizes general recommendations based on lessons learned from other states and areas of opportunities identified during conversations with ADOT staff.

Recommendation #1. Create a Strategic Plan

Lesson Learned: Creating a strategic plan to guide the digital delivery program is a good investment. It is important to take the time to assess digital maturity and set goals for desired targets; identify priorities for addressing the gaps, determine and execute change, communication and engagement, and risk management strategies. Tactical goals should be defined with details such as short description, desired outcomes, focus areas, alignment with digital delivery goals and objectives, human and financial resources, and coordination needs with other groups within the organization.

Challenges: The biggest challenge for ADOT will be prioritizing goals and activities to be added to the strategic plan. Recommendation to address this challenge is to focus first on establishing procedures, standards and piloting projects focusing on the design development of models, and contract administration and construction inspection activities. An additional area of focus may be establishing the requirements for digital as-built records for the top three priority assets using the FIS Collection Manual.

Assessment Result: ADOT is already investing to create a strategic plan as part of the current phase of the Digital Delivery Program. HDR will consider all lessons learned from other State DOTs to create a strategic plan that includes general guiding principles as well as specific activities that will need to be implemented to increase in digital maturity. These specific activities will be discussed during the prioritization meeting scheduled for April 26, 2023. The desired outcome for that meeting is to work with ADOT leadership and the digital delivery team to define a clear direction for prioritizing the areas identified in the gap assessment to increase digital maturity. The priorities will be organized in tactical and strategic goals in the Task 1B: Implementation Plan with specific activities and minimum requirements for completion and strategies for managing the implementation of digital delivery in Arizona.

Recommendation #2. Establish an Organizational Structure for Digital Delivery

Lesson Learned: Assigning a single Digital Delivery Lead whose job is to oversee the initiative in a full-time capacity and accountable for the program. This type of commitment from leadership sends a strong and clear message that they stand behind the program now and in the future. Other states

like Utah, Iowa, Minnesota, and Florida have one assigned individual as the spokesperson for digital delivery and the coordinator that works with other parties to advance the state's digital maturity. However, the staff responsibilities go beyond managing the digital delivery program. A more recent best practice is PennDOT's establishment of a permanent organizational structure. The PennDOT Digital Delivery Section resides within the Design Bureau, which is likely the closest to the IDO Division, in specific the Engineering and Construction Business area of ADOT; and it has a Digital Delivery Section Chief with three supporting staff members assisting with specific technical tasks and working directly with the HDR team in overseeing pilot projects and developing standards, guidelines, implementation of new technology, and updates to the CAD environment. The Digital Delivery Section Chief reports monthly to the Governance Committee composed of senior leadership on the progress of the program, and coordinates with business area champions on piloting digital delivery. Texas Department of Transportation (TxDOT) recently created a digital delivery team with a Digital Delivery Director, but HDR does not have any specific details about their program.

Challenges: Establishing a digital delivery organizational structure may take longer than recommended based on financial resources. ADOT may want to consider assigning staff with the aptitude and core competencies on temporary assignments until budgets may be established for a long-term solution.

Assessment Result: ADOT has an interim organizational structure composed of an executive champion, two digital delivery program leads, and three collaborating committees. While this arrangement is adequate for initiation of the program, ADOT should consider establishing a permanent organizational structure for the digital delivery program with dedicated resources to oversee long-term digital delivery policy, technology deployment and training, and overall technical support of standards, procedures and updates to guidance documents, and communication with internal and external stakeholders as the program matures. With the ambitious timeline to establish the ADOT Digital Delivery Program by end of calendar year 2025, it is recommended for ADOT to identify dedicated resources to start transitioning to a long-term organizational structure as soon as possible. ADOT should consider how a Digital Delivery Program fits into the current organization structure and assign a full-time employee to be the program manager, with two or three ancillary staff assisting in key areas in the short term, with a plan to expand the program staff in the future as digital delivery becomes the primary business practice. These roles could range from model managers at the project level, similar to the role of project manager today, but specific to managing digital delivery requirements for projects to key digital delivery technical leads that assist with CAD and construction applications. Suggested role responsibilities and core competencies for these new positions include:

- **DDP Manager (Program Level Role):** Responsible for digital delivery policy, technology deployment, training, technical support and for ADOT internal and external communication regarding the DDP. Core competencies considerations for these roles include strong leadership and communication skills, practical experience of project development and delivery, and general knowledge of technologies applicable for digital delivery.
- **DD Technical Leads (Program Level Role):** Technical staff responsible for working with the technical committee to develop procedures, deploy technology, develop and deliver training for key areas of digital delivery, such as roadway modeling, bridge modeling, drainage modeling, and construction inspection. Core competencies considerations for these roles include understanding of the ADOT project development and delivery processes, digital delivery practices and technologies being used for programmatic data, quality management reviews, discipline specific 3D modeling software, and construction 3D model viewing technology.

- **Model Manager (Project Level Role):** Technical staff responsible for coordinating with the DD Technical Leads to clarify project requirements and assisting project team members with development and execution of a project digital delivery execution plan, coordinating file management and federation of project models, educating project teams on digital delivery processes and expectations, and enforcing protocols establish for modeling standards and model integrity. This role may only be needed for large complex projects in which multiple disciplines are modeling portions of the project. Each discipline should also have a model manager responsible for discipline specific model integrity and completeness, and compliance with discipline specific CAD and modeling standards. For smaller projects in which only one discipline may be involved, only a discipline model manager may be needed. Core competencies considerations for this role include knowledge of modeling software specific to creating discipline-specific model elements, knowledge of ADOT project development requirements for a specific discipline (roadway, bridge, drainage, etc.)

Recommendation #3. Identify Digital Maturity and Select Target Desired Maturity for Short- and Long-Term Goals

Lessons Learned: Identifying key areas to increase digital maturity is an important starting point. It is difficult to create an implementation plan without understanding specific objectives for digital maturity for the next three or ten years. A useful tool to objectively assess digital maturity is the FHWA Organizational Digital Delivery Assessment Matrix, a product of the EDC-2 activities. This tool provides a quantitative approach to measuring digital maturity against the desired targets.

Challenges: ADOT may not be ready to address all planning elements to increase digital maturity before the end of calendar year 2025. ADOT may want to consider prioritizing areas that are the most mature, or those that can be accomplished by leveraging the work of other states. However, staff may be resistant to changing the ADOT way of doing things.

Assessment Result: ADOT has already determined its current digital maturity using the FHWA Organizational Digital Delivery Assessment Tool. The next step is to determine short-term and long-term targets for increasing digital maturity and prioritizing the areas of focus. The prioritization of focus areas will assist in developing an implementation plan with activities to achieve ADOT's goals. A more detailed approach to increasing digital maturity is part of Task 1B. Implementation Plan.

Recommendation #4. Establish Modeling Development Standards and Standard Operating Procedures

Lesson Learned: Modeling standards, data management procedures and clear guidance on standard model development procedures are critical to the success of digital delivery implementation. Creating and communicating expectations for model-based design in terms of LOD and LOI; and providing training on the procedures for delivering projects in a new manner will increase the success rate of adoption by all stakeholders. These standards also help contractors understand the design intent for preparing bids and executing construction activities. Modeling standards provide a way to communicate the accuracy and completeness of each design element being represented in the contract digital files.

Challenges: The core competencies and digital maturity differs between the various disciplines. Roadway design staff may be able to adapt quicker than other sections and groups, while those disciplines not used to creating models of their design may take slightly longer to become comfortable in learning new methods for preparing design deliverables. ADOT is already working on a plan to

provide technical assistance to all staff involved in the project development and delivery of projects, but the timeline may need to be extended to manage pace of change and get buy-in from stakeholders.

Assessment Result: ADOT has not established modeling standards nor operating procedures. One of the activities to be included in the implementation plan should be defining clear standards and procedures for creating models, project data management, quality management, milestone deliverables and methods of sharing information between stakeholders. A comprehensive digital delivery manual is recommended. ADOT should also consider reviewing other State DOTs digital delivery guides, modeling standards and setup of modeling software as a starting point in developing ADOT specific technical resources. Much of this guidance should be available to project teams ahead of initiating pilot projects, as these resources serve as portions of the training material to get them ready for successful implementation. Also, providing these technical resources minimizes the level of frustration during delivering pilot projects.

Recommendation #5. Create a Training Plan and Identify Opportunities for Improving the Project Development Process

Lesson Learned: ADOT staff is engaged and looking forward to implementing digital delivery, but are also concerned about not having the proper training or core competencies to transition to a full digital delivery environment. Providing the right level of training for specific target audience at the right time is necessary to increase knowledge transfer and retention and to avoid frustration. Another area of opportunity identified during the ADOT staff interviews was evaluating existing processes that could be eliminated or streamlined with digital delivery. Instead of fitting digital delivery in the current process, ADOT should consider using digital delivery to improve current ways of doing business.

Challenges: Executing the training plan will take additional resources and there is a limited pool of qualified personnel to develop and deliver training material. ADOT may want to consider finding additional funding through federal grants to hire an external provider to develop and deliver the training. HDR and other State DOTs (e.g., Montana, Maine and Kentucky) have had great experience with Envision CADD. They are efficient and knowledgeable not only in the use of the software, but also working with engineers to incorporate best practices in the training material. Also, creating a process map that clearly identify data exchanges may be advantageous in identifying process improvements. During the interviews, HDR created processes diagrams that focus on document and file exchanges. The data exchange process map would not include any document exchanges. HDR recommends evaluating the lifecycle process developed as part of the TPF-(375) BIM for Bridges & Structures pooled fund (shown in Appendix E) as a starting point for developing a similar lifecycle model exchanges for roadway, drainage and possible other disciplines. ADOT should consider applying for for the AID, ADCMS, and STIC federal grants.

Assessment Result: ADOT has already started a training and tool development plan as part of the Digital Delivery Program. A document with a list of training modules, with specific objectives, subject topics, target audience and recommendations for delivery plan will be provided as the deliverable for Task 1C: Training and Tool Development Plan.

Recommendation #6. Consider Evaluating Other State DOT's Guidelines, Technical Documentation, and ORD and OBM Workspaces and Object Libraries.

Lessons Learned: Other State DOTs further ahead in their digital delivery journey are willing to share guidance documents, standards, and manuals. Evaluating applicability of these available resources is a worthwhile exercise to avoid re-inventing the wheel.

Challenges: This best practice is often underutilized because State DOTs believe they are too different to be able to leverage standards and processes from other organizations. While using other State DOT standards, processes, and modeling software libraries may be questioned by the users, it is worth exploring. Managing change is part of the process, and stakeholders may be willing to accept these changes if they understand how this helps ADOT as a whole, and that digital delivery implementation may result in a faster and more cost-effective approach. It is recommended that ADOT investigate the use of other DOT modeling guidelines/standards to fill in gaps in things like the ORD workspace, to help minimize the cost and time to update these resources appropriately.

Assessment Result: ADOT has not started the development of these technical resources, and this recommendation should be considered as an approach to use in the implementation plan.

Recommendation #7. Consider a Phased Approach Piloting Program

Lesson Learned: Sometimes starting small and methodically increasing complexity in piloting digital delivery is the smartest thing for an organization that is risk adverse. Technical aspects of digital delivery are typically more manageable than the human factors and behavioral economics that drive the degree by which stakeholders will receive the new initiative and engage in the process, support the development of the program, and accept the solutions being proposed.

Challenges: Managing the pace of change may be tricky. It is important for the initiatives do not proceed too quickly and make people feel overwhelmed or progress too slow, making people feel frustrated they are not seeing progress. This challenge is truly a balance of human behavior and should be considered as a key element of the implementation plan.

Assessment Result: ADOT has not defined the piloting approach for digital delivery and managing pace of change should be a strong consideration moving forward.

Recommendation #8. Considering Using Contract Management at Risk Contracting Method for Initial Pilot Projects

Lesson Learned: Using alternative delivery methods such as CMAR has proven to be a best practice in managing risk for piloting digital delivery. Using a CMAR contracting method, the owner, the designer, and the contractor are involved from the very beginning, and it is much easier to use technology and digital delivery methods to find better design options, or improved construction efficiencies by leveraging this delivery method as compared to most Design-Bid-Build opportunities. This is a lesson learned shared by UDOT and MnDOT.

Challenges: No challenge identified for this recommendation.

Assessment Result: ADOT has not determined how to implement digital delivery pilot projects but should consider CMAR as an option.

Recommendation #9. Consider Creating Industry Partnerships

Lesson Learned: Leaning on their partnerships with industry, several DOTs are working closely with software and technology providers, consulting, and contracting communities to work together as partners in the implementation of digital delivery. As the saying goes, “it takes a village” and everyone in the process has something to contribute.

Challenges: Working with technology providers, like Bentley and Trimble will be essential to the success of ADOT’s Digital Delivery Program. Coordinating with the Information Technology Group to be directly involved in managing the relationship and piloting technology solutions may be a challenge.

Assessment Result: ADOT has started communications with ACEC and AGC regarding the Digital Delivery Program and should continue working through targeted committees that can provide input and possibly provide professional services to assist with the activities in the implementation plan. Having the right expertise and dedicated resources to work on digital delivery often results in a more efficient and effective approach to implementing a digital delivery program at the enterprise level.

Recommendation #10. Consider Participation in National Research Efforts, Pooled Funds and Technology Transfer Activities

Lesson Learned: Participating in NCHRP studies as project panelists guiding the research team often provides a preview into upcoming solutions and best practices for digital delivery. It takes a long time to publish studies, but project panel members have early access to interim draft deliverables, which is valuable in making decisions for digital delivery strategies. Also, participating on national transportation pooled funds may be a way to collaborate with other State DOTs and sharing financial resources to support larger activities that benefit everyone. For example, funding the development of national standards for digital delivery that can be implemented at the state level with slight modifications. These national standards may be viewed in a similar fashion as referencing AASHTO Guidelines and FHWA manuals, such as the Policy on Geometric Design of Highways and Streets (Green Book), the Load and Resistance Factor Design (LFRD) Bridge Specifications, and the Manual on Uniform Traffic Control Devices (MUTCD). Lastly, actively participating on working groups through AASHTO subcommittees working on digital delivery topics may be beneficial just to keep up-to-date on resources being produced by these groups. The JTCEES meets during the Committee on Design Annual Meeting in person, and virtually on a regular basis.

Challenges: ADOT staff may be overly committed with their everyday task duties to add these extracurricular activities. Nevertheless, it is important to ask staff for their interest in participating in these activities. Funding for supporting these activities may also be limited.

Assessment Result: ADOT is currently participating in the TPF-5(480) BIM for Infrastructure Pooled Fund and currently has a member of the GIS Group as the voting representative; and has had representation in the JTCEES. ADOT should consider:

- Discussing appropriate involvement in the TPF-5(480) BIM for Infrastructure Pooled Fund that will benefit the Digital Delivery Program. Adding a second person that represents project development to pooled fund meetings may be an option to consider. Pooled funds only account for covering direct expenses for one State DOT representative attending in-person meetings.

- Reviewing the guidance documents developed by JTCEES to extract information that may be applicable to its digital delivery program. Consider using the model element breakdown structure (MEBS) as a starting point for defining ADOT modeling standards but modifying it to incorporate the IFC data exchange standard that has been adopted in 2019 by AASHTO under Administrative Resolution AR-1-19.
- Making a recommendation for one ADOT staff member to serve as a project panelist for the upcoming NCHRP 08-174 Project: Development of a Surveying and Mapping Guide for Transportation Projects (for BIM). Project is anticipated to be added to the 2023-2024 list of projects, but a project panel has not been assembled. Should contact the NCHRP Project Coordinator Jennifer L. Weeks to ask for a status.
- Joining the BIM for Bridges and Structures Phase II Pooled Fund, currently soliciting contributors. Information is now available at TPF - Solicitation Details (pooledfund.org). ADOT should also consider contacting Kyle Clute at Khyle.Clute@iowdot.us to inquire about joining as a contributor for the current BIM for Bridges and Structures Pooled Fund. The project is in its last year but may not be too late to participate as a contributor.

Digital Delivery Score Card Recommendations

Based on the scoring of the readiness matrix, HDR recommends ADOT considers first establishing short-term digital maturity targets to manage the pace of change, resources, and schedule.

Strategy

Currently digital maturity score: 15

2025 Target digital maturity recommendation: 25.

Possible total score long term: 25

Organizational Mission and Goals: No recommendations. ADOT's organizational mission and goals are at level 5.

Digital Delivery Vision and Objectives: Develop DDP objectives for future phases that align with the ADOT roadmap. These should define the desire to shape the agency's mission, strategy, and culture around digital information exchanges across all disciplines; and align with ADOT Mission, Goals and Strategic Plan.

Management Support: Continue to explore options to fund appropriate resources (financial and human) for establishing an enterprise program with a dedicated organizational structure, and execution of implementation plan.

Digital Delivery Champion(s): ADOT has reached the target goal with executive-level support, albeit with limited time available. ADOT may consider the executive champion becoming more of a resource to be informed of challenges and proposed solutions, and progress. Consider the executive level champion to become the chair of the governance committee. The Digital Delivery Leads should report monthly to the governance committee.

Digital Delivery Committees: Interim organizational structure with the governance, steering and technology committee is a great initial approach, but may need to be re-structured once a long-term Digital Delivery Program Organizational Structure is established. Consider evaluating involvement of the disciplines with active involvement in the activities set out in the implementation for short-term goal and add members as involvement is required for assisting with the implementation of long-term goals. Continue to refine and adapt as the program matures.

Digital Delivery Use Cases

Currently digital maturity score: 0

2025 Target digital maturity recommendation: 4

Possible total score long term: 10

Project Use Cases: Identify use cases for each aspect of pilot project models, such as roadway modeling authoring to support earthwork MALD, 3D clash detection, quantity harvesting, fabrication, etc. as part of the implementation plan. Eventually this would be institutionalized and inclusive of all project development delivery groups. Short-term recommendation is to achieve level 4.

Operational Use Cases: Based on lessons learned during piloting, and in conjunction with the ADOT steering committees, create post-construction use cases to capture, organize, analyze, and manage

operational data for future maintenance and planning activities. Short-term recommendation is to defer increasing digital maturity at this point (level 0 target)

Processes

Currently digital maturity score: 0

2025 Target digital maturity recommendation: 4

Possible total score long term: 10

Project Processes: Focusing on achieving a level 3 target maturity is recommended to support the primary digital delivery uses necessary to successfully deliver all discipline MALD deliverables. Including the development of these processes and guidance documents should consider a high priority as an activity in the implementation plan.,

Organizational Processes: Documenting organizational digital delivery processes may be a planning element that may be deferred to after the individual project use case processes have been piloted and institutionalized. Organizational processes may include data management and digital workflows for project development, delivery and operations and maintenance activities. It is recommended to focus on project development and delivery first by institutionalizing standardized project processes documented through individual pilot projects. Short-term recommendation is to achieve level 1 maturity.

Data/Information

Currently digital maturity score: 0

2025 Target digital maturity recommendation: 8

Possible total score long term: 15

Model Elements Breakdown Structure (MEBS): ADOT should adopt a detailed model element breakdown structure for organizing model objects to be developed for each discipline using the IFC schema as a foundation. This recommendation would result in achieving level 3 maturity by end of calendar year 2025. ADOT should evaluate the status of industry standards in calendar year 2026.

Level of Development (LOD): Consider evaluating industry, AASTHO, and peer State DOTs to develop clear guidance for designers and modelers in communicating the rules for achieving the level of completeness to meet specific authorized uses at each milestone deliverable per current ADOT project delivery stages that are familiar to ADOT staff and industry partners, thus flattening the learning curve for adoption. Given that there is disagreement within the industry on how LOD should be defined for infrastructure at this time, ADOT should consider achieving level 2 maturity in the short term and re-evaluate the status of industry consensus in 2026.

Level of Information (LOI): Consider evaluating buildingSMART LOI specifications for applicability to ADOT digital delivery priority use cases. A similar approach for defining LOD applies with the current ADOT Project delivery Stages that are familiar to ADOT staff and industry partners, thus flattening the learning curve for adoption. LOIs should align with the information needs of supporting priority use cases and stakeholder needs, focusing first on project development, and construction delivery. ADOT should consider achieving level 3 maturity in the short term and re-evaluate the status of industry consensus in 2026.

Technology

Currently digital maturity score: 4

2025 Target digital maturity recommendation: 6

Possible total score long term: 10

Software: Consider exploring and evaluating technology available through ADOT's current contracts. The Digital Delivery Leads will need to coordinate with ITG in assessing the additional cost to access more licenses that are currently budgeted through the Bentley contract. Consider working with ITG in exploring the options available under the Trimble technology contract. Software systems should be setup to achieve optimum utilization of the technology working with the technology provider in finding best practices and workarounds when finding issues with the software. ADOT should work with software technology providers to explore the highest level of automation that results in reducing the amount of manual data entry and redundancy while providing a positive user experience. Software should be evaluated for industry advancements in open standards and file exchange. Staff should have access to all software that is deemed necessary to deliver projects in a digital manner. Achieving a level 3 maturity may be an appropriate short-term goal.

Hardware: Consider assessing current hardware against industry trends and other DOTs/industry partners to establish recommendations for procuring appropriate level of computers to support specific needs. For example, survey staff processing big data sets may need a computer that has more processing power and higher visualization cards to enable efficient workflows to produce files for their customers. Similarly, designers and modelers producing complex and large data sets would have a computer that provides the best user experience. Staff reviewing models using internet browsers may need less expensive computers. Achieving a level 3 maturity may be an appropriate short-term goal.

People

Currently digital maturity score: 7

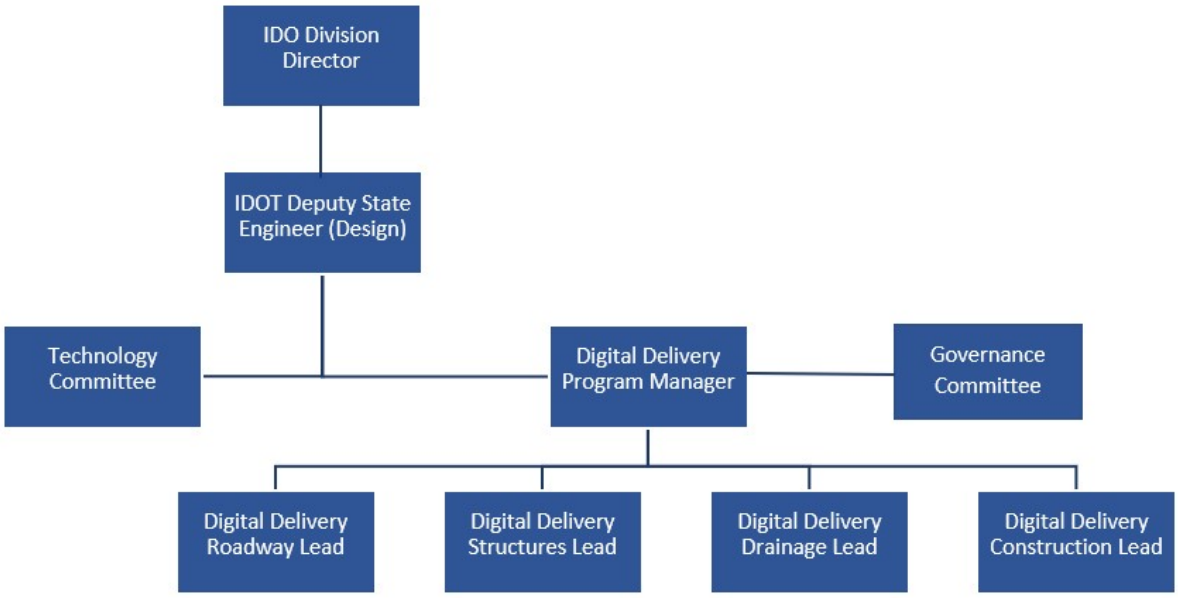
Target digital maturity recommendation: 27

Possible total score long term: 30

Roles and Responsibilities (R&R): Consider defining roles and responsibilities for project development and construction delivery staff related to digital delivery. Create a digital delivery execution plan template to assist staff with proper documentation of R&R on each pilot project being planned. Once the pilot program matures, institutionalize digital delivery R&Rs into ADOT project delivery policy. Re-evaluate R&R starting in 2026 to achieve higher digital maturity within the assessment matrix. Recommend a short-term digital maturity at level 3.

Organizational Hierarchy: Consider establishing small digital delivery organizational structure to oversee the development and execution of the implementation plan and evaluate needs of the program every year. ADOT may consider an organic and gradual growth of the Digital Delivery Program organizational structure. It is highly recommended that ADOT considers the DDP structure as a high priority, as this group will be instrumental in transitioning the organization to the desired state of maturity. Achieving a maturity level 5 is highly encouraged. Consider having the DDP reporting to the IDO Deputy State Engineer – Design directly. A suggested structure is illustrated in Figure 8.

Figure 8. Proposed Digital Delivery Program Organizational Structure



Education: Consider developing a communication and engagement plan that will provide regular events and dissemination of information for all stakeholders, including internal ADOT staff, industry partners, such as AGC and ACEC members, FHWA, and local agencies. Consider attending strategic industry events to collaborate with peer State DOTs and learning information on digital delivery advancements. Short-term maturity recommendation is to achieve level 3.

Training: Consider creating a detailed training plan that addresses general digital delivery education, procedures, and technology applications for specific functional tasks. A training plan will be delivered as part of Task 1C. Short-term recommendation is to achieve level 4.

Industry Receptiveness: Prepare a communication and engagement plan that describes specific strategies for engaging with industry partners and providing regular communication. An industry survey has been distributed to capture industry preferred methods for engaging and providing input to ADOT and receiving communication. Consider encouraging industry to actively participate on ADOT digital delivery committees. This will help ADOT improve industry receptiveness for proposed digital delivery requirements. Consider working closely with the State Board of Registration on updating rules for digitally signing and sealing model information. Short-term recommendation is to achieve level 4 maturity.

Change Readiness: Consider working towards building acceptance for digital delivery as an organizational culture standard. This will require a strong change management strategy as part of the implementation plan. This planning element is one of the most influential factors for success of digital delivery adoption. Short-term recommendation is to achieve full maturity at level 5.

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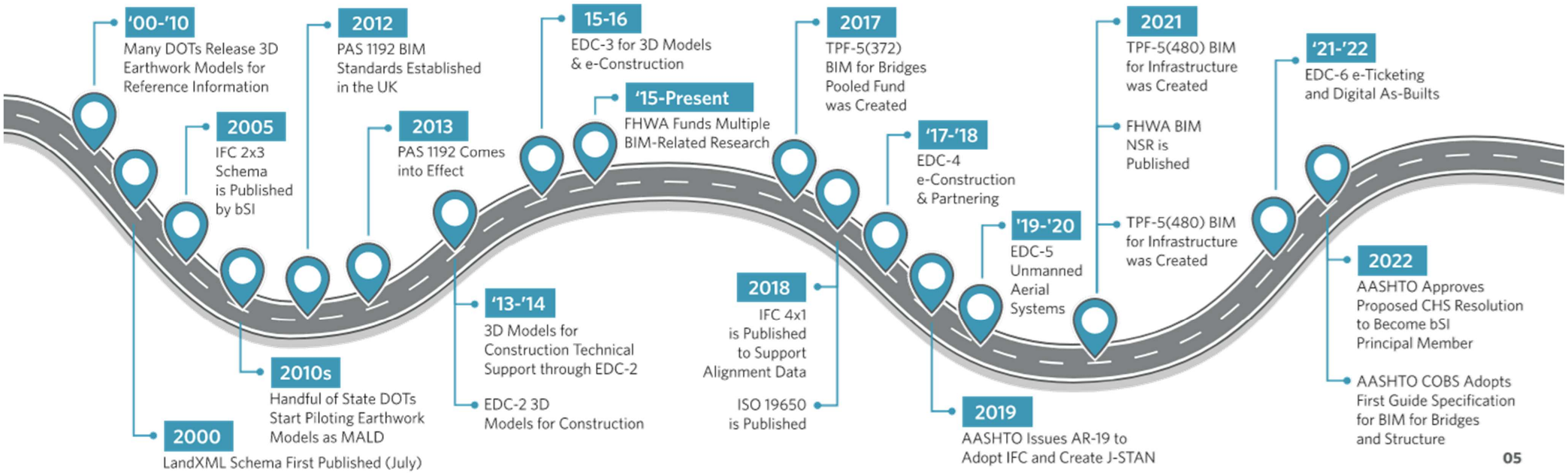
Appendices

Appendix A. Summary of National Efforts to Advance Digital Delivery[4]

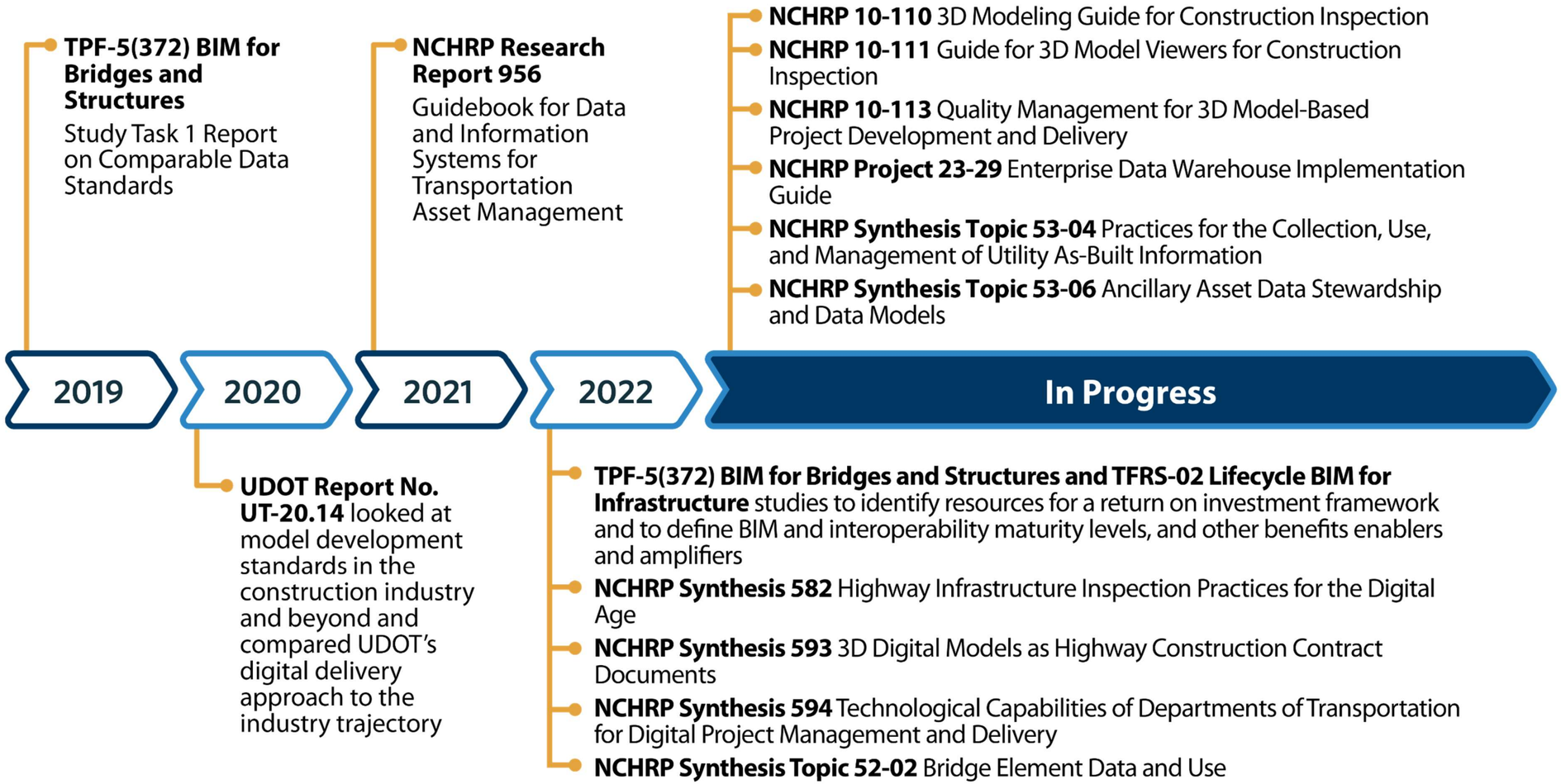
Figure 9 and 10 are illustrations of major efforts to advance the national digital delivery state of the practice. Some of the items identified in the figure to be applicable to ADOT's Digital Delivery Program were listed in Tables 1-4.

Figure 9. Digital Delivery Development Over the Years



[4] Note: Appendices D-F have been formatted as a tabloid 11" x 17" page using landscape view.

Figure 10. National and State Research Projects to Advance Digital Delivery



Appendix B. Areas of Opportunities Identified During ADOT Subject Matter Expert Interviews

The following are areas of opportunities identified during the ADOT SME group interviews conducted in February of 2023. They are organized into four groups: People, Processes, Data, and Technology. This aligns with the structure of the Digital Delivery Readiness Matrix as well.

People

- Establish multi-disciplinary committees to guide the implementation phase and beyond.
- Identify dedicated staff to manage the digital delivery program.
- Prioritize Department needs as they relate to digital delivery and create a short- and long-term implementation plan to achieve tactical (1-5 years) and strategic goals (5-15 years).
- Create a communication plan to explain why ADOT is embarking on this digital transformation initiative, the benefits of digital workflows, and tactical and strategic goals.
- Continue engagement with the internal staff and external stakeholder community, paying close attention to the needs of project development staff, contractors, construction staff, and external agencies.
- Review resource needs and ways to train internal staff to oversee ADOT data and technology initiatives. ADOT may also consider staff augmentation to assist internal ADOT staff with the development of tools and training for digital delivery. This should include more support staff for the advancement of the OpenX platforms and associated workspaces.
- Assess training needs specific to digital delivery to support project development and construction. An outline of recommended training initiatives will be delivered as part of this initial contract.
- Create on-demand, bite-sized training approach to support implementation of new tools and technologies for digital workflows.
- Develop a “train-the-trainer” program to increase capacity for training resources.
- Consider establishing a technology business lead to coordinate and assist in technology improvements that align with enterprise objectives. These technology savvy leads will use their business knowledge to advance innovation.
- Create a short-term collaboration plan to optimize digital information and reduce duplicate efforts.

Processes

- Guidance and support documentation will be needed to enable staff to perform their duties in a digital delivery environment.
- Establish processes and guidelines to leverage multiple types of digital data (CAD, tabular data, etc.).
- Create guidelines for model-based design, including extensive guidance for Level of Detail (LOD) and Level of Information (LOI) requirements for conveying design intent in the digital environment and focusing on more constructable models. There are many terms being redefined in the industry. ADOT may consider adopting some of those definitions, such as Level of Geometry (LOG), which refers to the level of geometric detail; and Level of Information Need (LOIN), which refers to the type of information that is needed for a specific use – for example bidding or asset management.
- Create guidelines for digital model review, including non-CAD users. Establish standardized collaboration processes for all stakeholders, including external parties.

- Update process maps for digital workflows to ensure ADOT has an information exchange map and strategic plan to manage their data and ensure consistency with the ADOT vision. It is recommended to focus on digital data exchanges only rather than document exchanges.
- Establish a plan to leverage digital design information in construction for management and inspection activities, as well as the collection of a digital as-built.
- Continue to utilize Construction Partnering on digital delivery pilots, potentially expanding its use during the implementation phase.

Data

- Develop strategic, business, and action plans for data management and prioritize focus areas. Suggest focusing on project development first.
- Establish consistent data storage locations and protocols for validating information.
- Establish standards and guidelines for:
    - File naming conventions and geospatial connections across systems.
    - Model development requirements per milestone submittal of highway and bridge projects, including level of development and information for each design component.
    - Information requirements for data collection of as-built records to support operations by asset class, including surveying accuracies, location information, asset properties and metadata. A prioritization plan may be needed to implement digital as-built requirement by asset class. Consideration to assets already having digital inventories may be a good place to begin (e.g., signs, guardrail, and culverts). Once information requirements are established, a process for validating and accepting deliverables may be created. Suggest looking at what MnDOT has done with their asset inventory requirements as a starting point. GPS As-Built Deliverable - MnDOT (state.mn.us)
    - Enterprise data requirements for storage and connection to ADOT warehouses.
    - Consider coordination with TSMO and other owners of FIS asset inventory data to determine which information may be added to the ORD and OBD model elements being produced during project development. A reconciliation of data dictionaries may be needed to complete this task.
- Update the Survey manual to include geomatic positional accuracies to support digital delivery use cases and authorized uses.
- Update the CAD manual to incorporate modeling standards and practices in the OpenX environment.
- Consider implementing the Information Delivery Manual (IDM) for the Design to Construction Data Exchange of Highway Bridges, 1st Edition as a digital delivery standard for model-based information. This is one of the products from the TPF-5(372) BIM for Bridges and Structures Pooled Fund.
- Explore the use of open data standards (i.e., LandXML and IFC) for data exchanges between ADOT and contractors.
- Consider modernizing Construction standards and policy manuals to better leverage digital information, including specifications and guidance on using design models for inspection, reporting and management of contractor work, automated machine guidance (AMG) uses by contractors and their surveyors, and the collection of as-built conditions for FIS (or a designated asset management solution).

Technology

- Assess the state of technology for all staff that will be engaged in digital delivery and determine what if any hardware and software they will need to deliver the vision of the digital delivery

initiative. Work with ITG to create a technology plan that addresses any deficiencies and is prioritized for those that will be directly engaged in active pilot projects.

- Work with ITG and Construction to define the functional requirements for the software replacement for FAST to include 3D model viewing capabilities.
- Work with geotechnical staff as they look for an enterprise system to manage statewide geotechnical data. It is important the new system considers data exchanges with CAD applications.
- Develop the CAD workspace to better align with digital delivery goals and objectives, including more standardization and enforcement of information, model-centric workflows that include bridge and drainage models, and custom attribution that aligns with construction and asset management needs.
- Consider Asset Management solutions that provide analytical tools along with geospatial mapping and attribution. Several systems are available on the market and ADOT should consider peer exchanges with other DOTs to discuss their approaches to Asset Management, such as Minnesota, Connecticut, Utah, or Iowa.
- While the FAST system will be replaced and aligned with digital delivery, inspection activities should be augmented with geospatial and other methods of data acquisition to verify contractor work. Many tools and technologies exist to support digital construction inspection and should be piloted and evaluated. Several other DOTs are using or investigating various inspection tools and could be consulted, such as Caltrans, Utah, Montana, Connecticut, Pennsylvania, or Minnesota.

Appendix C. Industry Survey Results

Two surveys were set up to get the input from contractors and consulting firms. A total of 13 from contractors and 23 responses were received from consultants. This section provides a summary of the input collected.

Summary of Contractor Responses

Overall, contractors are ready for digital delivery. Composition of respondents was 67% and 33% large and medium companies respectively. None of the respondents were Disadvantage Business Enterprise (DBE) companies, which is a concern as they are typically not as sophisticated when it comes to the use of technology. Most respondents were familiar with the ADOT Digital Delivery Program, and all respondents were interested in providing input and being involved. The survey was completed mostly by executives (33%) followed by estimators (22%) and operations and/or project management staff. It was surprising to see the roles of Digital Delivery Strategist and Digital Services Director responding to the survey. Table 6 provides details about the respondents who are willing to be contacted for follow-up discussions.

Table 6. Contractor Survey Respondents Available for Follow-Up Discussions

Name of Respondent	Company	Contact Information
Jacob Bottcher	FNF Construction	jbottcher@fnfinc.com (480) 784-2910
Connor Christian	Kiewit	connor.christian@kiewit.com (303) 681-1125
Craig Zimmerman	Rummel Construction	czimmerman@rummelconstruction.com (602) 695-4514
Ignacio De La Hera Sola	AZTEC	ihera@aztec.us (720) 201-4367

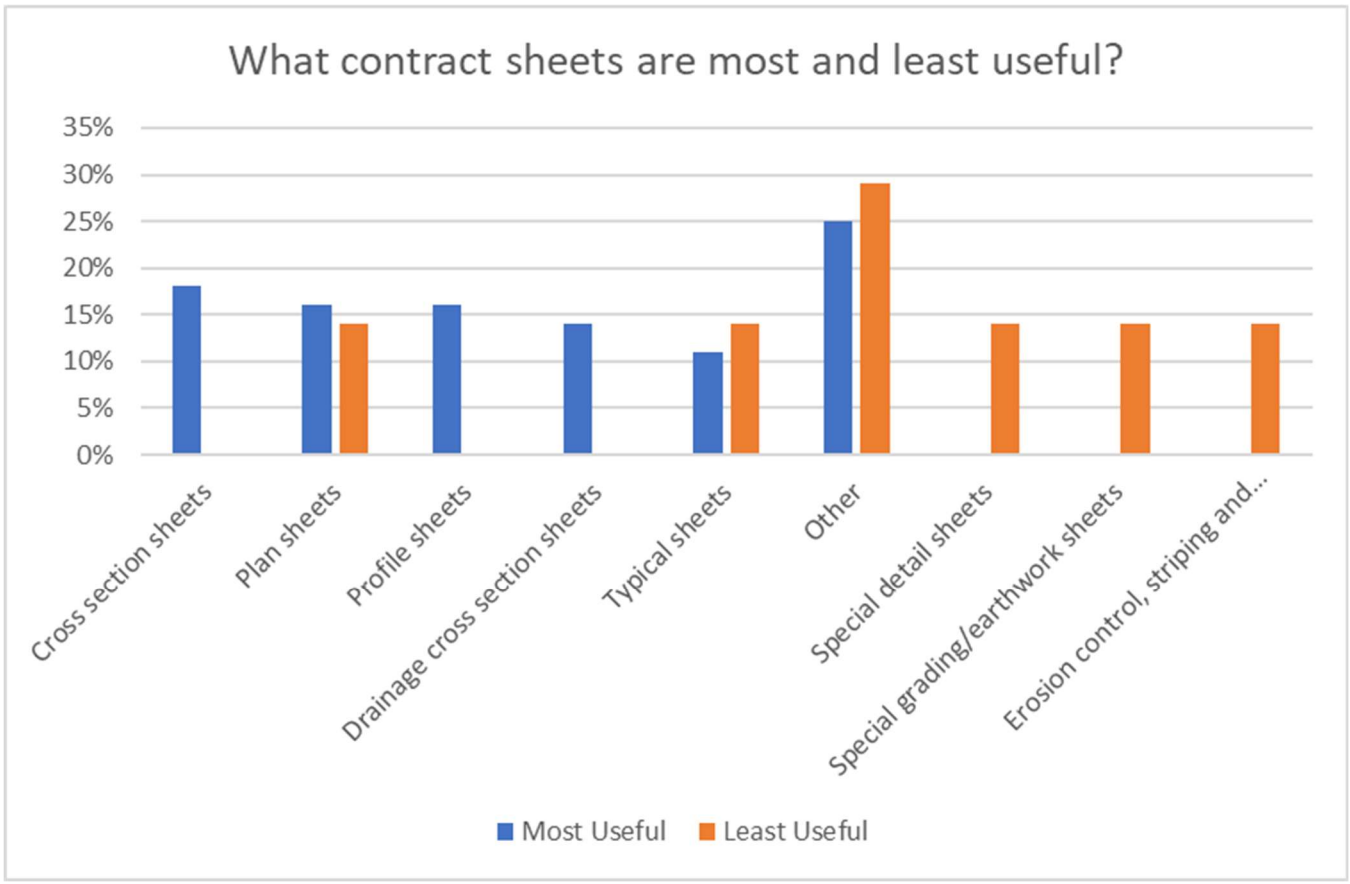
Contractors responding to the survey provide a variety of services to ADOT, including engineering surveys, earthwork and paving, bridges and structures, drainage networks and traffic control. Contractors in Arizona are using AMG technology for a variety of activities, including grading, asphalt and concrete paving, asphalt milling, and slip forming. Experience with providing digital as-builts to the owner after construction was limited to only six respondents. However, two of those contractors considered electronic plan sheets digital as-builts.

There were mixed responses regarding the use of digital terrain models delivered by design teams. Some, build their own or use the earthwork models after verifying the existing conditions while others do not trust design files or do not find digital files useful over electronic plans (PDF). However, other files like spreadsheets, 2D and 3D CAD, GIS and LandXML alignments and surfaces are helpful for

preparing bids and field activities while spreadsheets, 2D and 3D CAD files were the most useful for fabrication.

Most contractors (71%) use Trimble software for AMG activities. However, there is more variability in the software packages being used for quantity takeoffs, including Agtek, OpenRoads Designer, Civil 3D, Bentley Synchro, Navisworks, Bluebeam Revu and Microsoft Excel. Respondents are using a variety of advanced survey equipment and software, including GPS rovers, total station, digital levels, lidar scanners and unmanned aerial systems. While Trimble products are the most used, some contractors also use Agtek and Leica Captivate. One surprising discovery was that contractors are using a variety of products being used for preparing 3D models include Microstation and InRoads (21%), ORD (11%), OBD (11%), Agtek (16%), and AutoCAD and Civil 3D (21%). The perception has always been that contractors use or prefer AutoCAD and Civil3D products. Other products being used for preparing 3D models include Tekla (Trimble) and Revit (Autodesk). When asked which sheets within the contract plans are most and least useful, the responses did not provide a clear consensus when it came to plan sheets and typical sheets (Figure 11).

Figure 11. Comparison of Most and Least Useful Contract Sheets



Contractors indicated survey data is a concern, 63% of respondents indicated that sometimes survey data does not match existing conditions; and 38% said survey data often does not match existing conditions. This is a concern because survey data is the basis for proposed 3D models, and ADOT will need to follow up with contractors to understand this response.

The following are questions respondents are interested in answering:

- What are the new deliverables? (10%).

- What will be the process for updating models due to RFI's and who will update the 3D design models? (12%).
- What is the quality of the 3D design models? (12%).
- How do I access the right files? And How do I know I have the right files? (10%).
- What is included and not included in the 3D design models? (10%).

The following were provided as specific examples of any challenges experienced using digital models for construction with other owners:

- Accuracy of information.
- Conflicts between 3D model and drawings.
- Workspaces do not include necessary features.
- Software limitations for atypical projects.
- Incomplete models.
- Incorrect or outdated models.
- Typically, there are design models and construction models, and the LOD for each of these models is different and need to be adjusted.

When asked what would prevent you from moving forward with delivering and constructing projects in digital format (without physical contract plan sets)? The following items were shared:

- Accuracy, conflicting drawings, field use, computer power and licensing of the programs.
- If requested by ADOT, there is nothing that would keep Kiewit from delivering and constructing. A challenge from current business as usual, will be the verification of quality control. Currently we QC all model construction activities against the ready for construction plan set.
- Not having clear and specific digital strategy from the client.
- What do you need? And why do you need it?
- What are your intentions for future use of the models?
- We need a clear agreement and understanding of the BIM uses for all the phases. ADOT O&M/facilities management department input is critical.

Most contractors (50% of respondents) would prefer to receive monthly updates from ADOT, while 25% of respondents indicated they prefer quarterly ADOT/AGC/ACEC meeting engagements, and 17% of respondents said the best way to communicate is via ADOT/AGC/ACEC annual summits.

Most contractors indicated that the best medium to provide monthly updates is via an e-newsletter email.

Lastly, the following were additional information contractors wanted to share with ADOT:

- It will be a big struggle to get the inspectors and field staff on the same wavelength when not being able to have PDF or paper plan sets.
- We have a varied degree of experiences with digital delivery on projects across several DOT's and would welcome the opportunity to discuss our experiences with ADOT.

- The implementation of a project management tool will be key for success, Procore can really help.

Summary of Consultant Responses

Overall, consulting firms are more apprehensive to adopting digital delivery than contractors, which is not surprising considering the liability and standard of care required by professional engineers. Nevertheless, the responses were positive in the sense that consultants are willing to take on the challenge as long as there is a true partnership between ADOT and the consulting community. Consultants were more vocal about their concerns, and often provided comments related to what they thought the contractors needed or thought. In many cases, consultants are not fully aware about the capabilities of contractors in Arizona.

Composition of respondents was 29%, 24% and 48% large, medium, and small firms respectively; and 24% of all respondents were Disadvantage Business Enterprise (DBE) companies. Respondents typically provide roadway design (17%), ROW and/or utility coordination (18%), bridge design (14%), planning (14%), traffic engineering (17%), and other (21%) non-specified professional services. Surprisingly, 41% of respondents were not familiar with the ADOT Digital Delivery Program but were interested in learning more about it.

Table 7. Consultant Survey Respondents Available for Follow-Up Discussions

Name of Respondent	Company	Contact Information
Andrew Haines	Jacobs	andrew.haines@jacobs.com (602) 710-6310
Jason Pagnard	Burgess & Niple, Inc.	jason.pagnard@burgessniple.com (602) 244-8100
Brian Riley	POINT Engineers	briley@pointengineers.com (602) 814-0652
Sean Samsel	Psomas	ssamsel@psomas.com (520) 822-4581
Allen Hathcock	Kimley-Horn	allen.hathcock@kimley-horn.com (602) 678-3424
Rodney Bragg	AECOM	rodney.bragg@aecom.com No phone number provided
Manny Medrano	WSP	manuel.medrano@wsp.com (480) 449-7732

Name of Respondent	Company	Contact Information
Jeff Holzmeister	J2 Engineering & Environmental Design	jholzmeister@j2design.us (480) 250-2796
Robert Brantley	STV Incorporated	robert.brantley@stvinc.com (480) 262-5237
Keith Koprowski	Y2K Engineering, LLC	kkoprowski@y2keng.com (480) 320-9137
Paul Balch	Dibble	paul.balch@dibblecorp.com (602) 346-5770
Al Field	Al Field and Associates	al.field@alfield-assoc.com (602) 616-3618
Yogesh Mantri	YSMA	yogesh@mantrieng.com (480) 283-7229

As expected, the most mature discipline in producing 3D models is roadway engineering (43%), and the least mature is structures (48%) followed by drainage and utilities (38%). Figure 12 illustrates the respondents experience related to producing 3D models for ADOT projects. Figure 13 illustrates the percent of expert modelers by discipline. More than 50%of roadway staff are considered expert models compared to only 21% for drainage and utility and 8% for structures design staff. Engineers with 5-10 years of engineering experience are usually the ones developing 3D models (38%) followed by junior staff with less than 4 years of experience (29%). Only 19% of engineers with more than 10 years of experience develop 3D models. Surprisingly, only 14% of 3D models are developed by non-engineer designers or CAD technicians.

Figure 12. 3D Modeling Design Firm Experience by Discipline

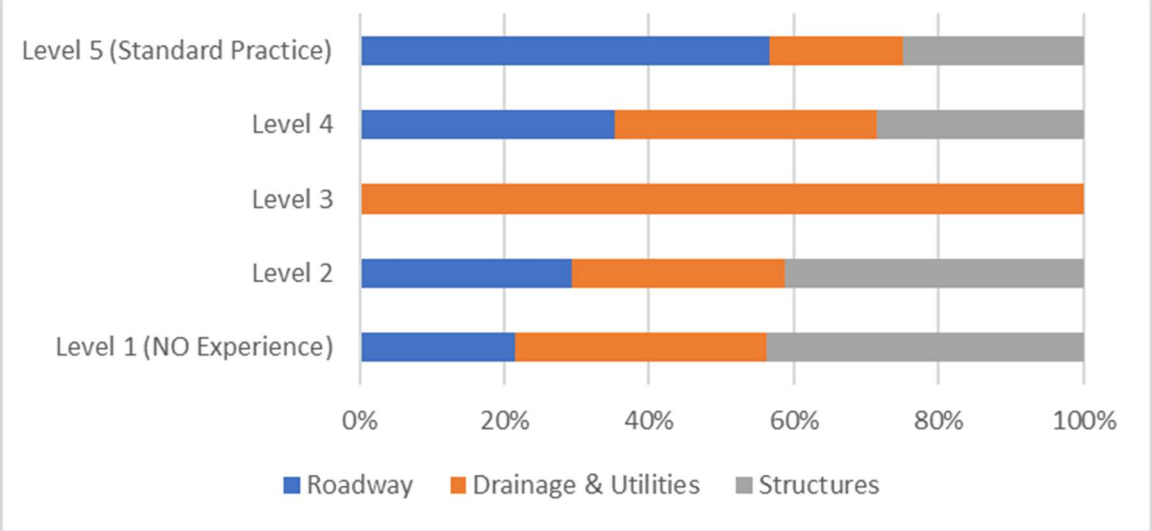
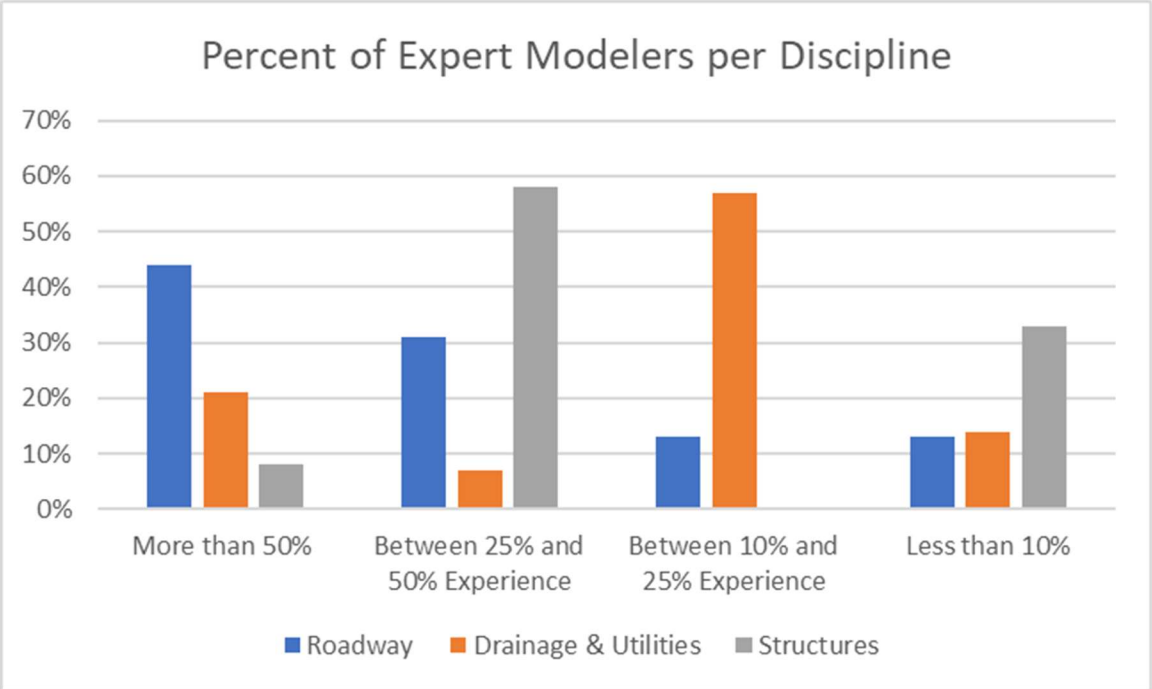


Figure 13. Percent of Expert Modeling Staff per Discipline



Most consulting firms have experience with incorporating bid documentation, such as pay items, specifications or model object attributes using modern CAD software (using Bentley or Autodesk products). Only 24% of respondents do not have any experience with this technology.

Design consulting firms provided the following concerns about delivering contractual design models for construction activities:

- Additional liability for producing more detailed models (16%).

- Additional time to model in more detail (16%).
- Lack of proper scope and fee for model-based design (15%).
- QC Review of model data (13%).
- Signing and sealing (11%).
- Other non-specified concerns (28%).

Concerns about digitally signing and sealing include:

- Model updates during construction and chain of custody (36%).
- Lack of QC tools and processes for ensuring the model is accurate (26%).
- Increased liability when producing a more detailed model (20%).
- Available technology for digital signatures on model elements/files (16%).
- Lack of staff availability (2%).

Table 8. Advantages and Disadvantages of Model-Based Design Versus Traditional Plan Delivery

Advantages	Disadvantages
• Better and easier clash/conflict detection (25%) • Less redundancy when creating notes, summary tables, annotations, etc. (18%) • Automation of quantity takeoffs (16%) • Reducing time in creating sheets (15%) • Easier to change the design when you don't need to create updated sheets (17%) • More accurately conveyance of the design intent (9%)	• Takes longer to create a more detailed model (26%) • Lack of guidance for preparing the models (what and how to model) (23%) • Non-CAD users cannot review model details (23%) • Models do not convey design intent as accurately (11%) • Quantities are not as accurate when harvested from the design model (2%) • Misuse of models by contractors • Very difficult to ensure sub consultants follow modeling guidelines (2%) • End user (contractor) familiarity with work product (2%) • End user (contractor and/or ADOT familiarity with the work products (2%)

Challenges and roadblocks perceived by the consulting community:

- Setting standards for expectations, risk management and full development of model, interpretation by end users of deliverables.

- Added time to create detailed models is not generally available in the design schedule. Detailed models increase file size which an overwhelm workstations, create bandwidth issues, slow down production, and file updating/sharing processes. Senior engineering staff and QC staff do not have the most current software and training. This complicates the design checking and quality process. Field questions/adjustments will lack easy “redline” capability with digital delivery Will the contractor develop a model for engineer review? Doi they have those capabilities yet?
- Lack universal expectation on the level of detail of modeling, universally accepting format. Difficulty for non-technical agency users to review design. Lack of consistent equipment technology among contractors to be able to fully utilize 3D model benefits,
- Our folks have found that OpenBridge has limited capabilities for complex structure analysis.
- Digital model produces cords on horizontal and vertical curves based on template drop intervals. How will this affect use of model for construction?
- OpenBridge Modeler has limited capabilities in analyzing complex structures.
- Have not had many specific issues yet.
- Accuracy of information insufficient for fabricator take-offs. Many dimensions are not known until the fabricators supply the products.

Consulting firms were also asked about their experience with working with contractors in a design-build D-B project, and this is what they had to say:

- Most design firms have experience working with contractors on D-B projects (76% of respondents).
- File types delivered to contractors on D-B projects include PDF plan sets (26%), 2D CAD files (17%), LandXML files (surfaces) (17%), LandXML files (geometry/alignments) (14%), LandXML files (breaklines/polylines), 2D and3D files (14%), and Revit and Navisworks 3D and BIM models (3%), and technical reports (1 response).
- Feedback received from contractors include:
    - ADOT required design software is almost never used by the construction community. They have their preferred software and file formats that sync with their earthwork packages, AMG, etc. Designers have to export/convert 3D info into file formats that are not easily checked or utilized by the root design software (InRoads/ORD). Contractors usually using this information at their own risk and generating a number of iterations between designers and contractors to arrive at the contractor’s desired outcome.
    - Breaking models into “construction stages” (rough grade, excavations, subgrade, finished grade) provides value for constructability, enables their automated equipment to be more efficient.
    - We’ve never provided a construction-ready digital model to a contractor on a D-B project.
    - Models are only as good as the existing information (topo or other data). Field personnel can sometimes rely too heavily on models and not correctly match field conditions.

- Bentley products being used on ADOT projects include ProjectWise (26%), ORD (26%), InRoads SS4/SS10 (16%), InRoads SS2 (11%), ORD Drainage and Utilities Modeling (10%), and other non-specified software (10%).
- Plan sheets that could be eliminated or significantly reduced from:
    - Roadway project sets include profile sheets (17%), summary sheets (17%), fact sheet (13%), typical sections (13%), plan sheets (11%), other non-specified sheets (28%).
    - Bridge project sets include Face sheet (21%), typical sections (17%), summary sheets (17%), profile sheets (17%), construction phasing sheets (17%), and other non-specified sheets (10%).

Most consulting firms indicated their preferred way of communication is quarterly ADOT/AGC/ACEC meetings (43%), ADOT/AGC/ACEC annual summit (28%), monthly updates (28%), and website (3%). In addition, consulting firms offered these additional comments related to receiving communications from ADOT:

- With the implementation timeframe, quarterly would be ideal.
- As often as changes occur. Since this is a major shift in our industry, it would be advantageous to stay as informed as possible. The design community needs to be aware of ADOT's goals, plans, decisions, and timelines so that we can best prepare to support ADOT in delivering quality design projects.
- As frequently as there are meaningful updates/changes to progress toward implementation. Advanced communication helps us to prepare for the future and give feedback while the process is being developed.
- Information should be easily searchable so that users can find when they need it.
- Project website for digital delivery project.
- Monthly, preferable, if there is movement; quarterly, minimum, seeing as there are perhaps 11 quarters until the transition is to occur.
- As often as possible when changed information or new information is available. Minimum quarterly.
- It all depends on your specific needs and interests. If we engage in a project that requires regular updates on the digital delivery plan, we may want to receive communications on a frequent basis, such as weekly or monthly. On the other hand, if we are only interested in high-level updates, we may prefer to receive communications less frequently, such as quarterly or biannually. The frequency of communications should be determined by your specific needs and importance of the information being shared.
- When asked what would prevent you or your firm from moving forward with delivering and construction projects in a digital format (without physical contract plan sets)? This is what consulting firms had to offer:
    - Resolving risk management elements; working with subs who are capable of performing services. DBE firms are limited in number as-is, and this could limit the number of capable firms further. One of the challenges we have seen in the industry I inflexibility between ORD versions with Bentley, and we have engaged Bentley at the leadership level to discuss these items. Having a good approach on software

and/or model version control, and consistency with ADOT's expectations, will help this process go smoothly.

- Vague or poorly defined guidelines and standards would be harmful to this shift in project delivery. Clear requirements and expectations from all parties involved – contractors, ADOT, field personnel, oversight, and design community would be critical to successful implementation. It is what ADOT has currently and would need to be in place for effective digital delivery. Is there a change in firms' liability and E&O insurance requirements? How are digital designs sealed by the engineer?
- Lack of clear expectations from ADOT on what the deliverables need to entail. Also note the inputs need to be good (survey quality) to reflect a quality output model.
- Unclear expectations what is needed form reviewers and unclear what is needed form field staff to execute construction.
- Knowledge or guidelines form AZBTR regarding sealing digital models.
- Clear guidance on what is expected from ADOT reviewers as well as construction/field staff.
- Document security concerns, ability of subconsultant teaming partners to be as fluent with the technology (costs may be prohibitive for smaller firms to buy in).
- Not having full integration/implementation between consultants, contractors and ADOT
- Subconsultants (especially smaller firms) that do not have the capacity/resources to acquire and use the software.
- Legal hurdles from AGC or our E/O Insurance.
- Resolving risk management elements; working with subs who are capable of performing services. DBE firms are limited in number as-is, and this could limit the number of capable firms further. One of the challenges we have seen in the industry is inflexibility between ORD versions with Bentley, and we have engaged Bentley at the leadership level to discuss these items. Having a good approach on software and/or model version control, and consistency with Department expectations, will help this process go smoothly.
- There can be several factors that may prevent some firms from moving forward with delivering and constructing projects in a digital format. Some examples could be lack of expertise, resource constraints (software training), resistance to change, compatibility issues, and cybersecurity concerns. All of the above examples have been addressed by our firm but many more can arise as we continue to move forward with digital format.
- Software costs, training, staff expertise.
- Qualified staff.
- ADOT not recognizing the extra cost and level of detail effort needed to develop a truly refined accurate model with every aspect and element carrying precision that is needed to build.
- Limited modeling expertise.

- As consultants, we will adjust to the client's needs.
- Not being a CAD user.

Other information consulting community would like to share with ADOT includes:

- Pilot projects that would be shared with the design and construction community would be beneficial.
- Detailed and comprehensive survey would be critical to the accuracy of a 3D design - this will cost more.
- 3D representation of existing utilities will need to be discussed. Additional SUE effort may be required to show buried facilities in a 3D design.
- We are supportive of digital delivery as the future of the industry, there are many benefits to be realized by consultants, agencies, and contractors. From a consultant perspective, if we can spend more of our budget/effort on refining the design and models instead of drafting often redundant information onto physical sheets, the resulting designs will be of a higher quality and avoid conflicts by enabling better clash detection.
- Alternative delivery methods for the first few projects would be required to ensure contractors are on board (we have done this in Utah for 8 projects).
- ADOT should use a Change Management expert to help engage the construction and engineering community as this is a big change in the way that business is done and there will be a lot of apprehension.
- As a general statement, our firm is seeing this initiative progressing in various other states and incorporating best practices (or collaborating initiatives) would be ideal. It is assumed that ADOT will be engaging others. We are excited to see how this progresses. I'm certain my firm will successfully adapt as we are already providing these services in Arizona to some capacity, and elsewhere in greater capacities.
- Currently design models are produced and brought up to a 90% accuracy level. To achieve the last 10% accuracy often comes with a greater effort than the first 100%. Simple projects are easier to achieve greater accuracy, but complex projects do not seem to achieve the benefit over the cost.
- ADOT is lagging behind other DOT's in the application of digital delivery and needs to refine and update standards and details, templates and requirements to establish a consistent delivery package that meets the needs of ADOT and protects consultants and ADOT from misuse and financial losses from contractor claims.
- I think smaller firms will be at a big disadvantage in being able to compete compared to the medium and larger size firms.
- As-builts by non-CAD users in the field seems like a pretty big hurtle.

Appendix D. Summary of ADOT Software

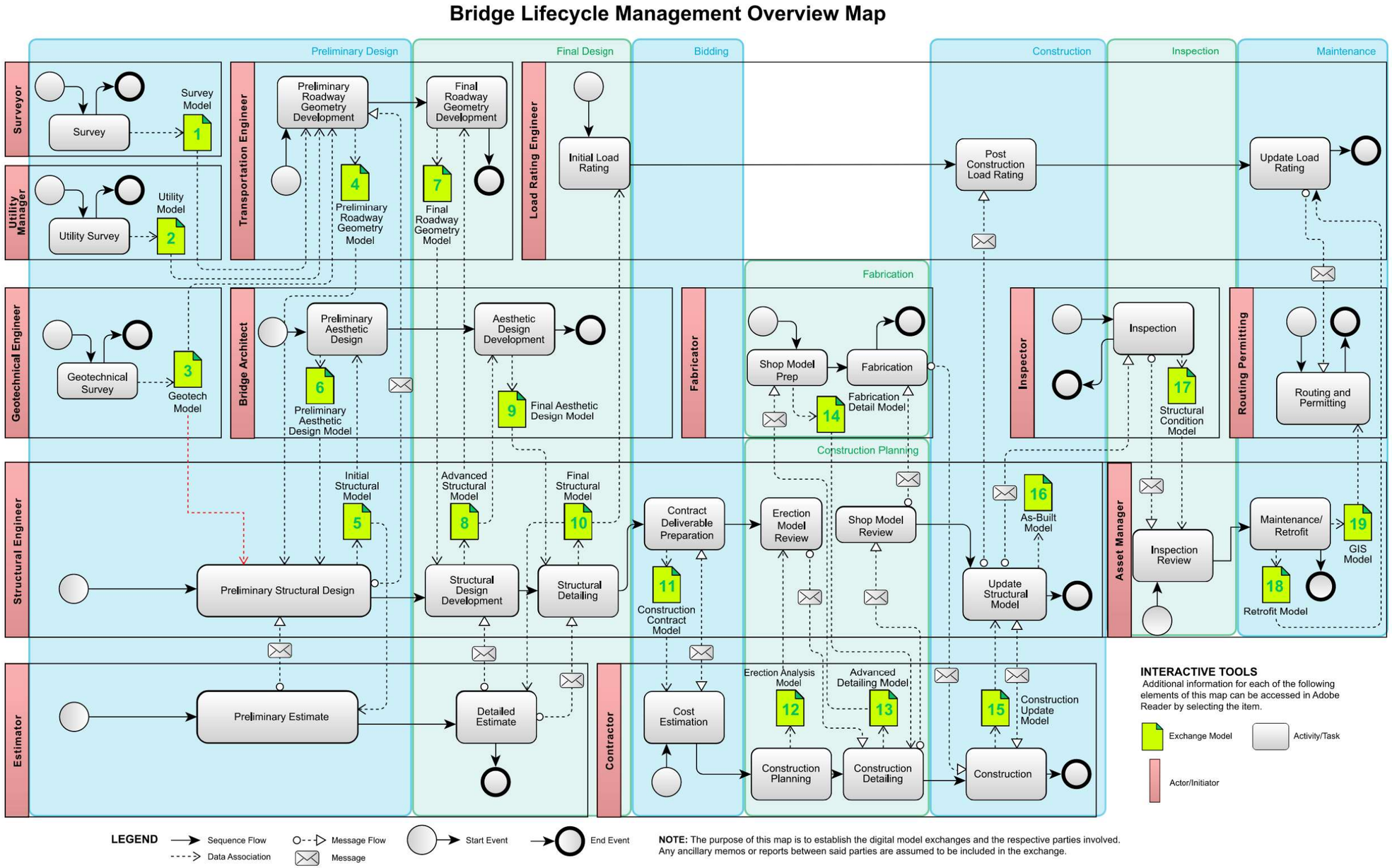
Software Name	Version	Publisher
Survey		
Carlson Civil Suite (IntelliCAD 10.1)	2022	Carlson Software
Cyclone	2022.1	Leica Geosystems
MicroSurvey StarNet 10	10.0.15.974	MicroSurvey Software Inc
Propeller		Propeller Aero
Trimble Access		Trimble, Inc.
Trimble Business Center	v5.70	Trimble, Inc.
Roadway Design Software		
Adobe Acrobat DC	22.001.20117	Adobe Systems Incorporated
AutoTURN Pro 3D 11	11.0.2.115	Transoft Solutions
Bentley InRoads Group V8i (SELECTseries 2)	08.11.07.615	Bentley Systems, Incorporated
CONNECTION Client	11.00.05.34	Bentley Systems, Incorporated
Google Earth Pro	7.3.1	Google
HY-8	7.7	Federal Highway Administration
Hydraulic Toolbox	5.1.4	Federal Highway Administration
Microsoft Office 2021	2112	Microsoft Corporation
Microsoft Office Importer	8.17q	AXIOM
MicroStation CONNECT Edition Update 13	10.13.01.01	Bentley Systems, Incorporated
MicroStation V8i (SELECTseries 10)	08.11.09.912	Bentley Systems, Incorporated
OpenRoads Designer CONNECT Edition 2019R2	10.07.03.18	Bentley Systems, Incorporated

Software Name	Version	Publisher
OpenRoads Designer CONNECT Edition 2021R2	10.10.21.04	Bentley Systems, Incorporated
Project Info Retrieval Tool - PIRT	7.3	ADOT
Drainage Design Software		
ArcGIS Desktop 10.8.2	10.8.2	Environmental Systems Research Institute, Inc.
cHECk-RAS	2.0.1	FEMA
Culvert Master	10.03.00.03	Bentley Systems, Incorporated
FLO-2D	2014	FLO-2D Software, Inc.
HEC-GeoHMS	10.2	U.S. Army Corp. of Engineers
HEC-GeoRAS	10.2	U.S. Army Corp. of Engineers
HEC-HMS	4.9	U.S. Army Corp. of Engineers
HEC-RAS	6.2	U.S. Army Corp. of Engineers
OpenFlows FlowMaster	10.03.00.03	Bentley Systems, Incorporated
OpenFlows StormCAD	10.03.04.53	Bentley Systems, Incorporated
Storm Water Management Model (SWMM)	5.2	US EPA
Surface-water Modeling System (SMS)	13.2.12	Aquaveo, LLC
Watershed Modeling System (WMS) Software	11.1.9	Aquaveo, LLC
Bridge Design Software		
BRASS-CULVERT	V 3.5	Wyoming Department of Transportation
BrRating	7.1	AASHTO
CONNECTION Client	11.00.05.34	Bentley Systems, Incorporated
GTStrud1	2016R1	Hexagon

Software Name	Version	Publisher
InRoads Group V8i (SELECTseries 2)	18.11.07.615	Bentley Systems, Incorporated
Iplot Organizer	08.11.11.56	Bentley Systems, Incorporated
LEAP Concrete Bridge	19.0.0.50	Bentley Systems, Incorporated
LPILE v2019	2019	Ensoft Inc.
MathCadd	2000	MathSoft Inc
MathCadd	15	PTC Mathcad
MathCadd Prime	3.1	PTC Mathcad
MDX Client	Client	MDX Software
Microstation CONNECT Edition	10.13.1.1	Bentley Systems, Incorporated
MicroStation V8i (SELECTseries 10)	08.11.09.912	Bentley Systems, Incorporated
NSBA Bridge Splice	1	NSBA Steel Bridge Suite
OpenBridge Designer CE 2021 Releae 1	10.10.0.26	Bentley Systems, Incorporated
OpenBridge Designer CONNECT Edition	10.08.0.17	Bentley Systems, Incorporated
OpenRoads Designer CONNECT Edition	10..07.03.18	Bentley Systems, Incorporated
Roadside Development		
Adobe Creative Cloud	5.8.0.592	Adobe Systems Incorporated
Trimble Sketchup	22.0.316	Trimble, Inc.
Pavement Design		
Backcalulation Tools	1.1.6	AASHTOWARE
DowelCAD	2.0.020	ACPA - American Concrete Pavement Association
OnBase		Hyland Software

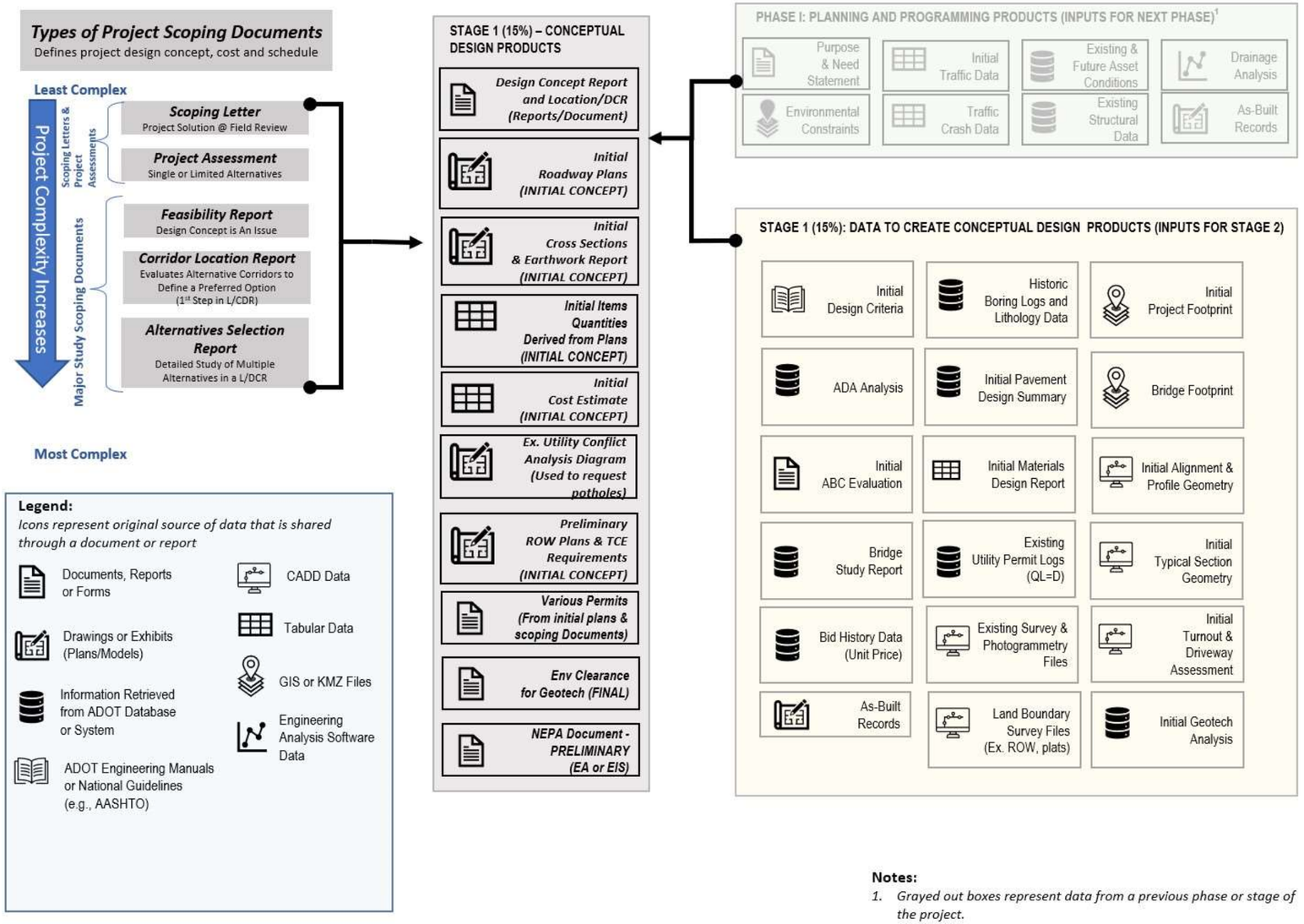
Software Name	Version	Publisher
Pavement ME Design	2.6.2.1	AASHTOWARE
SODA (Structural Analysis)		ADOT
Pavement Design		
Central Materials Testing Program (CMTP)		ADOT
PreDesign		
IHSDM 2018 Release V15.0.0 (remove only)	17.0.0	FHWA
IHSDM - Hiren and Walkups		
Traffic		
Acuity Visual		Acuity Brands
IHSDM 2018 Release V15.0.0 (remove only)	17.0.0	FHWA
OpenRoads SignCAD	10.02.00.11	Bentley Systems, Incorporated
PTV Vissim		PTV Group
Rodel Roundabout Analysis Software		Rodel Interactive
Synchro		Trafficware
Environmental		
TransCAD (MAG Traffic Data)		Caliper
C&S		
BidX		Infotech
ProjectBids		AASHTOware
Asset Management		
3-GIS		SSP Innovations
BrManagement		AASHTOware
dTIMS (Pavement Management)		
Feature Inventory System (FIS)	2019	SQL Server 2019
PECOS (Maintenance Database)		

Appendix E. TPF-5(372) BIM for Bridges and Structures Pooled Fund “Bridge Lifecycle Management Overview Map



Appendix F. ADOT Infrastructure Delivery and Operations Milestone Delivery Diagrams

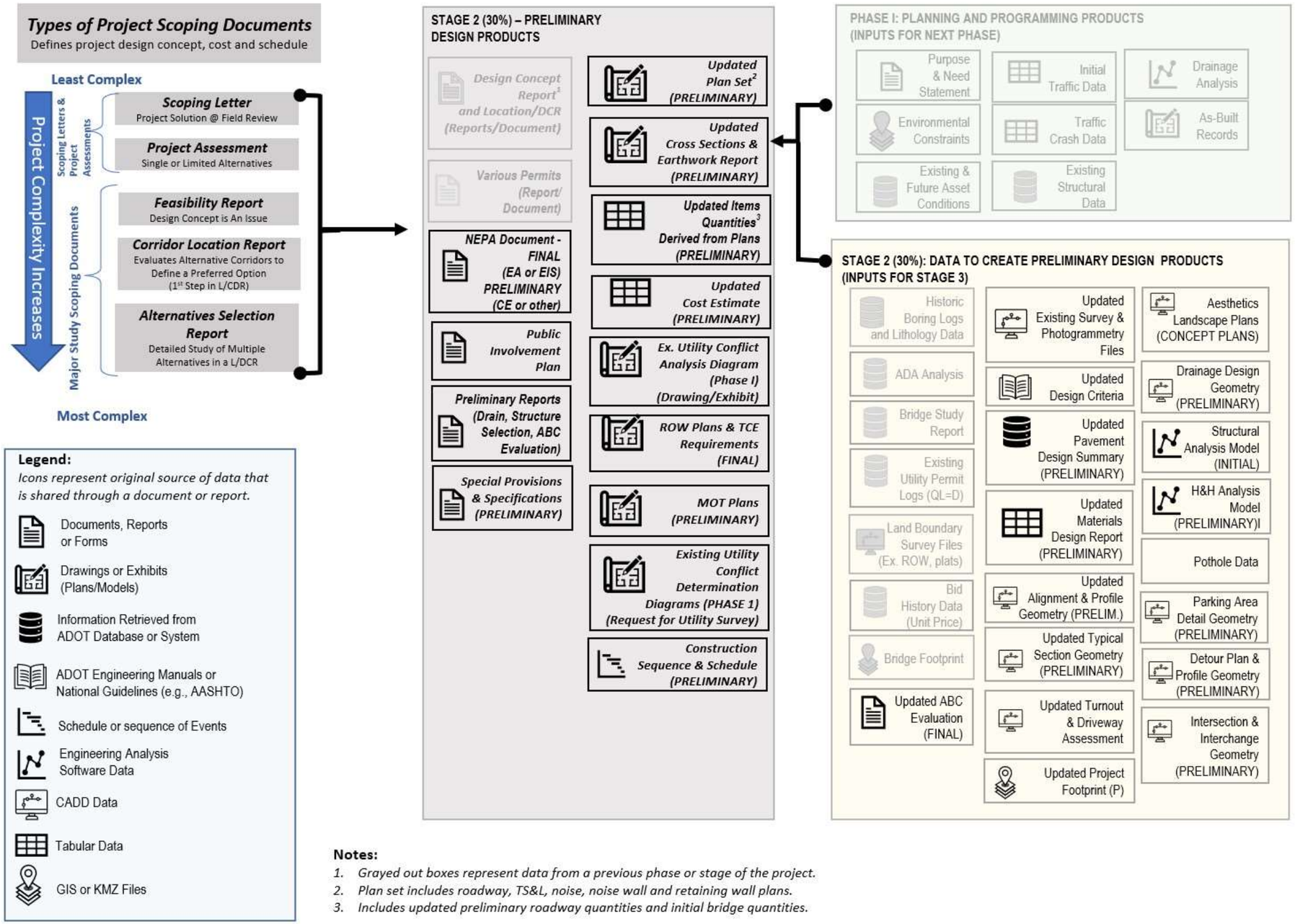
Stage 1 – 15%. Conceptual Design Data Exchanges Diagram



Notes:

1. *Grayed out boxes represent data from a previous phase or stage of the project.*

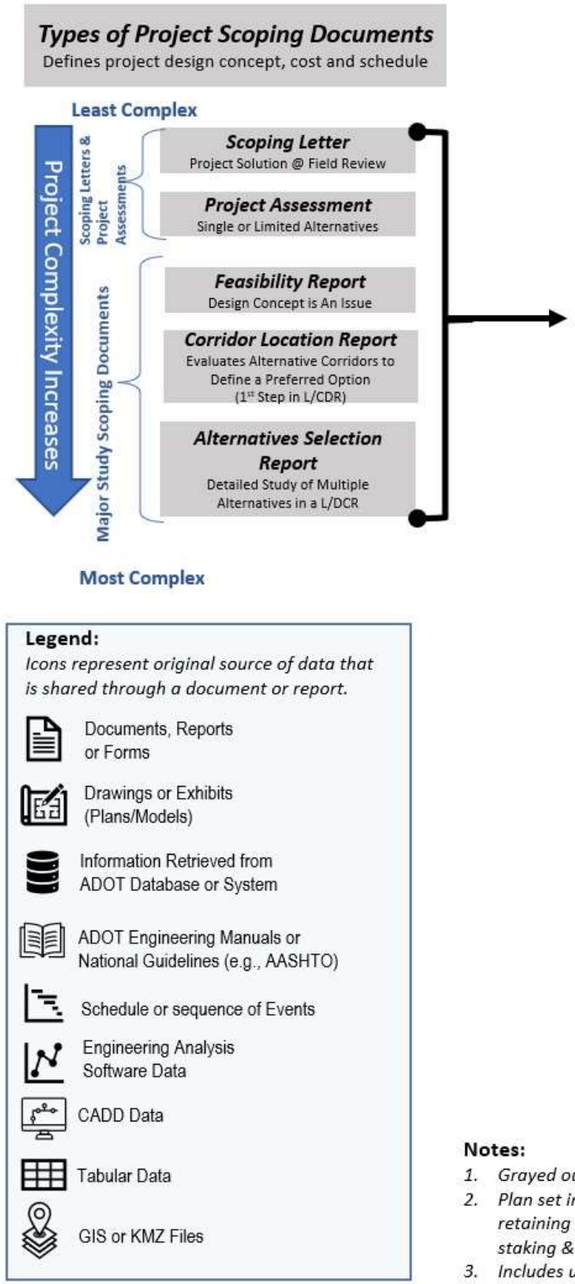
Stage 2 – 30%. Preliminary Design Data Exchanges Diagram

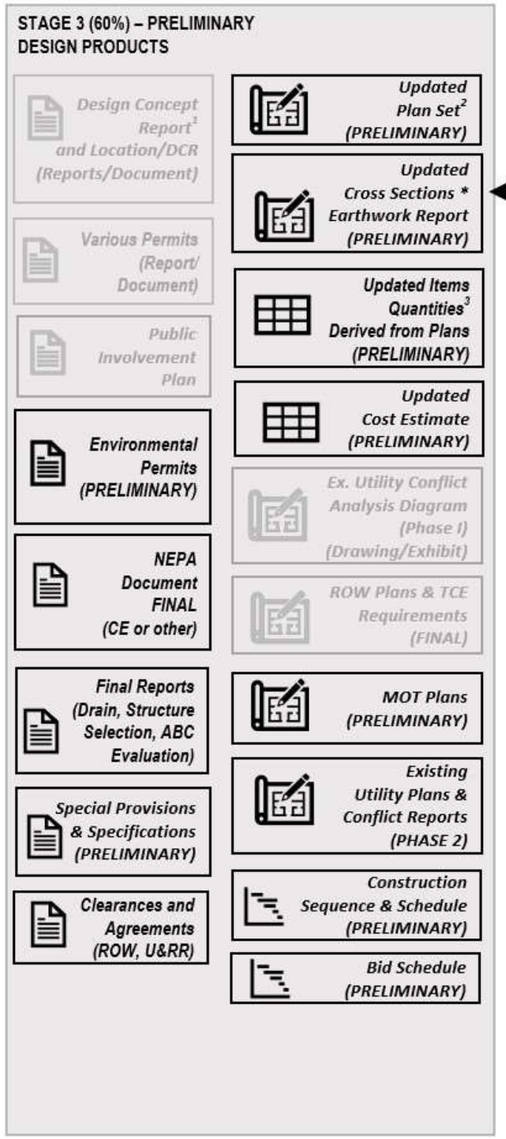


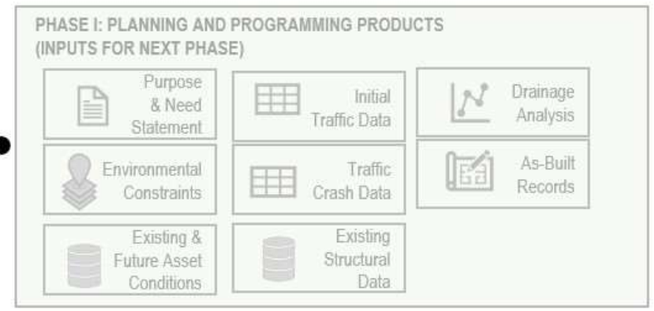
Notes:

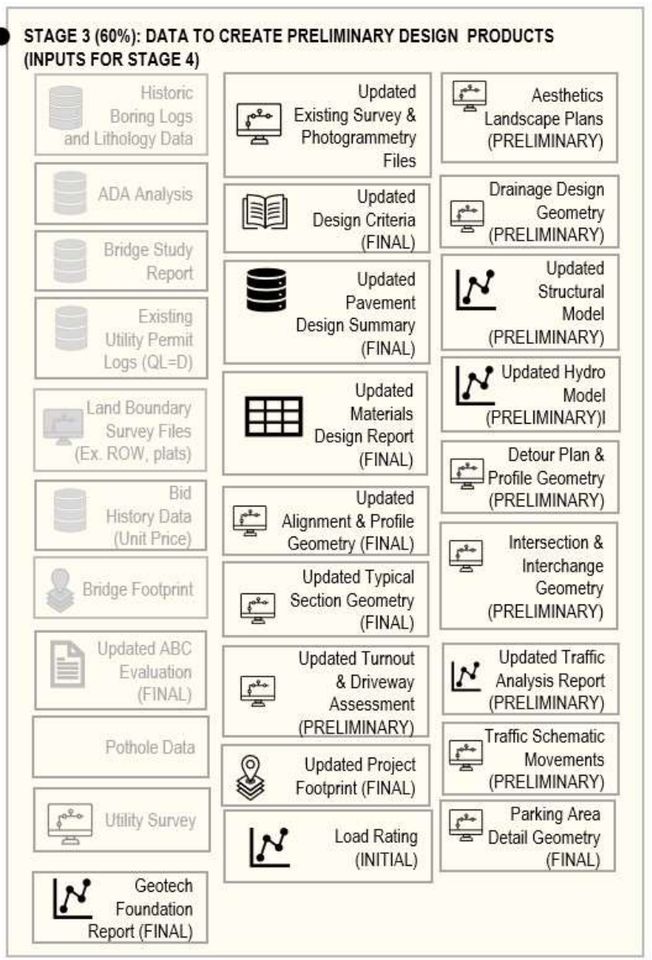
1. *Grayed out boxes represent data from a previous phase or stage of the project.*
2. *Plan set includes roadway, TS&L, noise, noise wall and retaining wall plans.*
3. *Includes updated preliminary roadway quantities and initial bridge quantities.*

Stage 3 – 60%. Preliminary Design Data Exchanges Diagram





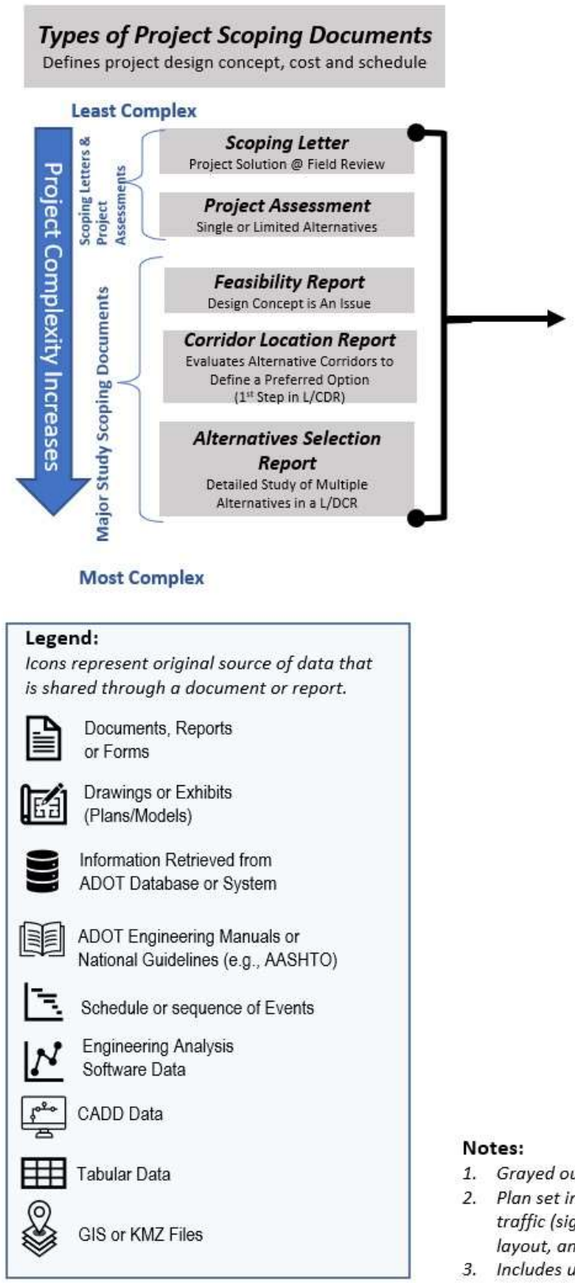


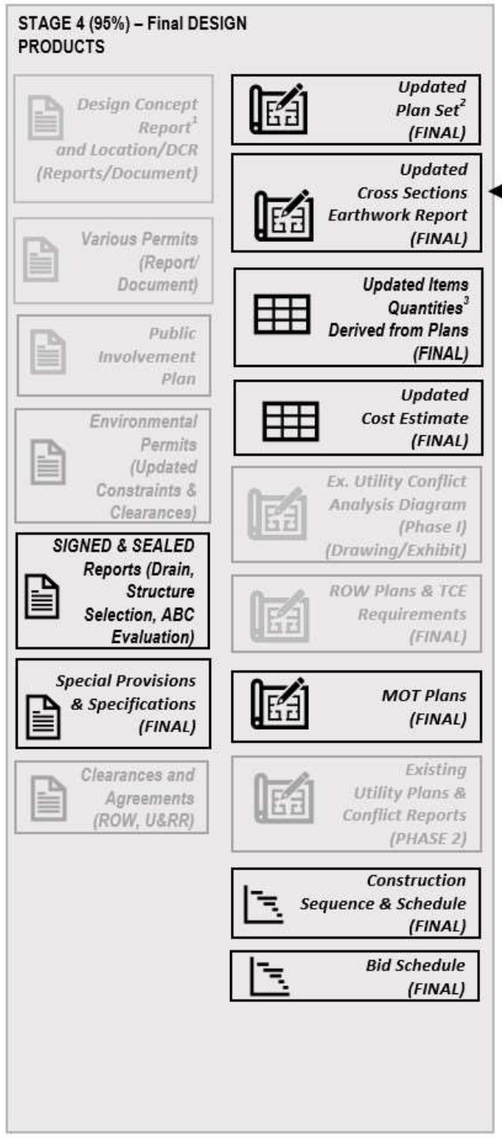


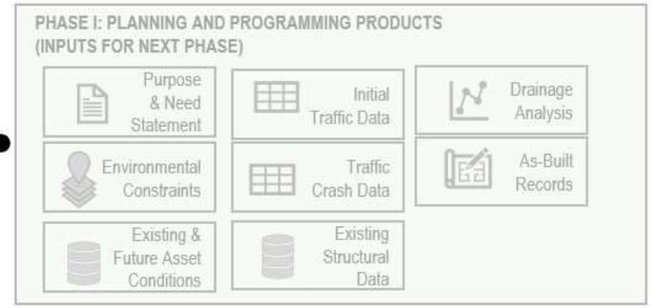
Notes:

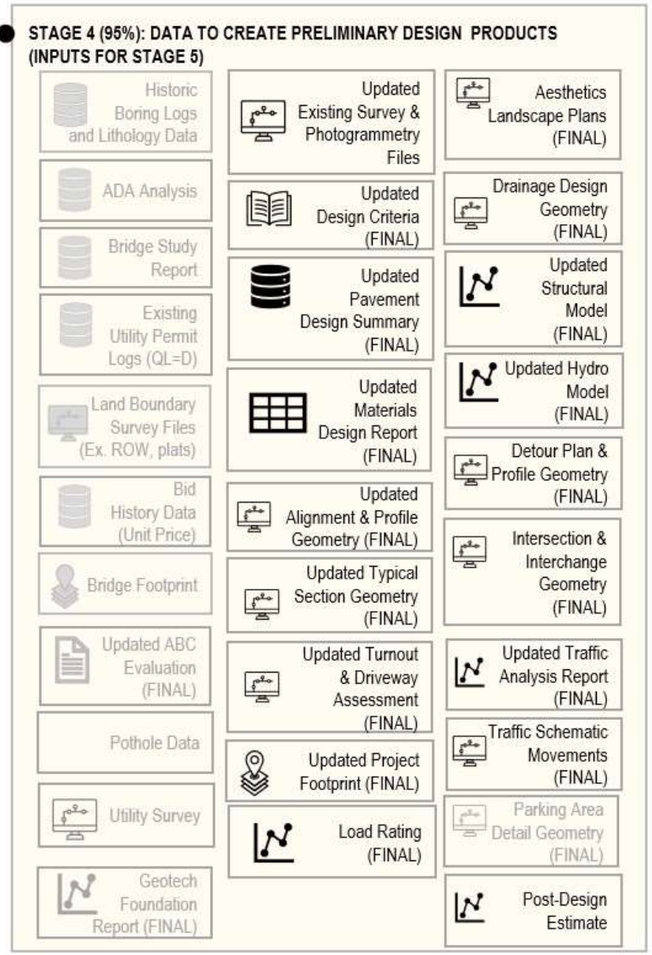
1. *Grayed out boxes represent data from a previous phase or stage of the project.*
2. *Plan set includes updated preliminary roadway, drainage, structural, noise & retaining wall, traffic (signals, lighting, signing, pavement markings, etc.), E&S, staking & joint layout, and fencing details, as well as topsoil plating.*
3. *Includes updated preliminary roadway & bridge quantities.*

Stage 4 – 95%. Final Design Data Exchanges Diagram





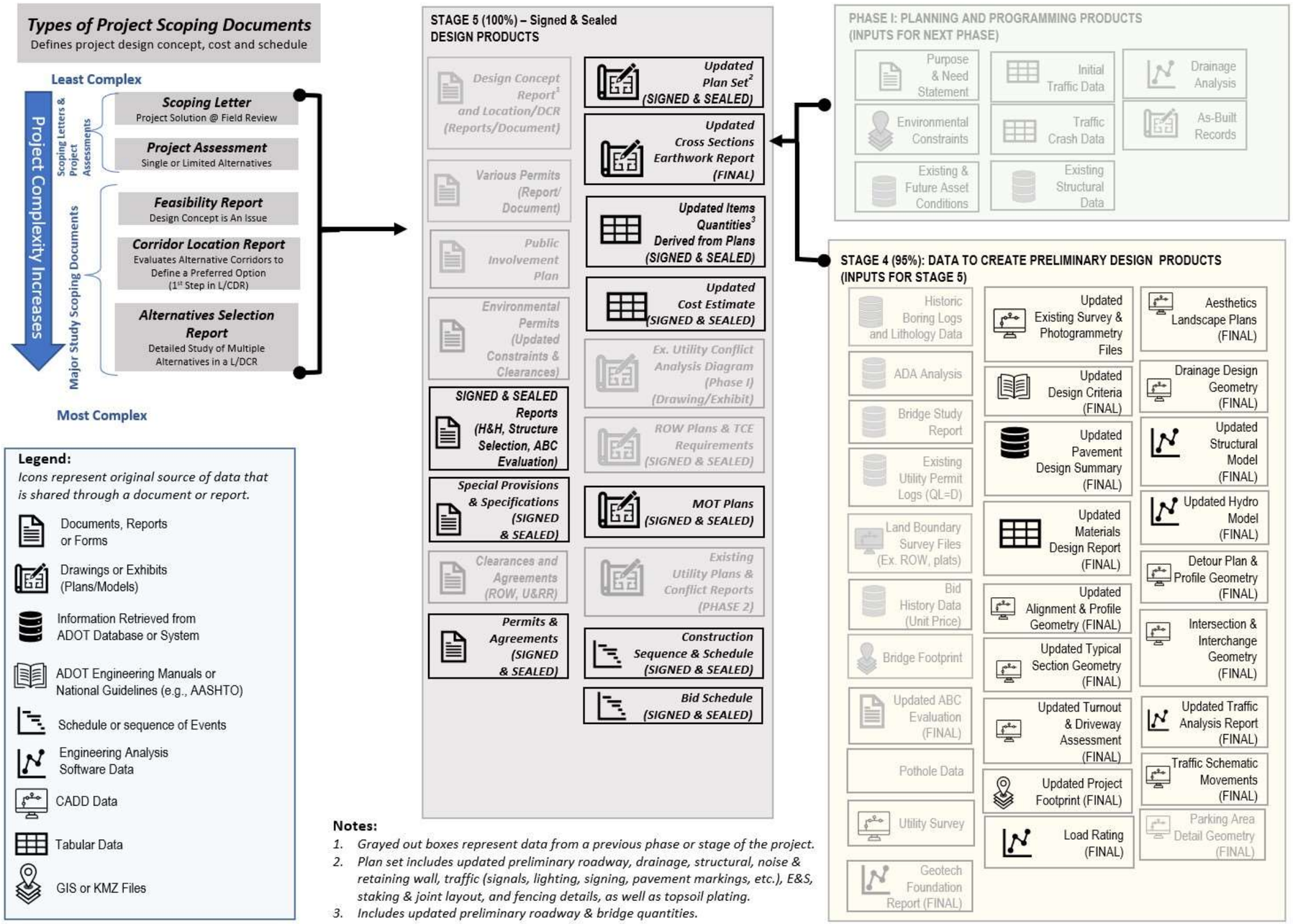




Notes:

1. *Grayed out boxes represent data from a previous phase or stage of the project.*
2. *Plan set includes final roadway, drainage, structural, noise & retaining wall, traffic (signals, lighting, signing, pavement markings, etc.), E&S, staking & joint layout, and fencing details, as well as topsoil plating.*
3. *Includes updated preliminary roadway & bridge quantities.*

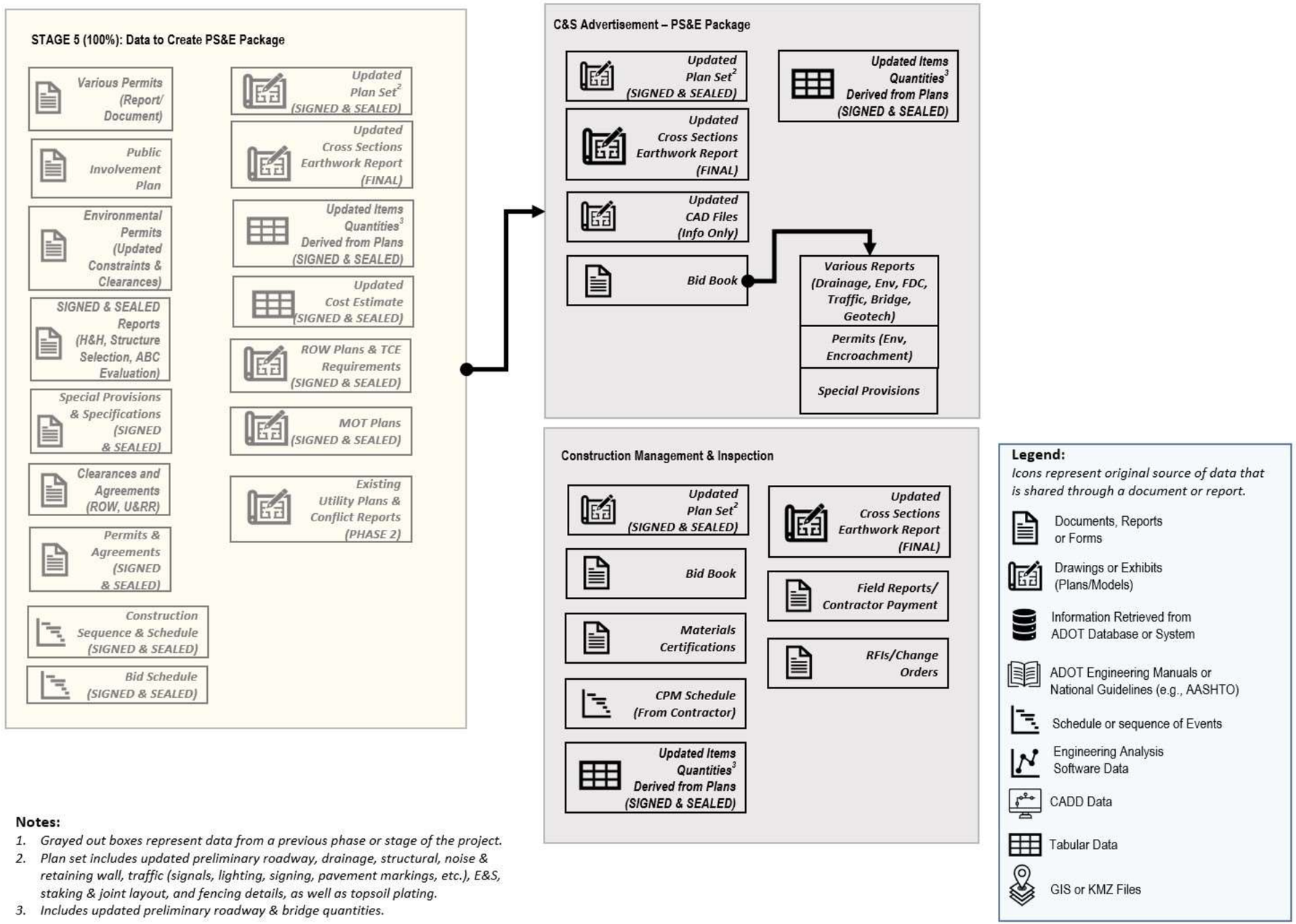
Stage 5 – 100%. Final Design Data Exchanges Diagram



Notes:

1. *Grayed out boxes represent data from a previous phase or stage of the project.*
2. *Plan set includes updated preliminary roadway, drainage, structural, noise & retaining wall, traffic (signals, lighting, signing, pavement markings, etc.), E&S, staking & joint layout, and fencing details, as well as topsoil plating.*
3. *Includes updated preliminary roadway & bridge quantities.*

Bidding and Construction Management/Inspection



Notes:

1. *Grayed out boxes represent data from a previous phase or stage of the project.*
2. *Plan set includes updated preliminary roadway, drainage, structural, noise & retaining wall, traffic (signals, lighting, signing, pavement markings, etc.), E&S, staking & joint layout, and fencing details, as well as topsoil plating.*
3. *Includes updated preliminary roadway & bridge quantities.*