Accelerated Implementation and Deployment of Advanced Digital Construction Management Systems (ADCMS)

Report to Congress

Federal Highway Administration
U.S. Department of Transportation

Table of Contents

I. Executive Summary

This report is required by Section 13006(d) of the Bipartisan Infrastructure Law (BIL) (enacted as the Infrastructure Investment and Jobs Act (Pub. L. 117-58, Nov. 15, 2021)), which directed the Secretary of Transportation to produce a report on Advanced Digital Construction Management System (ADCMS) technologies. It discusses advanced technologies, such as Electronic Construction (e-Construction), Three-dimensional (3D) Engineered Models, Unmanned Aircraft Systems (UAS), and Electronic Ticketing (e-Ticketing). The report also includes recommendations for integrating new technological developments into national design guidelines developed by the American Association of State Highway and Transportation Officials (AASHTO) and the Federal Highway Administration (FHWA) and provides a roadmap for measuring the impacts of ADCMS.

Data and statistics from FHWA's Every Day Counts (EDC) Program and the *Technological Capabilities of Departments of Transportation for Digital Project Management and Delivery* report developed by the Transportation Research Board's (TRB) National Cooperative Highway Research Program (NCHRP) are used to illustrate the extent of States' adoption, implementation, and development of ADCMS technologies. A total of 42 responses were received from 51 State departments of transportation (State DOT), with 37 reporting the use of ADCMS technologies for construction, 2 reporting the use of ADCMS technologies for program support, and 2 reporting the use of ADCMS technologies for other programming efforts. (State DOTs include the District Department of Transportation serving Washington, D.C.)

The data showed that nearly all the technologies and improvements reviewed are in some stage of development or implementation, or have been adopted for use by State DOTs and transportation agencies. State DOTs and transportation agencies almost universally require additional research and extensive field testing to demonstrate and evaluate the benefits and feasibility of deploying the systems in a live environment. The research and test results are essential to accurately identify the most effective ADCMS technologies that will aid State DOTs and transportation agencies in their construction management. Further research is also necessary to determine the most appropriate locations for deployment of different ADCMS technologies (i.e., to achieve maximum benefit) and to better understand how to match the proper technology to the specific capabilities of staff and to the project development process to assure the greatest safety impact in the most cost-efficient manner. Once ready for adoption, these technologies may be incorporated into educational efforts, including outreach programs needed to increase State DOT awareness of how the technologies work and how they are used to improve the construction management process.

II. Introduction

Section 503(c)(5)(C) of Title 23, United States Code (U.S.C.), as added by Section 13006(a) of BIL, provides $20 million of Technology and Innovation Deployment Program (TIDP) funds for each of fiscal years (FY) 2022 through FY 2026 to accelerate the deployment and implementation of ADCMS technologies. Due to the imposition of the obligation limitation, as well as reserving funds necessary for other activities to accelerate the deployment and implementation of ADCMS activities, such as peer exchanges, the development and deployment of best practices, and training, for each fiscal year, up to $17 million of these funds will be available for award under the ADCMS Grant Program. The actual amount available to be awarded under the Notice of Funding Opportunity will be subject to the availability of funds. Section 13006 of BIL amended 23 U.S.C. 503 by adding the following:

> The Secretary shall establish and implement a program under the technology and innovation deployment program established under paragraph (1) to promote, implement, deploy, demonstrate, showcase, support, and document the application of advanced digital construction management systems, practices, performance, and benefits. *See* 23 U.S.C. 503(c)(5)(A).

The BIL identifies 9 goals for the ADCMS program, the first of which is:

> (i) accelerated State adoption of advanced digital construction management systems applied throughout the construction lifecycle (including through the design and engineering, construction, and operations phases) that:
>
> I. Maximize interoperability with other systems, products, tools, or applications;
> II. Boost productivity;
> III. Manage complexity;
> IV. Reduce project delays and cost overruns; and
> V. Enhance safety and quality.

See 23 U.S.C. 503(c)(5)(B)(i).

Other goals in the legislation include:

- More timely and productive information sharing among stakeholders;
- Use of digital technologies on construction sites that enable construction workers to perform tasks faster, safer, and more accurately;
- Development and deployment of best practices;
- Increased technology adoption and deployment to integrate into contracts for construction;
- Technology training and workforce development;
- Guidance documents for State DOTs;
- Reduced environmental footprint of construction projects; and
- Enhanced worker and pedestrian safety.

See 23 U.S.C. 503(c)(5)(B)(ii)-(ix).

This new grant program provides funding to States to purchase technology platforms, train personnel, develop best practices, and develop guidance to assist in updating regulations, which allows project sponsors and contractors to capture fully the efficiencies and benefits of ADCMS, among other uses. Digital transformation in the construction and engineering sectors directly supports the advancement of Building Information Modeling (BIM),[1] which is a priority for the U.S. Department of Transportation (DOT) and specifically, FHWA; the ADCMS program will allow States to take advantage of this momentum.

In the sixth round of the FHWA EDC Program (EDC-6), which seeks to accelerate innovation in the transportation industry, FHWA promoted e-Ticketing and Digital As-Builts, which are components of ADCMS, to accelerate adoption of digital technology with State DOTs, local public agencies, and Tribes across the United States. The ADCMS Program works to ensure that FHWA plays a leadership role in the process of promoting equitable and cost-effective construction management systems into construction and engineering activities.
This report reflects the work of FHWA.

This report addresses the reporting requirements in Section 13006(d) of BIL:

> (d) ACCELERATED IMPLEMENTATION AND DEPLOYMENT OF ADVANCED DIGITAL CONSTRUCTION MANAGEMENT SYSTEMS.—Not later than 1 year after the date of enactment of this Act, the Secretary shall submit to the Committee on Environment and Public Works of the Senate and the Committee on Transportation and Infrastructure of the House of Representatives a report that includes—
>
> (1) a description of—
>
> (A) the current status of the use of advanced digital construction management systems in each State; and
>
> (B) the progress of each State toward accelerating the adoption of advanced digital construction management systems; and
>
> (2) an analysis of the savings in project delivery time and project costs that can be achieved through the use of advanced digital construction management systems.

In response, the report identifies recent FHWA rules, guidance, and resources that affect advanced digital construction monitoring as well as ongoing opportunities and challenges as FHWA moves ahead with its effort to implement ADCMS into managing construction and engineering activities.

A. Overview of Advanced Digital Construction Management Systems

The FHWA generally defines ADCMS systems as digital technologies and processes for management of construction and engineering activities, including systems for infrastructure planning and coordination, design, construction, maintenance, modernization and management, and asset management including hardware, mobile devices, software, “internet of things,” and personnel. It also includes the development and support of systems to enhance and share data

1 FHWA-HRT-21-064: Advancing BIM for Infrastructure: National Strategic Roadmap (dot.gov)

across an asset's lifecycle and between organizational silos, also referred to as maximizing interoperability.

Examples of digital construction systems include, but are not limited to, the following:

1. Commercial cloud-based advanced decision-support technologies for infrastructure planning and coordination
2. BIM for infrastructure
3. Digital 3D design software
4. e-Construction
5. 3D Engineered Models
6. Design Modules
7. UAS
8. e-Ticketing

The ADCMS program seeks to promote the adoption of digital tools to improve communication throughout project development, convey project decisions and environmental commitments through to the construction phase, reduce risks of project delays and errors, develop more sustainable infrastructure, and deliver projects faster and more cost effectively. An advanced digital construction management solution creates a central location for planning, allowing data from past projects to inform contingency budgets and make accurate cost-to-complete predictions.

For many years, digital design, construction, and management methods as components of BIM have been improving delivery in the "vertical" building industry, which refers to any construction that is built vertically, such as skyscrapers or high rises, and relies heavily on pre-construction design. The concept creates efficiencies that lower costs, generates fewer field "clashes," and increases the speed of construction.[2] Recently, some of those technologies have made their way into civil infrastructure and transportation projects and have been steadily gaining traction with both departments of transportation and industry. For example, the use of 3D models in e-Construction, in which traditional paper and electronic portable document format (PDF) documentation is replaced with digital information and tools to improve workflows and save time and money, has gained significant momentum. The use of BIM for Infrastructure is an open standards-based collaborative work method for structuring, managing, and using data about transportation assets and networks throughout their lifecycles. It liberates data from siloed systems in which repositories of data are controlled by one department or business unit and isolated from the rest of an organization. The open standards-based collaborative work method makes it easier for automated processes to generate asset information and distribute it to anyone within a State DOT when they need it.[3]

Some State DOTs have taken further steps to incorporate such digital technologies into their whole-enterprise business processes, moving toward the vision of BIM for life-cycle data management. Other State DOTs continue to use traditional techniques, while working to determine where digitalization provides the most benefits.

---

[2] FHWA BIM Strategic Plan: FHWA-HRT-21-064: Advancing BIM for Infrastructure: National Strategic Roadmap (dot.gov); Accessed: 02/14/2023

[3] Id.

Digital transformation in the construction and engineering sectors aligns with FHWA's strategic goals on infrastructure and innovation. The ADCMS program provides States with the opportunity to advance their deployment of ADCMS systems. The FHWA has studied the benefits of such systems, which include:

- Increased transparency;
- Improved safety;
- Enhanced quality;
- Reduced project costs;
- Accelerated project delivery; and
- Construction of more innovative, resilient, and sustainable infrastructure while reducing the project footprint and impact to the environment.

III. Methodology

This report's findings are based on an extensive review of the NCHRP synthesis on *Technological Capabilities of Departments of Transportation for Digital Project Management and Delivery*,[4] as well as a synthesis of data from FHWA's EDC-6 program. The FHWA EDC Program and the NCHRP synthesis identified five areas of opportunity for FHWA as it advances its ADCMS efforts:

1. e-Construction
2. 3D Engineered Models
3. UAS
4. e-Ticketing
5. Digital As-builts

The data from the NCHRP synthesis and the EDC program provide an overarching assessment of States' use of ADCMS technologies within their construction monitoring; however, the data are limited by the currency and accuracy resulting from State self-reporting. The intent of FHWA's TIDP is to accelerate the implementation and delivery of ADCMS innovations and technologies that result from highway research and development to benefit all aspects of highway transportation.

The following two sections provide more detailed information on the two data sources used for this synthesis.

A. Every Day Counts

The FHWA created the EDC program to accelerate the delivery of highway projects and foster an innovative culture in the transportation community. Through EDC's State-based model, FHWA collaborates with AASHTO and other stakeholders to rapidly deploy proven but underused innovations to shorten the project delivery process, enhance roadway safety, reduce

[4] National Cooperative Highway Research Program (NCHRP) Transportation Research Board National Research Council 2022 Report: *Technological Capabilities of Departments of Transportation for Digital Project Management and Delivery;* https://www.trb.org/Publications/Blurbs/182817.aspx; Accessed 02/15/2023

traffic congestion, and integrate automation. Many of these technologies and processes are now mainstream practices across the country.[5]

This report highlights the data from EDC-6 (2021-2022), including the benefits of digital technologies and some of the common challenges across innovations.

B. NCHRP Synthesis 594: Technological Capabilities of Departments of Transportation for Digital Project Management and Delivery

The NCHRP synthesis, which was developed by TRB's National Research Council, provides an overview of ADCMS and technologies that State DOTs are deploying in the delivery of highway projects from planning to design to construction to maintenance and asset management. The NCHRP project team reviewed FHWA documents and literature from professional organizations and administered an electronic survey to members of the AASHTO Committee on Construction, which includes representatives from State DOTs.[6]

IV. Technology Overview - States' Progress

The following sections provide an overview of States' progress in deploying five key ADC technologies, including:

- e-Construction
- 3D Engineered Models
- UAS
- e-Ticketing
- Digital As-builts

A. e-Construction

E-Construction management systems are systems in which documents are created and submitted electronically through a shared platform so that authorized users can view, download, or take other authorized actions. Document submission, cost estimates, meeting minutes, 3D models, schedules, and inspection reports are integral to the project delivery process, and by digitizing these processes, e-Construction enables State DOTs to manage their construction process more effectively.

Table 1 provides an overview of State DOTs' self-reported level of implementation of one or more components of e-Construction technologies. The following categories were used to define the level of implementation:

- Not Implemented: not yet brought into effect;
- Assessment: the evaluation or estimation of the nature, quality, or ability of a technology;
- Demonstration: the action or process of showing the existence or truth of something by giving proof or evidence;
- Development: a process that creates growth, progress, positive change, or the addition of physical, economic, environmental, social, and demographic components; and

[5] EDC-6 Progress Report #1 September 2021, page 2, Accessed: November 29, 2022; https://www.fhwa.dot.gov/innovation/everydaycounts/reports/edc6_progressreport1.pdf ; Accessed September 2021

[6] *Technological Capabilities of Departments of Transportation for Digital Project Management and Delivery*, https://www.trb.org/Publications/Blurbs/182817.aspx , Page 10, Accessed: October 29, 2022

- Institutionalized: established in practice.

Table 1: State DOT Implementation of e-Construction (2021 NCHRP Survey Data)

Technology	# of Agencies Reporting	Level of Implementation (% of Agencies)				
		Not Implemented	Assess-ment	Demon-stration	Devel-opment	Institu-tionalized
e-Construc-tion	N=52	0%	6%	25%	31%	38%

E-Construction provides numerous benefits to transportation projects. It provides State DOTs with more efficient workflow, time savings, improved accuracy, improved document security, and greater document transparency, and is a single source of information. It also allows for effective communication with stakeholders and is an environmentally sustainable way of storing project documents (i.e., paper reduction).

Some State DOTs are using a comprehensive client-server construction management tool. This construction management tool provides opportunities for data entry, tracking, reporting, and contract data analysis from contract award through finalization. These client-server tools are built on a multi-tier architecture, allowing for easy integration and data transfer. This allows FHWA and State DOT construction personnel, such as field inspectors, technicians, project managers, clerks, auditors, lab personnel, management, producers or suppliers, and contractors, to incorporate this tool into each of their construction management processes.[7]

Some State DOTs are using a cloud-based software to reduce the use of paper. For example, some States have reported that their cloud-based software enabled them to:

- Document the daily work reports, equipment, and labor;
- Pay for items of work;
- Document material testing and passing/failing test reports;
- Process change orders and additional time to the contract; and
- Make monthly payments to the contractor.

The States identified that this software is well structured and easy for stakeholders to use and benefit from.

As e-Construction use increases across State DOTs, engineers, surveyors, and inspectors are seeing enhanced safety, more efficient data management, and significant time savings compared to previous inspection work. However, as e-Construction continues to expand, State DOTs must also identify ways to address the issues surrounding software compatibility. By doing so, States will be able to boost project delivery by improving access to project documents and providing opportunities for data sharing across departments.

[7] AASHTOWare Project SiteManager, https://www.aashtowareproject.org/smr, Accessed: 12/7/2022

B. 3D Engineered Models

Modeling in 3D in transportation construction is a mature technology that serves as a key building block for the modern-day digital jobsite. The technology allows for faster, more accurate, and more efficient planning and construction by combining the horizontal and vertical aspects of a construction project into an integrated digital model. Using 3D software, design and construction teams can connect virtually to develop, test, and alter designs throughout the design and construction phases. Intricate design features can be viewed geospatially, in three dimensions, from multiple perspectives, and simulations can be run to detect and correct design conflicts and profile issues before and during construction. Data exported from the 3D models can be transferred to global positioning system (GPS) machine control equipment that guides and directs construction equipment such as bulldozers, pavers, rollers, and excavators. The connectivity allows workers to receive and work with the most accurate, up-to-date models, even if mid-cycle design changes are made.

Table 2 provides an overview of State DOTs' self-reported level of implementation of 3D Modeling technologies.

Table 2: State DOT Implementation of e-Construction (2021 NCHRP Survey Data)

Technology	# of Agencies Reporting	Level of Implementation (% of Agencies)				
		Not Implemented	Assess-ment	Demon-stration	Devel-opment	Institu-tionalized
3D Engineered Models	**N=45**	**2%**	**9%**	**56%**	**13%**	**20%**

State DOTs are benefiting greatly from 3D Engineered models, and typical benefits include:[8]

- **Faster project completion with improved quality and safety**: GPS-enabled construction equipment can run day and night with guidance from 3D model data and achieve accurate grades on the first pass, which reduces waste and economizes resources.
- **Significant productivity increases:** Productivity can be improved by up to 50 percent for some operations, and survey costs can be cut by up to 75 percent using the combined technologies of 3D modeling and GPS machine control. Reduced equipment and idle time, along with less rework, reduces fuel consumption and greenhouse gas emissions by up to 40 percent.
- **Reduction of manual tasks:** Automation decreases the need for certain tasks such as stringing lines, drawing fill lines, and setting grade stakes. In addition, the reduced number of workers onsite during construction increases project safety and efficiency.
- **Effective real-time control and monitoring of movement and location:** Control of constant movement and location changes can be achieved using "intelligent" technology, including 3D models, GPS machine control, and on-site laser-based positioning systems.

[8] FHWA 3D Engineered Models for Construction, https://www.fhwa.dot.gov/innovation/pdfs/factsheets/edc/edc_3d.pdf; Accessed 12/28/2022

Machine operators can also conduct grades, cuts, and fills to a high level of precision either automatically or with the guidance of an onboard system. Automated machine control is also used for effective Portland cement concrete and hot mix asphalt paving.

The construction industry is deploying 3D modeling and realizing improved efficiency, shorter scheduling, and reduced costs. As BIM continues to become the standard for design and construction of major commercial and industrial buildings, similar modeling is also becoming common practice in highway project design and construction. As part of this trend, 3D modeling and the transfer and use of 3D model data in GPS machine control equipment have been successfully demonstrated and used in many States nationwide. The technology is a cost-effective method for accelerating highway design and construction.[9]

C. Unmanned Aircraft Systems

To monitor and assess critical infrastructure, UAS, also known as unmanned aerial vehicles, are used across our Nation. The UAS are gaining popularity in the design construction industry as an acceptable alternative to traditional aircraft or ground visual inspection data collection and recording methods.

Table 3 provides an overview of State DOTs' self-reported level of implementation with UAS technologies.

Table 3: State DOT Implementation of UAS (2021 NCHRP Survey Data)

Technology	# of Agencies Reporting	Level of Implementation (% of Agencies)				
		Not Implemented	Assess-ment	Demon-stration	Devel-opment	Institu-tionalized
UAS	N=26	0%	42%	8%	50%	0%

State DOTs are using UAS to provide cost-effective and comprehensive analysis of applications, such as high-definition building or site photography and photogrammetric survey of topography or facilities on project sites (technology that obtains reliable information about physical objects and the environment through the process of recording, measuring, and interpreting photographic images and patterns of electromagnetic radiant imagery).[10] State DOTs are also using UAS to improve building inspection and bridge inspection safety by removing humans from potentially hazardous situations, which is particularly useful to State DOTs when repairing fire and storm-damaged buildings, or working in areas that are unsafe or hard to access. States typically use UAS for:

- High-definition roof, tower, and facility visual inspections;
- Access and inspection of hard-to-reach building areas;
- Photographic documentation of existing conditions;

[9] FHWA 3D Engineered Models for Construction, https://www.fhwa.dot.gov/innovation/pdfs/factsheets/edc/edc_3d.pdf; Accessed 12/28/2022

[10] State DOTs must comply with all applicable Federal Aviation Administration rules for the commercial use of UAS.

- Time lapse analysis;
- Creation of 3D models; and
- Development of base drawing for design renderings.

Documentation of these uses as well as other FHWA technical resources serve as guidebooks to assist State, Tribal, and local transportation agencies in incorporating UAS into existing planning processes.

D. e-Ticketing

Highway construction projects produce massive amounts of valuable data. Historically, information such as materials tickets and as-built plans were communicated via paper. Today's transportation agencies are improving on these paper processes by integrating them into electronic and digital workflows. E-Ticketing improves the tracking, exchange, and archiving of materials tickets. Digital information, such as 3D design models and other metadata, can enhance the value of contract documents and the future usability of as-built plans for operations, maintenance, and asset management. Both can increase project safety and quality through efficient data gathering and sharing.[11]

Table 4 provides an overview of State DOTs' self-reported level of implementation with e-Ticketing technologies.

Table 4: State DOT Implementation of e-Ticketing (2021 NCHRP Survey Data)

Technology	# of Agencies Reporting	Level of Implementation (% of Agencies)				
		Not Implemented	Assess-ment	Demon-stration	Devel-opment	Institu-tionalized
e-Ticketing	**N=49**	**10%**	**20%**	**41%**	**20%**	**8%**

State DOTs are using e-Ticketing to improve the tracking and exchange of digital information. States typically use e-Ticketing to achieve the following benefits:

- **Safety:** e-Ticketing enhances data collection while reducing exposure to adjacent vehicular traffic and construction equipment for inspectors and work crews while retrieving paper tickets.
- **Time Savings:** Real-time access, via electronic handling of tickets, reduces processing time for quality assurance and payment, decreasing the inherent delays in paper-based project administration.
- **Improved Quality:** Project documentation is more consistent and efficient using e-Ticketing platforms. Standardized data enables archiving for future reference, leading to improved design, construction, maintenance, and operations.[12]

[11] FHWA, EDC-6, e-Ticketing and Digital As-Builts; https://www.fhwa.dot.gov/innovation/everydaycounts/edc_6/eticketing.cfm; Accessed, 12/21/2022
[12] *Id*.

Providing stakeholders with an electronic means to produce, transmit, and share materials data and track and verify material deliveries enhances safety by reducing exposure to vehicular traffic, streamlines inspections, and improves contract administration processing.

E. Digital As-Builts

Using digital data such as 3D models to build road projects is slowly becoming an industry standard. Sharing the design model and associated digital project data allows agencies and contractors to streamline project delivery and contract administration and to collaborate on challenges virtually before they get to the field. The digital information is further leveraged when the model is updated, and other data incorporated, to reflect the project's as-built condition for future maintenance, asset management, and rehabilitation activities.[13] As-built drawings encompass nearly every element of a construction project's processes, from modifications to field changes, design changes, and extra work. In previous decades, as-built drawings were passed around and edited manually. Today, as most construction professionals have embraced technology, as-builts are being increasingly designed and edited on computers. However, depending on software programs and file formats, managing, and updating the drawings can still be a cumbersome process.

Table 5 provides an overview of State DOTs' self-reported level of implementation with Digital As-Builts technologies.

Table 5: State DOT Implementation of Digital as-builts (2021 NCHRP Survey Data)

Technology	# of Agencies Reporting	Level of Implementation (% of Agencies)				
		Not Implemented	Assess-ment	Demon-stration	Devel-opment	Institu-tionalized
Digital As-Builts	**N=53**	**36%**	**6%**	**18%**	**38%**	**2%**

State DOTs are using digital as-builts to improve and streamline project tracking, which helps provide cost- and time-efficient projects. States typically use digital as-builts to achieve the following benefits:

- **Safety:** Construction using digital information allows workers to visualize and avoid site safety hazards, which can lead to safer projects and shorter work zone traffic impacts.
- **Time Savings:** Digital design information provided for construction enhances planning and can streamline project delivery. Digital as-builts including utility locations and other asset information will improve post-construction decisions and shorten future project delivery.
- **Improved Quality:** Digital as-builts can provide enhanced historical data, enabling State DOTs to better maintain the transportation infrastructure and develop future projects.

Some State DOTs are recording as-built information on assets during construction. Several States are working to incorporate digital data into more effective construction delivery and

[13] FHWA EDC-6, e-Ticketing and Digital As-Builts; https://www.fhwa.dot.gov/innovation/everydaycounts/edc_6/eticketing.cfm; Accessed, 12/21/2022

management workflows. State DOTs are providing contractors with enhanced contract documents using the 3D model as they consider more integrated and streamlined approaches to project delivery.[14]

V. ADCMS Program Evaluation

This chapter outlines an evaluation framework that will enable FHWA to demonstrate the impacts of the ADCMS program and to meet the ADCMS reporting requirements. As added by BIL, 23 U.S.C. 503(c)(5)(D)(i) establishes annual reporting requirements for the program, which include:

> (i) Not less frequently than annually, the Secretary shall issue and make available to the public on a website a report on—
>
> (I) progress made in the implementation of advanced digital management systems by States; and
>
> (II) the costs and benefits of the deployment of new technology and innovations that substantially and directly resulted from the program established under this paragraph (23 U.S.C. 503(c)(5)).

Analysis of the following information may be included in the report:

- Federal, State, and local cost savings;
- Project delivery time improvements;
- Congestion impacts; and
- Safety improvements for roadway users and construction workers.

See 23 U.S.C. 503(c)(5)(D)(ii).

The following sections of this chapter describe the evaluation approach that will be used to assess program impact.

A. Evaluation Approach

Based on the goals outlined in BIL, FHWA identified key impact areas for ADCMS evaluation and developed evaluation questions associated with each (shown in Table 6). The evaluation questions require the collection of both quantitative and qualitative data.

For many of the quantitative measures, the recommended evaluation approach is a before and after design, enabling the comparison of baseline measures to post deployment measures. For a subset of evaluation questions, primarily those based on qualitative data, the recommended approach includes the collection of after-data only.

14 FHWA EDC-6; https://www.fhwa.dot.gov/innovation/everydaycounts/edc_6/eticketing.cfm; Accessed, 12/21/2022

The following sections provide more detailed information on the evaluation approach for each of the impact areas.

Increased Adoption of ADCMS
The FHWA has established the baseline for ADCMS deployment (as summarized in this Report) and will continue to track the deployment of ADCMS for the duration of the program to determine the extent to which increased adoption of ADCMS has occurred. The FHWA will track the projects funded through the ADCMS grant program and will work to document other ADCMS technology deployments (i.e., among entities that are not funded through this grant program). For each identified ADCMS technology deployment, FHWA will document the location, the agency and its partners, and the specific technology being deployed. In addition, since ADCMS comprises a range of technologies that typically impact different phases of the project lifecycle (e.g., planning, design and engineering, construction, and operations), FHWA also will track the project lifecycle phases that are targeted by the deployed technology to ensure the acceleration of ADCMS is occurring across all phases of the project lifecycle. The FHWA also plans to conduct outreach among States and metropolitan planning organizations and to assess the effect of those efforts on the increased deployment of ADCMS technologies.

Project Delivery Time Improvements
One anticipated result of ADCMS is project delivery time savings. The measure of time savings involves a comparison of time spent on an activity (or activities) before versus after deployment of the ADCMS. Depending on the technology being deployed, ADCMS grantees may need to tailor their data collection to maximize the likelihood of measuring an impact that can be attributed to the ADCMS. For example, if time savings are expected during the construction phase, then grantees should collect baseline measures for construction time (i.e., prior to technology deployment); following deployment of the technology, construction time should be measured for the subset of projects that are comparable to the baseline. It is critical that before and after measures involve comparable projects to ensure measured time savings are a result of the technology deployment and not differences in project nature. If time savings are anticipated during multiple phases of the project lifecycle, FHWA expects that grantees will measure these savings by specific phase.

In addition to quantitative data, FHWA anticipates that grantees will collect qualitative data on the factors that contributed to their time savings. Examples of key factors include (but are not limited to):

- Interoperability with other systems;
- Improved accuracy, quality of processes, or products;
- Improved information sharing with staff or stakeholders; and
- Improved ability to manage complexity.

These qualitative data may be collected via surveys or interviews of the staff who use the technology and may include anecdotal evidence that demonstrates the impact of the deployed ADCMS. Staff could also maintain logs of the benefits, best practices, and lessons learned from deploying the ADCMS technology. The information collected in staff logs would serve as a useful data source for demonstrating the impacts and benefits of the deployed technology.

Cost Savings
Quantitative data on time savings also can be used to measure the cost savings. For such an analysis, a comparison of costs before versus after deployment of the ADCMS may be performed, whereby cost savings are assessed for the specific phase of the project lifecycle where ADCMS was deployed.

Reduced Environmental Impacts
If the deployment of ADCMS is anticipated to have environmental or congestion impacts, ADCMS grantees should measure these impacts. For example, if an ADCMS deployment results in a reduced environmental footprint or an accelerated construction schedule, the grantee can calculate the reduction in right-of-way needed and the environmental impacts avoided. For congestion impacts, the grantee can determine the time savings for commuters traversing the project boundaries. There are also inherent economic and environmental benefits to reducing congestion impacts, which can be calculated and considered as part of this measure.

Safety improvements for roadway users and construction workers
Where applicable, ADCMS grantees should assess the safety impacts of their ADCMS deployments. Depending on the technology deployed, these safety impacts may affect staff (e.g., construction workers) or roadway users. Grantees could measure safety impacts quantitatively, for example, by measuring the number of exposure hours to unsafe conditions or the number of injuries before and after ADCMS deployment (however, the time frame for the evaluation may not be sufficient to measure a reduction in injuries). Grantees also may assess safety impacts using qualitative data, gathered through surveys, interviews, or staff logs. These data may include anecdotal evidence describing the nature of the safety improvements, either among construction workers (or other staff) or roadway users. Grantees also can measure safety impact by determining the benefit gained from accelerated construction schedules, which can mitigate the safety issues with prolonged and varied maintenance of traffic and construction activities.

Workforce Training and Development
Workforce training and development is an important step to maximizing the benefits of ADCMS deployments. The FHWA anticipates that ADCMS grantees will attend trainings specific to the ADCMS being implemented as part of their grant. Grantees will track the number and type of ADCMS trainings attended by project managers who use ADCMS technologies. In addition, grantees may collect qualitative feedback from project managers who attended the training(s) on the usefulness and impact of the training(s).

Best Practices and Lessons Learned
In support of knowledge and technology transfer, it is important that FHWA and ADCMS grantees document ADCMS best practices and lessons learned. This information will be made publicly available so that other agencies considering the deployment of ADCMS can benefit from the experience of agencies that have deployed these technologies.

Table 6 summarizes the type of data (quantitative or qualitative) that may be collected, the entity responsible for data collection, and the general evaluation approach for each evaluation question (organized by goal area). The FHWA will encourage grantees to choose from among the goals outlined in the table so that national progress can be measured.

Table 6: Evaluation Approach

ADCMS IMPACT AREAS AND EVALUATION QUESTIONS	Quantitative or Qualitative	Responsible Party	General Evaluation Approach
A. Impact Area: Increased Adoption of ADCMS			
1. What progress has been made in the implementation of ADCMS?	Quantitative and Qualitative	FHWA	Before and after comparison Summary descriptions
2. Have entities accelerated their adoption of ADCMS throughout the construction lifecycle (including through the planning, design and engineering, construction, and operations phases)?	Quantitative and Qualitative	FHWA	Track the deployment of ADCMS by project lifecycle phase
B. Impact Area: Project Delivery Time Improvements			
1. What are the project delivery time savings that resulted from ADCMS?	Quantitative	Grantees	Before and after comparison of comparable projects (measured in days, hours, or minutes)
2. What factors explain the time savings? For example, what system improvements account for the time savings, such as: • Interoperability/integration with other systems (e.g., contracts) • Improved accuracy/quality of processes/products (e.g., increased productivity) • Improved information sharing with staff and/or stakeholders • Improved ability to manage projects (e.g., better manage complexity) • Other?	Qualitative	Grantees	After data collected via staff interviews, surveys, or logs

ADCMS IMPACT AREAS AND EVALUATION QUESTIONS	Quantitative or Qualitative	Responsible Party	General Evaluation Approach
C. Impact Area: Cost Savings			
1. What are the State or local cost savings that resulted from the deployment of the ADCMS?	Quantitative	Grantees	Before and after comparison of comparable projects (measured in dollars)
2. To what extent are the projects funded by Federal dollars versus State or local dollars?	Quantitative	Grantees	Track the source of project funding for each deployed technology
D. Impact Area: Reduced Congestion Impacts [IF APPLICABLE]			
1. How did the ADCMS reduce congestion? For example: o Was there an accelerated construction schedule that reduced hours of congestion (i.e., resulted in travel time savings)? o What is the calculated economic benefit (in dollars) from the reduced congestion impacts resulting from ADCMS deployment? o What is the calculated environmental benefit (in GHG emissions) from the reduced congestion impacts resulting from ADCMS deployment?	Quantitative (preferred) or Qualitative	Grantees	Before and after comparison (e.g., travel time, travel time reliability) or After data (qualitative) on congestion improvements
E. Impact Area: Safety Improvements for Roadway Users and Construction Workers [IF APPLICABLE]			
1. What safety improvements for roadway users (including pedestrians, if applicable) resulted from the deployment of ADCMS?	Quantitative (preferred) or Qualitative	Grantees	Before and after comparison (e.g., number of exposure hours, injuries, fatalities) or After data collected via surveys, interviews, or staff logs
2. What safety improvements for construction workers resulted from the ADCMS?	Quantitative or Qualitative	Grantees	Before and after comparison or After data collected via staff surveys, interviews, or logs or Positive safety impact from accelerated construction

ADCMS IMPACT AREAS AND EVALUATION QUESTIONS	Quantitative or Qualitative	Responsible Party	General Evaluation Approach
			schedules resulting from ADCMS deployment
F. Workforce Training and Development			
1. What efforts are grantees undertaking to advance workforce training and development related to ADCMS?	Quantitative or Qualitative	Grantees	Before or after data on the number and type of ADCMS trainings offered (if applicable); Number of ADCMS trainings attended by project managers who use ADCMS; and Before or after data collected via surveys or interviews on project managers' perceptions of the ADCMS training (e.g., usefulness, impact)
G. Impact Area: Best Practices and Lessons Learned			
1. What are grantees' best practices based on their ADCMS deployments?	Qualitative	Grantees	After data collected via surveys, interviews, or staff logs
2. What are grantees' lessons learned based on their ADCMS deployments?	Qualitative	Grantees	After data collected via staff surveys, interviews, or logs

B. Grantee Reporting Requirements

As part of the implementation of this evaluation framework, ADCMS funding recipients will be required to prepare evaluation plans, annual progress reports, and a final report that documents their evaluation findings. The annual reports will include the following information:

- Summary of the project, including technologies being deployed;
- Current project status, including progress to date;
- Summary of performance measurement progress; and
- Challenges and associated lessons learned and best practices.

The FHWA will use the information from the grantees' annual reports to inform the development of its ADCMS program report, which will be issued annually.[15]

[15] See 23 U.S.C. 503(c)(5)(D).

VI. Next Steps

The funding from BIL will enable FHWA to provide eligible entities with financial assistance to deploy ADCMS. This new funding is critical to increasing ADCMS deployment across the Nation. In addition, FHWA is already advancing specific efforts, through EDC, addressing areas of opportunity in construction and their associated challenges. Guided by these identified opportunities and challenges, and with the funding provided in BIL and the new ADCMS grant program, both DOT and FHWA leadership are committed to advancing the deployment of ADCMS technologies, including the establishment of guidelines and best practices to support users of ADCMS. Based on the findings of the NCHRP synthesis and EDC data, FHWA will focus its upcoming efforts in four primary areas:

1) Assessing and revising FHWA policies, processes, and practices, if needed, to make it easier for State and local agencies to adopt and deploy ADCMS technologies. This ADCMS model encompasses practices in safety, planning, design, construction, operations, and maintenance to improve construction for all users. This Report to Congress provides a roadmap for this strategy.
2) Providing support through leadership, technical assistance, peer learning, and other means, to make implementation of ADCMS the standard of practice among local and State agencies.
3) Improving data collection capabilities and practices and developing performance measures using those data to support the evaluation of ADCMS.
4) Expeditiously implementing new program eligibilities and other provisions in the BIL that support ADCMS technologies.
5) Expeditiously awarding grants under the new ADCMS grant program.

VII. Conclusions

The FHWA has supported and encouraged State adoption of ADCMS technologies through existing programs. The implementation of the new ADCMS Grant Program under BIL will allow FHWA to provide resources to eligible entities to further accelerate the adoption of these advanced technologies. Through the ADCMS grant program, eligible entities will be responsible for implementing the technologies and reporting on the value. Using the suggested framework in this report, eligible entities will provide FHWA with information annually that will be used to report on progress made in the implementation of ADCMS, including the cost and time savings, as well as other benefits that resulted from this grant program.