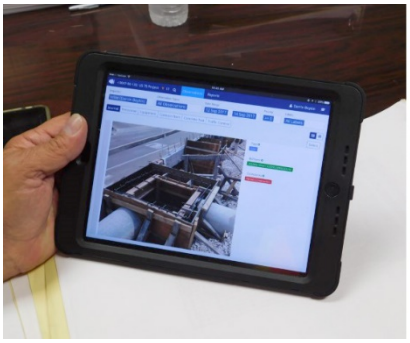
Technology Brief

e-Construction and Partnering: *A Vision for the Future*



Peer-to-Peer Exchange

Colorado, Michigan, Ohio, Pennsylvania, and Utah Departments of Transportation

Denver, Colorado

December 11–12, 2018

U.S. Department of Transportation
Federal Highway Administration

On-Ramp to Innovation
every day counts

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Unless otherwise stated, FHWA is the source for all images and figures presented in this document.

Background

Over the last several years, the Colorado Department of Transportation (CDOT) has been working to implement e-Construction and improve its partnering practices. Although CDOT has recently made some positive efforts to implement e-Construction and revitalize its Partnering Program, the agency is not where it would like to be. CDOT invited one representative each from four peer agencies to exchange ideas and solutions for overcoming common challenges when adopting an enterprise e-Construction and Partnering (eCP) program. CDOT hosted a 2-day, face-to-face peer exchange with the Michigan Department of Transportation (MDOT), Ohio Department of Transportation (ODOT), Pennsylvania Department of Transportation (PennDOT), and Utah Department of Transportation (UDOT).

The eCP peer exchange, sponsored by the Federal Highway Administration (FHWA) as part of round four of the Every Day Counts (EDC-4) technical assistance program, took place December 11–12, 2018, in Denver, Colorado. The State DOT representatives were joined at the peer exchange by staff from FHWA's Colorado Division and the Resource Center.

CDOT's e-Construction vision is to become paperless, improve efficiencies with time and costs (through enhanced mobility), and improve data quality by collecting data directly in the field using mobile devices. The agency is working on developing a strategic plan that will allow technology to be deployed using a managed approach rather than ad hoc methods. The responsibility for developing this strategic plan falls under the CDOT e-Construction team commonly known as *The Core 5,* which is a group of four volunteers and one full-time employee who was specifically hired to lead e-Construction efforts.

CDOT recently rebranded its partnering program as "Project First," the objective of which is to talk openly with stakeholders about risks and proactively manage them at the lowest level of responsibility. The agency wants to create a culture of open communication and collaboration with contractors, as well as build trust that everyone is working on good faith to resolve issues and construct projects together.

MDOT and PennDOT shared their mature e-Construction practices. ODOT and UDOT discussed their mature partnering practices and their most notable e-Construction use cases.

Table 1. Participating State DOT e-Construction technology and practices.

Application	CDOT	MDOT	ODOT	PennDOT	UDOT
Electronic Document Management	Bentley® ProjectWise® Microsoft® SharePoint®	Bentley® ProjectWise®	Microsoft® SharePoint®	PennDOT Project Collaboration Center (PPCC)[1]	Bentley® ProjectWise®
Electronic Daily Reporting and Construction Management	Paper Microsoft® Word® or Excel® Microsoft® InfoPath® Smart Forms AASHTOWare® SiteManager™ [2]	Info Tech® FieldManager™ Info Tech® Mobile Inspector® ProjectWise® Edge	GoFormz® Info Tech® Mobile Inspector® AASHTOWare® SiteManager™ [3]	Custom Mobile Apps[4] Engineering Construction and Management System (ECMS)	Aurigo® MasterWorks®
e-Signatures for Construction Contracts	Wet ink signatures DocuSign® (pilot)	ARX CoSign®	User-based authentication for document approvals, wet ink signatures for contracts	User-based authentication	User-based authentication for document approvals, wet ink signatures for contracts
Mobile Devices	Yes	Apple® iPad®	HP® 2-in-1 and Apple® iPhone®	Apple® iPad	Apple® iPad
Formal Partnering Program	Yes	No	Yes	Yes	Yes

[1] Custom program based on a SharePoint® platform.
[2] Only being used for issuing payments.
[3] Migration from SiteManager™ to AASHTOWare® Project Construction & Materials™ 4.1 scheduled for January 1, 2020.
[4] PennDOT develops a variety of custom mobile applications for accessing reference/contract documents and entering project site activities, etc.

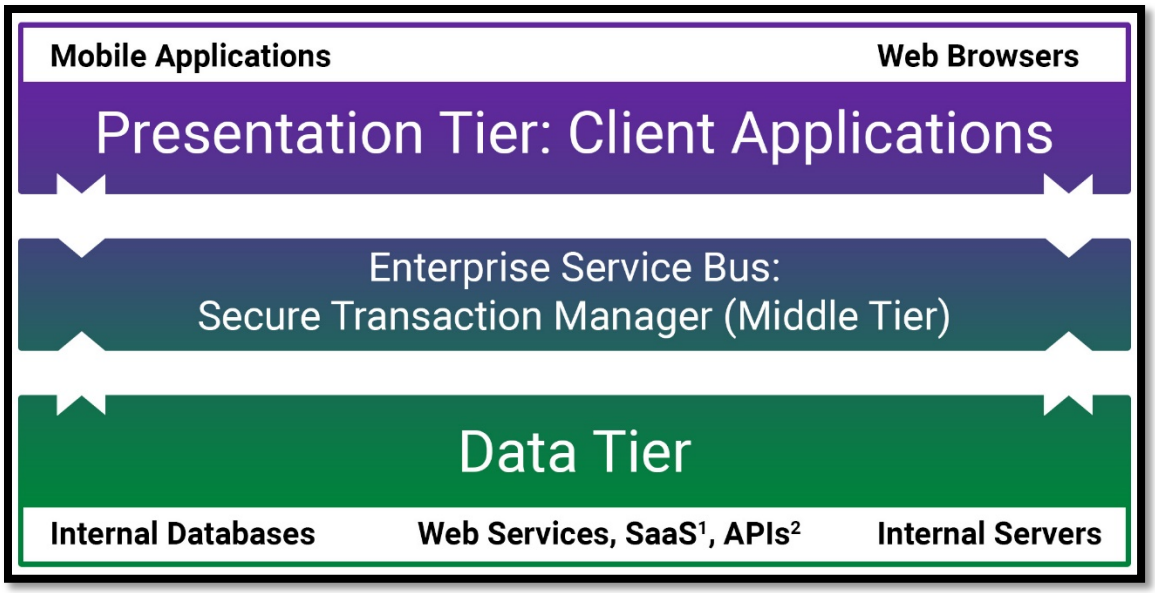
CDOT Implementation Approach

e-Construction

The greatest challenge CDOT faces with e-Construction is formalizing field data collection. Currently, there are too many ways to document construction activities (from paper to Microsoft® Word® and Excel® sheets). Therefore, CDOT is exploring multiple solutions that connect data from different sources to eliminate duplicate entry and have one authoritative source of information. The end goal is to select one consistent e-Construction software solution to deploy across the entire agency. Two software solutions currently being investigated are the use of Microsoft® InfoPath® Smart Forms

and Pavia Systems' HeadLight® software. Much like other software solutions, there are unique set of challenges that limit interoperability and effective uses by field staff.

Moving forward, CDOT would like to rely more on cloud-based solutions and implement a digital handshake or digital address book approach using and enterprise service bus (ESB) architecture. Essentially, the ESB would minimize program interfaces by allowing the data to reside in the source system and be exposed so other programs can access it. The ESB is a middleware that interfaces with other applications without the need for direct connections. An illustration of this system architecture is shown in figure 1.



[1] SaaS = software as a service
[2] API = application programming interface

Figure 1. Example illustration of an ESB architecture.

Another challenge CDOT is trying to solve is how to manage construction contract documents. The agency has adopted ProjectWise® as its official document management system, but there are challenges that limit use during construction. CDOT is working with the vendor to implement a cloud-based solution that is more user friendly and easier to configure. The new solution will be able to connect to multiple sources (SharePoint®, databases) and will have the option for additional services (deliverables management, performance dashboards, issue resolution, field data management, and notifications). CDOT is currently negotiating the terms of the software agreement in anticipation that the new solution will help share, organize, and manage documents more easily.

Partnering

CDOT engaged with the Colorado Contractor's Association and the American Council of Engineering Companies in rebuilding its partnering program. Now known as "Project

First," it is structured to draw on the strengths of CDOT and the contractor to identify and achieve mutual goals. The objective is scalable, effective, and efficient contract performance with cooperation and project completion within budget, on schedule, and in accordance with the contract requirements. The CDOT Project Engineer and the Superintendent are the lead representatives for ensuring staff from both organizations address issues in a timely manner and at the appropriate levels of responsibility to keep the project moving. Executive management from both organizations are encouraged to visit the project teams when available. Partnering is required on all projects with engineer estimates over $1 million.

Shared Effective e-Construction Practices

MDOT

MDOT was an early adopter of e-Construction, implementing FieldManager™ for daily reporting about 20 years ago, but was still printing paper documents in 2012 when the Michigan Infrastructure Transportation Association (MITA) requested a faster and better way to process contract documents electronically. This spurred MDOT's e-Construction initiative to eliminate paper. MDOT's timeline for implementation is illustrated in figure 2.

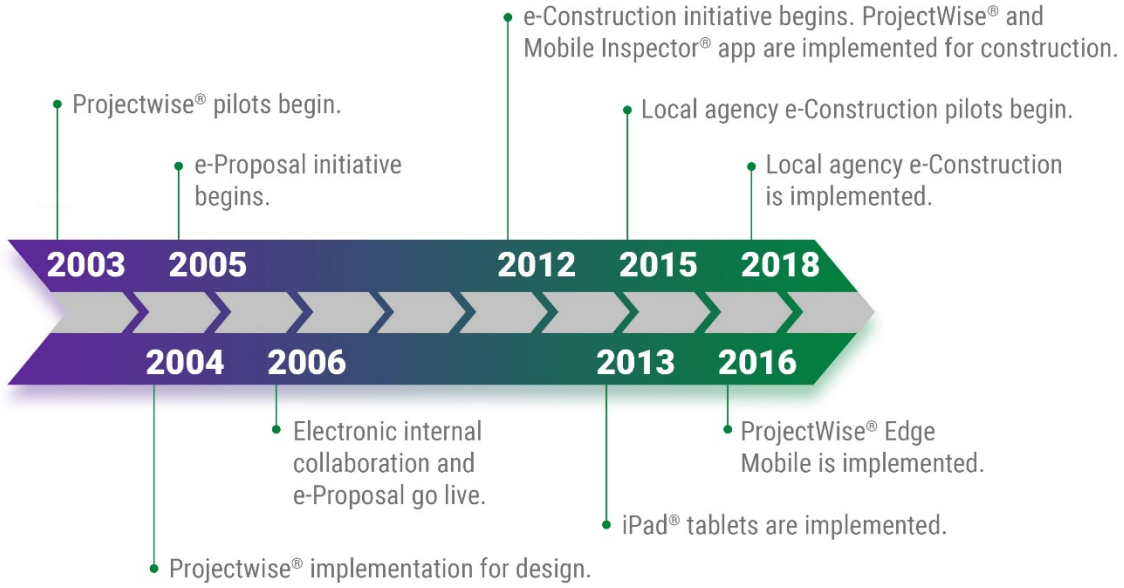


Figure 2. Timeline. MDOT implementation of e-Construction. Source: Information provided by MDOT.

MDOT chose iPad® as the standard mobile device for field staff and Bentley® ProjectWise® as its e-Construction solution. MDOT also uses Bluebeam® Vu® and PDF Expert® to markup documents, DocuSign® for signing contracts digitally, and Microsoft® Company Portal and Authenticator apps for mobile device management (MDM).

The agency's implementation of ProjectWise® started in 2003 when the solution was introduced to manage design engineering drawings. In 2005, MDOT implemented the

e-Proposal initiative to advertise all construction projects completely paperless, which was followed by the electronic collaboration initiative that used ProjectWise® as the internal collaboration platform.

Today, ProjectWise® is the official solution for managing all documents within the agency, including working documents, contracts, invoices, and submittal of deliverables. As the e-Construction solution, ProjectWise® is also used to manage construction administration documents and daily inspection reports. The folder structure within ProjectWise® is organized by project number using the naming convention shown in figure 3. ProjectWise® Edge is the mobile platform used to access documents from the field, allowing field staff to download documents to their mobile devices as an alternative to using a cellular or Wi-Fi connection to access files from the data source servers.

Another product MDOT is using as part of its e-Construction solution is the Mobile Inspector® app, which connects to FieldManager™ and enables inspectors to access the AASHTOWare® software right from the grade.

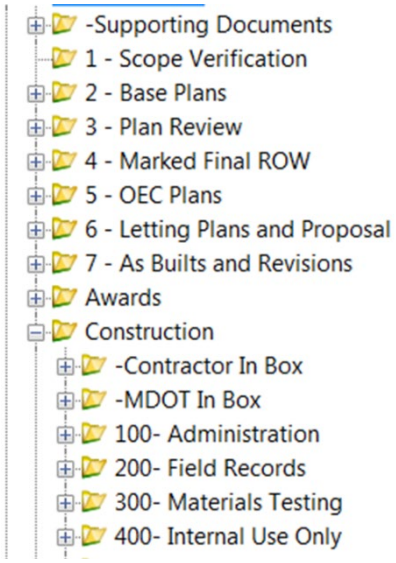


Figure 3. Screen Capture. Example of MDOT project folder organization in ProjectWise®. Source: MDOT.

ODOT

Although ODOT has been using SiteManager™ for construction management and SharePoint® as its official document storage and retention platform for several years, the agency's e-Construction initiative did not start until 2016 when Mobile Inspector® was introduced as the mobile interface to SiteManager™. Initially, ODOT offered its 12 Districts the option of LG® tablets, iPad® tablets, or Microsoft® Windows®-based laptops. By providing several device options, ODOT quickly achieved success in gaining acceptance by field personnel. In addition, ODOT wanted to ensure current and future mobile applications could run on a variety of platforms. After the initial rollout period, because of a limited budget, the agency streamlined device procurement and

deployment by making the HP® 2-in-1 tablet/laptop standard as the primary device along with the Apple® iPhone®. The primary device can be removed from its docking system to take into the field. Inspectors use their mobile phones for talk to text, GPS features, taking photos, and communicating via the Apple® FaceTime® app.

e-Construction is one of three initiatives ODOT is using to overcome the challenges of a diminishing workforce. Over the last several years, the agency has experienced a nearly 20 percent reduction in staff to oversee its growing construction program. The e-Construction initiative is being implemented along with risk-based inspection and an overhaul of project administration processes. ODOT underwent a process to prioritize inspection activities and documentation. As part of this exercise, ODOT streamlined and standardized the information project engineers and inspectors should collect. An inspection checklist was developed to coincide with ODOT's Construction and Material Specification book to the quantity of payments and quality of construction and materials. The new standard process is illustrated in figure 4.

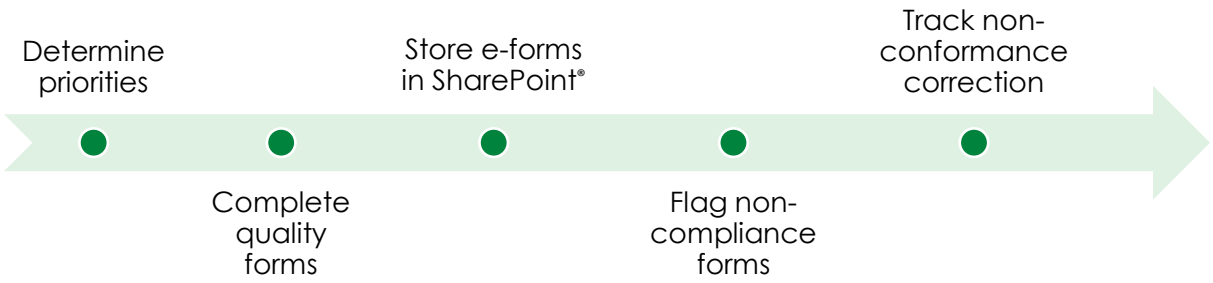
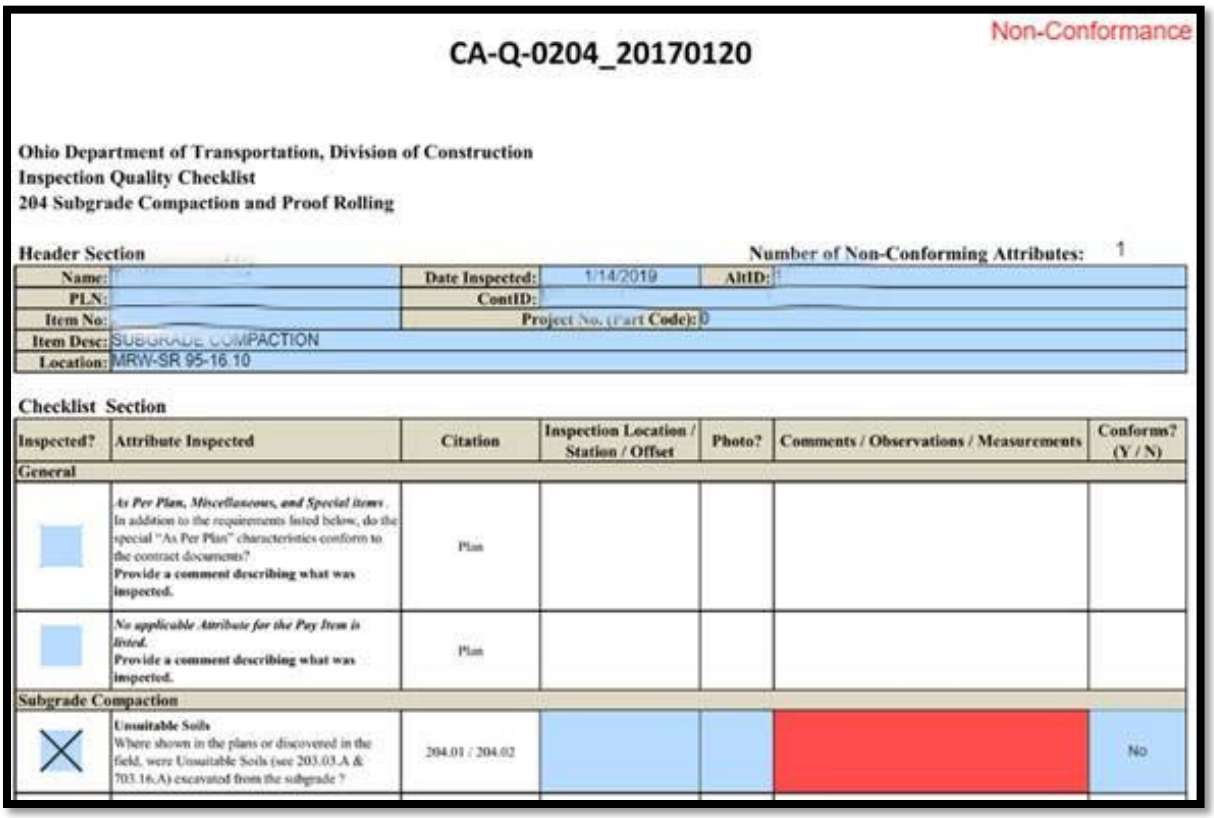


Figure 4. ODOT's workflow for risk-based construction inspection documentation.

The tool ODOT implemented to help field personnel with documentation of quality of materials and construction is called GoFormz® (figure 5). Effective January 1, 2018, after a successful piloting phase in 2017, the use of GoFormz® was required on all projects. While GoFormz® has been instrumental in the success of adopting e-Construction and risk-based inspection, it is an interim solution. ODOT is interested in better technology that can move the agency from paperless to digital data collection at the enterprise level. Future efforts for the agency include implementation of a database for housing inspection quality and asset attributes using three-dimensional (3D) models.



CA-Q-0204_20170120

Non-Conformance

Ohio Department of Transportation, Division of Construction
Inspection Quality Checklist
204 Subgrade Compaction and Proof Rolling

Header Section — Number of Non-Conforming Attributes: 1

Name:		Date Inspected:	1/14/2019	AltID:	
PLN:		ContID:			
Item No:		Project No. (Part Code):	0		
Item Desc:	SUBGRADE COMPACTION				
Location:	MRW-SR 95-16.10				

Checklist Section

Inspected?	Attribute Inspected	Citation	Inspection Location / Station / Offset	Photo?	Comments / Observations / Measurements	Conform? (Y / N)
General						
☐	*As Per Plan, Miscellaneous, and Special items* . In addition to the requirements listed below, do the special "As Per Plan" characteristics conform to the contract documents? **Provide a comment describing what was inspected.**	Plan				
☐	*No applicable Attribute for the Pay Item is listed.* **Provide a comment describing what was inspected.**	Plan				
Subgrade Compaction						
☒	**Unsuitable Soils** Where shown in the plans or discovered in the field, were Unsuitable Soils (see 203.03.A & 703.16.A) excavated from the subgrade ?	204.01 / 204.02				No

Figure 5. ODOT's GoFormz® inspection quality checklist. Source: ODOT

PennDOT

PennDOT is among State DOTs with the most mature e-Construction practices. The agency relies on four key systems to store digital data and electronic documents. The Engineering Construction and Management System (ECMS) is a Web-based platform the agency uses for managing all active contract documents for a project from advertisement to closeout. It is the backbone for all other systems. The Construction Documentation System (CDSv3), now in its third iteration, is a companion application to ECMS. It is used to document project site activities and contractor payments. The PennDOT Project Collaboration Center (PPCC) is a Web-based application built on the SharePoint® platform used to manage reference project documents and submittals. Documents submitted for review during an active project use automated workflows for routing to the appropriate approvers. For managing material sample information, PennDOT uses the Electronic Construction and Materials Management System (eCAMMS), which is also a Web-based solution. eCAMMS is the only PennDOT solution that is not integrated with other systems.

One key success factor of using mobile devices in the field is the ability to access data and documents using an easy and friendly interface to the backend systems. Thus, when PennDOT decided to issue iPad® tablets to construction staff, the agency invested

significant resources in creating a mobile computing (MC) development team that develops mobile applications to enhance user experience. Application development is conducted in 4-week sprints using an agile method for getting the programs in the hands of users quickly. Users test applications in the field and provide feedback to developers for improvements. This collaboration between the user and the development team is a key success factor for acceptance and buy-in. Once the applications are moved to maintenance, users are supported via a help desk. Table 2 summarizes the PennDOT MC applications currently in place or being developed.

Table 2. Summary of PennDOT mobile applications.

MC Application Name	Description
MC Docs	A view-only application that integrates with ECMS and PPCC. It houses project-specific documents (e.g., contracts, drawings, permits) and publications (e.g., reference manuals, standards) and PPCC documents.
Project Site Activity (PSA)	Application used to document project site activities. App is integrated with ECMS and CDSv3.
Punchlist	Application used to document resolved and unresolved punchlist items. App is integrated with ECMS.
Force Account	Application used to document daily force account items. App is integrated with ECMS.
Concrete Inspectors Diary (CID)	Application used to document all information related to concrete placement and testing. App is integrated with ECAMMS.
Maintenance and Protection of Traffic (MPT)	Application used to document work zone compliance. Will be integrated with ECMS.
Material Sample ID	Application used to document testing sample information by scanning a barcode attached to testing samples. Will be integrated with ECMS.
Erosion and Sediment Visual Site Inspection (E&S VI)	Application used to document stormwater pollution prevention plan compliance. Will be integrated with ECMS.
PennDOT Miles and Hours	Application used to document internal payroll information. Will be integrated with ECMS.

Note: *Italicized text* indicates the MC application is under development.

PennDOT has also conducted several e-ticketing pilots for asphalt paving and milling operations. The agency is investigating what information should be requested from the contractor e-ticketing system instead of making specific software requirements. Because the agency's goal is to capture digital data, PennDOT prefers to request information that can be imported into an enterprise system rather than receiving paperless tickets.

UDOT

UDOT's philosophy for implementation of e-Construction was to make sure the technology made tasks easier for field personnel. UDOT started evaluating e-Construction solutions in 2016. The agency chose Aurigo® Masterworks® (figure 6) as its official construction management system. This commercial-off-the-shelf (COTS) software is a multi-module, Web-based system that offers a mobile interface. UDOT started with the construction management module, which is now fully implemented.

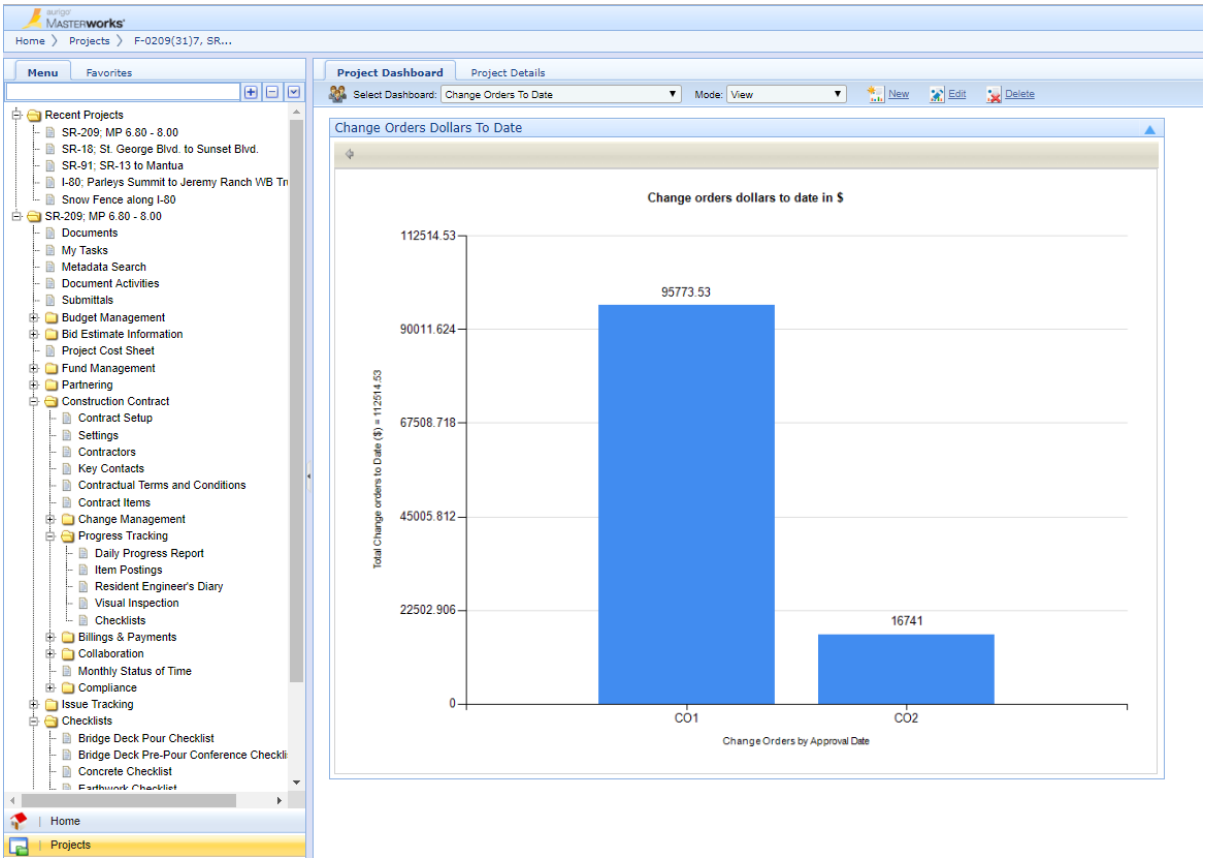


Figure 6. Screen Capture. UDOT's user interface of MasterWorks®. Source: UDOT

The agency is currently implementing and evaluating the materials and estimating and bidding modules, respectively. During the deployment of the selected e-Construction solution, UDOT tried to eliminate or improve as many forms as possible. The technology's rapid deployment did not make it possible to improve all business

processes. UDOT built defined workflows based on roles for reviews and electronic authorizations, but also built some flexibility to ensure forms could be reassigned to alternate approvers as needed. A key success factor of UDOT's implementation was the selection of a Software as a Service (SaaS) solution, which allowed the agency to transfer risk of implementation to the vendor and accelerate the timeline for deployment. UDOT uses the iOS® platform and issues an iPad® tablet to all inspectors in the field to access the Masterworks® mobile interface.

UDOT is evaluating e-ticketing and is working with industry to get pilots underway. Although UDOT has approached both the concrete and asphalt industry, the concrete industry is not ready to change its practices. UDOT projects consist of approximately two percent of the concrete industry's business, so investing in e-ticketing technology would yield no benefit to the industry for such a small market., so investing to accommodate such a small customer would not yield positive returns. On the other hand, the asphalt industry is completely engaged with the e-ticketing initiative, as it services a significant number of contractors building projects for UDOT. It is likely that the solution to be used for e-ticketing will employ truck license plates for tracking.

Although UDOT is in the early stages of implementing digital as-builts, the current practice is to require contractors to deliver marked-up electronic plans sheets, noting the as-built conditions. However, the agency is transitioning the responsibility to in-house staff.

Shared Effective Partnering Practices

ODOT

ODOT established a partnering program in 1991, but it was not until 2011 that the practice became part of the agency's culture. Specifications were developed to make partnering contractual, and many effective practices were set in place to ensure constant collaboration and feedback. ODOT has both informal (i.e. self-facilitated) and formal (i.e. externally facilitated) partnering, depending on the contract value. In either case, the goal is to proactively manage risk and resolve issues at the lowest possible level of responsibility. ODOT splits the cost of partnering with the contractor 50/50 when incorporating a professional facilitator onto the project.

To build a culture of partnership and ownership, ODOT implemented a partnering awards program in 2013 that celebrates good examples of effective partnering. Award-winning teams are showcased at an annual conference attended by more than 700 people from ODOT and the contracting industry. A YouTube® video is created for each winning category in which the team members highlight the effective partnering practices used in the project.

Although partnering is typically considered an external practice to collaborate with contractors to deliver construction projects successfully, ODOT has taken a similar

approach to tackling technology deployment. For example, construction staff are working with the agency's CADD (computer-aided design and drafting) Support Group to help develop a plan for implementing an inspection application that uses 3D models created in design to capture digital attributes. ODOT has joined forces with the Indiana DOT to use Federal funds for developing a mobile application that can integrate either a 2D or 3D digital model of the project with the construction inspection forms.

UDOT

UDOT's partnering program process is similiar to ODOT's. The program was established in 2002, but recent changes were introduced to make the process more effective. All UDOT projects must consider partnering founded on a risk-based approach. The partnering may or may not have formal facilitation. There is also a semi-formal process that is more of a structured format than the informal process, but at no cost to the project. The semi-formal process brings together trained mid-level UDOT staff with no authority to impact the project with the contractor. A risk matrix is used to guide what level of partnering is required on the project, but there is currently some bias (subjective ratings higher than likely should be and not getting truly independent analysis), which is presently being addressed. UDOT pays 100 percent for partnering up to a specific budget. UDOT requires a two-day training course for UDOT staff and contractors, but found that contractors were not attending due to no enforcement, so UDOT updated their specifications to include a provision that withholds payment from the first estimate until contractors are in compliance. The continuing education requirements are going to be updated to require an annual one-hour webinar for project leadership, which will be optional for others.

PennDOT

PennDOT's partnering program was established to follow the Utah processes.

MDOT

MDOT does not have a formal construction partnering program, but staffers work closely with industry to deploy innovations that help deliver projects effectively.

Key Takeaways and Lessons Learned

Participants put forth the following recommendations at the peer exchange, based on lessons learned from their programs.

Set an enterprise vision. When implementing e-Construction, it is important to understand the end goal so a clear direction can be set. Also, a managed approach to implementation will avoid ad hoc deployment of technology and help manage change.

Create the right system architecture. A document should reside in the system in which it originates. The key is tenable access by having a data layer that exposes data to and directs systems where to look automatically.

Collaborate with internal and external stakeholders. It is critical to work with field personnel to understand their needs and with IT to facilitate the best system setup. It is also important to work with contractors and consultants to ensure they can access the system without major difficulties. Allowing all stakeholders to access the documents enables transparency and accountability.

Identify and provide the right resources. Having both an executive and technical champion and a dedicated team to lead the implementation of e-Construction will help accelerate adoption. States with mature e-Construction programs have dedicated teams responsible for creating new processes, training, and deploying the technology. Their main responsibility is to implement the e-Construction program efficiently and effectively, so construction staff can concentrate on inspection.

Establish data governance. Data is produced and consumed by different stakeholders, but everyone needs a specific set of information. A data governance plan will allow you to set standards for how the data should be collected, attributed, and organized. Once the data is organized, it will be easier to select the tools/systems to access it.

Go beyond paperless. e-Construction goes beyond paperless workflows; it is about digital data being collected and includes 3D models, as-built conditions, and materials quality assurance information. It is time to make the connection.

Partner with both external and internal stakeholders. Partnering goes beyond issue resolution. Work with local public agencies, consultants, and contractors when deploying new policies and technologies. Also, internal partnering is just as important as external partnering. It helps staff break down the silos and find better solutions.

e-Construction and Partnering: A Vision for the Future

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FHWA e-Construction and Partnering innovation resources
https://www.fhwa.dot.gov/construction/econstruction

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