Technology Brief

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



Peer-to-Peer Exchange

Implementation of Automated Workflows

Lincoln, Nebraska
October 9–10, 2019

U.S. Department of Transportation
Federal Highway Administration

On-Ramp to Innovation
every day counts

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Background

The City of Lincoln, Nebraska, Department of Transportation and Utilities (LTU) is seeking to evolve its practice of using more automated workflows to improve measuring pay items, issuing payments, and developing record drawings (as-builts). To exchange ideas and solutions for overcoming challenges with implementation, LTU invited one representative each from four other public agencies to take part in a peer exchange October 9–10, 2019, in Lincoln, Nebraska. The Indiana Department of Transportation (DOT), Minnesota DOT, and Utah DOT participated in person, and the New York State Thruway Authority (NYSTA) participated remotely. Staff from FHWA's Nebraska Division and the Federal Highway Administration (FHWA) Resource Center attended in person.

The e-Construction and Partnering (eCP) peer exchange was sponsored by FHWA as part of round four of the Every Day Counts (EDC-4) technical assistance program. Information shared at the peer exchange by LTU and the four State agencies regarding their policies, practices, and use of technologies is summarized in this Technology Brief. See the final page of this Technology Brief for further information on certain limitations of this document and the non-binding nature of its contents.

During the peer exchange, INDOT shared information on the agency's mobile inspection solutions and recent radio frequency identification (RFID) research. MnDOT discussed work with capturing discrete geospatial location and inventory data of assets during construction. UDOT shared information on using geographic information systems (GIS) to support the project life cycle (see Figure 1). NYSTA provided information on its automated workflows for project life cycle.

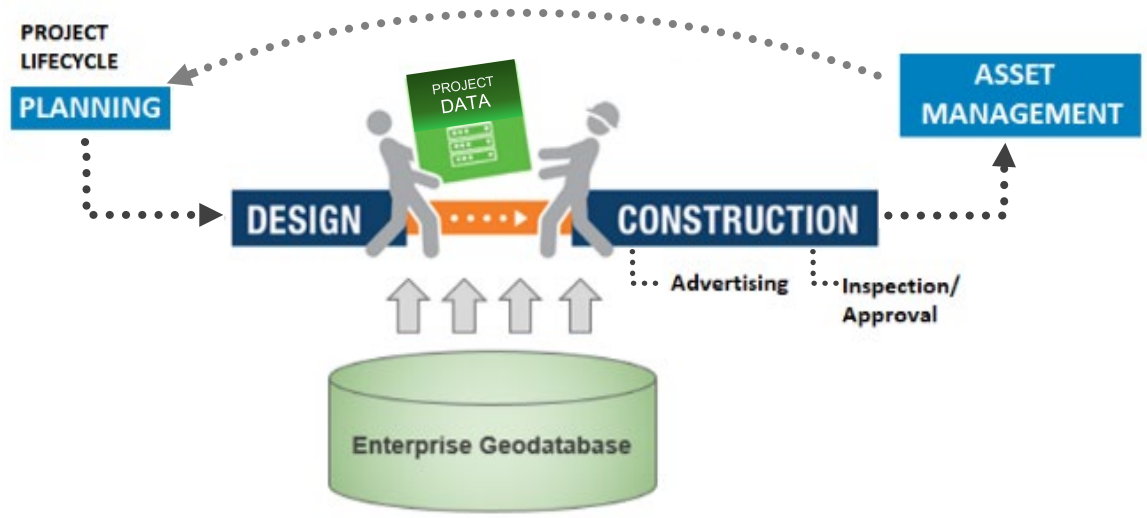


Figure 1. Illustration. UDOT's geodatabase integration for as-built data. Source: UDOT

Table 1 showcases different e-Construction technologies at each DOT.

Table 1. e-Construction technologies at participant DOTs.

Application	LTU	INDOT	MnDOT	UDOT	NYSTA
e-Bidding	Ion Wave	AASHTOWare® Project SiteManager™	AASHTOWare® Project SiteManager™	Custom	AASHTOWare® Project SiteManager™
Construction Management	Aurigo® Masterworks®	AASHTOWare® Project SiteManager™	AASHTOWare® Project SiteManager™ – transitioning to AASHTOWare® Project Construction & Materials™	Aurigo® Masterworks®	Custom suite of applications Oracle® Primavera Unifier (implementing)
Document Management System	Hyland® OnBase® – currently in testing phase of implementation	Bentley® ProjectWise® Custom-developed Electronic Records Management System[1]	Bentley® ProjectWise®	Bentley® ProjectWise®	Bentley® ProjectWise® Oracle® Primavera Unifier (implementing for non-CAD[2] documents)
Electronic Daily Reporting	Aurigo® Masterworks®	AASHTOWare® Project SiteManager™ Field Assistant Application (custom) and Bentley® inspection application (testing phase)	AASHTOWare® Project SiteManager™	Aurigo® Masterworks®	Custom application Oracle® Primavera Unifier (implementing)
e-Ticketing	None	None	None	Custom workflow using Safe Software™ FME® and Esri® Survey123	None
Mobile Devices	None	HP® Tablets and Apple® iPad® Tablets	Dell™ Tablets (for Citrix®) Apple® iPad® Tablets (for Info Tech® Mobile Inspector®)	HP® Tablets (for pilot demonstration) Apple® iPad® Tablets (for e-ticketing)	None (potentially will be used during Oracle® Primavera Unifier Phase 2 implementation)

[1] long-term storage
[2] computer-aided design

LTU e-Construction Approach

Strategy and History

In December 2018, LTU was granted accreditation by the American Public Works Association (APWA) as a result of its commitment to align its public works management with recommended APWA best practices, improve business performance and provisioning of services, and raise organizational standards of practice. As part of the accreditation process, LTU analyzed its policies and strategies and found gaps in how it was applying technology during project delivery. The gaps included manual workflows and the use of many separate systems. This awareness, coupled with LTU's commitment to innovation and incorporating effective, technology-enabled practices, has bolstered LTU's e-Construction vision for maximizing automation during construction.

LTU has made significant progress with deploying e-Construction innovations, including automated workflows before the construction contract award such as electronic bidding and online design/constructability reviews. During construction, LTU uses Aurigo® Masterworks® for construction management activities including pay estimates, change order processing, and progress reporting. However, the documents for change orders are touched by many project stakeholders and take significant time to process. LTU recognized that automating document management is a priority.

LTU's e-Construction activities include measuring pay items, issuing payment for accepted work, and recording as-constructed conditions. LTU believes time and money can be saved through automating many of these activities. For example, inspectors could use a Global Navigation Satellite System (GNSS) rover to orient themselves in reference to a pay item, measure and record pay item information (material location and inventory, quantity measurements, etc.), and upload information for processing/model development (if needed). Other automation ideas include populating the pay item postings in Aurigo® Masterworks®, identifying items paid for by LTU (or others), and automating the necessary pay request signatures simultaneously.

Current Efforts

After some analysis of the data exchange between project delivery phases, LTU decided to implement a middleware application (Hyland® OnBase®) in October 2018 to facilitate document management workflows and interfaces with several applications, including ProjectDox® for plan review, Aurigo® Masterworks® for construction/project management, Fulcrum Bee Hive for inspections, Ion Wave for electronic bidding, and Oracle® JD Edwards® EnterpriseOne for financial management. Implementation was underway as of this writing. LTU began the testing phase in October 2019. Business users provided feedback, and improvements were made to the application. Figure 2 illustrates the workflow architecture.

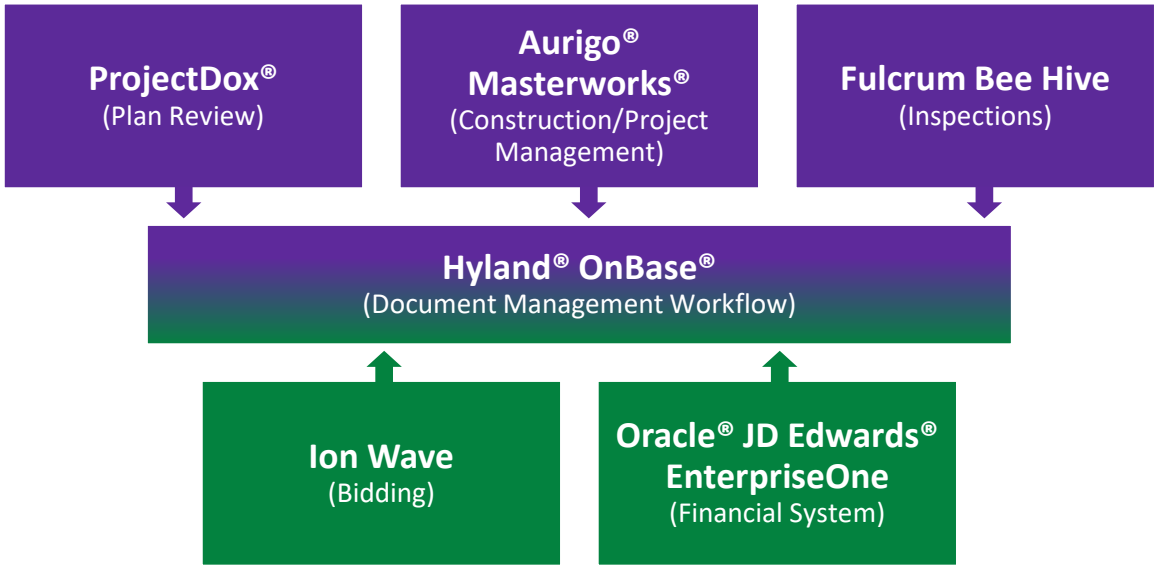


Figure 2. Illustration. LTU workflow automation architecture. Source: LTU

Hyland® OnBase® is an online application internal to the agency; however, there is an external portal for submitting permits. The application has tabs configured according to project delivery phases including programming (funding and costs), design, and construction. To the extent possible, each tab includes necessary information for downstream project delivery phases. For example, the construction tab includes information for asset management to initiate its workflows.

The automated workflows are dependent on dates, approvals, and other triggers defined and configured by the system administrator. These triggers will notify appropriate stakeholders for reviews, approvals, or other actions that follow in the workflow. A dashboard is available that can provide a high-level look at project status and performance for decision makers. LTU plans to build out each project delivery phase in the application to reduce duplicate entry and serve as a single source of information.

INDOT e-Construction Approach

Strategy and History

INDOT's initial e-Construction philosophy was focused on paperless workflows, but it is evolving toward intelligent design and construction. The agency's mission is to use intelligent, three-dimensional (3D) computer-aided design (CAD) models to support the life cycle of transportation assets (roads and bridges). The models provide data-driven predictive analysis and reporting capabilities that allow the agency to make better operational and strategic management decisions.

Currently, INDOT uses AASHTOWare® SiteManager™ and a custom-developed Field Assistant Application. The agency also uses several AASHTOWare® modules, Bid Express® for electronic bidding, and Bentley® ProjectWise® and Microsoft® SharePoint® for content management. INDOT also developed an enterprise record management system for a statewide document repository.

INDOT developed the Field Assistant Application in 2015 to provide a mobile interface for inspection reporting. The application works offline and enables construction inspectors to capture daily work reports and material test forms. Field Assistant is web-based and independent of any device, which allows for easier updates and improvements. Data are pushed automatically to the INDOT network when the device connects to the internet. Most of the data is sent to SiteManager™ to support relevant INDOT reporting requirements. Additional data fields were added to supplement other reporting. This information is stored in a separate table within INDOT's data warehouse.

INDOT contracted with Bentley® in December 2017 to develop a construction inspection mobile application to use with CAD models. The project kicked off in February 2018. The assets INDOT selected to test for the prototype were storm sewer pipes and structures, concrete panels, and hot-mix asphalt approaches. Development of construction inspection checklists was also part of this effort. Since Bentley® was working on a parallel and related effort for another DOT integrating 3D models into field activities, INDOT decided to focus on the portion of application development meant to work with two-dimensional (2D) CAD files. Figure 3 shows the 2D CAD elements that, once selected, will display the pay items for that component within the application.

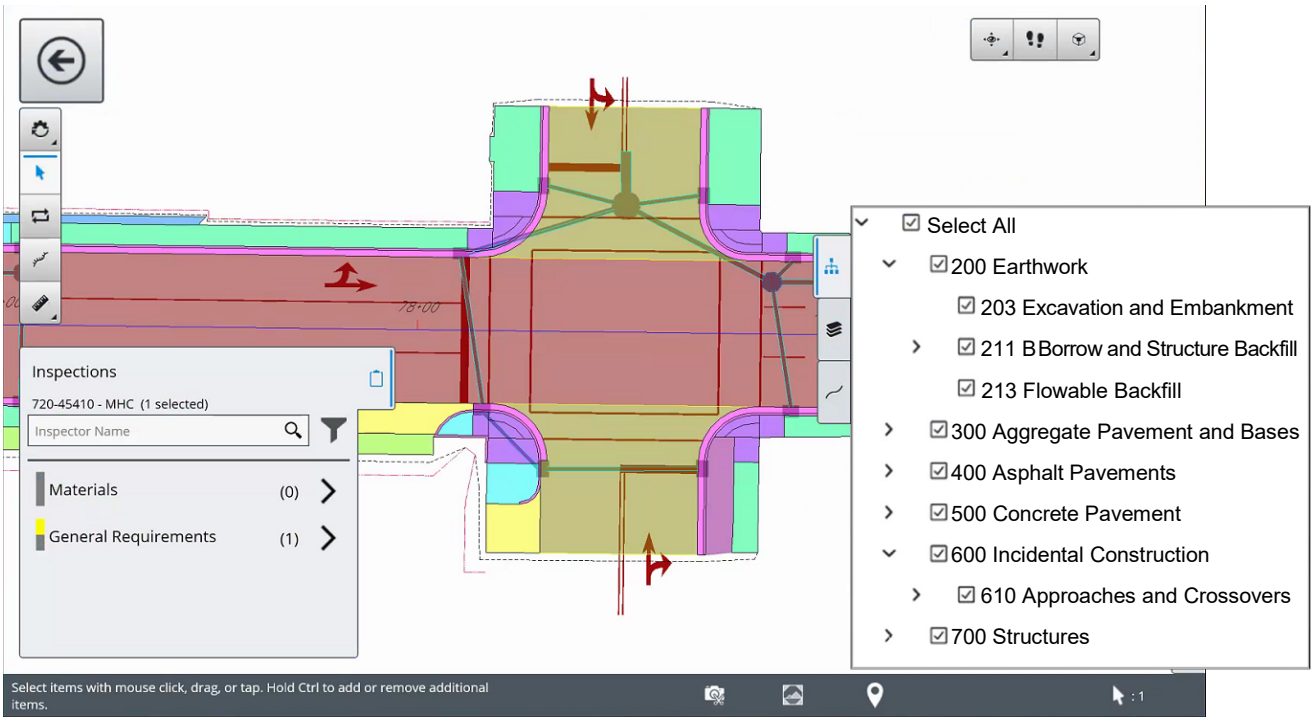


Figure 3. Screen Capture. 2D CAD elements with associated pay items in mobile application. Source: INDOT

In 2016, INDOT sponsored a proof-of-concept study for using RFID technology to understand how assets can be uniquely identified in the field. The study investigated passive and active tags and sought to answer specific questions about RFID tag longevity, storing information on RFID tags, cost, and market-ready RFID tag reader technology. The study initially evaluated RFID tags affixed to panel signs, sheet signs, and small culverts, then expanded to include guardrails during the field effort. The readers were used at intervals at 10, 15, 20, and 30 feet from the tags. The study found that distances up to 10 feet had a nearly 100 percent reading rate for all assets, but the farther distances did not perform well. Also, the study found that the metal did not appear to be a limiting factor in reading the RFID tags.

Current Efforts

INDOT wants to improve its construction inspection mobile application, digital as-builts capture, e-ticketing for materials delivery, and integration of asset maintenance.

The agency worked with Bentley® in 2019 on testing a prototype mobile application through a pilot project. The pilot tested the 2D model prototype in April 2019 on a recently completed construction project. This was not an active project, so the test was limited. In fall 2019, INDOT worked with Bentley® to determine suitable projects with which to test the form-based functionality. Tests of the 3D model functionality were planned to follow in 2020.

UDOT e-Construction Approach

Strategy and History

UDOT's efforts toward implementing digital delivery practices started in January 2014 with a visit to Iowa DOT to understand its processes for distributing electronic plan sets to contractors as information-only files. UDOT's takeaways from this visit were better understanding of data availability, documentation of lessons learned, and key activities to engage all stakeholders and improve processes. UDOT then worked with FHWA to host several workshops on 3D models, risks and challenges of model-based design and construction, and implementation of model as legal document (MALD). Since 2014, UDOT has awarded nine projects using MALD.

UDOT views digital delivery as the delivery of data through the entire project life cycle and is redefining business operations by leveraging technology to support a more digital workforce. UDOT's goals for digital delivery include producing more optimal designs, improving information transfer, obtaining and managing data to improve decision-making, and improving overall efficiency.

Current Efforts

UDOT was awarded an Accelerated Innovation Deployment (AID) Demonstration grant from FHWA to focus on the exchange of project data between design and construction, with select asset data to be tracked from design to asset management. The AID grant will be used to improve how 2D/3D CAD information is used, implement new scripts in workspace to create pay items, and redefine the as-built process based on asset management business user requirements. Figure 4 illustrates UDOT's proposed approach for using CAD and GIS data during design and construction.

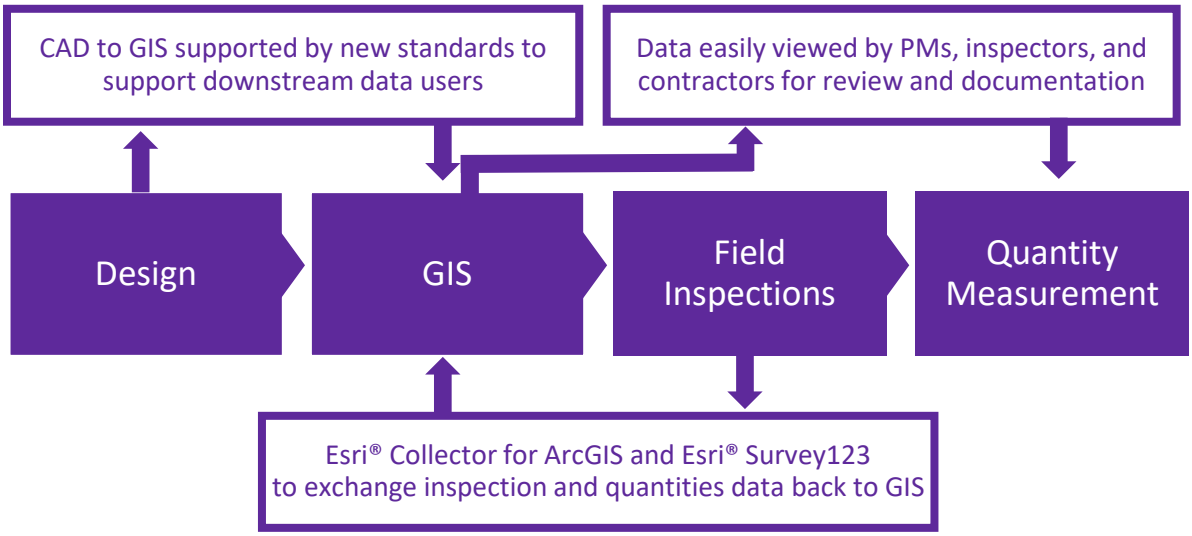


Figure 4. Process. UDOT's proposed process for GIS-enabled data exchange. Source: UDOT

UDOT noted CAD and GIS may involve work-arounds to achieve required objectives. For instance, CAD platforms often have continuously changing tools/functionality,

complex integration, and general incompatibility with other software. GIS is generally an incomplete solution with limited 3D visualization and breaking linear features, and it involves process changes to exploit functionality. As a result, UDOT's strategy is to develop its own tool to extract data and use a feature manipulation engine to enable the process. UDOT is currently updating its design workspace, building consistent processes, gathering as-built requirements, and testing functionality.

During construction, UDOT uses Aurigo® Masterworks® for construction management field activities including daily progress reports, visual inspections, engineer's daily diary, and item postings. Also, Masterworks® is used for contract and change management activities including pay estimates, document management (with automated workflows), change order processing, and reporting (queries and dashboards). Recent and upcoming improvements include using Masterworks® for materials testing, estimation and bidding, disadvantaged business enterprise and contractor registration, and GIS integration.

e-Ticketing is also a major initiative for UDOT given the expected benefits of having reliable and accurate ticket information (no lost, damaged, or illegible tickets), capturing location of material placement (no GNSS device used on haul trucks), and improved safety for inspectors by not increasing their exposure on the grade. UDOT intends to leverage and augment its existing suite of software to develop an e-ticketing solution. Using open data exchange formats, Safe Software™ FME®, Dropbox® and Google® Sheets™, and Esri® Survey123, the inspector will have an easy-to-use mobile application for capturing ticket information (see Figure 5).

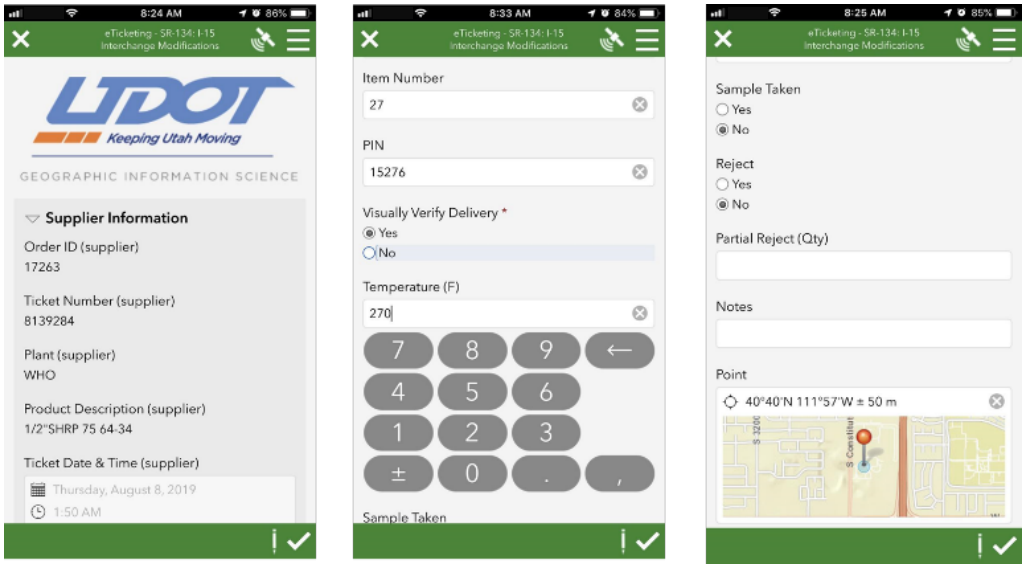


Figure 5. Screen Capture. UDOT's e-Ticketing solution. Source: UDOT

MnDOT e-Construction Approach

Strategy and History

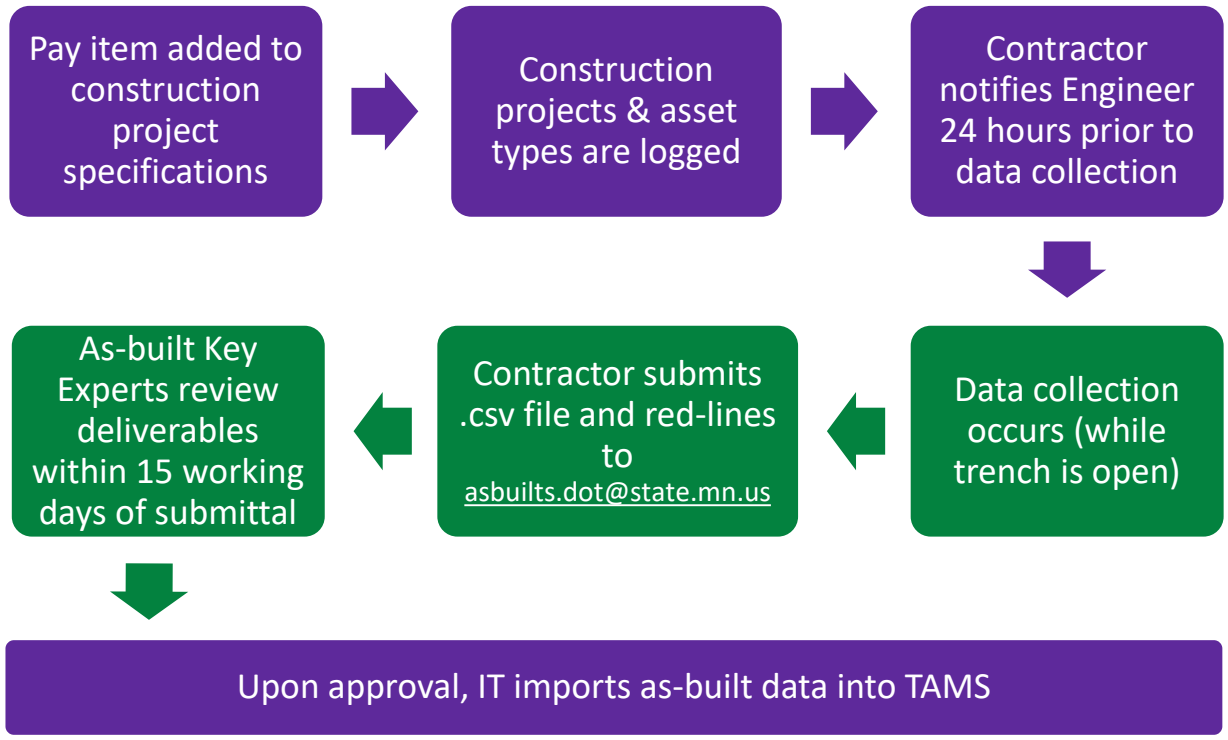
MnDOT includes an as-built special provision and pay item in nearly all projects within its district covering the Minneapolis-St. Paul metropolitan region (Metro District) and roughly half of the projects in Greater Minnesota. This special provision calls for as-constructed assets (10 asset classes) to be located using GNSS technology and inventoried in accordance with asset-specific requirements before project close-out. The as-built special provision originated from the need for understanding certain asset inventory information and where assets were located in the MnDOT right-of-way.

Starting in 2010, MnDOT created a committee dedicated to improving the as-built process. By 2012, MnDOT's Metro District as-built committee started piloting the special provision that created a uniform pay item for five asset classes (signs, lighting, drainage, signals, and traffic management systems). MnDOT recognized the following as benefits of creating a pay item for capturing this data:

- Costs for locating and inventorying assets can be tracked accurately.
- Capturing the data is enforceable, as payment can be held until data is delivered.
- Data can be immediately loaded into the asset management system to initiate maintenance protocols.

Current Efforts

The as-built special provision is now being used to some degree in all MnDOT districts for an additional five asset classes (barriers, retaining walls, noise walls, contaminated materials, and rumble strips). Its use varies by district depending on preference for project inclusion and by asset class being constructed. Currently, only the Metro District requires the as-built special provision on all projects. MnDOT is looking to add additional asset classes, to continue to build contractor proficiency, and to improve its processes and workflows. The current process and workflow for using the as-built special provision on projects is shown in Figure 6.



TAMS = Transportation Asset Management System
IT = Information Technology

Figure 6. MnDOT's as-built process. Source: MnDOT

MnDOT anticipates the use of the as-built special provision to expand to more of its districts and projects, which will transform the agency's asset management practices from collecting new data to validating asset inventories and attribution. However, for assets being built without the special provision, there are data and inventory gaps to be filled. Eventually, MnDOT wants to build a data mart to allow asset data to be exposed to other systems and inform decision support in other business areas.

Challenges for developing and using an as-built special provision with a uniform pay item include difficulty managing the as-built requirements for many asset types, increased MnDOT construction staff time, increased support from the districts in establishing consistent implementation approaches, change management, effective data quality review, and contractor communication and training. To address some of these challenges, MnDOT is developing a data conversion tool to help automate the review and exchange processes.

NYSTA e-Construction Approach

Strategy and History

NYSTA updated its contract management and capital planning systems, which it said were previously isolated and outdated, to allow better data workflows between stakeholders. The agency partnered with a system implementation consultant in 2019 to implement Oracle® Primavera Unifier using a two-phased approach.

Under phase one, NYSTA will replace three custom-developed legacy systems: capital planning management, contract management, and construction management. Also, NYSTA intends to improve workflows, integrate fiscal and field data, improve reporting (including regulatory compliance), enhance cash flow management and contract forecasting, and improve document management.

Current Efforts

NYSTA plans to implement two distinct user interfaces: one for contract management (progress payment, approval, and execution, etc.) and one for capital planning (planning, cash flow management and modeling, scheduling, budgeting, etc.). These distinct interfaces define the collaboration workspaces that have their own business processes, cost worksheets, reports, dashboards, document repositories, and users and groups. These interfaces will be connected through a tool being developed by the implementation consultant. The objective in connecting the two systems is to automate reconciliation of planning and contract finances and improve cash flow management and contract forecasting.

Under the planned phase two of implementing Primavera Unifier, NYSTA intends to expand its capability by adding external access for certain functions, building an interface between planning and asset management, and integrating with its budgeting system. NYSTA anticipates that Primavera Unifier will be fully integrated into its planning, design, and construction phases.

Cost and Benefits

INDOT invested over $50,000 (on 2D model functionality) in State funds toward developing its new construction inspection application. INDOT has also spent approximately $500,000 in both State and Federal funds for the development and implementation of Field Assistant over the past 6 years.

UDOT has not documented costs and benefit information nor performed a formal cost/benefit analysis for MALD and construction automation efforts. However, UDOT recognizes that it is in the investment phase of process development and technology implementation. It is expected that digital delivery will allow UDOT to better satisfy project delivery responsibilities. There is broad recognition of this goal within UDOT and commitment to achieving it. UDOT is satisfied with the consistent progress and plans to continue investing in the initiatives.

Some costs associated with implementing digital delivery for UDOT include mobile devices, additional software, outreach and education of consultants and contractors, and consultant contracts for pilot projects (independent cost estimates, quality assurance, etc.). UDOT identified reduction of paper, improved design intent, and readily available data information as the top benefits of digital delivery.

MnDOT is tracking its as-built special provision use on projects in accordance with the assets being constructed as well as pay item costs based on contractor's bid. For example, MnDOT's Metro District has the most experience with using the special provision and requires the special provision on all projects. As a result, as-built asset data records were delivered for the specified assets being constructed on an average of 85 percent of projects. In other MnDOT districts (where the special provision is currently not required on all projects), projects that include the as-built data records for the specified assets being constructed vary from 26 to 72 percent. MnDOT found that each data record received and accepted costs approximately $15.

Key Takeaways

Based on lessons learned from their programs, peer exchange participants suggested the following key takeaways:

Network with peer agencies. Peer agencies that have followed similar paths with implementing innovative practices and technologies are willing to share information and help exploring agencies improve their maturity. These relationships also help validate their respective e-Construction objectives.

Communicate effectively and often. Looking beyond the immediate value of streamlined information and data exchange, agencies can incorporate communication protocols built on these efficiencies to create a lasting benefit to all stakeholders. Proactive and frequent communication often resolves any conflicts quickly and encourages open feedback for continued improvement of e-Construction practices.

Also, encouraging end users to share their perspectives helps implement improvements and ensures long-term success.

Implement innovations that can provide quick returns. The tasks most likely to succeed with little investment in time and costs (e.g., electronic signatures) will have an immediate positive impact on business processes and generate momentum toward the agency's vision.

Educate information technology (IT) staff on intricacies of construction systems. It is important that the appropriate construction staff are educating and informing IT staff responsible for system administration or integrations. This improves system performance and grows a culture of trust.

Empower the right staff to make decisions on system development/configuration and integrations. Evaluating solutions as objectively as possible is important so that what is implemented will be successful and sustainable for the agency. Construction staff can provide this perspective and can offer practical insight on construction system functionality and integrations.

Cater to end-user experiences and functionality. Less customization of applications will allow for easier updates and improvements. Achieving a base level of functionality that meets end-user needs will get the initial deployment and subsequent improvements in their hands quicker.

Empower construction staff by equipping them with tools and expertise. UDOT construction staff using GIS tools and model-based processes appeared to be more engaged by actively contributing to the success of the project.

Seek to make progress, not perfection. Managing expectations of decision makers and end users can be challenging; however, the objectives of any implementation should be to make progress with improving business or technical operations since a perfect solution is not realistic. Incremental improvements can be planned and implemented quickly and more reliably.

e-Construction and Partnering: A Vision for the Future

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FHWA e-Construction and Partnering innovation resources
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