U.S. Department of Transportation
Federal Highway Administration

e-Construction & Partnering Case Study

Minnesota and Iowa DOT Solutions for Capturing Asset Information during Construction

Innovative As-Built Data Collection Delivers Enterprise Value

Typically, the practice of recording as-built conditions during construction involves marking up paper or electronic portable document file (PDF) plan sheets. The purpose of the marked-up plans is to have a permanent record of what is built and accepted during the construction project. This information is kept in electronic or physical cabinets and later used to extract asset data for routine maintenance activities. However, with the advent of geospatial technologies such as light detection and ranging (LiDAR), Global Navigation Satellite Systems (GNSS), and geographic information systems (GIS), some States are collecting data after construction—using these technologies to populate asset management GIS databases.

The challenge with this approach is that only data on the assets visible above ground is collected. Another approach to capturing information on as-built conditions is to enable construction staff to collect asset data using geospatial tools as they accept the work being installed. The advantages of collecting asset information during construction are that maintenance workers do not need to return after the work is completed to collect the information, and the location and conditions of installed underground and aboveground assets are captured all at once.

Collecting as-built information on assets during construction is exactly what the Minnesota Department of Transportation (MnDOT) and the Iowa Department of Transportation (Iowa DOT) have set out to accomplish.

Key Takeaways

- Making progress toward a vision is more important than a perfect solution.
- Educating and communicating with all stakeholders is critical.
- Nurturing an inclusive change management process is important for sustaining success.
- Be flexible and agile for deploying technology, as initial plans will change.
- Learn from others as much as possible.

For the past several years, MnDOT has included a special provision in its construction contracts requiring contractors to deliver specific geometry and inventory information for distinct asset classes to help populate the already established maintenance GIS database. This effectively ensures certain digital as-built data is captured before construction closeout and preserved for downstream uses.

Iowa DOT also captures asset information in the field during maintenance and operation of its infrastructure assets, as well as during construction. The processes and workflows for capturing asset information

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from the field have matured more quickly for maintenance inspection, but the construction staff is working to implement the same solutions.

Both agencies capture asset data from the field during construction, verify the data meets certain requirements, and use the data to support their asset management programs. MnDOT's collaboration with contractors on collecting asset information during construction and Iowa DOT's use of mobile applications for capturing asset information in the field are important practices that can be readily implemented to advance a digital as-built process.

Intelligent Infrastructure Requires Contextual Understanding

Having accurate information on all infrastructure assets is crucial for managing a statewide transportation network. While data may be collected for certain asset types, the management of these assets is largely done using disparate systems with limited use outside the immediate needs of the asset owner. Building information modeling (BIM) for infrastructure is challenging this traditional approach by focusing on managing asset information (inventory, geometry, and condition characteristics) throughout the asset life cycle. This enables the decision-making process for repair, rehabilitation, and reconstruction of infrastructure assets.

The vision of many asset owners is to enable an enterprise asset management strategy by applying intelligence. This intelligence comes in many forms, including complete records of asset information, as determined by the asset life-cycle phase. After the asset is constructed, this information brings actionable insight that feeds the agency Transportation Asset Management Plan (TAMP) immediately, so infrastructure improvement can be planned and programmed with confidence. Achieving the required level of intelligence to support and enhance the agency TAMP requires specific data to be captured during infrastructure asset development and construction. MnDOT and Iowa DOT have implemented unique solutions for capturing digital as-built data during construction to improve their asset management approach with more forward-looking strategies.

Description of the Practice

MnDOT includes the as-built special provision in nearly all projects within its district covering the Minneapolis-St. Paul metropolitan region and roughly half of the projects in Greater Minnesota. The requirements are described by asset class, data collection method, and mark-up requirement. The data collection method is determined by either sub-foot positional accuracy (Method 1) or sub-meter positional accuracy (Method 2). The following list includes the asset classes in the special provision; however, the special provision allows other assets to be included on a case-by-case basis as long as the data collection method and mark-up drawing requirement is specified:

- Drainage or stormwater. (Method 1 and mark-up drawings required.)
- Traffic Management Systems. (Method 2 and mark-up drawings required.)
- Lighting. (Method 2 and mark-up drawings required.)
- Signing. (Method 2 required.)
- Traffic control signals. (Method 2 required.)
- Traffic barrier. (Method 2 required.)
- Earth retaining systems. (Method 2 required.)
- Noise walls. (Method 2 required.)
- Landscaping. (Mark-up drawing only required.)
- Rumble strips. (Method 2 required.)

MnDOT focuses on using contractor resources for capturing specific high-accuracy asset data. Iowa DOT has implemented a proven solution that empowers construction staff to collect asset geometry, asset inventory, and specific form data. Iowa DOT deploys mobile devices with Esri® applications to collect vector data (points, lines, and polygons) of specific features in the field (using Esri® Collector) and to capture asset-specific form/attribute data (using Esri® Survey123 for ArcGIS™). Iowa DOT now collects asset data for several asset classes including:

- Culverts.
- Lighting.
- Traffic barriers.
- Walls.
- Fencing.
- Patching.
- Signs.

Recently, Iowa DOT started capturing asset information during construction using Survey123 for collecting material sample data. Survey123 is a form-based application that replicates standard Iowa DOT forms. Survey123 is also used to record the location of pavement core samples, pipes, and signs using GPS coordinates and to enter descriptions and other metadata on smart forms. Both Survey123 and Collector were deployed to align field data collection with the Iowa DOT asset inventory database overseen by the maintenance staff. Construction staff is planning to use Survey123 to add data collection for assets being installed and inspected.

Iowa DOT is transitioning its as-built drawings and documentation processes from paper markups to PDF redline markups using Adobe® Acrobat® Pro. As-built drawing records are created by inspectors after the project has concluded. Iowa DOT uses Adobe® Acrobat® Pro instead of a computer-aided design (CAD) program because its current workflows are unable to support the resource requirements for CAD development and management.

Understanding the Needs of the Enterprise

MnDOT, by statute (One-Call legislation), is the designated owner of underground assets within its right-of-way. As such, MnDOT needs to know the location of those assets. In response to the 2012 Moving Ahead for Progress in the 21st Century Act, MnDOT established risk-based requirements for its State TAMP that were expanded to include additional assets on its entire State highway system, including highway culverts, deep stormwater tunnels, overhead sign structures, high-mast light tower structures, ITS assets, noisewalls, signals, roadway lighting, and buildings. As a result, it was necessary to accelerate improvements to its as-built process. MnDOT selected the asset geometry and inventory characteristics through a committee dedicated to the as-built process.

In 2010, MnDOT's Metro District formed an as-built committee with representatives from maintenance, water resources, traffic, and the regional transportation management center, along with several subject matter experts for underground assets. Each representative solicited input from their subject area and brought feedback to the committee for discussion and dialog to create the as-built requirements. The initial vision was that this would be a technically oriented working group that would sunset after the work was completed.

In 2011, through several rounds of discussion, the committee created a special provision that was included as a pilot in five construction projects. After seeing the special provision succeed within these pilot projects, MnDOT began including the special provision on all Metro District projects in 2015. After the success of the Metro District committee, MnDOT expanded the conversation to its other districts and formed a statewide as-built committee in 2018. Figure 1 shows the evolution of MnDOT's enhanced as-built process since formalizing its efforts.

Through this special provision, MnDOT asset management and construction staff work closely to ensure the data received from the contractor passes any verification requirementsand that the data is of sufficient quality. Iowa DOT initially sought to improve its maintenance processes, given advancements in geospatial technology and the need for staff to be as mobile as possible. The identified mobility requirements include disconnected editing, reliable performance and connectivity, collection and storage of photos, data-driven forms and queries, multi-user functionality, and ease of use. In 2011, Iowa DOT started collecting culvert data using Apple® iPad® devices for maintenance purposes. The evolution to Esri® ArcGIS® Online and Collector started in 2013, and the agency has since expanded its use of these tools to include additional asset classes for maintenance.

When the Iowa DOT construction staff became aware of what maintenance staff was doing with mobile devices and applications, they opened a dialog with them to evaluate usefulness for construction purposes. The logical first step for deploying Survey123 and Collector during construction was to replicate their material sample collection forms. The use of Survey123 and Collector is supplemented by a program that includes annual updates to training materials, annual field training, and information technology (IT) support as needed. As construction becomes more proficient, additional needs and requirements are likely to be identified.

Figure 1. *Evolution of MnDOT's enhanced as-built process.*

Setting the Framework for Data Collection

The framework MnDOT implemented for capturing as-built data through a special provision includes contractor requirements and a dedicated website for guidance, district contact information, and additional submittal procedures. The website contains information on asset classes, including feature index tables (see Table 1) and an example data submittal table (see Table 2). The feature index table describes feature codes used during data collection and data collection locations. Drainage or stormwater assets (new or regraded ponds and infiltration/ filtration basins) require the contractor to submit a digital surface model and CAD file in addition to the point file. Once MnDOT accepts the data, most of the asset data is imported into the agency's Transportation Asset Management System (TAMS) containers for the specific assets.

Table 1. *Traffic barrier asset class feature index.*

Feature	Feature Code	Collection Location
Guard Rail – High Tension Cable	HTCB	Every 250' and 50' on curves
Guard Rail – 3-Cable	GRCA	Every 50' and change in direction
Guard Rail – Plate Beam (longitudinal metal barrier)	GRPB	Every 50' and change in direction
Barrier – Concrete	BARC	Every 50' and change in direction
Crash Cushion	CCUS	X, Y, and longitudinal distance
End Terminal	ETRM	X, Y, and longitudinal distance
Transition	TRAN	X, Y, and longitudinal distance

Table 2. *Example data submittal for barrier asset information.*

Point1	SP#[2]	Date of Collection[3]	X[4]	Y[5]	Z[6]	Feature Code[7]	PlanID[8]	Asset Class[9]	Comments[10]
6003	8214-41	5/31/2017	555379.692	115952.985	931.213	ETRM	CR1	BARRIER	None
6004	8214-41	6/1/2017	555372.215	115953.693	930.047	CCUS	CR1	BARRIER	None
6005	8214-41	6/2/2017	555349.253	115979.381	929.331	CCUS	CR1	BARRIER	None
6006	8214-41	6/3/2017	555342.682	116000.825	928.743	CCUS	CR1	BARRIER	None
6007	8214-41	6/4/2017	555334.888	116030.233	930.107	CCUS	CR1	BARRIER	None

[1] **Survey/ GPS point number.**
[2] **State Project ID.**
[3] **Date that the data was collected.**
[4] **X-coordinate corrected from longitudinal degree** (appropriate Minnesota county coordinate system to be noted as well).
[5] **Y-coordinate corrected from latitudinal degree** (appropriate Minnesota county coordinate system to be noted as well).
[6] **Z-coordinate.**
[7] **Refer to Feature Index Table (Table 1) to determine what code to use with each feature.**
[8] **The ID that is obtained from plan set or existing data given to contractor (not all features have a PlanID).**
[9] **The Asset Class for the feature.**
[10] **Additional comments can be added as needed (some asset classes require comments).**
If a linear element is being collected, a ***string ID*** is to be provided in the comments.

Note: only one feature per x, y, z location.

Iowa DOT worked to define what material sample data was to be collected in the field using Survey123. The material sample form replaces the paper form. It can be partially filled out ahead of time by the inspector with some fields automatically populated, including date and time, inspector information, and data from previously submitted forms. Some fields have integrated calculations to simplify data entry. The Survey123 material sample forms can be used offline and include barcodes and geopoints. The data is hosted by Esri® and then downloaded to local Iowa DOT servers. Iowa DOT plans to have the data exchanged directly from the mobile device to Iowa DOT servers, but that transition is not yet complete.

Investigating Collection Methods

MnDOT and Iowa DOT started collecting asset information as part of their maintenance activities. The workload for maintenance staff to collect asset information after construction completion was substantial. Even though shifting this data collection into the construction phase increased construction staff time and project costs (slightly), the reduction of resource load on maintenance staff leveled out any overall cost increase while improving data accuracy and completeness of asset information. MnDOT has started tracking costs associated with as-built data collection by contractors and will use this information in the future to better understand the costs and benefits of the practice. Table 3 illustrates the cost information MnDOT is tracking on its use of the special provision.

Table 3. *Examples of information MnDOT uses to track special provision usage.*

District	Engineering Estimate[1]	Contractor Estimate[1]	Signs[2]	Lighting[2]	Drainage[2]	Signals[2]	TMS[2]
1	$78,000	$94,000	29%	69%	16%	86%	50%
2	$36,000	$93,000	63%	75%	24%	85%	100%
3	$85,000	$113,000	44%	25%	43%	100%	100%
4	$39,000	$46,000	44%	25%	14%	50%	0%
Metro	$963,009	$776,811	75%	93%	78%	84%	94%
6	$150,000	$85,000	66%	75%	21%	100%	100%
7	$156,000	$189,000	58%	58%	82%	26%	11%
8	$58,000	$56,000	38%	75%	0%	100%	50%
Average	$195,626	$181,601	52%	62%	35%	79%	63%
Totals	$1,565,009	$1,452,811	n/a	n/a	n/a	n/a	n/a

[1] Project-specific use.
[2] Asset-specific use (ratio of as-built pay item used).
n/a – Not applicable

MnDOT decided that having the construction contractor (guided by the special provision) was the best method to capture as-built data for underground assets because the agency did not have the internal resources to collect the information during construction. Also, collection of asset information after construction by maintenance or asset management staff was not timely and often resulted in incomplete data. Prior to 2011, MnDOT had several asset classes with different as-built information requirements in the construction specifications, so the new as-built special provision created one unified pay item and special provision. The newly created special provision meets the data collection enterprise needs for as-built information and brings uniformity to how that data is collected.

Noteworthy Procedures and Methods

Multi-Disciplinary Collaboration

MnDOT's as-built committee comprises specific representatives from key areas that are impacted by the as-built process, including construction. The committee meets regularly and emphasizes clear and open communication to ensure requirements are being met without burdening the contractor or agency staff.

The success of implementing data collection of asset information during construction is a direct result of MnDOT working proactively with its district offices and construction staff to understand specific information needs, manage changes, and draft an effective special provision. MnDOT established monthly statewide working group meetings to check the status of and discuss updates to the special provision, then incorporated lessons learned and improvements based on the discussions.

Iowa DOT works closely with its IT group to continually improve processes with data storage and delivery. For example, it was necessary for the agency to use the Esri® cloud solution (i.e., ArcGIS® Online) for storing and exchanging data, but it has since set up services from Oracle® and is now migrating to a Microsoft® SQL Server® system with the help of its IT staff.

Additionally, Iowa DOT is collaborating with several downstream users of data to strengthen the requirements framework for specific applications. As a result, several Iowa State University research projects were informed by available data, including studies investigating in-service performance evaluation of cable barriers and culvert extensions that leveraged asset locations and condition information for corridor project analysis.

Piloting innovations that capture asset information

MnDOT piloted the collection of asset information during construction using the newly created special provision on five Metro District projects as the first step toward improving the process for recording as-built conditions. The pilot projects were largely successful and enabled the Metro District to require the special provision on all its projects in a short amount of time.

The pilots took a while to complete, given the as-built stage is at the end of construction, but each pilot consistently showed the special provision was an effective vehicle to enable collection of asset information during construction. After the pilots concluded, there were minor updates to the special provision and a website was developed specifically for these improvements.

Business process improvement

MnDOT's process to record as-built asset conditions has been enhanced by collecting the information during construction rather than waiting until the project has ended. As MnDOT continues to improve the requirements for asset information collection, the agency will continue marking plan sheets to document as-built conditions. This duplication of work is an interim solution as the agency transitions to an all-digital data collection approach.

Iowa DOT focused on enhancing its existing processes by replacing paper with electronic tools. For example, Iowa DOT's form for sample test identification was created in Survey123. Once the form is filled out, the Feature Manipulation Engine (FME®) spatial extract, transform, and load process platform developed by Safe Software, Inc. generates an email to the designated lab (and other identified stakeholders). The email contains a PDF report created from the data fields in Survey123 and formatted to look like the traditional paper form.

Challenges and Successes

MDOT's biggest challenge in implementing data collection of asset information during construction was change management. It took significant buy-in for construction staff to adjust their processes. For example, inspectors must now coordinate with the contractor to verify the asset information was completed per the contract requirements to issue final payment. Managing district expectations and developing construction staff skill sets were significant changes to address. The distributed structure of MnDOT also creates some nuances with communication protocols and managing expectations more broadly. However, the agency continues to work with its districts to overcome those challenges.

Implementation process challenges for MnDOT include tracking large numbers of construction projects and the timing of receiving as-built data. Managing the data quality assurance process is also a challenge for construction staff working with many diverse types of contractors.

Iowa DOT is seeing some challenges with integrating or exchanging asset data between its GIS system (Esri®) and CAD system (Bentley® MicroStation®). This is a common issue given the major proprietary CAD systems have developed limited GIS capability within their suite of applications. The CAD systems allow GIS data to be imported, but any advanced GIS functionality such as spatial analysis or integration at the database level is not available.

Future Outlook

MnDOT is expanding its as-built data collection specification usage statewide and to include additional asset classes. MnDOT is also working on a streamlined process to import the as-built data into TAMS and provide mobile application options for contractors.

Iowa DOT is in the process of deploying AASHTOWare® Project™ Construction and Materials, which will impact its use of Survey123. Also, Iowa DOT is looking for dashboarding tools for different levels of granularity that support decision-making as well as improved data integration for staff engineers.

The use of the Esri® solutions for collecting data during construction will likely expand, given the recent successes with Survey123. The use of Collector will enhance the inspection process with geometry, inventory properties, and photos collected directly from the field.

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Key Words

- As-built
- GNSS
- Geospatial
- Digital data
- Asset management
- Minnesota Department of Transportation
- Iowa Department of Transportation

Notice

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