U.S. Department of Transportation
Federal Highway Administration

Developing Model-Based Digital As-built Processes at Minnesota Department of Transportation

For over a decade, the Minnesota Department of Transportation (MnDOT) has pursued Digital As-Builts (DABs) both strategically and pragmatically. MnDOT uses DABs to maintain current information about specific asset classes as they are renewed or created through the construction process. However, manual, fieldbased processes are resource intensive. MnDOT is now considering how new design technology can introduce efficiencies into the DABs process. MnDOT has two pilot projects that have developed and piloted a more streamlined, modelbased methodology.

This case study describes how MnDOT is maturing the DABs program by considering the Transportation Asset Management System (TAMS) data needs while implementing digital project delivery. The case study further describes the model-based workflows developed on one pilot project that will be used to deliver DABs on a second pilot project. Finally, this case study describes how MnDOT has continuously evolved the DABs program alongside new developments in TAMS data collection to make use of the most efficient data collection method for each asset class.

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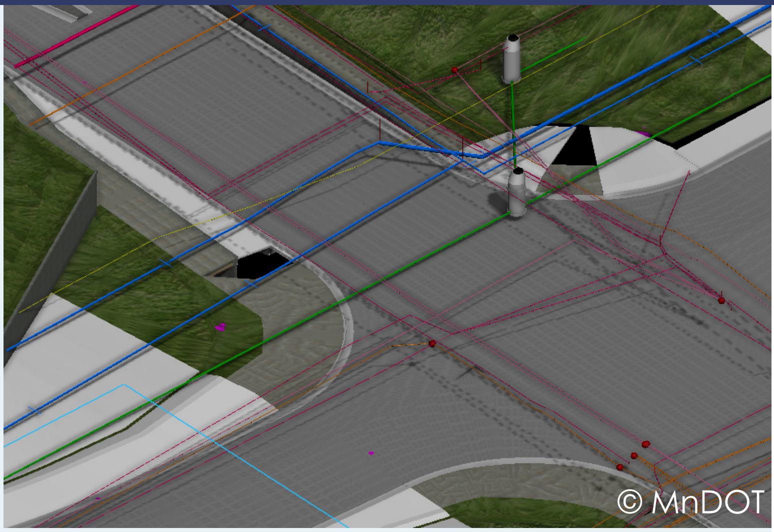

Figure 1: A rendering of a 3D design model showing existing utilities under the pavement.

Background

MnDOT began using DABs in 2011 with a special provision that required the contractor to deliver locations and other information for certain asset classes. Initially, the DABs resolved an issue for asset experts who were not reliably receiving the asbuilt information that they needed. After developing its first Transportation Asset Management Plan (TAMP), MnDOT included five ancillary asset classes. These asset classes were chosen based on risk of failure and in order to understand the current state of practice for each asset class. The results were successful, so in 2018, MnDOT added even more asset classes to the next version of the TAMP, solidifying MnDOT's proactive approach to managing an entire system of assets.

Asset data needs to be current and accurate in order to be used to perform life cycle planning, set performance measures, evaluate targets, and forecast future investment needs. In 2015, MnDOT began implementing an enterprise asset and maintenance management software system, called Transportation Asset Management System (TAMS). This setup a repository for asset inventory and condition data and software tools to use and maintain the data. MnDOT created an Asset Management Strategic Implementation Plan (AMSIP), which established a 5-year plan for improving the management of highway assets. The AMSIP clearly defined the role of DABs in maintaining MnDOT's asset information. MnDOT's journey with DABs has made it clear that the project development process generates a rich well of information that MnDOT could tap for asset management purposes—if the data could be conflated into TAMS.

MnDOT is implementing digital project delivery using Building Information Modeling (BIM). BIM is a process to manage the production, sharing, and use of data-rich, 3D models. MnDOT plans to align their development of digital project delivery to their TAMS data needs. This is consistent with the international standard, ISO 19650-1:2018, which establishes the concepts and principles for the organization of information for buildings and civil engineering works using BIM. BIM-derived design models contain detailed information about the included assets affected by the project. Figure 1 shows a 3D model with existing utility assets below a reconfigured road.

TH 169 Redefine Elk River

A project to redefine Trunk Highway (TH) 169 in Elk River is MnDOT's first digital project delivery pilot project that uses 3D, model-based design tools to deliver a paperless roadway construction plan set. The project uses the Construction Manager/General Contractor (CM/GC) alternate contracting method. Construction began in 2022 and is set to be complete in 2024. The scope is to convert a 3-mile stretch of highway into a freeway section. There were over 58 miles of utilities to relocate, several new bridges, and significant earthworks volumes to convert at-grade intersections to underpasses.

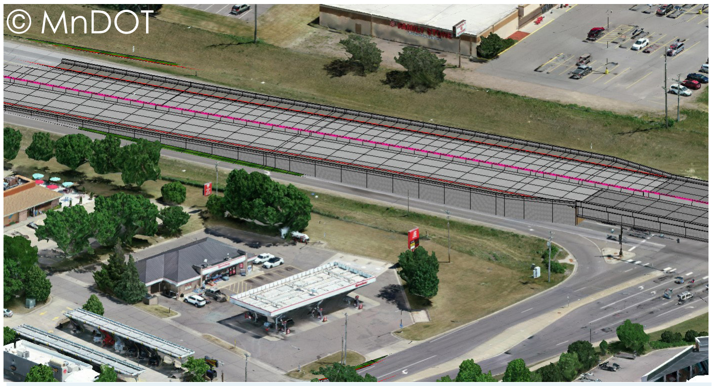

Figure 2: A view of the model of a TH 169 overpass at an at-grade intersection.

The CM/GC procurement method enabled MnDOT, the consultant, and the contractor to determine how to best transfer digital information, including 3D design model files. This enabled the consultant to use technologies such as 3D and 4D modeling to rapidly prototype design concepts. The prototyping helped to refine the design to a concept that could be built within a guaranteed maximum price of $130 million.

Reviewers could collaborate asynchronously in the cloud-based environment, creating comments and mark-ups that other reviewers from different organizations could see and respond to. This more collaborative design review process helped improve the efficiency of the design iterations. As the design developed, the construction cost estimate trended lower. In August 2020, the estimate was over $135 million. By February 2021, the estimate had dropped below the

The consultant designer worked closely with software vendors to develop data-rich, detailed 3D models of the roadway, earthwork, bridges, drainage, and utilities. These models were referenced together into a "federated model," providing a 3D view of the complete project. The federated model was stored in the cloud with a web-based suite of review tools. This provided opportunities to examine the design in new ways. Figure 2 is a view of the design model showing a proposed overpass and reconfigured intersection.

Figure 3: Reduction in unallocated risk and total construction cost over time.

guaranteed maximum price threshold. A year later, the estimate had fallen below $125 million, with a total savings of $15 million. As Figure 3 shows, half of the savings resulted from mitigating and managing construction risks during the design phase.

The digital project delivery process involves using BIM to create data-rich 3D models that are dynamically linked to the 2D plan sets. The plan sheet annotations and graphics update dynamically with each design iteration. Reviewers were able to correlate the information they saw within the model with the data that they saw on the plans because both visualize the same data. This gave reviewers confidence in using the 3D models to review the design and enabled the use of visualizations to explore the design in more depth. Figure 4 shows a utility conflict identified by a clash detection routine in design review software.

The team recognized that the design model contained valuable asset information. They contacted MnDOT's asset management office to discuss how the pilot project could help advance DABs workflows by extracting the asset information. Currently, MnDOT's field-based DABs program supports twelve of the seventy-four asset classes identified in the AMSIP. The methods developed by the TH 169 project team have advanced MnDOT's knowledge of opportunities to update TAMS data to reflect changes to assets caused by construction. Specifically, the TH 169 project was an opportunity to test the practicality and efficiency of creating asset data in design and construction with digital project delivery. The project brought several software technology providers together to see and understand asset data content and structure. The project piloted software interoperability improvements that streamlined the creation of DABs.

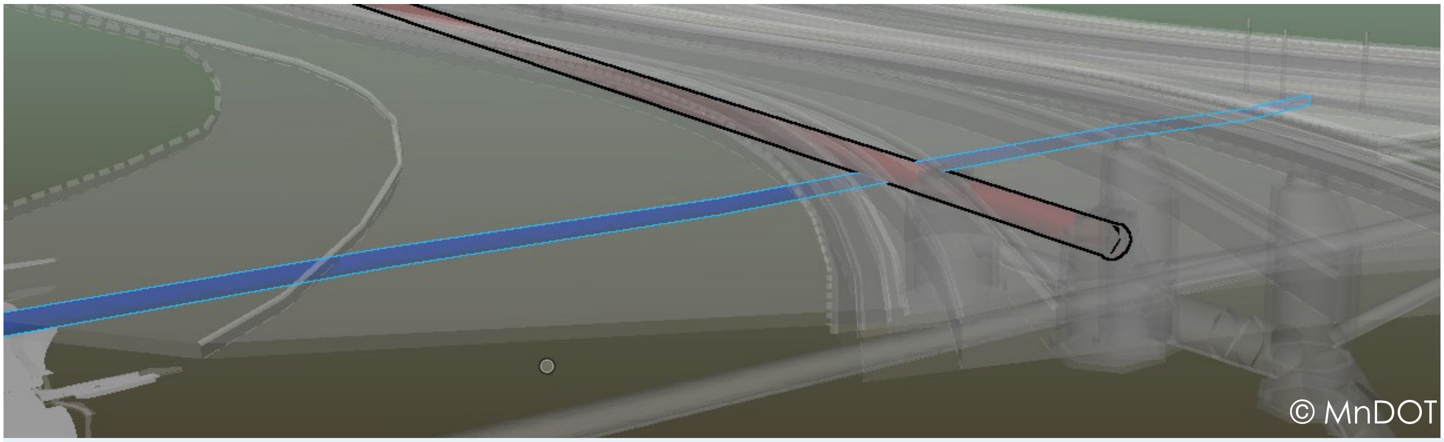

Figure 4: A utility conflict identified by an algorithm in the cloudbased review software.

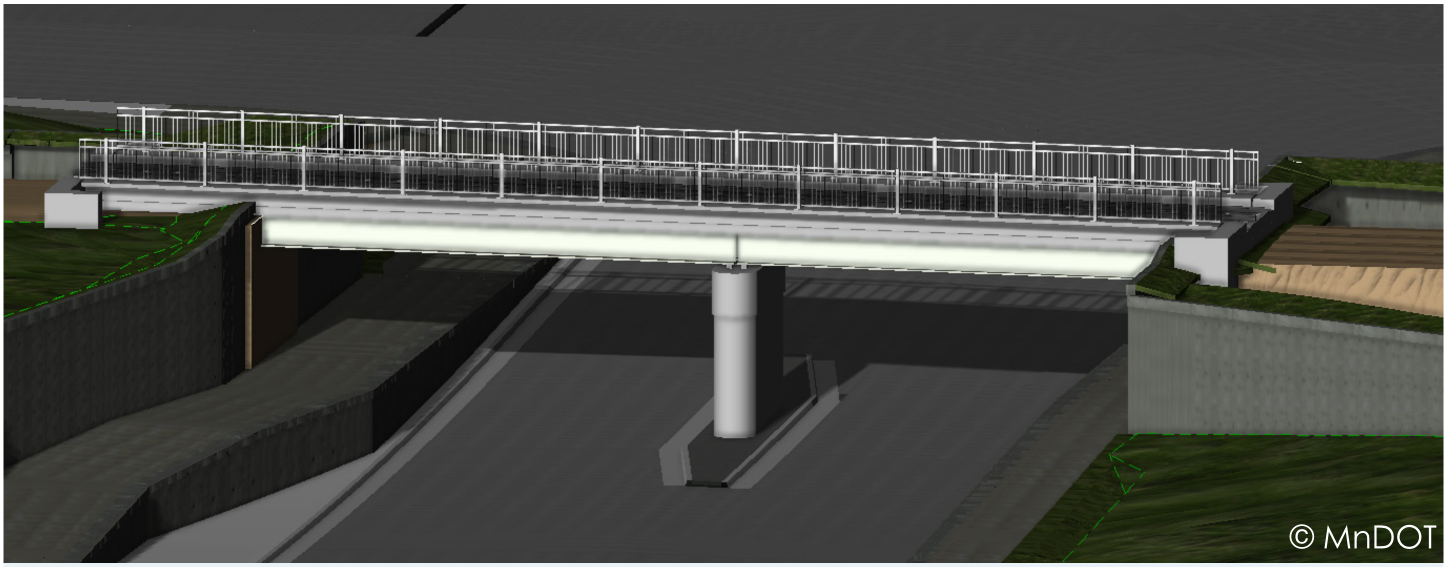

Figure 5: A rendering of one of the 11th Street Underpasses and the rebuilt US10/US75.

11th Street Underpass

The 11th Street Underpass project located in Moorhead, MN is another complex project being delivered using CM/GC that makes use of digital project delivery. Moorhead is an old railroad town with historic properties and a busy freight and Amtrak rail corridor. About 70 trains cross the US highway routes per day causing about five hours of road closure every day. The scope is to grade separate two sections of 11th Street under the railroad lines and reconstruct a section of US-10/US-75 between the two railroads.

The project is currently in design and construction is planned for 2024-2026. There are many challenges, including the need to keep the railroads active with shoefly bridges, drainage considerations, extensive subsurface utility relocations, contaminated soils and impacts to properties regulated by Federal preservation laws.

The project team is using the same digital strategy to develop the project design and produce visualizations to aid in stakeholder and public engagement. Figure 5 is a visualization of one of the 11th Street underpasses. The designer will continue to support the project during construction, specifically to update the design model to reflect any field changes to the assets and then use model-based processes to develop the DABs. The model-based process creates an opportunity to deliver DABs for the City of Moorhead as well.

Model-based DABs

The TH 169 project team met with individuals from MnDOT's Asset Management Project Office (AMPO) and Engineering Services Division, where staff have expert knowledge and provide support for MnDOT's design software. The group met often to brainstorm ways to incorporate asset inventory information into the design models. A key focus was on how the asset information in the design model would be transferred to construction, where it could be updated to reflect as-built conditions, and delivered as a DAB. The DABs component of the pilot project had two goals. The first goal was to develop a proof of concept that would be repeatable and scalable to other project types and sizes within the MnDOT program. The second goal was to develop the model-based workflow to create asset information in design, deliver it to construction for verification or updates before delivering it using the established DAB delivery process. The five key steps for the pilot are shown in Figure 6. They reflect both strategic and technical challenges for the group.

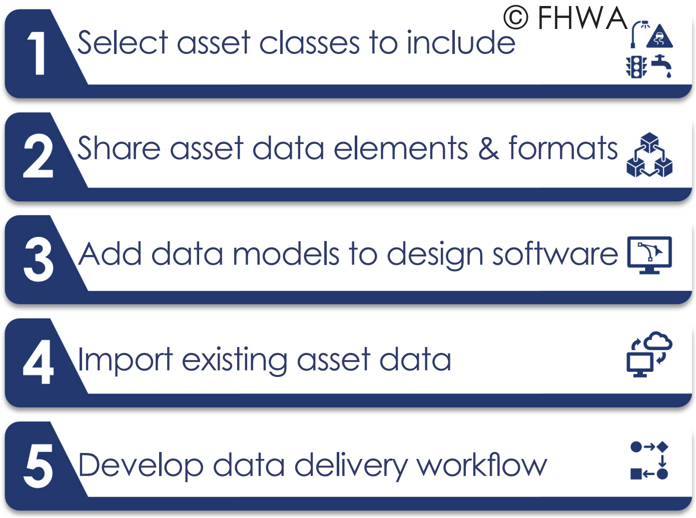

Figure 6: Key steps for the pilot projects.

The selected asset classes were the same assets that MnDOT currently collects with its DABs special provision. The design team could draw on the TAMS templates that are published on the MnDOT DABs website to develop the asset data models. The AMPO identified other attributes that may be of interest to include in the DABs. Examples are inventory data and fields that could be important for managing the asset and programming its treatments. The fields could be created in the design model to be populated later, after construction.

The design software workspace was updated to include standardized lists of attributes that the AMPO provided. The designer then attached attributes to model entities (which represent individual assets) using pick lists of standardized attribute data. These attributes included information specific to the asset class, like the type of pipe, the pipe material, and a unique asset identifier. The challenge was to develop the workflows for extracting the asset information from the design model. Figure 7 shows the typical flow of asset data through the design and construction process.

MnDOT's project team, central office staff, and the software technology providers collaborated closely to develop the data extraction solution. The workflow developed on the TH 169 project that will be used on the 11th Street Underpass project uses interoperability between software products from three software technology providers. This is a workflow using proprietary data formats that was made possible through vendor collaboration. Other vendor collaborations result in tools that export data, for example into Geographic Information Systems (GIS) format. These kinds of vendor-led solutions are improving the value that agencies can get from their design models as sources of asset data. Work currently in progress to create open data formats for highway and bridge assets will enable even more digital workflows to transfer asset data in the future.

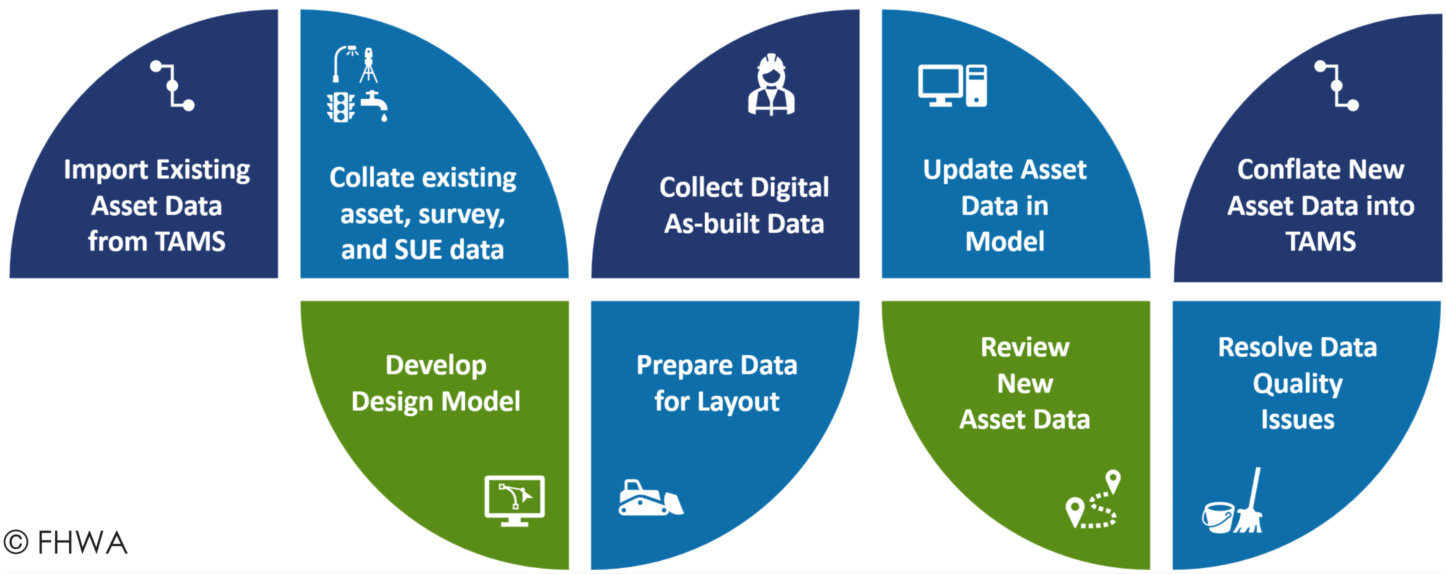

Figure 7: The digital workflow for asset data from planning to construction acceptance.

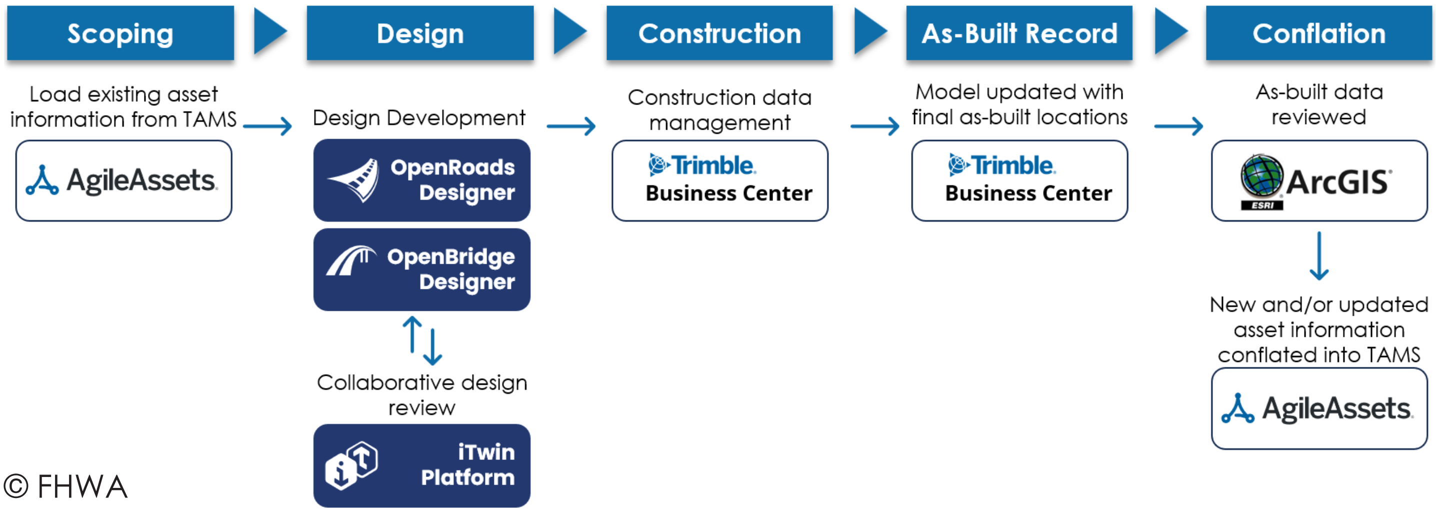

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Figure 8: The digital workflow for asset data on the 11th Street Underpass Project.

Figure 8 shows the workflow and software solutions used to migrate asset data on the 11th Street Underpass project. The asset data starts in TAMS, which is a Trimble® Agile Assets® solution. Asset data is then transferred into the Bentley® Open Platform (e.g. OpenRoads Designer and OpenBridge Designer) for design development. The design is migrated into Trimble® Business Center construction software, where the asset attributes can be viewed and updated if necessary. Any changes to asset locations are captured using field survey methods and the locations are updated in the Trimble® software. After processing the changes and performing verification and quality control, the data is conflated into TAMS in a more automated manner.

Phased DABs Maturity

MnDOT has taken a phased approach to implementing DABs. Figure 9 shows the four stages and their major changes. As noted above, the first phase began in 2011 with the standard special provision for DABs. Initially, this pragmatic, field-based approach that used familiar survey field codes was used for just five asset classes: signals, lighting, Intelligent Transportation Systems, hydraulics, and signs. In this phase, MnDOT also developed robust inventories of twelve asset types using mobile lidar, data mining, and other collection techniques resulting in the release of MnDOT's second generation of TAMS.

Beginning in 2020, the second stage started to implement the AMSIP. MnDOT developed TAMS data templates to make the quality of the contractor's deliverables repeatable and streamlined data conflation processes. This led to developing automation tools and the expansion of the DABs program to twelve asset types. Each asset type also had a designated key processing expert. The twelve asset types were the original five asset types plus noise walls, earth retaining structures, traffic barriers, bridges, rumble strips, and message signs.

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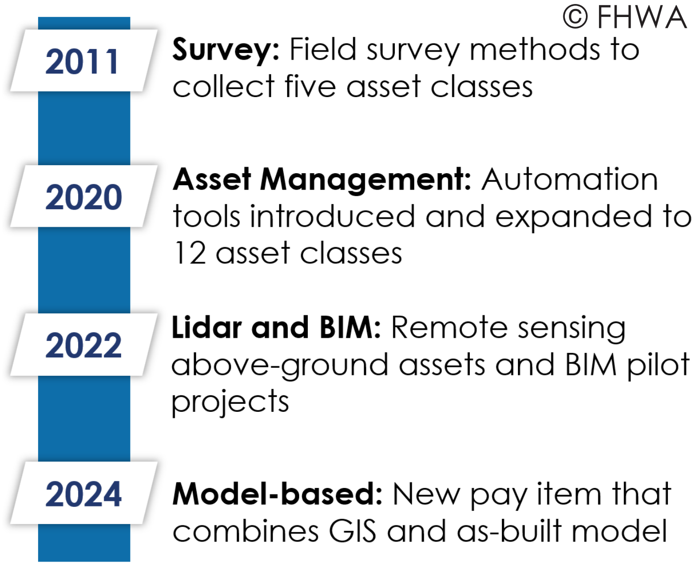

Figure 9: The four stages of MnDOT's DABs and digital project delivery development.

Beginning in 2022, the third phase made use of bulk data collection using mobile lidar to capture a snapshot of the above-ground assets, resulting in the third generation of MnDOT's TAMS. To prepare, MnDOT's AMPO met with sixty different stakeholders to understand their needs. They held eight meetings with District asset experts to refine the asset data models and data collection specifications. MnDOT extracted data for twenty asset classes, each with clearly defined accuracy criteria for location, elevation, and attributes. MnDOT also improved the process for reviewing the asset data and streamlined the process of conflating the data into TAMS.

In 2022, MnDOT also started to implement digital project delivery, beginning with developing the new design software workspace. This is when MnDOT started working on new asset data workflows using BIM with the TH 169 project. MnDOT plans to reach full asset data maturity in 2025, which is the conclusion of the plan laid out in the AMSIP. MnDOT plans to complete the digital project delivery implementation at the same time, with mature BIM workflows that result in paperless construction plans and asset data transfer using fully digital processes.

Data Collection Strategies

Some states have expressed concern with contractors being able to provide quality asset data. These states are considering workflows that minimize the contractor's manipulation of asset data. However, MnDOT has had success over the past decade with the quality of the data delivered by their contractors. This reflects the resources that MnDOT has assigned to the DABs program. These resources include data collection

BIM and TAMS Alignment

MnDOT recognizes that a well-developed digital project delivery implementation will be a more efficient way to capture the changes to assets during project development than manual, field-based processes. MnDOT plans to evolve the DABs process to take the asset data created in design, verify or update it to reflect as-built conditions, and deliver it to the various asset data stewards who will conflate it into TAMS.

The ISO 19650-1:2018 standard provides a framework for incorporating asset information within project datasets and then extracting that information when the assets are commissioned at the end of construction. The ISO 19650-1:2018 standard defines a workflow to develop asset and project information requirements as well as the relationship between them. Figure 10 illustrates the workflow, as follows:

1. The process begins with Organizational Information Requirements (OIR), which are high level agency policy that creates a need to manage asset information, like "Vision Zero."
2. The OIR inform the Asset Information Requirements (AIR), which are the asset-specific policies that implement the organizational policy, like performance metrics for guiderail repairs.
3. The AIR inform the Asset Information Model (AIM), which is the data that the agency needs to maintain in order to implement the asset-specific policies defined by the AIR, like the dates of guiderail damage reports and repairs.
4. The AIR also inform the Project Information Requirements (PIR), which are the goals for using data on a project. These goals often relate to design and construction objectives, but can include goals related to asset data needs. For example, recording the position and type of guiderail posts and beams.
5. The Project Information Model (PIM) is the information created during the the project. DABs are a subset of the PIM that deliver the information needed to update the agency's asset information. For example, the design model includes model elements that reflect the guiderail, which is exported in a format compatible with TAMS conflation.

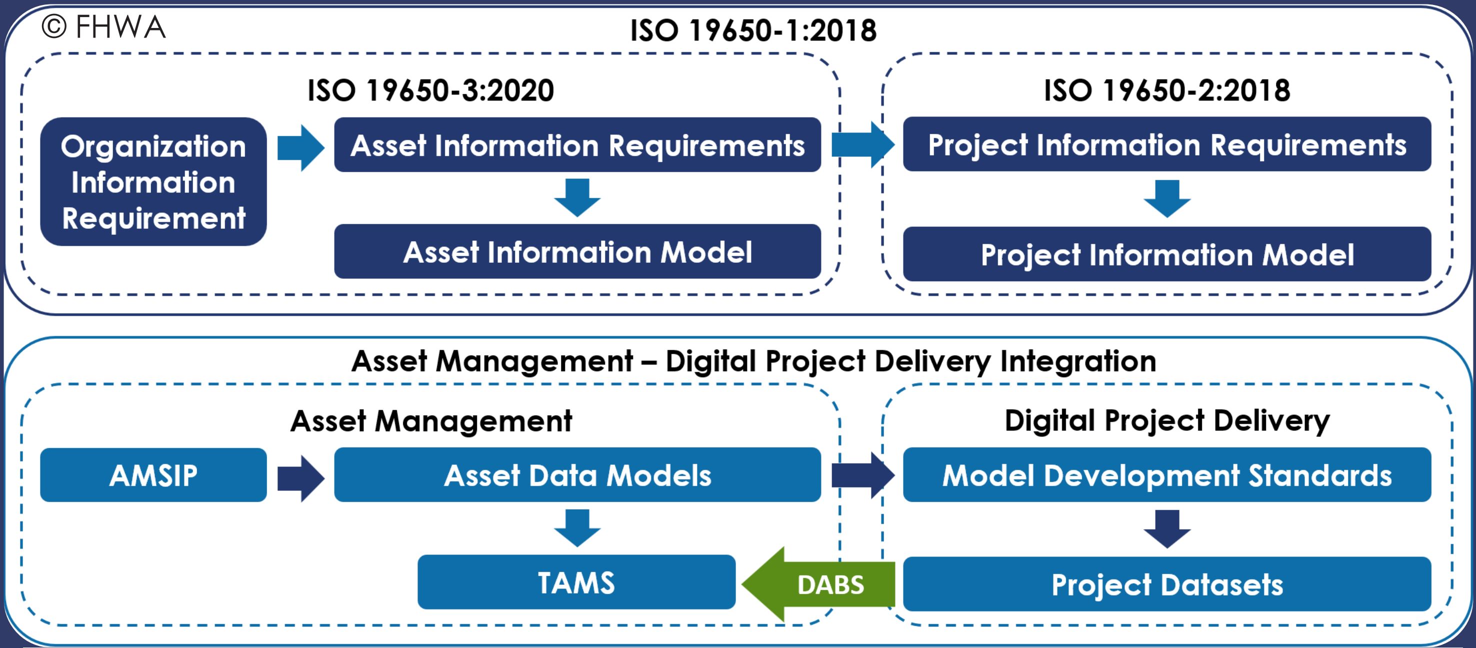

Figure 10: The ISO 196501:2018 workflow compared to the workflow followed by MnDOT to align asset management and digital project delivery.

While MnDOT did not intentionally follow the ISO 19650 processes, the strategic work that MnDOT has completed is compatible with the standard, as shown in Figure 10. The figure shows the workflow as follows:

1. MnDOT's AMSIP could represent OIR. It identified seventy-four asset classes and assessed the risks for each asset class, identified the investment strategy, and derived the data needs.
2. MnDOT has created data models for the assets that MnDOT has determined need inventories. These could represent AIR.
3. The asset data models are implemented in MnDOT's TAMS, which stores the asset data. TAMS could represent the AIM.
4. With MnDOT's current approach to DABs, using the DABs standard special provision, MnDOT publishes the asset information requirements on its website and provides data templates for contractors to use on projects. The project-specific information requirements are documented in a special provision used on the project. These could represent the PIR.
5. Currently, contractors use the data templates to collect DABs using field-based processes. The digital project delivery process will insert asset information into the design models so that it can be extracted from the resulting project datasets as DABs at the conclusion of the project. These project datasets could represent PIMs.

templates and clearly defined roles and responsibilities at the central office and in the Districts to coordinate and review the asset data before conflating it into TAMS. MnDOT has also defined the DABs delivery process to ensure that Construction does not accept the DABs for payment before the data is accepted for conflation into TAMS.

Contractor-collected data is an important source of data to meet MnDOT's asset data needs as MnDOT lacks the resources to collect this data during construction. MnDOT has worked hard to determine the best data collection strategy for each asset class and combines different approaches to data collection. Using model-based processes that automate data exchanges will improve the ease and efficiency for contractors to produce consistent and reliable DABs data. The automation avoids unintended changes to data that was carefully reviewed during design, then verified in construction.

MnDOT has analyzed the cost data from its DABs special provision and compared the cost per asset data point to the cost of using annual, cyclical remote sensing (with mobile lidar) and partially-automated desktop data reduction to extract assets. MnDOT has found that,on average, the cost per asset data point is half with the remote sensing approach. This informed a decision to prioritize remote sensing to develop current inventories for surface assets. New automation tools can compare different remote sensing datasets to isolate changes since the last data collection run. In future, MnDOT may be able to use automation tools for some of the assets currently being collected with DABs and reallocate those resources to collect different assets.

Program Sustainability

MnDOT's asset management program has grown slowly over the past decade. Each expansion was supported by evidence of the value that the as-built data and accurate asset information brings. Growth has targeted improved data processing and improved utilization of the data. In 2015, MnDOT formed the AMPO in order to provide dedicated resources to advance strategic asset management within the agency. Leadership continues to see the criticality of asset data and analytics and focuses resources on asset-related efforts.

MnDOT's AMPO has utilized different funding sources such as Federal funding authorized by the Fixing America's Surface Transportation (FAST) Act, State funds prioritized through the asset management steering committee and external grants, like the Advanced Digital Construction Management Systems grant created by the Bipartisan Infrastructure Law. Some of the internal resources fund GIS specialists in the Districts and support staff in the AMPO. GIS coordinators within the Districts provide services for both the project development (i.e. DABs) and maintenance functions These

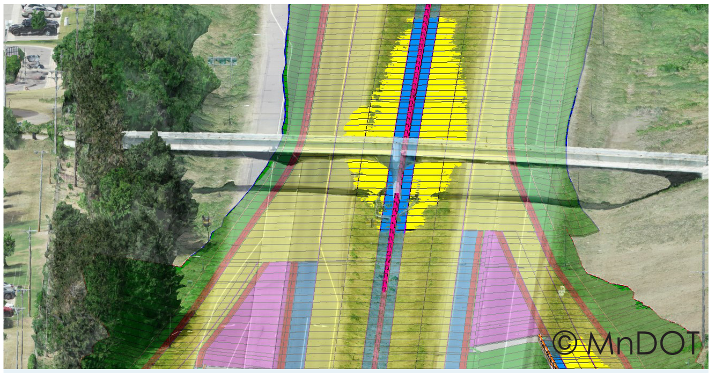

Figure 11: The four stages of MnDOT's DABs and digital project delivery development.

services include setting up and maintaining dashboards and other analytical tools. MnDOT is also in the process of establishing Asset Management Specialist positions that will be physically housed within each District and supervised by the AMPO.

Conclusion

The TH 169 and 11th Street digital delivery pilot projects have demonstrated the benefits that BIM can bring to complex design projects and proved the concept for model-based data transfer. MnDOT's strategic alignment of BIM and asset management data sets the agency up to maximize the value of the investments in digital project delivery, such as the design 3D model shown in Figure 11.

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