TECHBRIEF: ORGANIZING THE ENTERPRISE TO DELIVER DIGITAL AS-BUILTS EFFICIENTLY—CONNECTICUT DOT'S STORY

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EXECUTIVE SUMMARY

The Connecticut Department of Transportation (CTDOT) uses digital as-builts (DABs) as a method to generate project- and asset-specific data during the design and construction phases. These data are then exported into an enterprise geographic information system (GIS) for use in the post-construction phase. DABs are pivotal to CTDOT's goal of maintaining current and authoritative asset inventories for the efficient extraction of valuable information by users. To achieve this, the agency adopts a systematic approach wherein asset-specific data attributes, also known as design asset features, are assigned to the computer-aided design (CAD) feature of a particular asset. These asset-specific attributes are predetermined through a collaborative process involving the stewards of the respective assets.

At CTDOT, the transportation asset management (TAM) division is in the Bureau of Engineering and Construction (BEC). The BEC is responsible for capturing data attributes for the asset classes of interest. In the preliminary design phase, CAD and GIS personnel integrate the design asset features into the Building Information Modeling (BIM) models. These data models are passed on to subsequent project lifecycle phases and updated throughout their lifecycle. Construction inspectors validate the accuracy of their representation in the BIM models, while the contractor-supplied data attributes are added to the models. Post-construction, the BIM models are extracted, transformed, and loaded into the enterprise GIS system. The asset stewards assume the responsibility for keeping the models updated and current for their asset classes.

Technological infrastructure plays an important role in the DABs process. CTDOT's process is driven by COMPASS and ATLAS. COMPASS, a SharePoint-based solution to manage project data, track progress, and integrate CAD and BIM models for the project lifecycle. ATLAS is an upgraded Esri-based system that provides authoritative data including route identifications, develops data layers for asset inventories, and scans project-specific data. Integrating ATLAS and COMPASS with other applications facilitates seamless data exchange and enhances efficiency and information extraction.

INTRODUCTION

CTDOT is responsible for the maintenance of State roadway infrastructure, which includes 4,137 miles of roads, of which 346 miles are interstate highways, and 8,183 bridges and structures. CTDOT manages a budget of $4 billion for its capital and operating program.

CTDOT's BEC is a centralized office structure for planning, construction, and maintenance. The TAM division is in the engineering department. The architectural engineering construction applications department, which falls under the BEC, is tasked with developing asset inventories for TAM purposes.

CTDOT considers DABs as a process to create project- and asset-specific data during design and construction and transfer the data into the enterprise GIS environment for post-construction use (FHWA, 2022). The DABs are central to CTDOT's need for maintaining up-to-date and authoritative asset inventories, complete with metadata for various asset classes. These inventories also allow valuable information to be harvested efficiently. Currently, CTDOT maintains an asset inventory for traffic signals, rights-of-way, signs, and guiderail barriers in the GIS environment.

IMPLEMENTATION TIMELINE

Figure 1 is a timeline of the CTDOT's digital information management journey. DABs are the latest undertaking in this journey.

This journey began with the recognition of the need for improved data and information management for construction projects. In 2011, CTDOT transitioned from using retired mylars to PDF Contract Plans and PDF Design Review, which enabled engineering drawings to be preserved and stored in the cloud via ProjectWise.

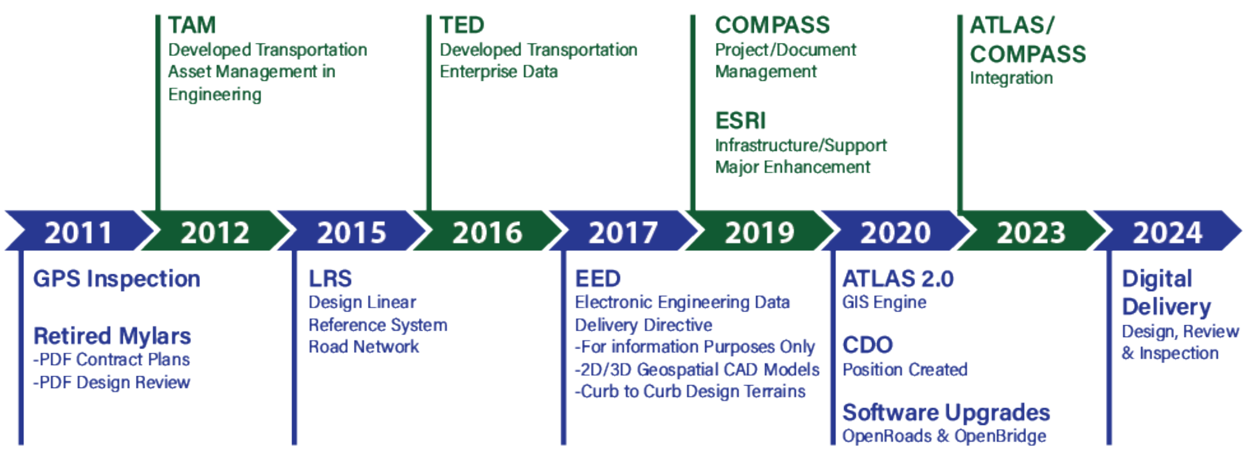

Figure 1. Timeline of CTDOT's Data Efforts.

After the Moving Ahead for Progress in the 21st Century Act (MAP-21) legislation, the TAM division was established within the BEC in 2012 to focus on asset data organization. This further necessitated the collection and upkeep of accurate and up-to-date asset inventories to support the agency's TAM objectives.

A customized linear reference system (LRS) was conceived in 2012 and operationalized in 2015 to facilitate the integration of roadway data into a digital road network. In 2016, the

Transportation Enterprise Data, a unified data platform, was formed to host geospatially linked transportation data from various CTDOT units. In the corresponding year, the ATLAS 1.0 system was implemented for capital projects and asset tracking. ATLAS 1.0 included 18 authoritative GIS layers for LRS, bridges, and signals; and hosted project attributes from historical records.

An Electronic Engineering Data Delivery Directive was published in 2017 and updated in 2023 (CTDOT, 2017, 2018). This directive guides project design staff to the necessary standards for creating CAD files and digital civil engineering data files for construction projects. Around the same time, the agency transitioned from ProjectWise to a Microsoft Azure cloud-based SharePoint project management solution. In 2020, the agency implemented OpenRoads and underwent a transformation of its enterprise GIS infrastructure. Additionally, a new position for a chief data officer was created within the agency to oversee data governance, data platforms, and data analytics efforts, including its enterprise GIS. A technical group, consisting of 14 multi-disciplinary engineers with expertise in areas such as bridges, signals, traffic, and highways was established to guide the agency's efforts on CAD standardization, intelligent feature modeling, DABs, and BIM models.

OBJECTIVES

This Technical Brief outlines CTDOT's overall strategy for DABs, detailing the implementation timeline, work processes, and technological infrastructure. It discusses the workflow from organizing asset-specific information in BIM models in the preliminary design phase through the exchange of data with the enterprise GIS system for post-construction use. The brief also highlights how the integration of COMPASS, the agency's cloud-based SharePoint project management solution, and ATLAS, a cloud-based GIS infrastructure, facilitates a seamless information flow from project planning to operations.

TECHNOLOGICAL INFRASTRUCTURE TO SUPPORT DIGITAL AS-BUILTS PROCESS

The CTDOT's digital transformation journey is underpinned by the integration of two key systems: COMPASS and ATLAS (Asset Tracking and Location System). COMPASS is a common data environment (CDE) that functions as a "virtual filing cabinet" for project data. COMPASS also provides document control and project scheduling and tracking capabilities. ATLAS leverages GIS technology to organize and manage project and asset data geospatially on a base map, which is then used for locating projects and harvesting asset data. Together, ATLAS and COMPASS enable digital workflows and a seamless exchange of data between projects and other downstream uses.

COMPASS – The Project Management Solution

COMPASS is a customized project management solution that is built within a SharePoint environment and is tailored specifically to meet the project needs of the agency. It integrates both CAD and BIM models. It also creates a CDE to meet the data needs of the entire project lifecycle, including inception, design, construction, and operations. COMPASS manages project submittals, transmittals, document reviews, and approvals, thereby automating the progression of documents through the review process. This feature ensures that all project-related documents are controlled, tracked, and easily retrievable. The system allows all stakeholders, including internal CTDOT staff, consultants, and contractors, to access the system. The system's OneDrive synchronization of project libraries from SharePoint enables the agency to work in any environment with any non-Microsoft application.

Until 2018, CTDOT used ProjectWise as the cloud-based platform for project management. The agency made a strategic decision to transition to SharePoint to centralize project management applications. SharePoint was advantageous for managing workspaces, facilitating collaborative design sessions, and providing seamless integration with Office 365, including OneDrive, which makes it an ideal platform for integrating non-Microsoft tools like OpenRoads Designer and OpenBridge.

ATLAS – The GIS Solution

The ATLAS application, which was initially developed using an open-source GIS environment, has recently been upgraded to an Esri-based system. The application was originally conceived to address the need for authoritative data, particularly route identifications. The authoritative data would aid CTDOT in understanding the location and characteristics of a road segment, such as daily traffic volume, functional classification, and accident data; and enable harvesting valuable information for streamlined processes.

CTDOT practitioners use ATLAS to identify project locations and gather valuable information on assets. This application facilitates the development of various data layers, which can be scanned for information relevant to a given project work area. It allows for the configuration of underlying asset inventories, including linear referencing system routes, right-of-way information, guidelines, bridges, and traffic signals.

Also, ATLAS includes information on programmed projects, maintenance resurfacing projects, historic resurfacing projects, and FHWA work types and codes. The application also includes environmental layers from the Connecticut Department of Energy and Environmental Protection. ATLAS contains detailed information, including 80 to 90 project attributes, for projects that were completed after 2011. It also includes legacy projects dating back to the Great Depression with limited information and comprises over 10,000 projects.

ATLAS allows project-specific data to be scanned within the footprint of project work areas. These configured asset inventories are then available for automated scans for project inclusion. Together ATLAS with COMPASS automatically push the scans to the SharePoint project site. Asset inventories and other relevant information within the scanned project footprint are automatically uploaded to the SharePoint site through the integration of ATLAS with COMPASS.

Other project development applications, including AASHTOWare Project, Bentley products (e.g., OpenRoads Designer and OpenBridge Modeler), Bluebeam, and Trimble, are integrated with this "connected data" environment facilitated by COMPASS and ATLAS. Figure 2 presents the major enterprise applications in this connected data environment.

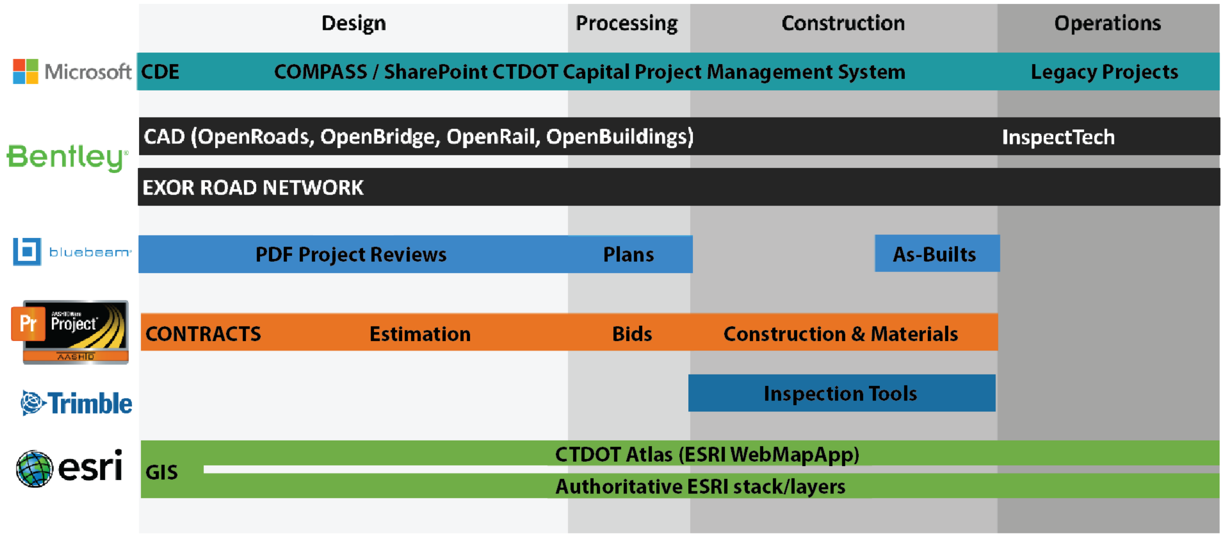

Figure 2. Enterprise Applications Associated with Digital As-Builts.

WORKFLOWS FOR DIGITAL AS-BUILTS

As previously discussed, the BEC is responsible for incorporating asset intelligence (e.g., signal attributes) into its design models for post-construction use. This intelligence forms the data models for a given asset class. The data models undergo updates at every stage of their lifecycle. Therefore, it is essential to maintain efficiency and consistency while managing them across multiple stages. This is a collaborative cross-disciplinary effort that involves various teams including CAD and GIS personnel, designers, construction inspectors, and asset stewards. Figure 3 illustrates the high-level process of workflows associated with the DABs process.

The CTDOT process requires mature asset inventories characterized by extensive coverage, comprehensive metadata, and robust maintenance practices. Regular updates are required to these inventories to accommodate changes resulting from capital projects and maintenance activities. At present, there are approximately six mature asset inventories. These inventories are considered to meet the necessary quality and maintenance standards to support this process. Through an enterprise-level exercise, the agency has developed asset data models and schemas that provide a structured format for representing data attributes within the design models to facilitate the automation of processes and inventory updates.

CTDOT has established a process flow, represented through swim lane illustrations, for managing matured assets. This process includes the steps involved from the project's initiation, through the construction phase, and extends into the maintenance phase. These process representations effectively communicate the procedures for data processing and management, necessary checks and balances, and handling of decommissioned elements. This ensures a systematic and efficient approach to asset data management.

The following sections describe the process in each stage in more detail.

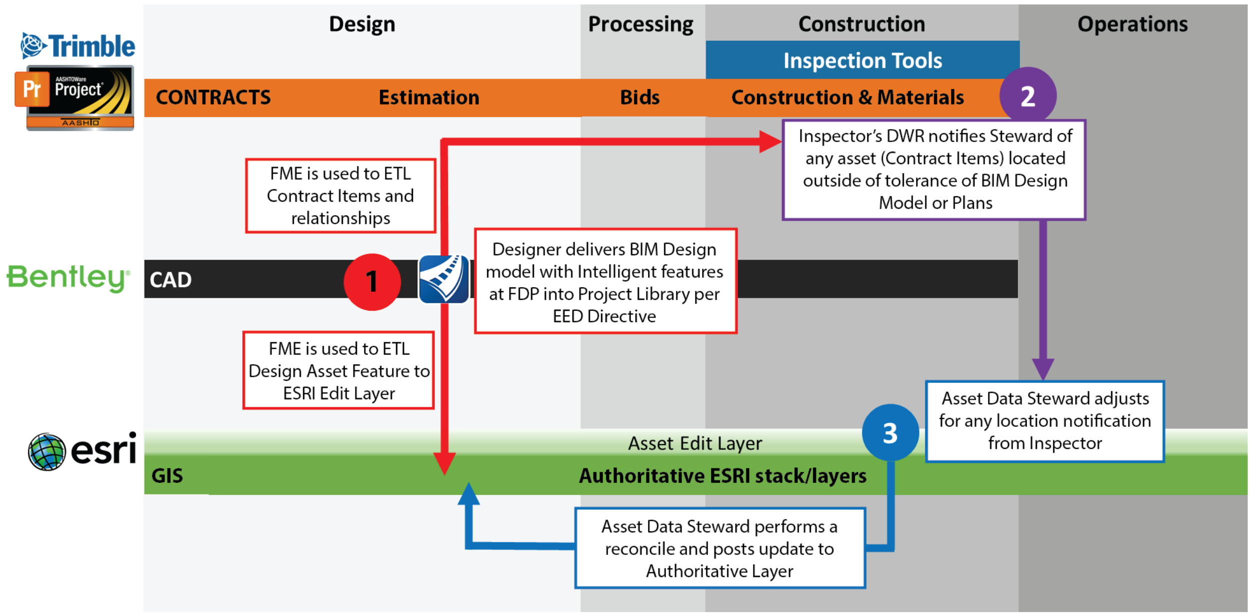

Figure 3. Workflows Associated with Digital As-Builts.

Project Planning

During the project planning phase, the agency's goal is to identify the asset inventories within the footprint(s) of a proposed project at an early stage. Information about these assets, such as work programs, program completion status, and project schedule, can be relayed back to the inventories of their respective asset classes. This step prevents the duplication of projects in the work program.

The asset information is extracted for the proposed project using a feature manipulation engine from ATLAS, and subsequently, transformed and loaded to CAD models. This information sharing enables managers who oversee concurrent projects and maintenance work orders for these assets to access data pertinent to the proposed project. This results in enhanced coordination and operational efficiency in project execution.

Design

In the design phase, the agency's goal is to integrate intelligent CAD components as design features and embed asset intelligence into BIM feature models. This integration can be initiated as early as the preliminary design phase using both two-dimensional and three-dimensional models.

Two data models are employed for each asset. The "Pay Item Related" model includes attributes tied to the pay item, such as the item number and description, bid quantity and units, and total installed units. These attributes enable automated quantity harvesting within the CAD environment. The "Authoritative Asset Features" model records data attributes to align with authoritative asset features in GIS. This typically includes asset-specific attributes such as item description, component type, and model type. Once the design asset features are complete, the data from the CAD models are extracted, transformed, and loaded (ETL) into the GIS data layer using a feature manipulation engine.

Traffic signals, considered among the most complex assets, require different data models for financial and GIS purposes. Guide rails serve as another instance where standard post spacing and other details can be auto harvested from the CAD model and formatted into GIS asset inventories.

Early in the design process, CAD designers and GIS personnel are engaged in developing these data models. These models are then passed to State designers and consultants for each asset class. Designers are not required to perform tasks beyond their current responsibilities, particularly those related to developing data models. As these models advance through the construction phase and reach the final commissioning stage in the authoritative CDE inventory, they provide substantial benefits to asset stewards and the TAM team.

Construction

In the construction phase, the agency's goal is to ensure that assets are accurately represented and recorded in the BIM models. At the outset, CTDOT was careful not to overwhelm construction inspectors by managing the GIS or BIM models in the field, but rather allowed inspectors to do so. Inspectors are tasked with identifying features in the model that have not been placed in the field as intended and certain allowances are provided for assets such as catch basins. If an asset is located within the tolerance of its position in the model, there is no need for re-collection as the geolocation and attributes are already known. The inspectors could make use of construction management tools to aid in flagging a given asset to indicate that it is outside the tolerance for revision during future inventory updates.

The agency recognizes that not all elements can be modeled within the BIM model. For example, the contract allows the contractors to select proprietary items such as attenuators for guide rails or barriers, and those items cannot be modeled within the BIM model. In such cases, the field inspector would add the attenuator type to the database, or the asset stewards would need to extract pertinent data from the project's payment system.

Operations

In this phase, the agency performs an ETL process using a feature manipulation engine for each asset class. This process entails transferring data from the design model to the editable version of the asset inventory. The data transferred to the GIS system includes intelligent features in the CAD models, contractor-input attributes, and the final cost of assets. The asset data steward makes adjustments for any location notifications from the inspector. After construction, the asset data steward is responsible for performing reconciliation and updates to the respective authoritative layers.

SUMMARY

CTDOT has successfully demonstrated its DABs approach for specific asset classes, including guiderails and traffic signals. Currently, there are approximately six mature asset inventories that possess the necessary quality and maintenance to support this process.

The integration of COMPASS and ATLAS is transforming the way CTDOT manages assets throughout the project lifecycle. By leveraging BIM and GIS for DABs, the agency enhances CAD models with asset-specific intelligence, validates accuracy during construction, and makes asset data available for various purposes. The transfer of information from the BIM models to the GIS environment enables harvesting of valuable information related to assets within project footprints, while the asset stewards ensure that data remains accurate, reliable, accessible, and secure across all systems and processes.

The success of CTDOT's DABs process hinges on critical factors such as enterprise-wide acceptance and collaboration among various departments including CAD, GIS, design, and construction; and asset data stewards. In summary, CTDOT has implemented a robust data governance framework that manages workflows for collecting, modifying, verifying, and managing asset data within a connected data environment. The roles and responsibilities of all stakeholders—ranging from designers and construction inspectors to asset data stewards—are explicitly defined.

The importance of developing and maintaining mature asset inventories, characterized by comprehensive coverage, metadata, and robust governance practices, is paramount. To assess maturity levels and identify areas for improvement, CTDOT employs the Capability Maturity Model Survey. As the agency continues to invest in foundational capabilities such as data talent, standardization, and technological lifecycle processes, it is well-positioned to progress in its data management maturity. This will enhance the efficiency and effectiveness of its infrastructure data management.

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