U.S. Department of Transportation
Federal Highway Administration

e-Construction & Partnering Case Study

Indiana and Ohio DOT Collaborative Solutions for Digital Construction Inspection

Construction inspectors advance e-Construction practices by working with digital inspection technology such as global navigation satellite system rovers, mobile devices, and e-ticketing. However, the use of digital design data during construction has been limited—until now. The industry is shifting toward maximizing the use of digital data across project delivery phases through provisioning design intent models for construction placement in addition to verification activities. Equipping construction inspectors with the knowledge and ability to inspect pay items directly from the design intent model is being realized through advancements in technology as well as collaborative approaches to solution development.

Key Takeaways

- Model-based construction inspection applications bridge digital delivery practices between design and construction.
- Linking pay items to model and plan elements enables easy access to inspection checklists and forms.
- Interagency collaboration can mean funding goes further.
- When working on collaborative software solution projects, delineating scope of work items specific to each agency can minimize procurement challenges and create distinct value for the participants.

The Indiana Department of Transportation (INDOT) and Ohio Department of Transportation (ODOT) are prioritizing digital delivery practices and have made significant progress with enriching digital workflows for design and construction. Most recently, the two agencies collaborated on developing a construction inspection application that incorporates easy-to-use inspection checklists and an interactive inspection experience using design intent model elements. This collaboration included working directly with a common software vendor to advance their respective interests in improving digital construction inspection practices.

The collaboration stemmed from the agencies' ongoing relationship at various levels through pilot projects and technology demonstrations. ODOT began piloting quality-based inspections in 2016, which resulted in construction inspection checklists being developed to assist with prioritizing observation and documentation requirements. INDOT became aware of these checklists and initiated discussions with ODOT on broader improvements to construction inspection workflows. One result was the conceptualization and development of a construction inspection application that linked inspection checklists directly to the relevant pay items and model elements. The application's development underwent several iterations to accommodate the agencies' priorities. For instance, INDOT and ODOT

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June 2020
FHWA-HIF-20-051

decided to optimize their solution requirements to avoid conflict and redundancy. INDOT found that the use of the two-dimensional (2D) model and plans was more appropriate for its current needs, and ODOT decided to proceed with developing inspection functionality using a three-dimensional (3D) model. The joint development of the construction inspection application yielded several significant benefits for both agencies and for the broader DOT community.

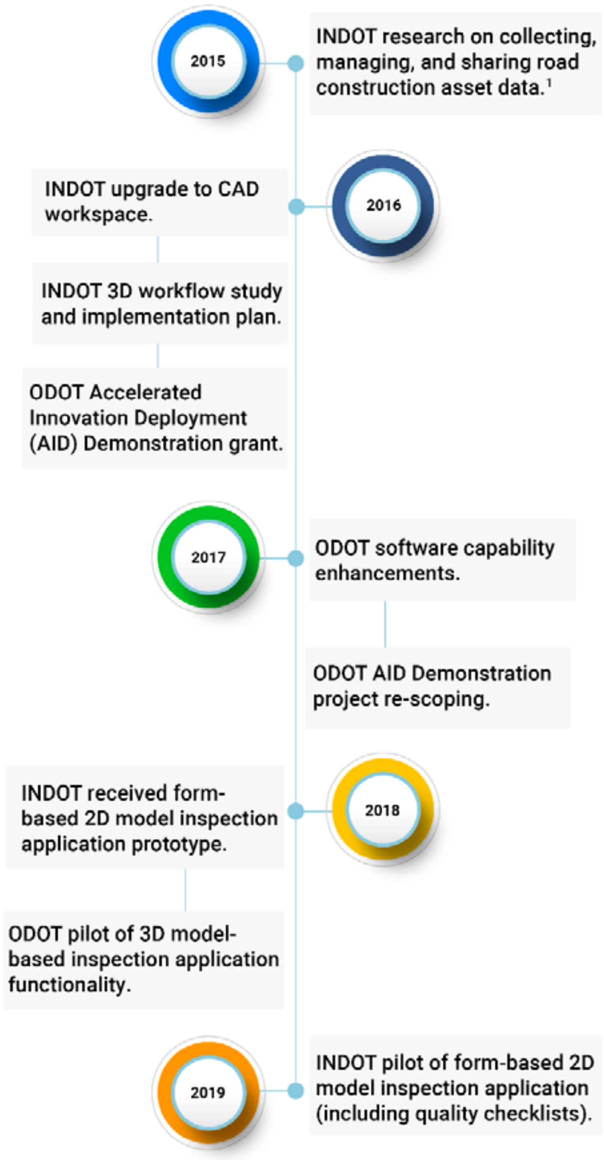
Joint Development of a Digital Construction Inspection Solution

Throughout recent years, INDOT and ODOT have participated in each other's technology demonstrations and held general discussions on emerging technologies and practices. This has yielded substantial advancements in their respective e-Construction practices, including quality-based inspection and model-based inspection workflows. These practices also led to the agencies jointly developing a construction inspection application that empowers construction inspectors with contextual guidance for pay item inspections. Figure 1 shows the timeline for its development.

Technology Description

Traditionally, INDOT construction inspectors have used a homegrown application, known as Field Assistant, on mobile devices to document inspection observations and quantities. The Field Assistant application is Web-based but can also be used offline. It contains several modules for documenting specific tasks, including daily project reports, material samples, hot-mix asphalt, and erosion and sediment control compliance.

While the Field Assistant application empowers the construction inspector in the field, it has limited capability for collecting and using asset data. As a result, when INDOT started looking to transform its business practices toward maximizing the use of asset data and computer-aided design (CAD) models, it decided to make changes to its construction inspection processes.



[1]*Synthesis study SPR-3707 is available at* https://doi.org/10.5703/1288284316005

Figure 1. *Timeline. Events at INDOT and ODOT that led to the development of the construction inspection application. Source: FHWA*

Recognizing an industry shift toward model-based project delivery, in 2015 INDOT sponsored research on collecting, managing, and sharing asset data and provided a framework that leverages the construction inspection and documentation processes to collect data on constructed assets. The research detailed the concept of creating a mobile application that could use specific pay items to connect the design intent model with construction inspection tasks.

INDOT's software vendor conducted a 3D workflow study the following year and developed an implementation plan that identified the changes to INDOT business processes, practices, and standards required to incorporate 3D models into its highway program. To define strategies for filling the gap in the agency's construction inspection workflows, the study included a review of INDOT's initial research on collecting, managing, and sharing asset data as well as an evaluation of its existing stack of technologies.

The software vendor coordinated with both INDOT and ODOT on developing requirements for a new construction inspection application based on existing technologies used by the agencies. The agencies highlighted preferred functionalities for the application.

The primary functionality of the resulting construction inspection application is the ability it provides for inspectors to select an asset feature from the model and receive a prompt to answer asset-specific questions to verify and measure pay quantities. INDOT chose to focus on the form-based 2D model capability, and ODOT chose to focus on the 3D components. Figure 2 shows a screen capture of the construction inspection application's form-based 2D model functionality where the model element is selected, and associated questions prompt the construction inspector for completion.

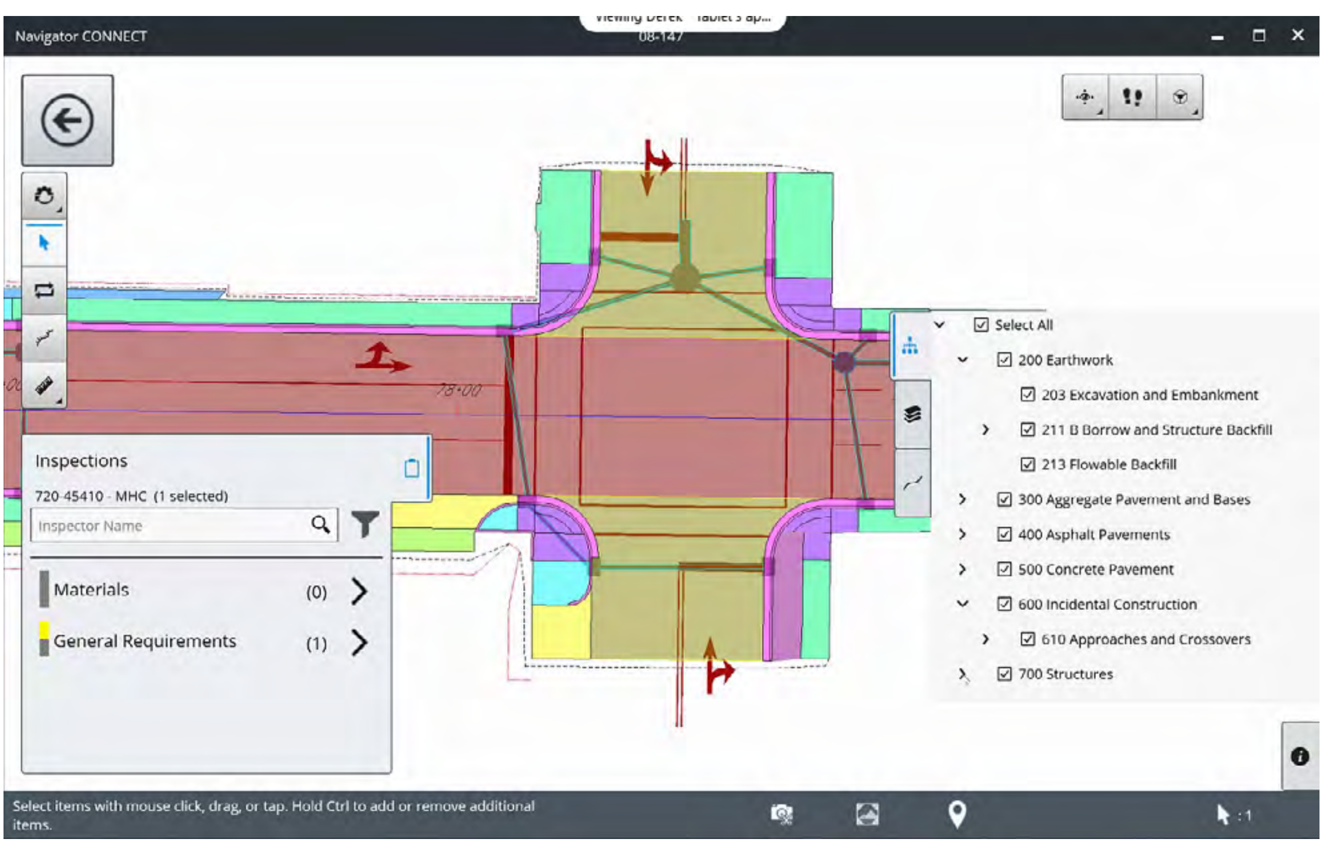


Figure 2. Screen Capture. *The construction inspection application's 2D CAD elements with associated pay items. Source: INDOT*

In 2015, ODOT received a Federal grant under the Federal Highway Administration's Accelerated Innovation Deployment (AID) Demonstration program for an electronic project delivery management and field inspection automation pilot project. Then, in 2017, ODOT's content management system underwent a significant update, adding capabilities that were not available at the start of the AID Demonstration project. These new capabilities addressed many of the initial project objectives, so ODOT decided to pivot the scope of the AID Demonstration project to other related capabilities.

The pilot project's scope was refined to focus more on demonstrating how ODOT's technology can use 3D models. This included a demonstration of its work with quality-based inspections, which was ripe for integration with the construction inspection application. It was clear to ODOT that if e-Construction and paperless workflows were its objectives, it was important to understand how to maximize its use of 3D models.

The refined objectives for ODOT's AID Demonstration project were:

- Demonstrate a construction inspection application with integrated field and office capabilities utilizing digital design data.
- Automate processes during inspection by integrating 3D models into field activities.
- Optimize project collaboration and communication.
- Demonstrate digital inspection processes (including quality-based inspections).
- Connect with ODOT's content management system.

Figure 3 shows ODOT's vision for project information and data mobility between and across project delivery phases, including those data flows retained from traditional processes. In early 2018, INDOT conducted a pilot for the construction inspection application prototype that highlighted its anticipated functionality as well as important areas for improvement, including hardware specifications. Similarly, ODOT showcased its 3D model-based functionality later in 2018 through a field demonstration.

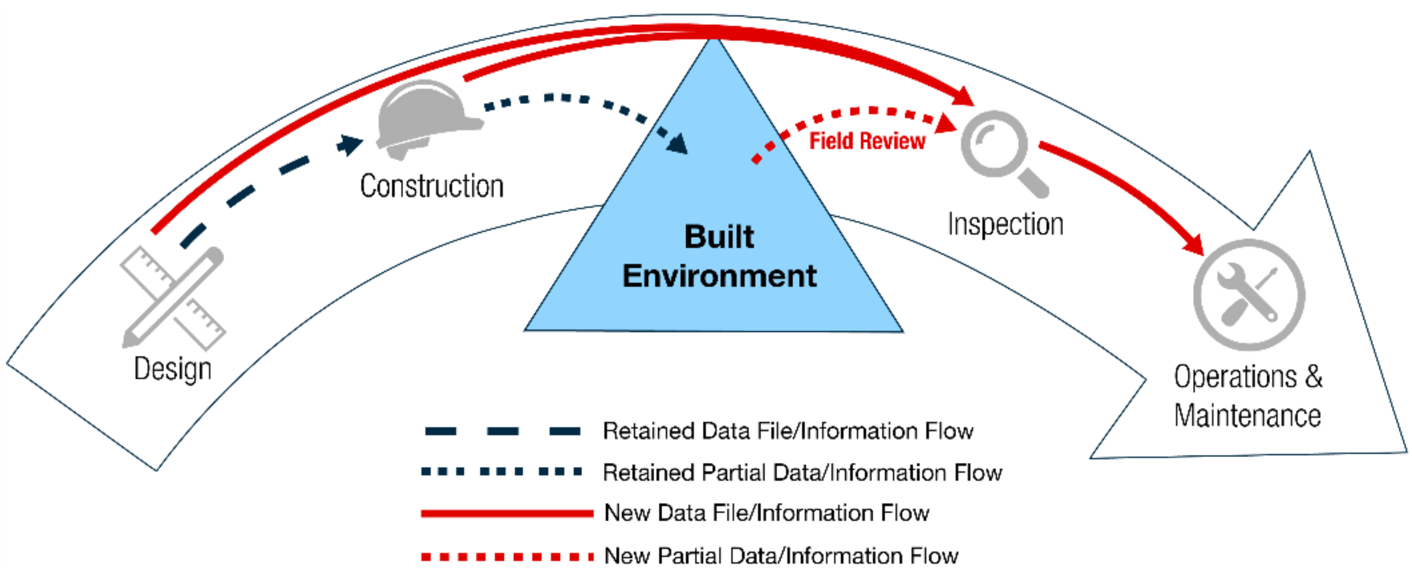


Figure 3: *Workflow. ODOT's desired state for data flow between project delivery phases. Source: ODOT*

Noteworthy Practices

INDOT and ODOT recognize several noteworthy practices as arising out of developing the application, including equipping construction inspectors with information and resources in the field, integrating quality-based inspection checklists with pay items linked to model elements, proactive outreach for innovation demonstrations, and separating and aligning functionality based on agency capability maturity levels.

Field Access to Digital Design Data and Resources

The construction inspection application provides inspectors with the design intent model and inspection standards and practices in the field through a single interface. This is significant because immersing construction inspectors in the design environment provides important contextual information from which to verify contractor activities. Simplifying the verification and measurement of pay items creates efficiencies and improves the quality of inspection activities by enabling inspectors to link their observations to model elements and log their observations as close in time and proximity to the activity as possible.

Quality-Based Inspection

Construction inspectors are charged with ensuring the contractor constructs the project according to project requirements and specifications. ODOT instituted a quality-based inspection practice that focuses the inspection activity on certain attributes listed in its quality forms and on documenting what was observed.

The quality forms provide construction inspectors with the inspection standards and framework necessary to identify ODOT's inspection and documentation priorities for certain items. These forms provide key direction to construction inspectors on what to document for every item. At least one quality form is required by ODOT for each pay item on a project. Quality forms provide the primary documentation of conformance with the quality attributes noted in the contract documents.

ODOT acknowledges that for plan items, and many other situations, specific quality attribute questions will not be directly listed on the form. The construction inspector is instructed by ODOT to review the plan note describing the item to determine what has been altered or added to make it a plan item. Thus, in ODOT's practice, it is the responsibility of the inspector to record any observed nonconforming activities on the form. Integrating these forms into the construction inspection application allows the inspector to document the items as close to the observation time and location as possible. ODOT finds that this benefits the quality assurance and payment processes significantly. Figure 4 shows the ODOT construction inspection standards document that helps with prioritizing ODOT's inspection and documentation requirements (including associated quality forms for pay items).

Outreach and Collaboration

INDOT and ODOT found that collaboration between States can serve as a catalyst for sharing effective e-Construction practices and technology.

The relationship between INDOT and ODOT is informal and aimed at encouraging innovation, as well as influencing decisions on implementing e-Construction practices.

Separate and Aligned Functionality

During the initial conversations leading up to developing the construction inspection application, INDOT and ODOT realized their requirements were being duplicated by the other agency or were in conflict. It was determined that separating functionality by each agency's capability maturity with digital delivery practices would create a more valuable solution for the broader industry. INDOT's current CAD workspace (upgraded in 2016) and modeling practices aligned better with form-based functionality using 2D design elements than with the 3D model-based functionality ODOT was exploring. ODOT's existing technology stack (upgraded in 2017) and modeling practices aligned better with the 3D model-based construction inspection functionality.

Unit Accuracy for DWR Entry	Code	Inspection Priority	Doc Priority	Tickets Rqd?	Spec Chair	Quality Form	Quantity Form
0.1 yd2	A-1	2	1		Pavements	CA-Q-0251	CA-D-2 Area
0.1 yd2	A-1	2	1		Pavements	CA-Q-0251	CA-D-2 Area
0.1 yd3	V-1	2	1		Pavements	CA-Q-0251	CA-D-2 Volume
0.1 yd3	V-1	2	1		Pavements	CA-Q-0251	CA-D-2 Volume
0.1 yd2	A-1	2	1		Pavements	CA-Q-0251	CA-D-2 Area
0.1 yd2	A-1	2	1		Pavements	CA-Q-0251	CA-D-2 Area
0.1 yd3	V-1	2	1		Pavements	CA-Q-0251	CA-D-2 Volume
0.1 yd3	V-1	2	1		Pavements	CA-Q-0251	CA-D-2 Volume

Inspection Priority

Level	Short Description	Long Description
1	Full Time Inspection	Inspection performed continuously while the item is actively under construction. This level of inspection is required for items where the consequence of failure could result in a catastrophic, life-threatening safety hazard.
2	Intermittent Inspection	Inspection performed daily on an as needed basis but focusing on initial setups and critical attributes when the item is actively under construction. This level of inspection is specified for items where the consequence of failure would directly affect environmental compliance, or where repair would delay the project or cause safety considerations. This priority level also includes items that require multi-activity construction processes. Inspection may occur as interim activities in the construction process are completed and before being covered or hidden by subsequent operations.
3	End Product Inspection	Does not require inspection and construction quality documentation while the item is actively under construction, but inspection must be completed before the project is accepted. This level of inspection is specified for items where the consequence of failure is considered minimal in terms of Project performance. Generally, inspection may be completed by observation of the end product.

Documentation Priority

Level	Short Description	Long Description
1	Daily / Per Segment	Construction quality documentation frequency is typically required on a daily basis during active work specific to the item.
2	Once per PLN	Construction quality documentation frequency is required at major intervals in the construction process of the item (e.g. prior to being covered by subsequent work) and shall not occur less than once during the Project.
3	Once per group	Construction quality documentation is required once per Project for all similar items (e.g., all shrubs, all traffic symbols…).

Figure 4: Screen capture. *ODOT's quality inspection guidance document. Source: ODOT.*

Challenges and Successes

The development and demonstration of the construction inspection application highlighted agency challenges such as using sole source procurement for proprietary solutions, distinguishing between funding sources, and identifying supportive technologies. However, INDOT and ODOT were able to implement strategies to help address these issues.

Sole Source Procurement

For its AID Demonstration project, ODOT envisioned that enhancements to its existing proprietary enterprise content management system would deliver the results it needed. However, these enhancements required a sole source contract with the software vendor. As would be the case for most public agencies, outsourcing goods and services without competition was a major challenge for ODOT. ODOT decided to pivot its AID Demonstration project toward related activities that did not require a sole source procurement. These activities focused on automating processes for integrating 3D models into field activities and increasing the accessibility and mobility of project data.

In light of this procurement challenge, ODOT found that to mature its e-Construction practices and implement paperless workflows, it was important to demonstrate its technology stack using 3D models.

Funding Sources and Constraints

INDOT largely invested State funds in its research efforts and the activities supporting the development of the inspection application. This provided the agency with flexibility in timing and capability development. State funds can be harder to allocate for certain efforts than Federal funds, but using State funds allows INDOT more control over the scope and schedule.

ODOT used the Federal funds from its AID Demonstration grant to achieve new workflows and capability development for the construction inspection application. Using Federal funds limited ODOT's ability to deviate from the proposed initiative due to certain Federal funding requirements, but allowed ODOT to make significant progress toward its much larger vision of enhanced project collaboration and digital business processes.

INDOT and ODOT found that if they had pooled their funding for developing the construction inspection application, the funding could have delivered more meaningful outcomes while minimizing administrative activities and maximizing value. The States found that differing funding sources limited capability integration between the agencies and impacted the deployment timeline.

Supportive Technologies

INDOT and ODOT found that the demonstrated construction inspection application used significant computing power, so an important next step will be to test and evaluate the optimal mobile device to handle the application's resource load.

INDOT noted that the laptops used for the demonstration were insufficient for handling model elements; therefore, scrutinizing the device (laptop or tablet) performance requirements to ensure it can handle resource surges without negative impacts to user experience and functionality is recommended. If the user is not able to access or use the application intuitively over the duration of a typical construction day, the application is unlikely to be successful.

Outlook

Digital construction inspection practices and technology present significant opportunities for DOTs to improve their digital delivery practices with limited investment. INDOT and ODOT believe that equipping construction inspectors with the capability to toggle model elements for specific inspection data fields and questions in the field is highly desired throughout the industry. As mobile devices and e-Construction practices mature, construction inspectors will become stewards of asset information from design to asset management, thus closing a major gap in asset information exchange.

Indiana and Ohio DOT Collaborative Solutions for Digital Construction Inspection

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Distribution

This case study is being distributed according to a standard distribution. Direct distribution is being made to the FHWA Divisions and Resource Center.

Key Words

- Construction inspection
- Collaboration
- Quality-based inspection
- Digital delivery
- Model-based inspection
- Indiana Department of Transportation
- Ohio Department of Transportation

Notice

Non-Binding Contents

Quality Assurance Statement

June 2020 ***FHWA-HIF-20-051***