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RE-MODELING THE MIXMASTER

From Mobile Mapping to 3-D Modeling— An Innovative Approach to DOT Construction

BY ERIC **ANDELIN, CP, GISP**

Dallas commuters are all too familiar with traffic bottlenecks, especially those who must travel the tangled convergence of freeways and interchanges known to locals as the Mixmaster. This notorious stretch of interstate takes place at the intersection of IH 30/IH 35E and is ranked among the country's worst congestion spots, responsible for numerous accidents and delays. Despite ever-increasing traffic volumes, the freeway has not undergone any material improvements since completing its construction in 1962.

In 1999, the Texas Department of Transportation (TxDOT) proposed an aggressive 25-year plan to implement a comprehensive redesign of the interstate system. As a pull-out from this larger effort, TxDOT announced in 2011 its plans to transform a particularly problematic section of the Mixmaster known as the Horseshoe. Named for the U shape of the project area, the Horseshoe project involves upgrading the IH 30 bridge, part of the Mixmaster and the IH 35E bridges, both northbound and southbound. The Horseshoe project relies on an innovative design-build approach to improve construction and cost efficiencies and dramatically shorten project timelines.

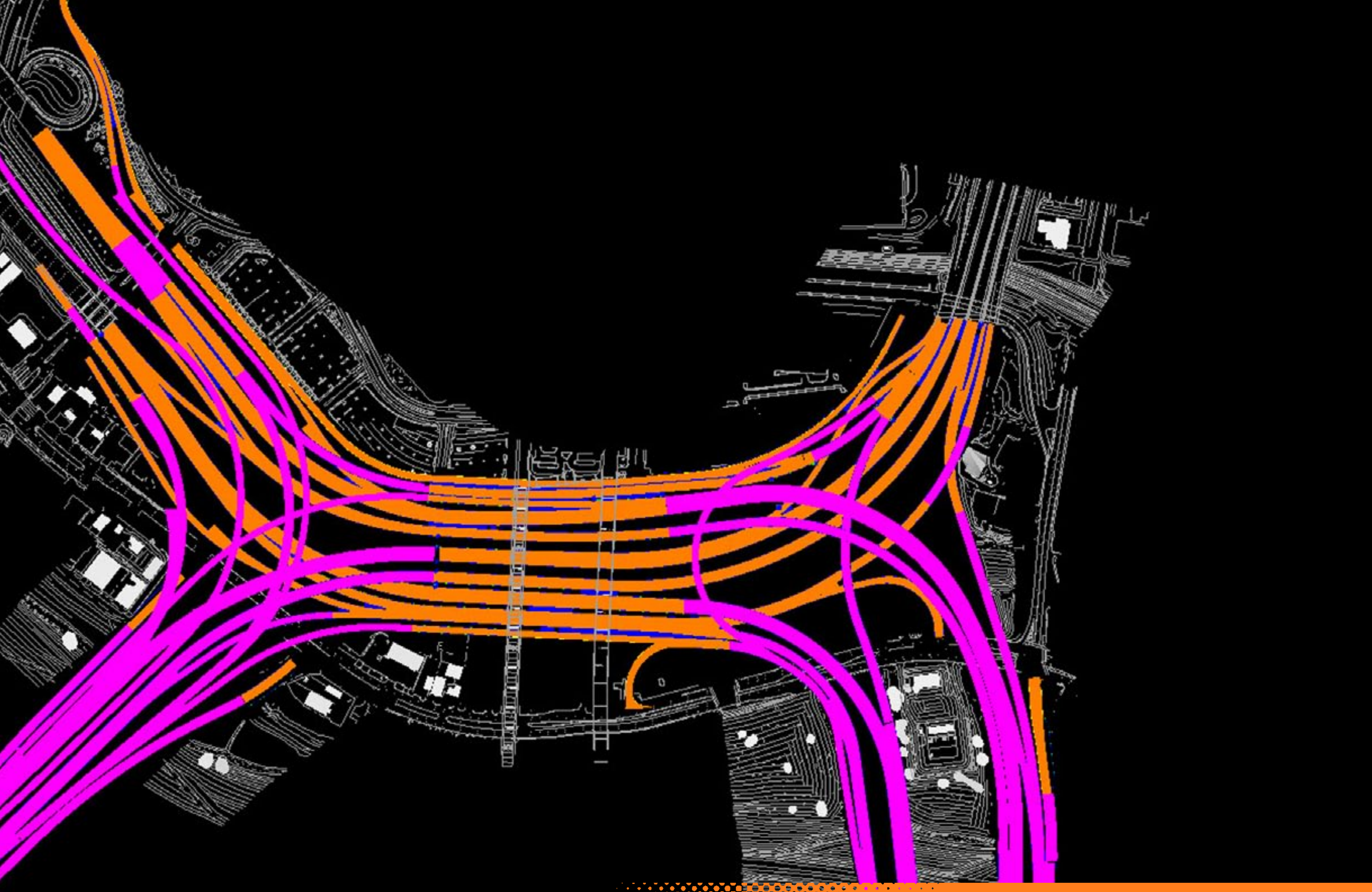
Although design/build is not a new approach in construction, it is new for TxDOT. And effectively applying this streamlined construction method on a complex freeway interchange requires the use of cutting-edge technology, a substantial amount of data management expertise and the latest 3-D modeling techniques. Through its contracted partners, TxDOT has access to all of them.

An overhead map view of the project's 3-D model shows a complex network of freeways.

Mobile Mapping and Data Acquisition

To manage the survey and data acquisition, TxDOT's Dallas District contracted the mobile mapping experts at Woolpert, a firm that has worked on numerous projects for TxDOT, both under the Woolpert name and through its Dallas operations of Bohannan Huston.

The survey began in September 2011, and involved collecting high-accuracy road surface data along a four-mile stretch of interchange as well as side streets, underpasses and approximately 400 bridge columns. Adding to the project's complexity was the region's high traffic volumes, and this interchange is always well-trafficked. Woolpert's mobile



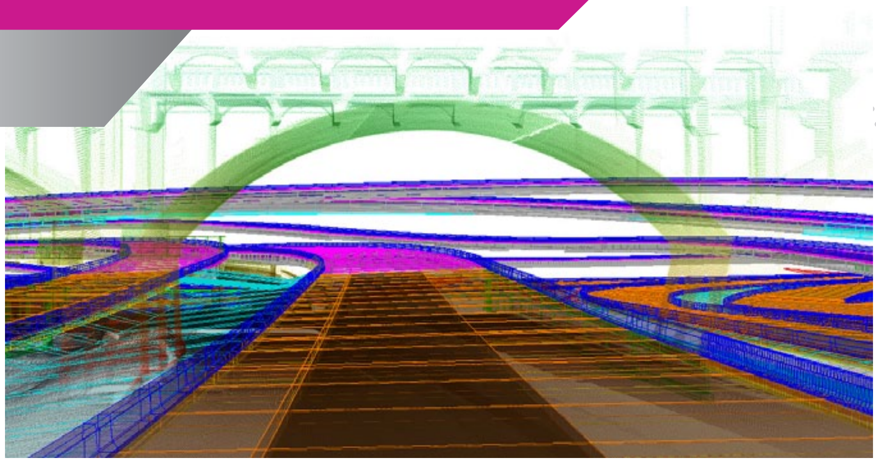
mapping crews worked in the evenings to avoid the highest traffic volumes and minimize disruptions. The crew used the Optech Lynx Mobile Mapper M1 to perform the survey, making two passes in each direction on the interchange, one on the inside lane and one on the outside. Requiring no lane closures and traveling at posted freeway speeds, the team collected LiDAR data up to 1 million points per second (1MHz).

However, mobile mapping at freeway speeds alone would not pick up the level of detail required on many bridge columns, and there were some areas the team could not access with the mobile mapping vehicle. To fill in these gaps, the team utilized multiple acquisition technologies and fused them with existing datasets to obtain a single, high-accuracy dataset while still minimizing the time crews spent in the field.

Woolpert's static LiDAR survey crews scanned the bridge columns with Leica ScanStation C10 laser scanners configured for remote operation using Android-based tablets. Additional field crews set ground control for the mobile and static scans to fill in any remaining obscured areas. As with the mobile mapping surveys, all of the static scanning took place at night to minimize disruptions and ensure maximum crew safety.

In addition, previous contracts handled by Woolpert's Dallas operations meant that there was a substantial amount of data already available in-house. Surveyors pulled up static laser scans of the bridges that were collected six years earlier. A two-foot, auto-correlated surface from a 2007, 17-county orthophotography project also filled in some of the open areas. Woolpert's team took all of the available data into consideration to determine where mobile mapping should be used and where other methods—specifically, static scanning and traditional surveying—could be integrated to avoid duplicating previous surveying efforts.

Within two days, all the mobile LiDAR data had been collected. The



3-D model uses mobile LiDAR dataset to ensure tight clearance at an overhead arching structure.

bridge column scans and traditional surveys were completed in about a week. All that remained was the monumental task of combining, processing and registering the massive amounts of data.

A known limitation of today's commercial software packages is the inability to effectively merge datasets with different accuracies, such as those with which the Woolpert team was compiling for the Horseshoe. To fill in these gaps, Woolpert relied on its Applied Research and Development (ARAD) group to write routines for macros that work within existing software programs. Through these routines and the expertise of Woolpert's technicians, the team processed the different datasets from the Horseshoe, reconciled the surfaces, and converted them to MicroStation for the TxDOT deliverables—all within a four-month time frame.

Creating a 3-D Model From the LiDAR Datasets

Once Woolpert had extracted the data and provided deliverables in TxDOT standards along with point cloud data , their processed LiDAR data was ready to be handed off to the design team. TxDOT hired HNTB to provide the 30 percent design of the Horseshoe's redesign because of the firm's expertise in 3-D modeling with LiDAR data. The project was slated early on to utilize a 3-D modeling approach in order to identify potential conflicts and facilitate the coordination with the design-build team to be hired later in 2012.

For the Horseshoe project design deliverable, HNTB was on a very tight schedule—five months from notice to proceed to delivery. In order to produce a plan set and design models with a high level of confidence, HNTB used the combined mobile and static LiDAR datasets to collect the as-built conditions for the project.

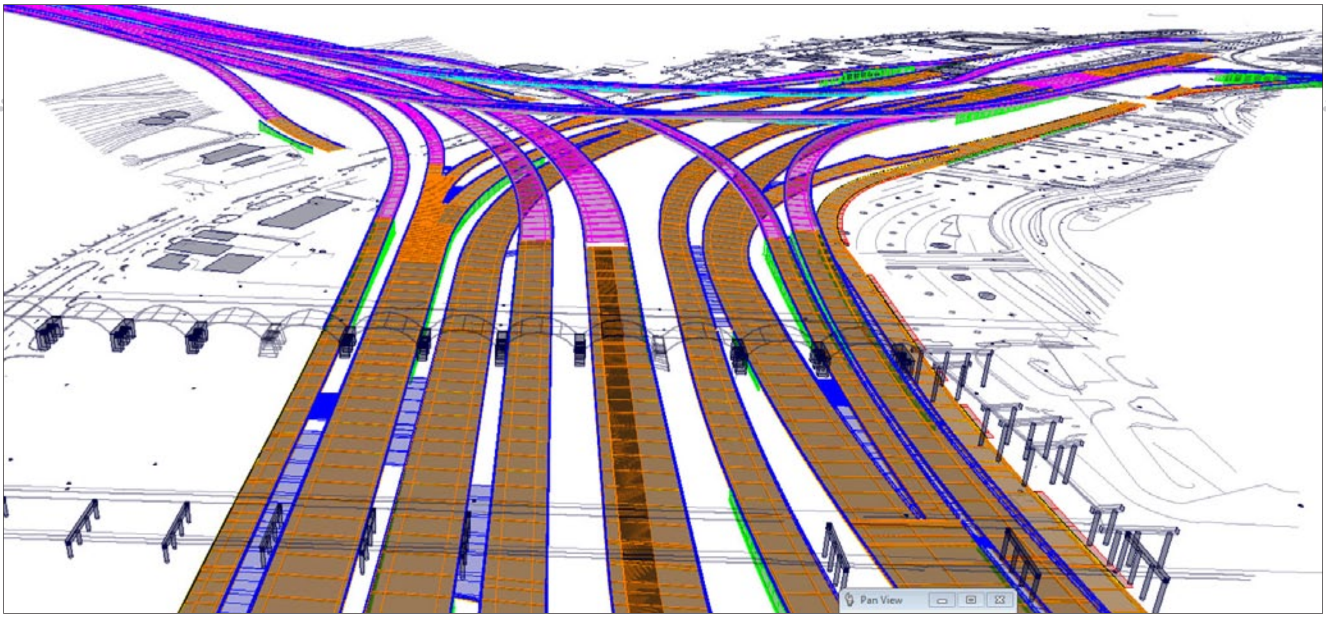
Were it not for HNTB's willingness to take on the challenge of adopting mobile LiDAR into the design process in the early stages of the technology, an aggressive project scope such as the Horseshoe would be much harder to complete. For more than four years, HNTB has focused on developing best practices for incorporating LiDAR data and making it meaningful in the design process. According to Paul DiGiacobbe, Director of Strategic Technology at HNTB, a complete LiDAR dataset is the most beneficial resource for beginning a design project. "There is no better way to start a design project than with a mobile mapping dataset, because it gives us such an all-inclusive, rich dataset. As a designer, all of our answers lie within the LiDAR dataset," DiGiacobbe said.

The major challenge of a large infrastructure project like the Horseshoe is to have enough accurate data about the existing structures to effectively integrate new work into the design. With LiDAR data as the basis for HNTB's 3-D modeling, the decision to widen a road or relocate a ramp was based on the precise location within the 3-D model, leaving nothing to chance with regards to where new design meets existing structures. HNTB's engineers had the answers to those questions already at their fingertips within the dataset, helping them quickly make design decisions and keep the project moving forward. "In retrospect, the project team could not have developed the design models in the short delivery schedule without the use of LiDAR," DiGiacobbe said.

HNTB designers analyzed many extremely tight clearance conditions as the proposed design was threaded through a myriad of arched structures and other complex geometry constraints. With traditional survey methods, designers typically encounter numerous data gaps, and crews must be continually redeployed during the design process to conduct spot surveys to fill in these gaps.

"A conventional survey could not provide the detail needed to design, check for clearance, redesign and check again. The presence of millions of measurable points from the LiDAR in the MicroStation 3-D design space made the iterative design process possible," said DiGiacobbe.

HNTB refers to its process as the "integrated model" approach. It starts



Bird's eye view of the project's 3-D model with LiDAR-extracted existing bridge features

with a very precise LiDAR acquisition followed by feature extraction, and then the modeling process can be accomplished with Bentley Civil's Roadway Modeler design tools. But, it is vitally important that the LiDAR meets the requirements of the modeling effort. "The Woolpert team understands this process, and the Horseshoe project benefited greatly from their expertise," said DiGiacobbe.

In the end, HNTB produced the 30 percent design plans on schedule and to a much higher degree of modeling accuracy than using traditional methods. Woolpert's LiDAR data, extracted terrain and structural models made the job much easier to accurately complete. The final product is now being used by TxDOT to deliver to prospective bidders on the design-build portion of the project.

LiDAR: More Than Just a Map

While TxDOT is one of the few DOTs willing to embrace these cutting-edge design methods, it's clear that this technology has enormous upside to other DOTs and large infrastructure projects. Mobile mapping and 3-D modeling are innovations that are changing the way design work is completed. The bottom line is that there are efficiency gains and less rework. Designers can get answers quicker and are ultimately cutting the DOT's costs because of their ability to work faster and smarter.

More than a traditional map, a LiDAR dataset is the basis of a map that any group within a DOT or in engineering can use to rapidly exploit the rich data for the information they seek. When you put it all together, it's not just about mapping; it's about mapping and design, and preparing a rich construction document—all of which can be accomplished more effectively with LiDAR.

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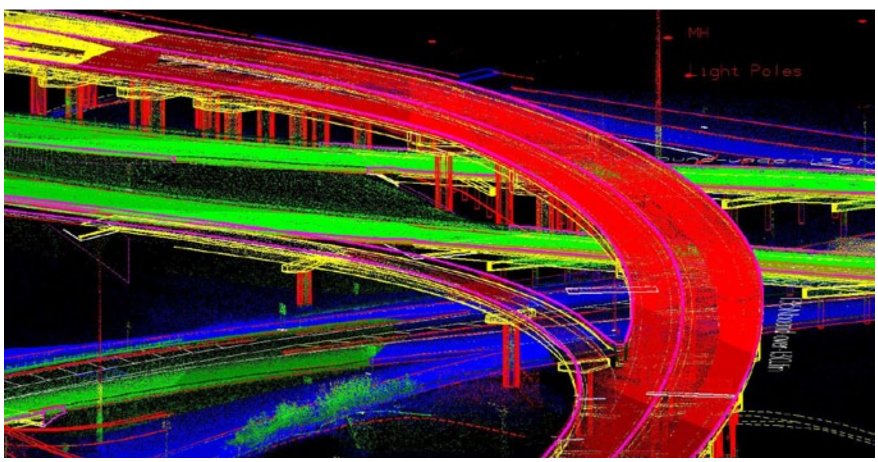

Aerial view of the IH 30/IH 35 "Horseshoe" exchange in Dallas