POINT OF BEGINNING
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Viable Viaducts

February 1, 2004

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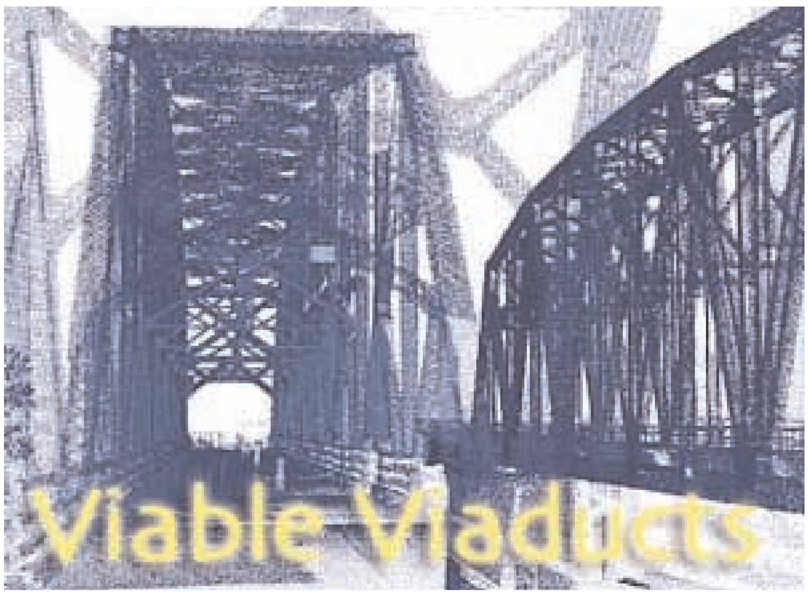


Getting stuck under an overpass while on a delivery is a trucker's nightmare. For many truckers, knowing all of the heights of the proposed bridges they will likely encounter on deliveries, thereby avoiding such an instance, is a dream. To answer this call, the Nebraska Department of Roads (NDOR) pioneered an automated truck permitting system last year. The Internet-based system is designed for truck companies to set up profiles for their trucks. When a trucker seeks a permit for a delivery through the system, the route analysis program scours the path the truck is to take to ensure the bridges along the way will accommodate the truck for weight and clearance. With this system, the NDOR may just set an example for similar organizations.

To implement such a state-of-the-art structure, the NDOR set out to conduct a bridge clearance height survey to verify the clearance data of all 400 structural assets in the state before implementing the online automated permitting system for Nebraska's truck companies. And the agency threw in another request: to have the project completed without closing a single lane of traffic. This would require some pretty efficient workers and even more efficient tools.

NDOR selected Lamp, Rynearson & Associates Inc. (LRA), multi-disciplined civil engineering consultants of Omaha, Neb., in June 2002. We at LRA were confident that our team could complete this project without any major unforeseen problems because we had worked on a variety of laser scanning projects in the past. At project's end, we realized we had accomplished this goal.

Establishing a Plan

LRA set out to complete the bridge survey, beginning with the selection of various field and office tools. We initially considered using a reflectorless total station to help us work with reduced traffic lanes, but decided that the speed and accuracy of 3D scanning had great potential to conduct a faster and more thorough survey of each bridge site—and keep us out of traffic. At first, the NDOR was skeptical of using 3D scanning for such a large project. The organization was not familiar with the technology and wanted us to verify the accuracy before beginning the project.

After a field test where we captured more than one million data points, the vertical measurements were extracted and checked in the field using a laptop computer. NDOR engineers matched known measurements with our new data to within 1/8 of an inch. After this test, NDOR was satisfied and let us move the project forward by applying scanning technology.

Project Time Analysis

TASK	Pilot Project	Project	Time Savings
Field Data Collection Time	0:40	0:15	0:25
Post Processing	1:00	0:30	0:30
Total Time x 400 Bridges	666 Hours	300 Hours	366 Hours

While we were analyzing the best possible way to commence this project, a multitude of factors came into play. Safety was our No. 1 concern.

"The most important feature of 3D laser scanning was safety," says Ellis Tompkins, PE, rail & public transportation engineer. "Most of the structures are located on Interstate 80 with 75 mph traffic."

How could we keep our field personnel out of harm's way while collecting survey information on an interstate system?

"The laser scanning could be accomplished without lane restrictions or extensive signage," Tompkins says. "The equipment was located in the median with no disruption of traffic, and therefore safe for both the highway user and the crew completing the data collection."

Maintaining a high degree of accuracy played a close second in importance on the job. Speed ran a not-so-distant third since the less time we spent on the highway, the safer we would be. Some of the other considerations of the project involved point cloud registration, data management, efficient data extraction and, of course, an end product that the client would find more beneficial than traditional methods.

By addressing these concerns at the beginning of the project, we were able to obtain the best equipment and methods to meet our needs. Relying on previous experience and assistance from various vendors, we tested and designed a workflow that would help us finish the project within the projected time.

Comparison table of using total station technology versus laser scanning.

Channeling the Equipment

With the success of the field survey test, LRA and NDOR decided to proceed on the project using the Riegl LMS-Z360 (Riegl USA Inc., Orlando, Fla.) laser scanner. On this particular project, the LMS-Z360 had many features that addressed our project concerns. For one, we were able to level the scanner using a conventional tribrach—a major advantage to us since we were extracting vertical elevations and needed highly accurate data. The unit also had a satisfying field of view of 360∞ x 90∞ and an impressive speed of 1 scan/sec to 20 scans/sec at 90∞ scanning range. We were also able to collect new latitude and longitude points and high-resolution digital images of each structure with our complete inventory of equipment, including a Kodak DX4900 digital camera (Eastman Kodak, Rochester, N.Y.).

On a scanning project, more than one instrument is typically onsite: the scanner and a total station, or the scanner and GPS unit. Checking the instruments against each other is the most common method of quality control. We often use a Leica GS50 backpack GPS/GIS data collection system (Leica Geosystems, Norcross, Ga.) in our work, but since GPS often does not work well around overhang structures such as bridges, it was not accurate enough to conduct the QC checks on this project. The QC checks required were vertical clearance dimensions that were directly under the bridge. We decided instead to use a Leica DISTO pro4 handheld laser distance meter to collect these measurements, which worked out extremely well.

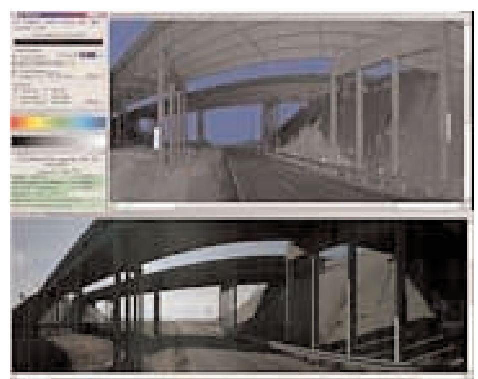
By adding more field personnel and setting up software macros to make post processing more efficient, LRA learned the benefits of scanning throughout the bridge project.

A Passage for Data Processing

We needed a fast and accurate way to transfer the raw data we collected in the field to the Omaha home office for processing. Winter weather was nearing and we wanted to get the project done before the end of the year to satisfy our client's schedule. Our project involved collecting two scans per bridge over a 25- to 30-minute period, equating to 80 Mb of field data for each bridge site.

After transferring the field data to our Omaha office overnight on CD-ROM, there was much post-processing work to be done. First, we had to register two or more scans together into a common coordinate system. Then, we extracted the vertical measurements and exported them to a spreadsheet that could be used by the NDOR. Additionally, we had to organize the latitude/longitude data and more than 700 digital images.

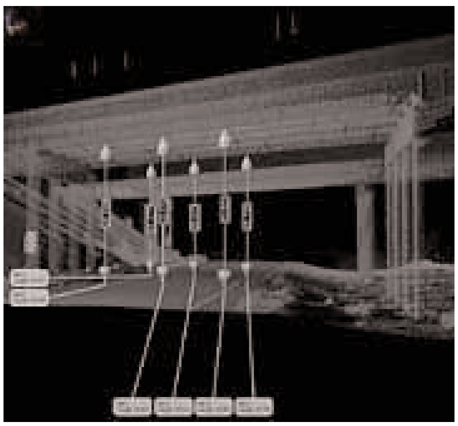
Our post-processing workflow—designed especially for this project—involved a combination of PolyWorks point cloud processing software (InnovMetric, Quebec, Canada) and the LaserGen (BitWyse, Salem, Mass.) existing conditions data management technology. This was the first time as far as we know that these data processing software packages were used together on a large infrastructure project, and the combination worked very well. Both software packages included time-saving macros that turned numerous software operator actions into routines, which were quickly accomplished without operator intervention.



The scanning software allows the operator to obtain a photogrammetric view of the data collected on the project site right in the field on the laptop.

Linking Project Management

With bridge sites throughout Nebraska, we needed a way to manage the enormous amount of data that was collected and processed. LRA's Geographical Information Systems (GIS) group recommended a database management system to monitor the project. We installed ArcPad GIS software (ESRI, Redlands, Calif.) onto our Panasonic Tough Pad (Matsushita Electric Corporation of America, Secaucus, N.J.) and used it for navigation and collection of updated latitude and longitude coordinates. While in the field, our operator used ArcPad to graphically display a map of the state and locations of each bridge site, and to monitor completion status from a geographical perspective.



This view in the Polyworks software shows the measurement tools used to extract bridge clearance dimensions.

Bridging the Field Work

Initially, the Nebraska bridge survey project utilized the scanner, laptop, backpack GPS unit, handheld distance meter, digital camera, one 4x4 truck and one field operator. A typical bridge site scan averaged approximately 40 minutes of actual equipment setup, data collection and tear down time. The scanner took a little more than four minutes to collect three million data points from one side of a bridge. The operator needed to collect and update the structure's location using the Leica GS50, collect a digital image of one-half of the structure and highway, and collect a vertical height sample for quality control measurements on every one of five bridge sites using the Leica DISTO pro4 handheld.

At the end of every field day, the scan data, digital images and ArcPad database were backed up to a CD and sent to the office.

"The laser scanner collected data from every point on the roadway to every point on the bottom of the structure and provided a graphical view," Tompkins says. "Though the project was used to implement an automated truck permit system, there are other uses for the data. For example, if a structure was damaged by a traffic accident or natural disaster, we can have an after-scan taken for comparison and determine the amount of change in the structure."

After reviewing the fieldwork, we decided to add a second field operator to the one-man crew. This shortened the elapsed time per bridge to less than 15 minutes! On our best day, we were able to capture 31 bridges in a 10-hour period, including drive time between sites. Having a second pair of eyes also added value for safety and quality control.

"The system is fast," Tompkins reports. "Conventional surveying would have required approximately two to four hours per structure. It [the system] provided accuracy down to a hundredth of a foot and still maintained the speed of setup and collection of data."

The field technician can operate the scanner from the back of his vehicle.

Aligning the Scans

Once the field operators began sending data to the Omaha office, our office post-processing specialist, Jack Cudaback, was challenged with keeping up with the field crew. The raw data was collected and stored in Riegl's native format using Riegl's 3D RiScan Pro software. Post-processing included a number of different steps to build the final deliverables.

"The raw data sent back to the office averaged 1.5 Gb per day," Cudaback notes. "Some engineering and surveying firms would not manage that much data over a one-year period, much less in one day."

One of our largest challenges initially was keeping up with the speed of the field crew. We were collecting data from 15 and 18 bridge sites per day. Our post-processing specialist aligned various scans into one coordinate plane, verified accuracy, did minor cleanup and extracted vertical height measurements.

The first step of the post process began by converting the raw data from 3D RiScan Pro to a PolyWorks format. These raw data files were extremely large and quite time-consuming to process. In the field, an operator took two scans of the bridge site that required point cloud-to-point cloud alignment in a coordinate plane. PolyWorks incorporated algorithms within the software that analyzed the geometry of every point within the cloud. It used all of the geometric information within each point cloud to conduct a best-fit alignment procedure of millions of corresponding points. Because it is based on the shape of the natural features in the scenery, the PolyWorks alignment technique did not require the use of reflective targets in each scan to align the point clouds. This method allows for faster and safer field operations. The alignment of two scan locations took approximately 10 minutes. Once the scans were aligned into a single dataset for each bridge site, it was easily geo-referenced to real world coordinates.

Twelve million data points capture this image of a truss bridge.

Subtracting for Extracting

Bridge heights were extracted at every overhead clearance point. Our next step was to extract the vertical clearance data from the aligned dataset. Initially extracting vertical measurements with PolyWorks took approximately 40 minutes per bridge site. To expedite the process, we, along with the InnovMetric support team, exploited PolyWorks' ability to create reliable and automated software macros to automate the bridge height extraction process. This lowered the initial 350-plus mouse clicks down to 12 and reduced the time to process each bridge site from 40 minutes to 10 minutes. This one process alone saved us 200 hours of processing time.

The impressive field of view allowed the field operator to not only collect the bridge data itself, but also collect the surrounding site conditions.

A Conduit for the Data

Our post-processing specialist created a spreadsheet using the existing structure names and modified it to incorporate the vertical height measurements. The digital images taken with the Kodak camera were named and organized in the corresponding project directories and the updated coordinates of the structure were uploaded into the spreadsheet. By properly managing the incoming data, one 3D application specialist was able to process almost 400 bridges and keep up with the hectic pace of the field crew.

The quality control we had in place to check accuracy involved manually measuring the bridge height with the Leica DISTO pro4. The Riegl Z360 data with extracted measurements were compared to the manual field measurements with a typical accuracy of +/- 1⁄4".

"Delivering" the Bridges

When the project began, the NDOR did not realize the power of collecting millions of measurements of these bridge sites. During the project, periodic update meetings were held and the NDOR had a chance to view the 3D data in raw form.

To provide final viewable deliverables, we used LaserGen to create multiple 3D models at one time. Through LaserGen's Distiller program, the software macros eliminated most of the user involvement related to converting the datasets into models. It also allowed NDOR users to view point cloud data in a familiar MicroStation environment, as AutoCAD and MicroStation alone do not allow millions of 3D points to be displayed in an efficient manner.

With raw field data amounting to 35 Gb per site on more than 400 field sites, the project management aspect of the job was critical. After the conversion to PolyWorks and then to LaserGen, the final count of data was a massive 140 Gb. This is enough data to fill four hard drives on today's average desktop computer.

By establishing a plan from the beginning, we managed this project with few obstacles and eliminated many mistakes that could have resulted in lost revenue. By applying efficient project planning, quality control procedures and project management skills, a project like this one can be quite successful. By using previous experience and sourcing knowledgeable support, LRA was able to pledge an efficient and effective project—and fulfill our promise. Three dimensional laser scanning technology allowed LRA to accomplish this project with increased productivity. We met and exceeded the NDOR's project requirements and were able to provide accurate deliverables within budget and on time.

Russ L. Tamblyn, a project manager with Lamp, Rynearson & Associates Inc., has worked in the 3D industry for almost 10 years. Tamblyn has worked on more than 50 successful laser scanning projects in a variety of fields, including civil/infrastructure, architectural, industrial and several hybrid applications.