Quality Matters
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from the Quality Assurance Branch (QAB) of Highway Design

Light Detection and Ranging:

Applications for transportation

Light Detection and Ranging (LIDAR) is a surveying tool that utilizes an optical remote sensing technology to measure properties of scattered light to determine range and other information about a target. LIDAR allows highly accurate 3D (x, y and z) measurements to be taken. Collectively, these data points are called cloud points and are among a multitude of data collected using lasers.

The lasers are emitted from the LIDAR unit in pulses that contact multiple objects. The amount of time it takes the laser beam to return from the object to the sensor is used to calculate range distance for a point on an object. In addition to lasers, the unit uses the Global Positioning System (GPS) and Inertial Navigation Systems (INS) to give a geospatial component to the data.

LIDAR has its roots in the 1960s and 1970s when laser remote sensing instruments were employed for lunar laser ranging, satellite laser ranging and oceanographic atmospheric research.

Possible Applications

- Drainage and erosion control analysis
- More accurate earthwork quantities
- Cross sections every 10 feet
- Corridor planning
- Right of way relocation assessments
- Waste or borrow site selection
- As built plans
- Identify geometric properties
- Pavement assessment
- Utilities
- Clash detection
- Structural analysis
- Scour mitigation
- Slope stability
- Rock wall stability
- Obstructions in clear zone
- Inventory
- Sight Distance
- Vegetation management
- Pedestrian access deficiencies
- Accident reconstruction
- Autonomous vehicles

LIDAR was initially ground-based or terrestrial being fixed in one place. In the 1980s, GPS made airborne scanning possible and later gave way to *mobile scanning*. While LIDAR has been around for more than 40 years, technological advances have made it more commercially available and users everywhere are imagining new uses for this technology.

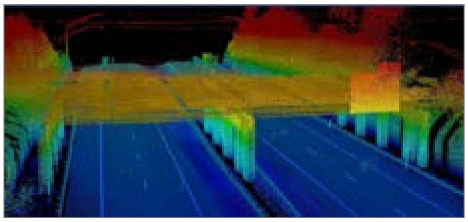
Transportation related industries account for a small portion of the potential uses of LIDAR. However, the potential uses for LIDAR as a whole are monumental.

LIDAR can be used to collect more surveying data in an hour than traditional surveying methods could yield over the course of several months. Traditionally, a crew of surveyors would take cross sections every 25 feet for an existing or proposed roadway using at least one person to hold the rod, one to use the instrument and one to document. More crew members might be required if terrain conditions made a clear line of sight difficult. Total stations eventually made taking these shots quicker, but time was required to interpret the data giving it shape in the form of roadway or cross section plans.

Mobile LIDAR scans taken from a moving platform can make a single pass of a roadway or waterway collecting data at the rate of 400,000 points per second covering every viewable surface. The amount of data collected by a mobile scan during a one hour period can easily approach a terabyte of computer data sending users scrambling for faster computers and bigger hard drives. Traditional methods are unable to match this amount of data.

Airborne and mobile LIDAR units are matched with a Global Navigation Satellite System that connects to the GPS and an Inertial Measurement Unit that is used to cover during the lapse of GPS satellite coverage. These positional systems provide geospatial data that allow point clouds with known horizontal and vertical control points set by a surveyor to be tied down and overlaid with adjacent point clouds to provide more complete coverage of a roadway or waterway.

Mobile scans have a 360 degree field of view and collect a swath of data points viewable from the mounted height of the unit on the moving platform for a given roadway or waterway. Recorded data points are limited to what the mobile unit can view. For example, locations behind a median barrier wall will not be viewable on a first pass; therefore, a second pass in the opposite direction may be required to get a complete set of data points for that roadway.



LIDAR image created from a mobile scan from the Watterson Expressway by the Kentucky Transportation Center

Aerial photo showing Watterson Expressway at I-65 courtesy of Kentucky Transportation Center

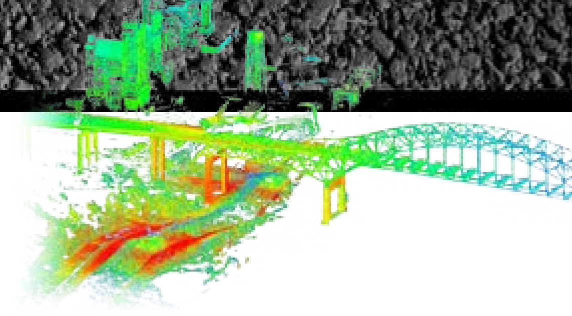
In the case of the Interstate 65 bridge over the Watterson Expressway (see above picture) a mobile scan from the Watterson Expressway provides cloud data for the underside of the bridge while a mobile scan from I-65 will provide cloud data for the top of the bridge. Combined point clouds can be utilized by computer software to provide a complete 3D model of that structure. Additionally, the mobile scan from the Watterson Expressway can be combined with an airborne scan.

LIDAR can become an essential tool for you. The possible applications for your job are just waiting to be discovered. Use of a living point cloud file (that is regularly updated), similar to KYTC's photo log viewer, provides highly accurate information that becomes more cost effective every time it is utilized.

Explore this interactive 3D model of I-60 in Texas developed from mobile and airborne LIDAR scans: *http://www.certainty3d.com/pdf/models/TxDOTModel.pdf* .

by Shawn Russell PE, AVS

Inside:
Kentucky Transportation Center: LIDAR Research In Motion
Research Project: Evaluation of MSE walls for bridge ends.
Lessons Learned: American Disability Act requirements and existing intersections



Kentucky Transportation Center:

LIDAR Research In Motion

LIDAR is a revolutionary technology that is rapidly developing across the U.S. to assist transportation planners, designers, surveyors and contractors to view their world in a whole new dimension - 3D. Like computer-aided-design (CAD) revolutionized the drafting world to move from the drafting table to visually enhanced world of PCs, LIDAR is moving "light-speed" ahead of conventional surveying practices and simplifying how we collect and visualize our survey data.

With so much excitement building around this new technology for transportation applications and infrastructure assessment nationwide, LIDAR is already being utilized in Kentucky to help address some of the more difficult transportation data needs. LIDAR should be considered a necessary component to any transportation project. Before a project begins, maybe all transportation planner/designer/constructor officials should ask, "Where is my LIDAR data?"

Traditional LIDAR and beyond:

Multiple entities within Kentucky are collecting aerial, stationary and mobile LIDAR data for various transportation project planning, design, and delivery purposes. There is a statewide initiative to collect aerial LIDAR for the entire state by 2015 so that planners, designers and other governmental agencies can have access to better topographic information for project planning and design.

Other entities are utilizing stationary and mobile LIDAR to assist in gaining valuable project level design information. Even researchers at the Kentucky Transportation Center (KTC) on the University of Kentucky campus are exploring the benefits of utilizing LIDAR in areas such as project planning, project development, construction, operations, maintenance, safety and asset management. It is in this research environment that LIDAR can be pushed to determine how many additional opportunities truly exist to utilize it for transportation applications. Through KTC's technology exchange program and educational outreach, others can gain valuable information about LIDAR's benefit to projects.

A recent LIDAR application study conducted by KTC and KYTC Project Preservation identified the relative accuracy of mobile LIDAR could be within 1.2 inches of the actual field measured dimensions when determining the clearance heights beneath the overpasses on the Watterson Expressway (I-264) in Louisville. This project identified LIDAR capabilities of being efficient and safe. The data was collected for multiple bridges within hours, and no one had to leave the vehicle while collecting the data at 45 mph. The traveling public never knew valuable transportation asset information was being collected.

Other areas of LIDAR research are currently underway at KTC, as well. These research initiatives are intended to push the capabilities of LIDAR technology beyond those of traditional applications often found in design. Examples of current KTC research include forensic evaluations at high crash locations, failure analysis for structures and geotechnical projects, cross slope evaluations for finished grades, ADA compliancy and other safety and asset management needs for highway infrastructure.

Stay tuned to future articles to learn more about promising developments in LIDAR as it relates to transportation applications and infrastructure assessment.

by Brad Rister, PE
KTC Senior Research Engineer

Why LIDAR?

PROFICIENCY:

Research conducted by Dr. Dadi, G.B. (2013) states that in a lab environment an individual given a 3-D model of an object to build will be 10 percent more proficient at building that object as compared to when given only a 2-D model of the same object. Therefore individuals, and especially minds of a younger generation, will be more proficient in designing and constructing our future transportation infrastructure using 3-D models.

EFFICIENCY:

When it comes to collecting field data surveyors can typically occupy a location for five seconds to achieve an accurate location using GPS technology (TRB 2010-NOAA). However, LIDAR technology can collect 3,000 to 5,000,000 points in that same five-second time frame.

SAFETY:

Imagine the amount of safety that can be excised when collecting edge of pavement shots on urban interstates using LIDAR technology. You may not ever have to get out of the truck again to get your data. That is not to say you don't need to survey anymore, because for design purposes LIDAR data actually needs to be tied down to geodetic control, but the 3-D point cloud can be collected while driving a mobile LIDAR unit within the normal traffic stream. Tying the LIDAR data down to geodetic control can be achieved by surveying in control points every 500 to 1,000 feet along the corridor. As long as you can see these points in your collected LIDAR point cloud in post-processing, you can assign the correct surveyed position to the individual LIDAR point at your marker location. Thus, creating a geodetic controlled 3-D point cloud for either Microstation or AutoCAD.

Photo courtesy of Kentucky Transportation Center

Research Project:

Evaluation of MSE Walls for Bridge Ends

When space is limited, such as at urban interchanges, vertical retaining walls are many times the solution to keeping the footprint of a roadway to a minimum. Such walls are typically made of reinforced concrete and designed as either gravity or cantilever walls. However, as the height of a wall increases and/or when poor subsoil conditions exist, the cost of a conventional reinforced concrete wall increases rapidly.

Mechanically Stabilized Earth (MSE) walls have been developed to offer significant technical and cost advantages over conventional reinforced concrete walls. MSE walls also offer the potential to reduce the overall length of a bridge, which leads to less initial cost and reduced maintenance cost over the life of the bridge. Because of these reasons MSE walls are being utilized more at bridge ends across the nation.

In Kentucky, there are a limited number of MSE walls at bridge ends due to various concerns. Issues such as maximum MSE wall height, site conditions where MSE walls should or should not be utilized, the various methods of constructing MSE walls and the overall stability and long term performance of MSE walls are all concerns that remain unclear.

In 2011, a research project titled "Evaluation of Mechanically Stabilized Earth Walls for Bridge Ends in Kentucky, What Next?" was launched to evaluate and better understand these unknowns. In the Summer of 2013, the research project was completed, and shortly thereafter, received attention on the national level, as it was featured in the Sept. 17, 2013, TRB E-Newsletter.

A copy of the report and other documents produced through the research can be found on the Kentucky Transportation Center website at http://www.ktc.uky.edu/projects/evaluation-of-mechanically-stabilized-earth-walls-for-bridge-ends-in-kentucky-what-next/. The following is a brief description of the main areas of focus and products that came from this research project:

Nationwide MSE wall survey

A survey concerning MSE walls at bridge ends was sent to 49 states in the U.S. and five provinces in Canada. Thirty-nine states and two provinces responded. Of those that responded, 33 states/provinces indicated they allow the use of MSE walls at bridge ends. Three states/provinces indicated they had a formalized maintenance rating system for MSE walls at bridge ends. Two states/provinces indicated they had an inspector's handbook for MSE walls. Other questions ranged from allowable types of tensile reinforcement and allowable backfill materials, to frequency and type of MSE wall failures. See the report for a full list of the survey results.

Develop guidance manuals for MSE walls

As a product of this research project, two guidance manuals were developed as resources for professionals involved with designing, constructing and maintaining MSE walls. One manual covers MSE Wall Design Guidance. The other manual covers Inspection Guidelines for Construction and Post-Construction of MSE Walls. Both manuals have been presented to KYTC and are being reviewed. At this point the review has primarily been focused on the MSE Wall Design Guidance. Review and incorporation of the Inspection Guidelines will likely depend on the design guidance adopted. Both manuals are available on the same webpage as the report; just follow the KTC webpage link stated previously.

MSE wall abutment inspection/ rating in KY web application

The web application gives maintenance engineers and inspectors a resource for maintaining an inventory and details of pertinent data for all MSE walls at bridge ends; a system for storing condition ratings, pictures, and other related inspection files online; and the ability to map out all locations stored in the web application. To view the web application, go to: http://www.ktc.uky.edu/kytc/MSEWall/index.php

By: Michael Vaughn, PE, AVS

Lessons Learned

American Disability Act requirements and existing intersections

What activities are considered 'alterations' and trigger the requirement to bring the intersection to current ADA standards?

Recently, District 5 ran into an issue where the introduction of a shared use path at an intersection triggered the obligation to upgrade the entire intersection to current American Disability Act (ADA) standards.

The purpose of the project was to reconstruct the Interstate 265 interchanges at U.S. 60 and Interstate 64. As part of the project, a 10-foot shared use path was installed along U.S. 60. The path ended at the intersection of U.S. 60 and North English Road. The original intent was to tie the path into the existing sidewalk ramp and install a new pedestrian button at the intersection for walkers. This effectively upgraded only a portion of the intersection.

Connecting the shared use path to this intersection triggered the need to upgrade the entire intersection to meet current ADA requirements. To ensure the intersection was compliant, one sidewalk ramp along with the adjacent sidewalk, curb and gutter were removed and reconstructed. Three new sidewalk ramps and four new pedestrian signal pedestals were installed while two pedestrian signal heads were relocated.

According to Title II of ADA, state and local governments are obligated to meet ADA requirements whenever streets, roadways or highways are altered. According to Federal Regulation CFR 35.151, an alteration is a change that affects or could affect the usability of all or part of a building or facility.

Activities considered alterations are reconstruction, rehabilitation, resurfacing, widening and projects of similar scale and effect.

When the shared used path was connected to the intersection, the usability of the intersection was altered and thus, the obligation to bring the entire intersection into compliance, instead of a portion, was required.

See the following link for the guidance from FHWA on ADA requirements when streets, roads or highways are altered. http://www.fhwa.dot.gov/civilrights/programs/doj_fhwa_ta.cfm

by Eileen Vaughan, PE, AVS

Lessons Learned Database Available Online:
http://transportation.ky.gov/Highway-Design/Pages/Lessons-Learned.aspx

GIS Resources for Designers

KYTC has several online GIS resources that designers may find helpful. Click here to jump the listing included in this issue. Most of these data sources are publicly available. However, a few are only available internally through KYTC's intranet.

Many more publicly available maps are on the KYTC Maps page at: http://transportation.ky.gov/Maps/. There are several internally available maps as well on the GIS Support Services page at: https://intranet.kytc.ky.gov/work/gis/.

Farewell Travis

After serving as the Post-Construction Review Coordinator for nearly a year, we say farewell to Travis Carrico. The Quality Assurance Branch will miss Carrico and we are forever grateful for all his hard work and dedication. He contributed greatly to the Post-Construction Review program and the other programs in QAB (Lessons Learned, Constructability and Value Engineering). He also provided excellent ideas for articles in the Quality Matters newsletter. Carrico has joined the Roadway Design Branch of the Division of Highway Design and is the Location Engineer for Districts 3 and 8. If you would like to contract him, his email remains the same: Travis.Carrico@ky.gov

Upcoming Training:

Kentucky Engineering Center:

(http://www.kyengcenter.org/)

- April 11 – 401/404 Permitting–Louisville
- April 24 – Spring Dendrology & Native Tree Identification–Clermont
- April 29 – May 2 – Microstation/Inroads–Frankfort
- May 13 – Microstation/Inroads–Frankfort
- May 21 – KSPE annual convention–Lexington
- June 17 – Microstation/Inroads–Frankfort
- June 17 – One day Seminar, Various Presenters–Paducah

Staff

Vacant
Quality Assurance Branch Manager

Eileen Vaughan, PE, AVS
Lessons Learned Coordinator
Eileen.Vaughan@ky.gov
(502) 782-4916

Michael Vaughn, PE, AVS
Value Engineering Coordinator
Mike.Vaughn@ky.gov
(502) 782-5631

Vacant
Post-Construction Review Coordinator

Shawn Russell, PE, AVS
Constructability Review Coordinator
Shawn.Russell@ky.gov
502-782-4926

Dawn Morrow
Kentucky Design & Print Services
Graphic Designer Coordinator
Dawn.Morrow@ky.gov
502-782-4720

Applications of MOBILE LIDAR SCANNING

Asset Management

- Billboard management
- Automated/semiautomated extraction of signs
- Modeling and inspection
- Inventory mapping

Maintenance

- Drainage/flooding
- Vegetation management
- Bridge inspections
- Power line clearance

Research

- Unstable slopes
- Landslide assessment
- Coastal erosion

Project Development

- Feature extraction for CAD models & baseline data
- Virtual 3D design (alternatives and clash detection)

Operations

- Traffic congestion/parking utilization
- Land use/zoning
- Building Information Modeling (BIM)
- Bridge Information Modeling (BrIM)
- Emergency response
- Clearances

Construction

- Machine control and construction automation
- As-built/repaired documentation
- Post construction quality control
- Pavement smoothness/ quality determination
- Quantities
- American with Disabilities Act (ADA) compliance

Safety

- Extraction of geometric properties and features for analysis
- Forensics\accident investigation
- Driver assistance autonomous navigation

Tourism

- Virtual tour of attractions
- Historical preservation

Project Planning

- Roadway analysis
- Topographic mapping
- Environmental studies
- General measurements

Addapted from
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_748.pdf

GIS
Resources For Designers

Geology

- **Kentucky Geoportal:**
  http://kygeonet.ky.gov/govmaps/
  Data on topography, elevations and other web based maps of Kentucky. The Geologic Mapping link leads to the University of Kentucky Geologic Map which contains information on coal boreholes, oil & gas wells, & sinkholes.

Bridge & Drainage Structures

- **Pipe and Culvert Drainage inventory:**
  http://kytcmaps.kytc.ds.ky.gov/drainageinventory/
  Drainag e inventory containing location of pipes and culverts (<20' span) on state maintained roads.
- **KYTC Bridge Data Miner:**
  http://maps.kytc.ky.gov/bridgedataminer/
  http://kytcmaps.kytc.ds.ky.gov/bridge/
  Click on a bridge for details about structure.

Projects

- **Various Interactive, Mobile and Printable GIS Maps:**
  http://transportation.ky.gov/Maps/
  Displays links to over 30 maps. These maps can be downloaded, viewed on a mobile device or printed.
- **Active Highway plan:**
  http://maps.kytc.ky.gov/syp/
  Link to data in PMToolbox. Displays data on active construction, planning, design, ROW and Utilities projects. Use the ID button to click on a project then click on the file link.
- **Project Plan Archive:**
  http://maps.kytc.ky.gov/projectarchives/
  Link to project plans on project wise. Use the ID button to click on a project then click on the file link for the plan pdf.
- **Lessons Learned:**
  http://maps.kytc.ky.gov/lessonslearneddatabase/
  Displays KYTC projects that have received a Post Construction Review or Value Engineering Change Proposal.

Roadway Data

- **KYTC Traffic Counts:**
  http://maps.kytc.ky.gov/trafficcounts/
  Displays traffic count locations, most recent AADTs and functionally classified roads.
- **General Highway Map of Kentucky:**
  http://maps.kytc.ky.gov/generalhighwaymap/
  Displays roadway mile point information
- **Sign Viewer:**
  http://kytcmaps.kytc.ds.ky.gov/signviewer/.
  Sign Inventory, picture of sign, mile point, MUTCD code.
- **Roadway Photo viewer:**
  http://maps.kytc.ky.gov/photolog/
  Zoomable, searchable, drivable photo log of the Kentucky road system. It also displays mile point and date for each picture.

District Analysis

- **District Specific Interactive Maps 3, 9, 12:**
  https://intranet.kytc.ky.gov/work/gis/
  Custom built maps with district specific data. Other districts may request this data set up through GIS.

Survey

- **LIDAR data available for KYTC projects:**
  http://maps.kytc.ky.gov/lidartiles/
  Displays the areas of the state with available LIDAR data. Information on how to request LIDAR data is available on the page. Also available from the Highway Design Survey Coordination page.

Global

Internal only