Using Photogrammetry and LiDAR for Asset Data Collection and Life Modelling

By Melissa Buelow, P.Eng. and Debbie Burns

The Asset Management theory is beneficial for large organizations that have billions of dollars in infrastructure assets. It is an excellent practice to look at your assets and analyze how to spend your limited budget to keep things in the best repair possible and to have the data and scenario analysis tools in hand to make the case for project funding. But in order to get this process started there is a certain amount of data that needs to be known:

1. What do we have (in assets)?
2. When will they need to be fixed (need an expenditure)?
3. How much will it cost?

The Ministry of Transportation Northeastern Region covers 299,100 square kilometres of territory from Muskoka north and is responsible for 14,655 lane kilometres of highway. Managing and renewing infrastructure is an ongoing process. A significant amount of data is already on file for major highway assets. However, the data is all in hard copy format or scanned images, and it requires a large amount of time to sift through it all and pull out the pertinent facts about the assets so that a timeline and a cost can be estimated for each of the assets. In addition, the hard copy papers do not give an indication of performance. Asset performance needs to be field checked to verify if the assets are on the path to reaching their expected life cycle duration or if there are certain local conditions that are affecting their performance. There is a lot of work required to get an asset data inventory and management program set up in order to provide realistic results.

In order to develop an asset inventory and answer questions about the remaining life cycle and the cost for repairs, the Ministry hired Stantec Consulting. The assignment involved collecting inventory information on three of Northeastern Region's major highways (Highway 6, 11 and 17) and to prepare a cost and a timeline model that could be used to consistently estimate the remaining lifespan and cost for replacement of each of the assets in the inventory. In total approximately 1,900 centreline kilometres of highway were inventoried.

In order to complete the assignment, Stantec first collected high-resolution right-of-way video, GPS and Light Detection and Ranging (LiDAR) data for Highways 6, 11 and 17 in both directions, resulting in approximately 3,800 km of data. The collection vehicle was equipped with:

- A GPS Receiver to collect location, speed, direction, and time.
- A Distance Measurement Instrument (DMI) to provide a reference measurement for the vehicle, linear referencing system.
- An Inertial Measurement Unit (IMU) used to sense motion. An IMU measures the type, rate, and direction of the collection vehicle's motion using a combination of accelerometers and gyroscopes. The data collected from these sensors allows a computer to track the vehicle's position.
- An Accelerometer to measure acceleration and magnitude and direction of acceleration as the vehicle bounces in response to the pavement surface profile.
- A Light Detection and Ranging (LiDAR) Sensor, an optical remote sensing technology that measures properties of scattered light to find range and/or other information of a distant target. The range to an object is determined by measuring the time delay between transmission of a light pulse from the laser and detection of the reflected signal.
- Two High Resolution Cameras.
- A System Control to monitor data collection. Geo3D Kronos software was used on-board to collect and monitor the data in real time.

By gathering video and GPS data in the field Stantec was able to obtain:

- Sub-meter (real time GPS) to sub-foot (post processed GPS) positional accuracies.
- High-resolution geo-referenced digital video log in both directions for Highways 6, 11 and 17 collected at 5m intervals (approximately 500 GB) which provided the ability to extract feature attributes in the office via the collected data and to assign digital images to each feature collected.
- LiDAR data (approximately 500 GB).

Data Collection

Mobile Data Capture – What's on the Truck?

Once the data was collected, a team of staff in the office

Equipment on the Data Collection Vehicle

started work to extract the following assets in order to build an inventory.

- Concrete Barriers
- Clear Zones (Rock Cuts)
- Intersections
- Paved Shoulders
- Guiderails
- Curb and Gutter
- Catch Basins
- Entrances
- Auxiliary Lanes
- Crossings
- Linear Passing Zones
- Lane Width Measurements (taken every kilometre)

Asset extraction is the exercise of collecting the spatial and physical information of the assets. The principal software used in the asset extraction process was Geo-3D's Trident 3-D Analyst, which provides the ability to perform feature extraction through digital video photogrammetry. To do this, the collected digital video and GPS data was loaded into Trident and the asset inventory file was set up. Stantec created a GIS layer for each asset to be extracted along with the requested attributes for each asset. The technicians could then fill in a pre-set form for each asset type to provide the complete inventory required by MTO.

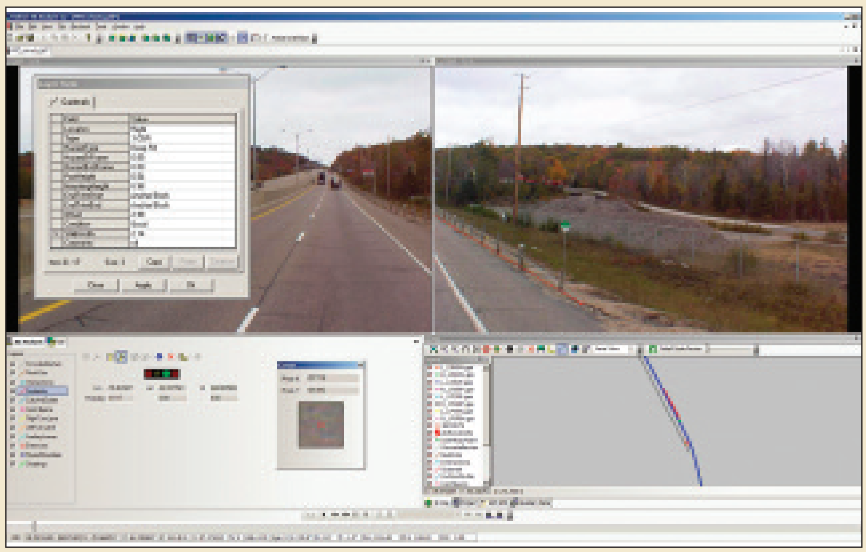
Stantec technicians processed one highway and one direction at a time, i.e. all of Highway 6 was processed from south to north then north to south before commencing work on Highways 11 and 17. For each highway, both the left and right camera files were uploaded into the Trident software along with the GPS and LiDAR data. The related GPS data trace was automatically overlain on the Ontario Road Network (ORN) centreline shapefile in the Trident map window, and the two video files were synchronized to start on the first frame of each file. The technician then "drove" through the video and extracted each of the assets in the inventory list along with the required attributes.

LiDAR

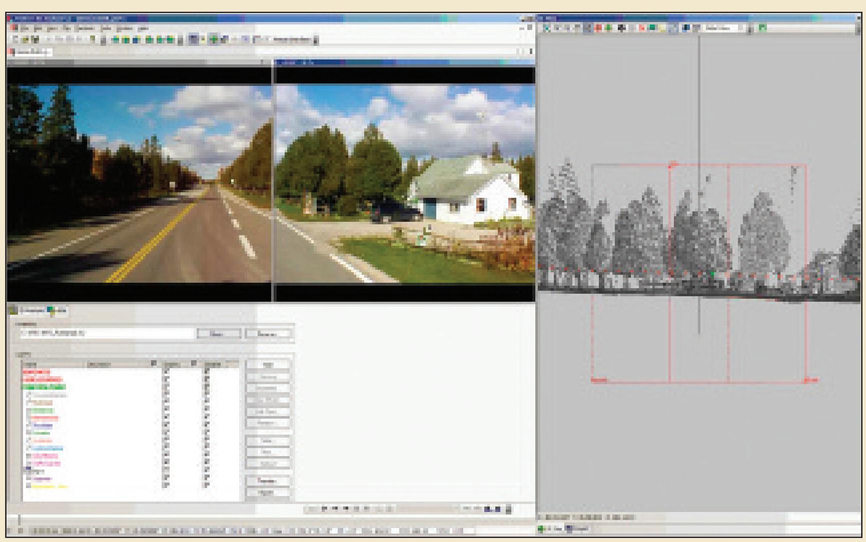
The collected LiDAR data was used in the office to assist with height measurements for assets such as clear zones (rock cuts) and guiderails. The point cloud data provided by the laser facilitated accurate height measurements. The LiDAR sensor provided point cloud data where each point collected contains GPS coordinates (x, y, z) that can be viewed from any angle along with the digital video data.

Quality Assurance

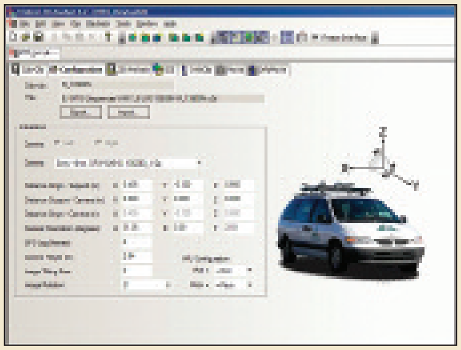
A comprehensive Quality Assurance program was developed that included an Asset Extraction Manual which



Trident 3-D Analyst Extraction Software Illustrating a Collected Guiderail



LiDAR and Digital Video Data

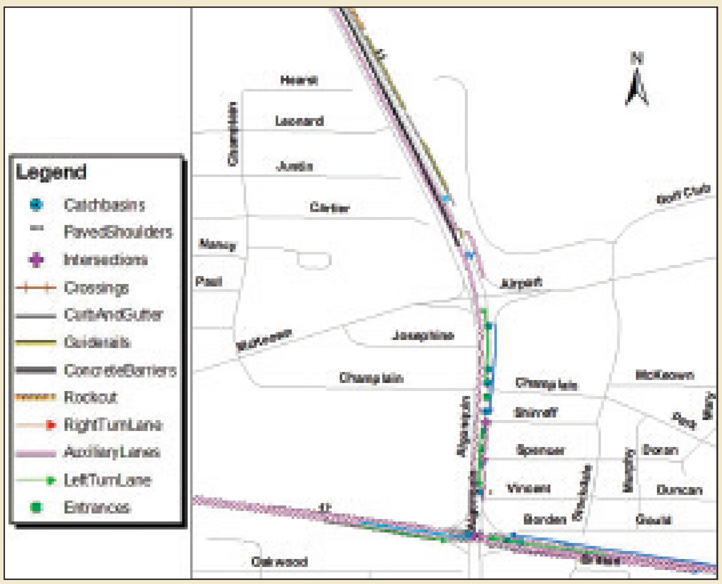


Camera Calibration File

detailed exactly how to collect each asset and described each attribute to be recorded. Data validation check points were installed throughout the data collection and extraction process. During extraction the technician loaded an associated camera calibration file for each video file so that the position of each camera relative to the location defined by the GPS unit could be calculated within the software to provide optimal positional accuracy.

Resultant Asset Inventory

The end result of Stantec's data collection and asset extraction efforts is an inventory with 26,106 individual assets identified for the three highways. The inventory is currently stored in an Access database, but it is expected that as it grows with the addition of further asset categories and additional highway corridors, a larger more robust database system will be required.



Map of the Results of Data Extraction (North Bay)

26,106 Assets Collected on Highway 6, 11 & 17

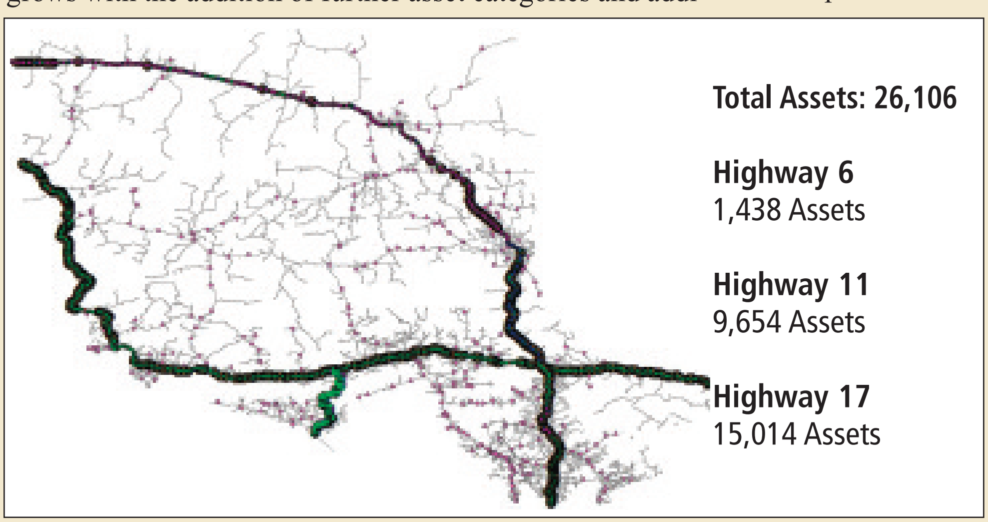
Total number of assets collected for all three highways:

- 299 Concrete Barriers
- 3,054 Clear Zones (Rock Cuts)
- 1,269 Intersections
- 913 Paved Shoulders
- 3,409 Guiderails
- 1,176 Curb and Gutter
- 1,055 Catch Basins
- 7,783 Entrances
- 496 Auxiliary Lanes
- 50 Crossings
- 2,602 Linear Passing Zones
- 4,000 Lane Width Measurements

On October 3, 2008, MTO staff Melissa Buelow, Senior Project Engineer and Paul Church, Senior Surveyor along with Debbie Burns, Project Manager with Stantec Consulting Ltd. provided a presentation at the 13th Annual Geomatics Picnic at York University in Toronto outlining this project. The event was organized by the Association of Ontario Land Surveyors (AOLS) and was attended by approximately 100 members of the Geomatics industry. The Picnic focused on applications that link the Geomatics sciences to the needs of the user community and was sponsored by the York University Department of Earth and Space Science and Engineering and the AOLS Continuing Education Committee.

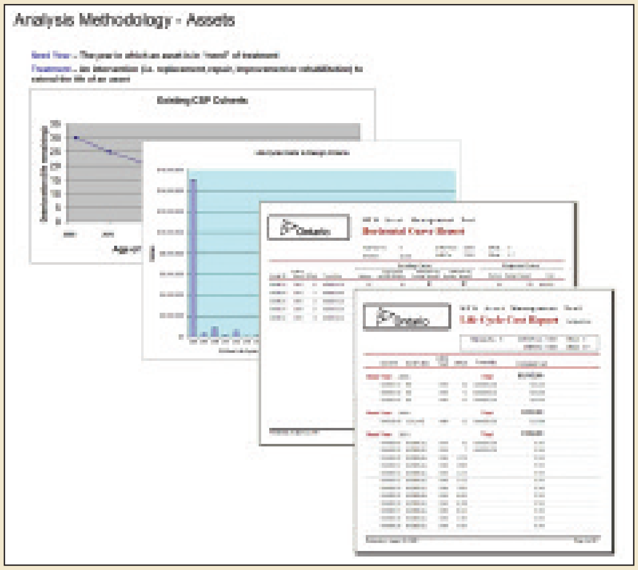
Analysis of the Data

The next step is to take the asset inventory information and assign a cost and life cycle to each of the assets. It is recognized that some of the inventoried items such as rock cuts and horizontal and vertical curves do not have specific life cycles, so a cost would only be assigned when the alignment or cross section is changed. For the purposes of this initial phase of the asset management program it was decided to approach with an unconstrained viewpoint in order to set up a base case for future comparison. Therefore, all the geometric-related items without a specific deterioration life cycle were compared to design standards and if they did not meet the design standard then it was assumed that they needed to be changed in year one of the cycle.

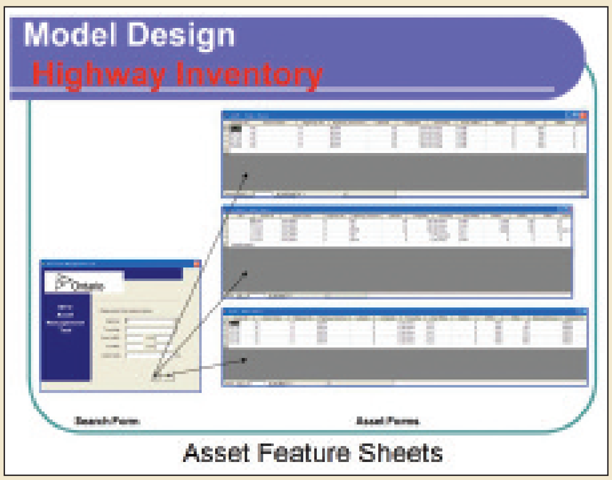


26,106 Assets Collected on Highway 6, 11 & 17

As part of the assignment Stantec set up a cost and timeline model using the inventory database to determine a cost and replacement timeline for each of the assets within a 25-year

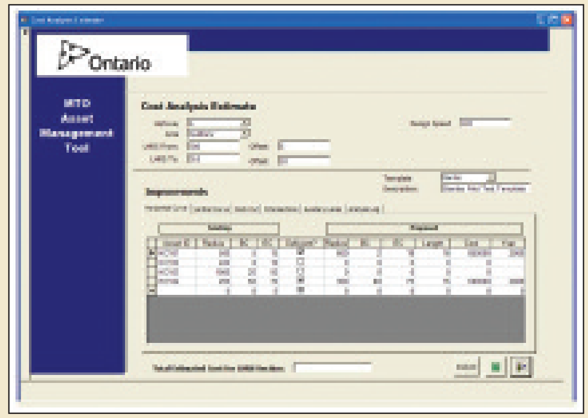


period. Having a model ensured that the cost and timelines are estimated consistently and provides a methodology so the results are reproducible. With this approach, as more information is collected on asset conditions and/or as



market prices change, the model can be adjusted and the new timelines and costs produced efficiently.

Having the asset inventory information organized in a database format improves efficiency for the many users of the information, but it also introduces many challenges in terms of data management: the need to maintain the data integrity and trustworthiness (i.e. security features and change tracking features will need to be added), the need to update the inventory as assets change (i.e. by maintenance and construction staff when assets are replaced or repaired), and the need to have accessibility (i.e. for planning, design, corridor management, maintenance and construction staff).



Cost Analysis Estimate Form in Model

The next steps for the asset management project in Northeastern Region of MTO are to collect additional inventory information, determine an approach for addressing the data management needs and to work on developing a methodology for constraining the asset analysis so that it becomes a more realistic reflection of how assets will be addressed (i.e. combining the improvement of highway assets with pavement and bridge reconstruction or rehabilitation happening in the project areas).

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Sites to See

Maps in Our Lives

http://www.loc.gov/exhibits/maps/maps-overview.html

The Library of Congress presents *Maps in Our Lives*, an exhibition in recognition of a thirty-year partnership between the Library's Geography and Map Division and the American Congress on Surveying and Mapping (ACSM), the nation's primary professional organization dedicated to surveying and mapping activities. This exhibition explores four constituent professions represented by the ACSM—surveying, cartography, geodesy, and geographic information systems (GIS)—and draws on both the Library's historic map collections and the ACSM collection in the Library of Congress. Visit the Online Exhibition.