HIGH ACCURACY PAVEMENT COMPARISON BETWEEN LOW LEVEL MAPPING AND MOBILE LIDAR MAPPING FOR AN INTERSTATE PROJECT FOR THE PENNSYLVANIA DEPARTMENT OF TRANSPORTATION (PennDOT)

Michael Loose C.P., Photogrammetry Manager
Pennsylvania Department of Transportation
Photogrammetry and Surveys Section
81 Lab Lane
Harrisburg, PA 17110-2543
mloose@pa.gov

ABSTRACT

The increasing commercial use of Mobile Mapping LiDAR Technology, especially for transportation applications, is revolutionizing the way that pavement elevations are captured. However, existing technologies such as low altitude mapping photography (LAMP) or helicopter based photogrammetry are still used largely because of their proven accuracies and known cost factors over many years of use.

Mobile LiDAR has the potential to increase accuracy, improve speed in project delivery and reduce costs for data collection. To test the feasibility of replacing LAMP based photogrammetry, PennDOT's Photogrammetry and Surveys Section, along with engineering District 4-0, are working (at the time of this abstract submission) to compare mapping data collected by traditional LAMP methods and data compiled from mobile LiDAR. The area chosen was a six mile section of Interstate 84 in Pike County, Pennsylvania. Mobile LiDAR data was captured with an Optech Lynx M1 Mobile Mapping System (MMS) owned and operated by Photo Science, a Quantum Spatial Company, LAMP photography was flown at a negative scale of 1:600 (300 feet AMT) by Richard Crouse, Inc both companies were under contract with PennDOT. Ground truthing will be done by survey grade GPS combined with field differential leveling to provide a minimum of 40 test points that will be used to access and compare the horizontal and vertical accuracies of both data sets. Time and cost comparisons will also be documented.

The oral presentation will provide information on the investigation's general approach, project design parameters, testing procedures and results, as well as, final conclusions.

KEYWORDS: mobile LiDAR, LAMP, helicopter, transportation, pavement

INTRODUCTION

PennDOT has utilized low altitude helicopter photography, typically flown at 300 feet above mean terrain, as a base for photogrammetry projects requiring very high accuracy pavement mapping and elevations. This practice, commonly known as a Low Altitude Mapping Photography (LAMP) has been a standard for many years when highly accurate mapping is requested by engineering districts. It is a proven technology.

Anytime accurate pavement mapping and elevations are required on dangerous highways, LAMP mapping is preferred due to increased safety and efficiency. It also eliminates the need for lane closures. On most projects, LAMP mapping is combined with traditional photogrammetry. Traditional photogrammetry, typically flown at 1500' above mean terrain (amt), is used to collect mapping outside of pavement surfaces. Most mapping corridors vary between 500' to 1000' wide.

PennDOT has been evaluating Mobile LiDAR as a possible replacement for LAMP mapping for several years. Initially, the increased cost and varying information with regards to accuracy and control requirements made it an unacceptable alternative. However, costs have been decreasing in the last year to the point that Mobile LiDAR is competitive or even less costly than using LAMP. Additionally, there is much more evidence of the accuracies that can be expected and the control required. However, because LAMP techniques are proven and have been used for more than a decade within PennDOT, there has been some reluctance to accept the technology by project managers and surveyors throughout our organization.

In order to get more information and prove the technology within PennDOT, PennDOT's District 4-0 and the Photogrammetry and Survey Section agreed to run tests on a current interstate project. The data would be heavily tested for accuracy and the ground control requirements and other techniques would be known.

APPROACH

In the summer of 2013, PennDOT's District 4-0 and the Photogrammetry and Surveys Section were in the middle of a large LAMP project on I-81 and I-84 in Pennsylvania's Lackawanna, Wayne and Pike counties. The project totaled approximately 24 miles. Accurate pavement mapping was necessary in order to design pavement replacement to Interstate specifications. Traditional fixed wing based photogrammetry at 1:3000 (1500 amt) was used to map a 1000' wide corridor outside of the pavement area.

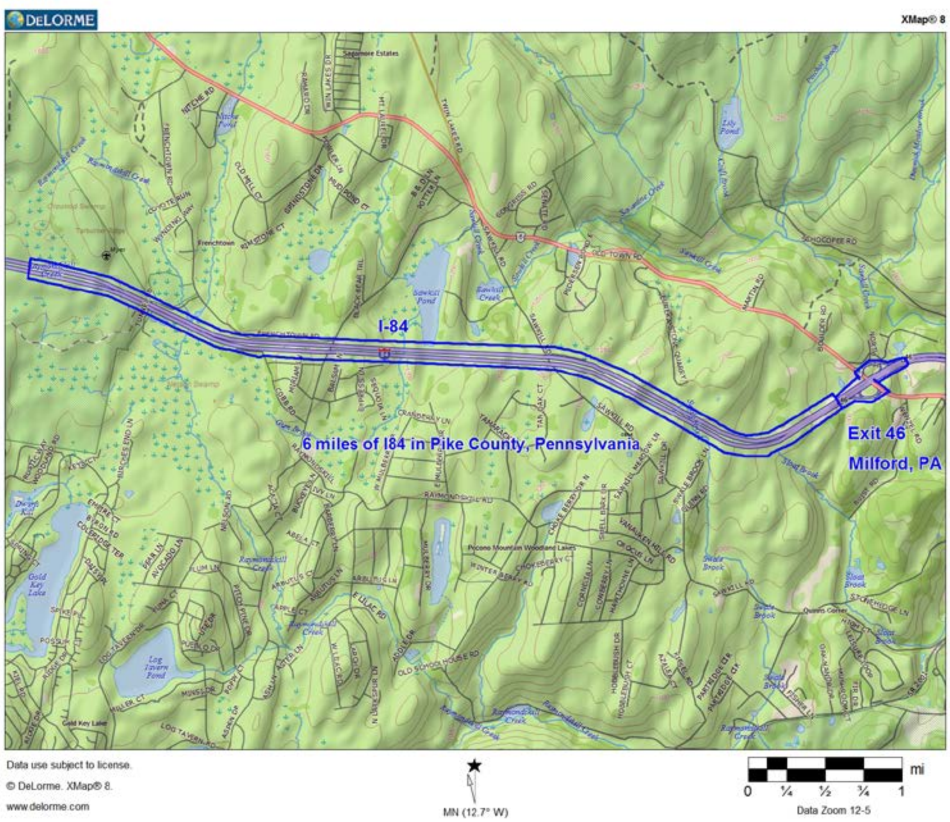

Figure 1. Project location – LAMP compiled east and westbound lanes – Mobile LiDAR processed on eastbound lanes only

It was about this time in the summer of 2013 that we became aware of the increased competitiveness of mobile LiDAR pricing. A 6 mile stretch of the project was selected based on traffic conditions that would allow for a safe and thorough map test survey. Mobile LiDAR was captured in both the east and west bound lanes of I-84 near Milford, PA. (figure 1) However, only the eastbound lanes were processed. Interstate 84 is 2 lanes in each direction and include shoulders. This gave us a very large sample dataset from both methods to compare.

LAMP mapping

The LAMP imagery was flown with a helicopter at 1:600 (6" lens -300' amt). The camera was a film based Leica RC30. The film was scanned at 14 microns.

Control was placed on both shoulders of the I-84 corridor at an approximate spacing of 250'. Analytical Aerial Triangulation (AAT) was performed to densify the field survey control.

Mapping compiled from the LAMP dataset was thoroughly checked in a rigorous QA/QC process. The LAMP process as described above has been used at PennDOT since 2004.

Mobile LiDAR

Mobile LiDAR was collected with an Optech Lynx V200 Mobile Mapping System (MMS) with the POS LV510 Inertial Navigation System (INS) unit and four 5-MP Digital Cameras owned and operated by Photo Science.

The unit was driven on both lanes in both directions (4 lanes) of the same 6 mile section of I-84 as described above. The same control as used in the LAMP dataset (~250' spacing) was used to process the mobile LiDAR data. Both directions of travel were used to process the data, but mapping was only extracted from the eastbound lanes.

A Trimble R8 GNSS (GLONASS Enabled) receiver was used to occupy a ground control monument which was utilized to control kinematic adjustment of the mobile mapping system data. The project planning was set to allow for a minimum number of 6 satellites visible during the project and a positional dilution of precision (PDOP) of not more than 3.5.

Ground Survey

The mapping would be tested using a series of 7 profiles containing 87 vertical test locations and 11 cross sections containing 55 vertical test locations. Profile points were about 25 feet apart and started and finished at painted targets along the shoulder of Interstate 84. Cross sections were collected at the shoulder edges (2), road edges (2) and the white line between lanes (1).

For the map test profiles, a geodetic control network was established for the map test survey. The final adjusted GPS network orthometric heights were replaced with the adjusted differential elevations on all test points. The established photo control stations for the Low Level project estimated accuracies are ± 0.026 feet RMS horizontally and ± 0.015 feet RMS vertically relative to NAD 83(2007) and NAVD 88.

For the map test cross section survey, a robotic total station was used to establish coordinates based on permanent monumented control and temporary project map control and map test points as surveyed above.

MAP ACCURACY TESTING

Horizontal Testing

At the time of this submission, an independent horizontal test has not been performed on the two data sets. However, Photo Science conducted their own horizontal test and determined the horizontal accuracy of the mobile LiDAR data set to be 0.044' RMSE relative and 0.057' RMSE absolute.

Vertical Testing

All of the map testing points collected by ground survey had both horizontal and vertical coordinates. All mapping was delivered in Microstation V8i format. The horizontal coordinates from the ground survey were plotted in the CADD file. A surface file built on the mapping data was used to determine the map elevations at those horizontal locations. See figures 2 and 3.

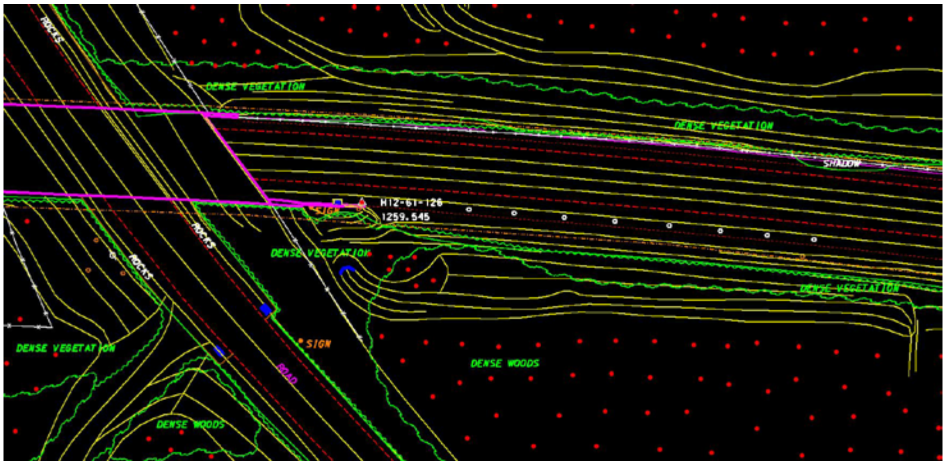

Figure 2. LAMP mapping project CADD data showing a sample test profile. Includes traditional 1"=50' mapping data outside of pavement

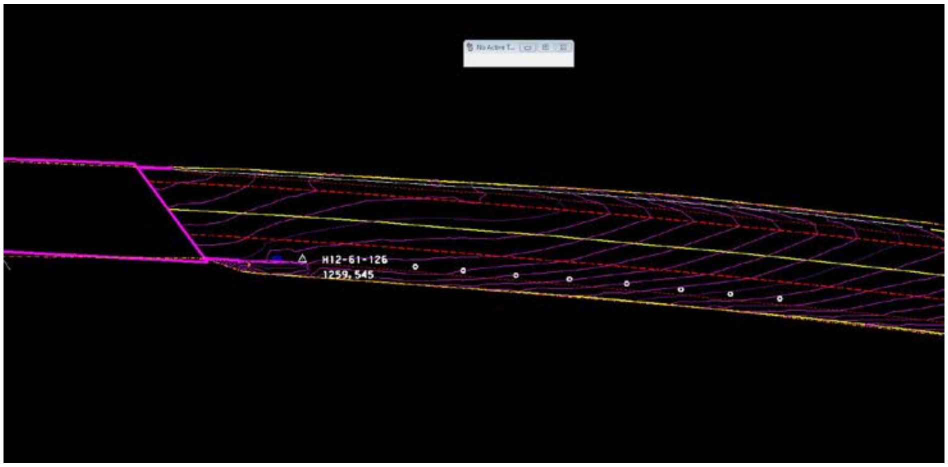

Figure 3. Mobile LiDAR project CADD data showing the same sample test profile.

RESULTS

LAMP mapping test results

Map test profile results for the LAMP data set are as follows in figure 4. RMSE is shown at the top along with all errors exceeding 1.5 x the RMSE value. The errors are also color coded by the profile that they belong to. This seems to indicate that the higher errors are distributed throughout the seven test profiles.

RMSE	0.0518'
Errors exceeding 1.5x RMSE	
12-61-182.325	0.11
12-61-033.200	0.11
12-61-048.225	0.11
12-61-073.125	0.1
12-61-165.275	0.1
12-61-048.275	0.1
12-61-088.150	0.1
12-61-165.75	0.09
12-61-165.225	0.09
12-61-073.150	0.09
12-61-033.25	0.09
12-61-048.250	0.09
12-61-182.225	0.08
12-61-165.200	0.08
12-61-048.200	0.08

Figure 4. LAMP data set test results

At the time of this submission, test data was not yet available for the 11 cross sections.

Mobile LiDAR test results

Map test profile results for the mobile LiDAR data set are as follows in figure 5. RMSE is shown at the top along with all errors exceeding 1.5 x the RMSE value. The errors are also color coded by the profile that they belong to. This seems to indicate that the highest errors are more concentrated in three of the seven test profiles.

RMSE	0.0308
Errors exceeding 1.5x RMSE	
12-61-088.50	0.07
12-61-088.25	0.06
12-61-010.150	0.06
12-61-048.50	0.05
12-61-048.225	0.05
12-61-048.275	0.05
12-61-048.300	0.05
12-61-088.100	0.05
12-61-010.300	0.05
12-61-048.125	0.05

Figure 4. Mobile LiDAR data set test results

At the time of this submission, test data was not yet available for the 11 cross sections.

CONCLUSIONS

Accuracy

The mobile LiDAR data set, utilizing the same ground control network, reached an RMSE of 0.0308' (0.0604' at 95%) which is significantly better than the LAMP data set at an RMSE of 0.0518'(0.1015' at 95%).

The errors in the Mobile LiDAR set appeared to be concentrated in particular areas, but this does not appear to be an issue since the overall accuracy was so much better than LAMP.

Costs

It is somewhat difficult to evaluate the costs of the two methodologies. The LAMP dataset was contracted along with traditional 1"=50' mapping and other survey tasks. Also, it included both directions of travel. One must also consider that these pricing models change constantly.

Taking all of this into consideration, LAMP mapping cost approximately $7,800 per mile, while mobile LiDAR cost approximately $3,800 per mile. Every attempt was made to eliminate the 1'=50' mapping component costs, and the additional two lanes of mapping done by LAMP methodology. The ground survey costs were also eliminated since the same survey was used for both sets.

There is still some question regarding the actual survey control layout required by Mobile LiDAR. Additional saving may result in a less dense control layout, but the effect on accuracy is unknown.