# TRANSPORTATION APPLICATIONS FOR MOBILE LIDAR : A STATE-OF-THE-PRACTICE QUESTIONNAIRE

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## ABSTRACT

The relatively recent emergence of mobile Light Detection and Ranging (LIDAR) technologies as a potentially transformative tool for numerous transportation engineering applications coupled with a lack of existing standards has resulted in the need for an improved understanding of how this technology is currently being implemented, and what challenges are limiting its adoption. To that end, a questionnaire was administered to State Departments of Transportation (DOTs) to document and evaluate the state-of-the-practice regarding mobile LIDAR in transportation applications. Representatives from each of the 50 U.S. states and 6 additional transportation agencies completed the questionnaire, for a total of 74 responses. A second service provider questionnaire was completed by 14 companies experienced with mobile LIDAR services. Interestingly, it was determined that more DOTs have used mobile rather than airborne LIDAR services in the last year, even though mobile scanning is a less established technology. Additionally, the results showed that DOTs perceive cost to be one of the most significant challenges to the adoption of mobile LIDAR, indicating that more evidence and education are required regarding benefit to cost comparisons of the technology. The questionnaire also revealed current struggles as DOTs transition from two- to three-dimensional workflows and modeling. These questionnaires established a technology adoption baseline that can be used to measure future progress and provide the foundation for national guidelines currently under development.


## INTRODUCTION

To evaluate the state-of-the-practice regarding mobile Light Detection and Ranging (LIDAR) technology in transportation applications, a questionnaire was administered to U.S. State Departments of Transportation (DOTs) to determine their current usage, interest, and knowledge of LIDAR technology. A key purpose of the questionnaire was to establish an overall technology adoption baseline for all of the State DOTs, which could then be used to develop upcoming, national, performance-based guidelines that address current challenges with mobile LIDAR for transportation applications. A related service provider questionnaire was distributed to experienced surveying and mobile LIDAR companies. The questionnaires also provide insight as to how mobile LIDAR is being considered for future transportation applications.

Mobile LIDAR technology can be used for various transportation applications (Table 1). Mobile LIDAR systems can map a roadway while travelling at highway speeds, thereby providing enormous safety benefits by reducing the number of personnel required to obtain survey data across the road (*1*). The three-dimensional (3D) acquisition technique results in a 3D point cloud, which enables virtual exploration of a corridor (Figure 1).

One of the primary strengths of mobile LIDAR is that once a dataset has been collected, it may be used many times for several purposes by multiple people in an agency. Furthermore, a variety of sensors can be mounted on a single platform, enabling more efficient field data collection. Yen and colleagues (*2, 3*) compared the features of several available mobile scanning systems revealing that this technology presents multiple safety, efficiency, accuracy, technical, and cost benefits to DOTs. However, mobile LIDAR presents some challenges, including a steep learning curve, large datasets, equipment costs, and software costs.

**TABLE 1 Sample of common applications using mobile LIDAR data in transportation.**

| **Planning** | **Design** | **Construction** | **Asset Management** |
|---|---|---|---|
| General mapping | Topographic mapping | As-built documentation | Inventory mapping |
| Topographic mapping | 3D design alternatives | Quality control | Modeling and inspection |
| Measurements | Clash detection | Pavement smoothness | Feature extraction (signs, striping) |
| Land use/zoning | | Machine control | |
| | | Construction automation | |

| **Safety** | **Operations** | **Research** | **Tourism** |
|---|---|---|---|
| Accident investigation | Emergency response | Unstable slopes | Virtual tour |
| Driver assistance | Traffic congestion | Coastal erosion | Billboards |
| Geometric measurements | Building Information Management (BIM) | Landslide monitoring | |
| | Bridge Information Management (BRIM) | | |

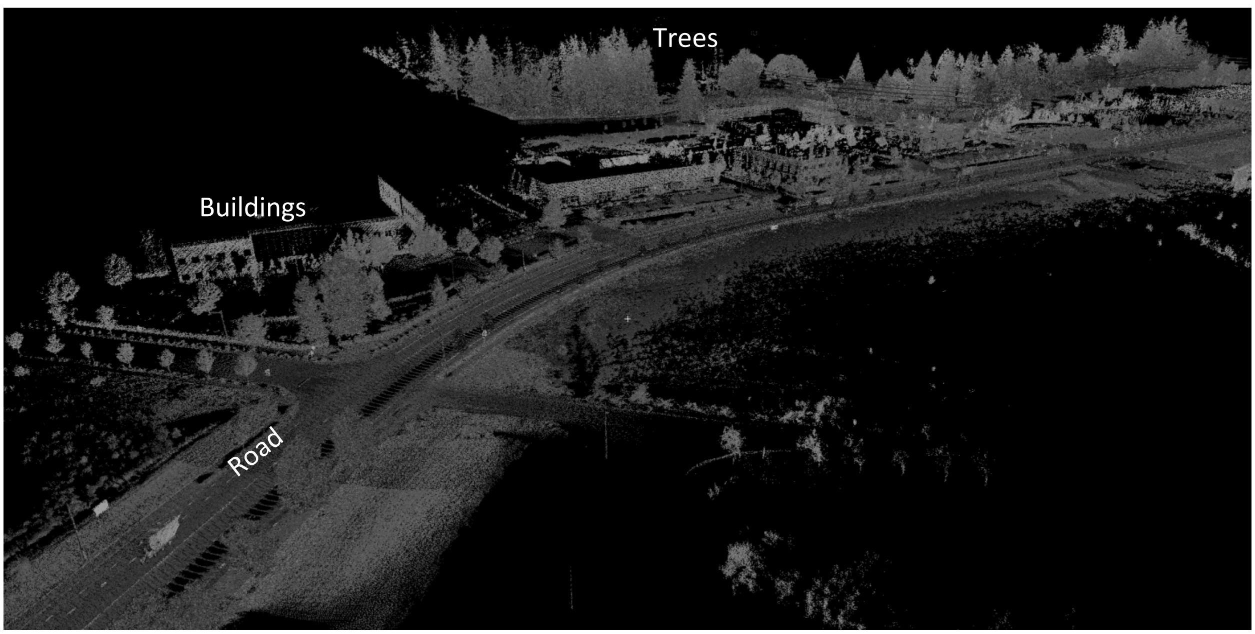


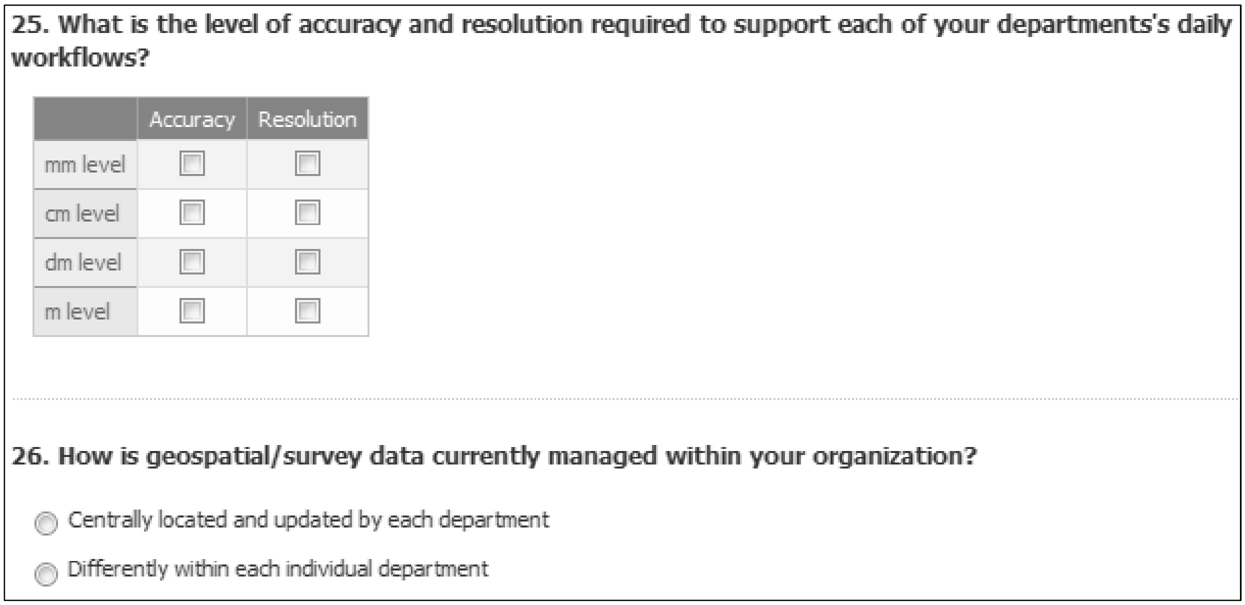

**FIGURE 1 Example of a point cloud acquired by mobile LIDAR.**

## METHODOLOGY

The research methodology employed was centered upon three critical elements as follows:

- The creation of the questionnaire;
- Identification of the appropriate respondents; and
- Measures to ensure an adequate level of response.

These methodological elements are discussed in further detail in the following sections.


**25. What is the level of accuracy and resolution required to support each of your departments's daily workflows?**

| | Accuracy | Resolution |
|---|---|---|
| mm level | ☐ | ☐ |
| cm level | ☐ | ☐ |
| dm level | ☐ | ☐ |
| m level | ☐ | ☐ |

**26. How is geospatial/survey data currently managed within your organization?**

○ Centrally located and updated by each department

○ Differently within each individual department

**FIGURE 2 Example of the formatting seen by questionnaire respondents.**

### Questionnaire Creation

To facilitate the acquisition of a nationally representative sample of State DOTs and other transportation agencies actively using or planning to use mobile LIDAR, an internet-based questionnaire tool (SurveyGizmo) was selected. The questionnaire tool was required to use a variety of question and response types to acquire the most meaningful and representative information from respondents. Seven free, online questionnaire services were compared to determine if they met the functional requirements of the questionnaire task for this research project. FIGURE 1 shows an example of two question types in the questionnaire.

### Questionnaire Participants

The DOT questionnaire considers a subset of the population of State DOT employees from across the country. The initial contact list of professionals was intended to be individuals from within State DOTs with knowledge in the field of surveying, geographic information systems (GIS), and other geospatial technologies. More specifically, a focus was placed on identifying persons with an interest in LIDAR and modeling. The contact list was not segregated based on departments within the State DOTs. The rationale for contacting these specific individuals was to identify respondents who had a useful knowledge base for developing guidelines that reflect the current conditions in mobile LIDAR usage. The DOT questionnaire was also sent to several federal and international transportation agencies for alternate perspectives. In a further effort to ensure that appropriate respondents were identified, the DOT questionnaire recipients were encouraged to pass the DOT questionnaire along to other colleagues who they believed may be more appropriate to respond.

A second questionnaire was created for and distributed to mobile LIDAR service providers (Service Provider Questionnaire). The purpose of the Service Provider Questionnaire was to obtain further insight concerning the current challenges in providing mobile LIDAR services and the need for performance-based guidelines. This questionnaire was also used to obtain an external perspective of how DOTs are utilizing the 3D data provided by mobile LIDAR.

### Level of Response

As a result of the keen interest from the target population regarding the questionnaire topic and follow-ups from the Project Team, the overall response rates were high. In total, 74 respondents completed the DOT Questionnaire, representing DOTs from all 50 U.S. states and 6 additional transportation agencies. Forty DOTs responded as a result of the initial email prompt or two additional reminder emails. Subsequent phone calls and directed emails were made to the 10 remaining DOTs to ensure at least one response from all 50 State DOTs. During the data acquisition process, additional contacts were provided by the respondents to the online DOT questionnaire or during the service provider phone interviews. These likely respondents were subsequently contacted to increase the respondent sample size.

Although the results are reflective of the responses that were received from individuals within each DOT, in some cases, the respondents may have been unaware of mobile LIDAR activities and usage outside of their division.

In total, 14 industry leaders were interviewed. Given the relatively small sample size and the desire to provide each service provider with the opportunity to discuss issues that may not be specifically covered in the questionnaire, the respondents were interviewed via telephone. Note that although comparisons are made in this paper between the DOTs and service providers, equal weight should not be placed on the responses since there were significantly more DOT responses.

## DATA ANALYSIS AND RESULTS

Full details of the questionnaire can be found in an upcoming National Cooperative Highway Research Program (NCHRP) report. This paper describes the most interesting results of the survey. These data are aggregated into the following subsections: familiarity and importance, workflow visualizations, present and emerging applications, challenges, accuracy and resolution requirements, and considerations for adoption.

### Familiarity and Importance

To assess how pervasive mobile LIDAR is becoming relative to other forms of LIDAR, state DOT respondents were asked if static, mobile, or airborne LIDAR scanning had been conducted by their DOT in the last year. Unexpectedly, responses indicated that more State DOTs conducted mobile LIDAR scanning in the last year (54%) than airborne LIDAR scanning (44%), even though mobile LIDAR is the more recent technology. Additionally, 68% of state DOTs conducted static LIDAR scanning last year and 8% of respondents were not sure which, if any, method their organization had used.

**Respondent perspectives were sought regarding levels of familiarity and importance with mobile LIDAR scanning within their DOT. This series of questions was based on a 10-point scale, ranging from *unfamiliar* or *unimportant* (1) to *expert* or *very important* (10). In general, State DOT respondents tended to be more familiar with LIDAR (mean of 6.4) compared to mobile LIDAR systems (mean of 5.4). Regardless of their current familiarity with mobile LIDAR, the DOT respondents considered these technologies to be very important to their future operations (mean of 7.8). In fact, 69% of the respondents ranked the importance of these technologies as ≥8 out of 10, with 30% defining it as "very important". Line graphs for these three questions appear in the top panel of**

FIGURE 3.

**Three-dimensional workflows are a logical extension of the collection of 3D scanning data obtained with any technology platform. To examine the current practice of State DOTs, respondents were asked to specify what percentage of technical workflows within their DOTs used 3D data. They were then asked to provide their perception of what percentage of workflows would benefit from the use of 3D data or visualization. The percentage of technical workflows within the DOTs that used 3D data or visualization varied from 0 to 100. However, as seen in**

FIGURE 3, the data were skewed to the left, suggesting that many DOTs are currently using minimal 3D data in their workflows. When asked if 3D data or visualization would be beneficial, many respondents thought that it would be "very beneficial".

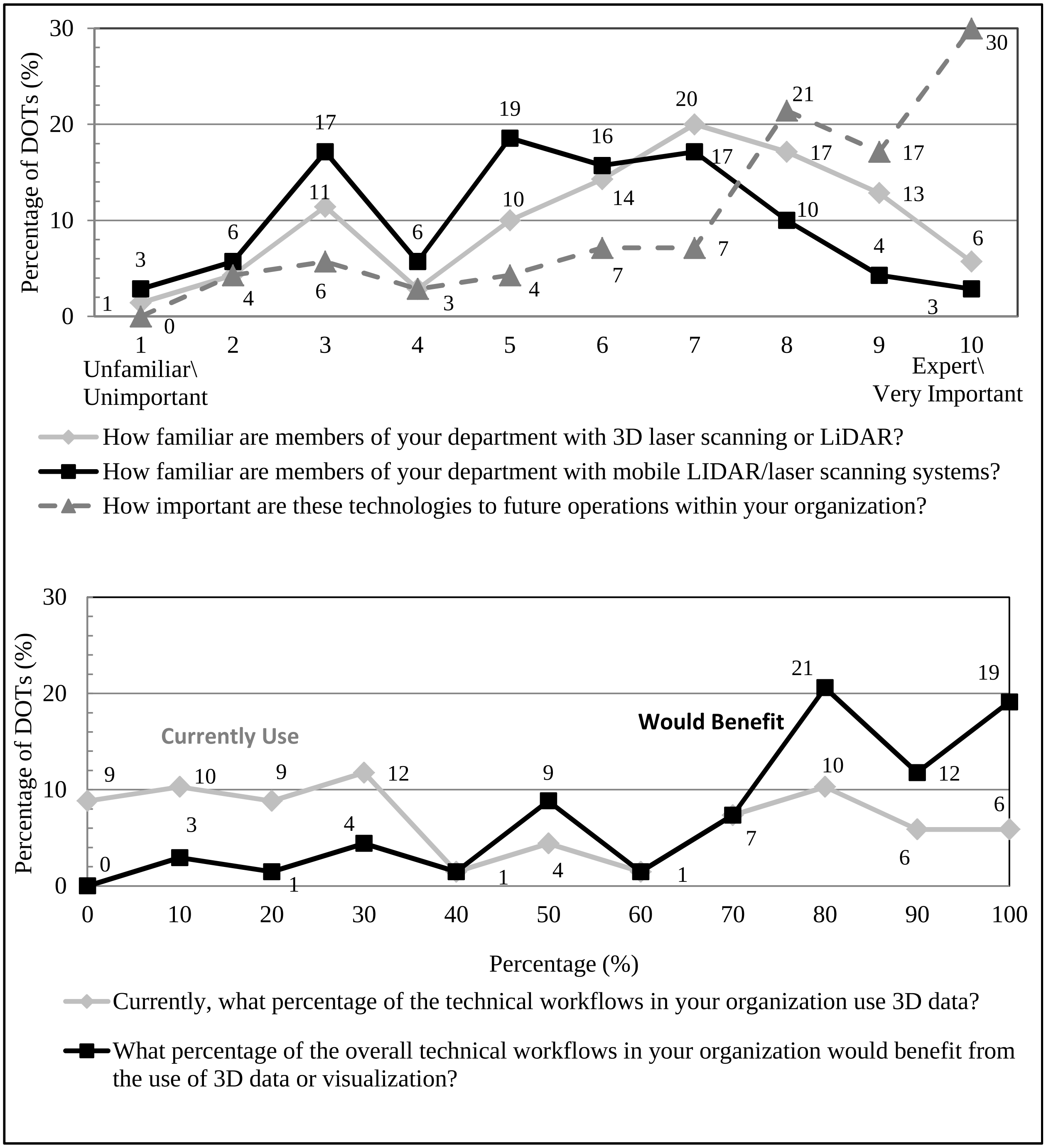



**FIGURE 3 Familiarity and importance of LIDAR scanning (top panel) and percentage of workflows that use or would benefit from using 3D data (bottom panel) among State DOTs.**

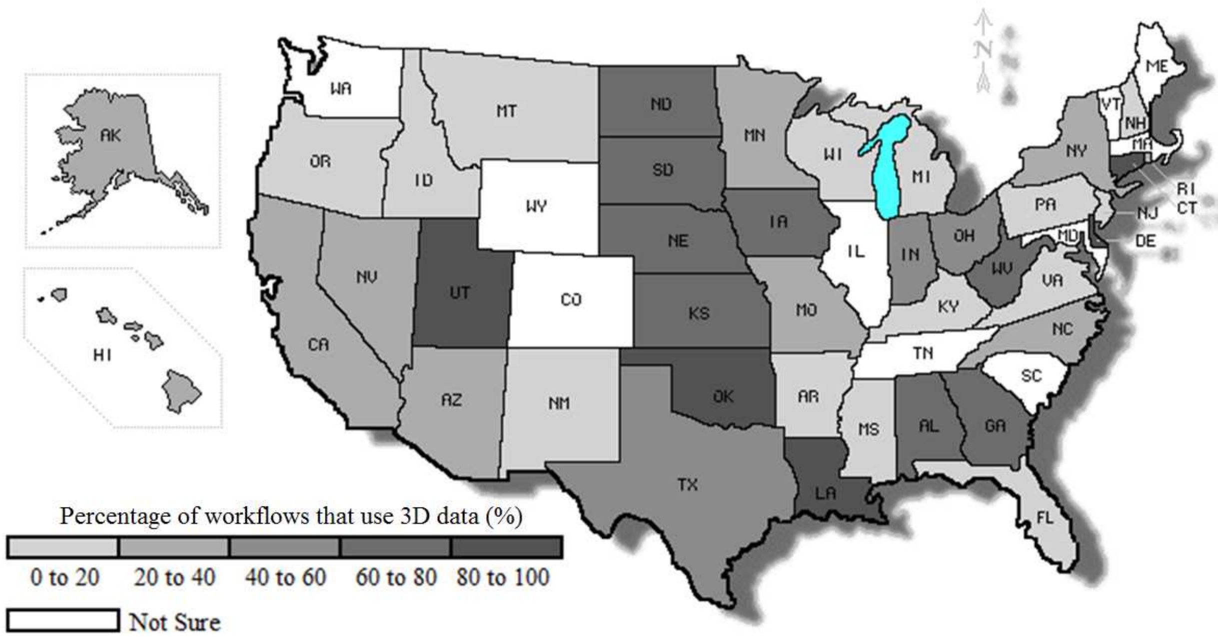
**Workflow Visualizations**

The upper panel of figure 4 shows the percentages of current technical workflows, by State DOT, that use 3D data. Data are aggregated into groups of 20% and range from a low percentage of 3D workflow (0-20%, light gray scale) to considerable 3D workflows (80-100%, darker gray scale). The DOTs that responded “not sure” are colored in white. A visual inspection of the geographic distribution may suggest a “hot spot” for significant 3D workflows in a north-south band in the middle of the country (including North and South Dakota, Nebraska, Kansas, Oklahoma, and Louisiana).

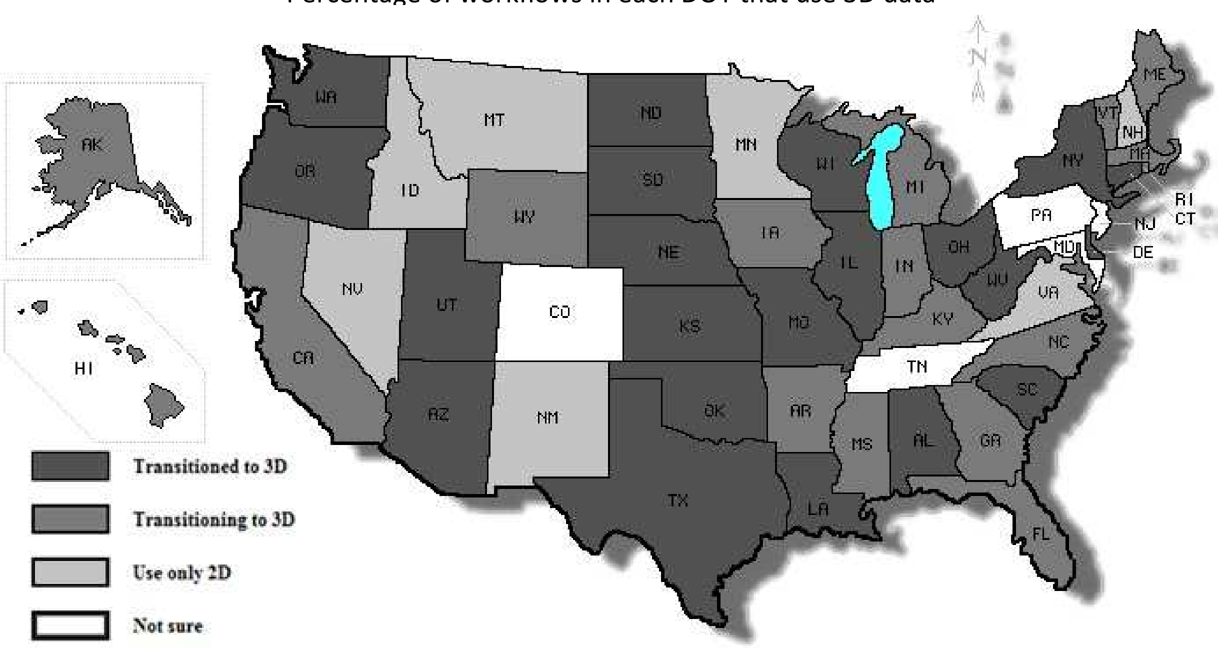
The lower panel of Figure 4 considers responses to the question, “Where is your organization in terms of the transition from 2D to 3D?” Among the responders, 10% were not sure, 14% reported using only two-dimensional (2D) computer-aided design (CAD) and GIS software, 34% reported that they are currently transitioning to 3D workflows, and 42% have transitioned to 3D workflows in CAD and GIS software. The research team postulates that these clusters are perhaps using 2.5D (i.e., only one Z value for X and Y values) and Digital Terrain Models (DTMs) but probably are not using full 3D design models. Most of the State DOTs that indicated they are currently transitioning from 2D to 3D are located east of the Mississippi River.

Supplemental comments about workflows provided some insight into the answers given by the respondents. Some DOTs have implemented 3D modeling workflows, but the significant learning curve of the technology and the infrequent occurrence of large projects that would immediately benefit from 3D modeling restrict their full adoption. California, for example, mentioned that they have utilized 2D paper plans for decades, making the move to 3D products such a large shift that “many are afraid of the risks with new procedures”. These users agreed that 3D data and visualizations could benefit their DOT, but at the moment, this shift is too great and would require unavailable staff. This sentiment was reiterated by the North Dakota DOT, who indicated that their “largest hurdle is manpower”. Other DOTs were not sure that 3D workflows were worth the investment.

In contrast, many service providers felt that DOTs were far from a transition to 3D workflows. In most cases, service providers stated that they are delivering 2D or 2.5D CAD or DTM models to DOTs, rather than 3D point cloud models. Many of these are delivered as traditional plan and profile products. These data reveal an important disconnect between the people responsible for acquiring 3D LIDAR data and those responsible for using the data in the design workflows.




Percentage of workflows in each DOT that use 3D data




Transition of State DOTs from 2D to 3D

**FIGURE 4 Status of 3D workflows in State DOTs.**

## Applications (Present and Emerging)

The intent of this questionnaire was to generally identify present and emerging applications where DOTs were using mobile LIDAR data, in one form or another. In many cases, many other applications rely on geospatial datasets that can be derived from a variety of technologies, such as photogrammetry and/or LIDAR, without the end-user being aware of the actual acquisition source of the data. For example, features may be extracted from both a mobile LIDAR point cloud and photogrammetric data and integrated into CAD linework or GIS features. Hence, it is likely that mobile LIDAR will be useful for creating many of these derivative products needed for a variety of applications that may not yet be directly identified in this questionnaire, which may be more focused on the delivery applications rather than data use applications.

*State DOT Responses*

Of the 50 DOTs sampled, 25 reported having had direct experience with mobile LIDAR. Of those 25 DOTs, 80% have utilized LIDAR for engineering survey applications, which is the most common usage (see Figure 5, upper panel). After engineering survey applications, the most pervasive applications were mapping (68%) and digital terrain modeling (64%). Accident investigation (8%), drainage analysis (4%), and emergency response (0%) were applications in which mobile LIDAR use was relatively rare. Other applications provided by the respondents included planning, land inventory, structural analysis, and research.

There was a significant correlation between current and emerging applications of mobile LIDAR within the DOTs. Respondents expressed the belief that the top three mobile LIDAR applications that their DOTs would pursue within the next 5 years would be the same top three applications that the DOTs have direct experience with currently. Other applications that DOT respondents frequently selected as likely to be pursued in the next 5 years included clearance surveys and pavement analysis. The DOT respondents expressed that they expect all of the applications listed in the questionnaire to be pursued in the next 5 years. They indicated that applications for which mobile LIDAR use is currently rare (drainage analysis, accident investigation, and emergency response) will be pursued at reasonable participation rates (46%, 16%, and 30%, respectively). Operations and maintenance, railroad catenary work, state-wide traffic operations, pavement striping, and asset inventory were identified as other potential applications of mobile LIDAR.

*Service Provider Responses*

Although the responding service providers indicated that they currently support many of the applications that they were asked about, they also anticipate supporting significantly more applications within the next 5 years (bottom panel of Figure 5). Currently, most mobile LIDAR projects by service providers involve engineering surveys, mapping, and DTM, with 100% of responding service providers providing all of these applications. Applications that the service providers have been least involved with include accident investigation (14%), slope stability/ landslide analysis (43%), urban modeling/GIS (50%), and emergency response (50%).

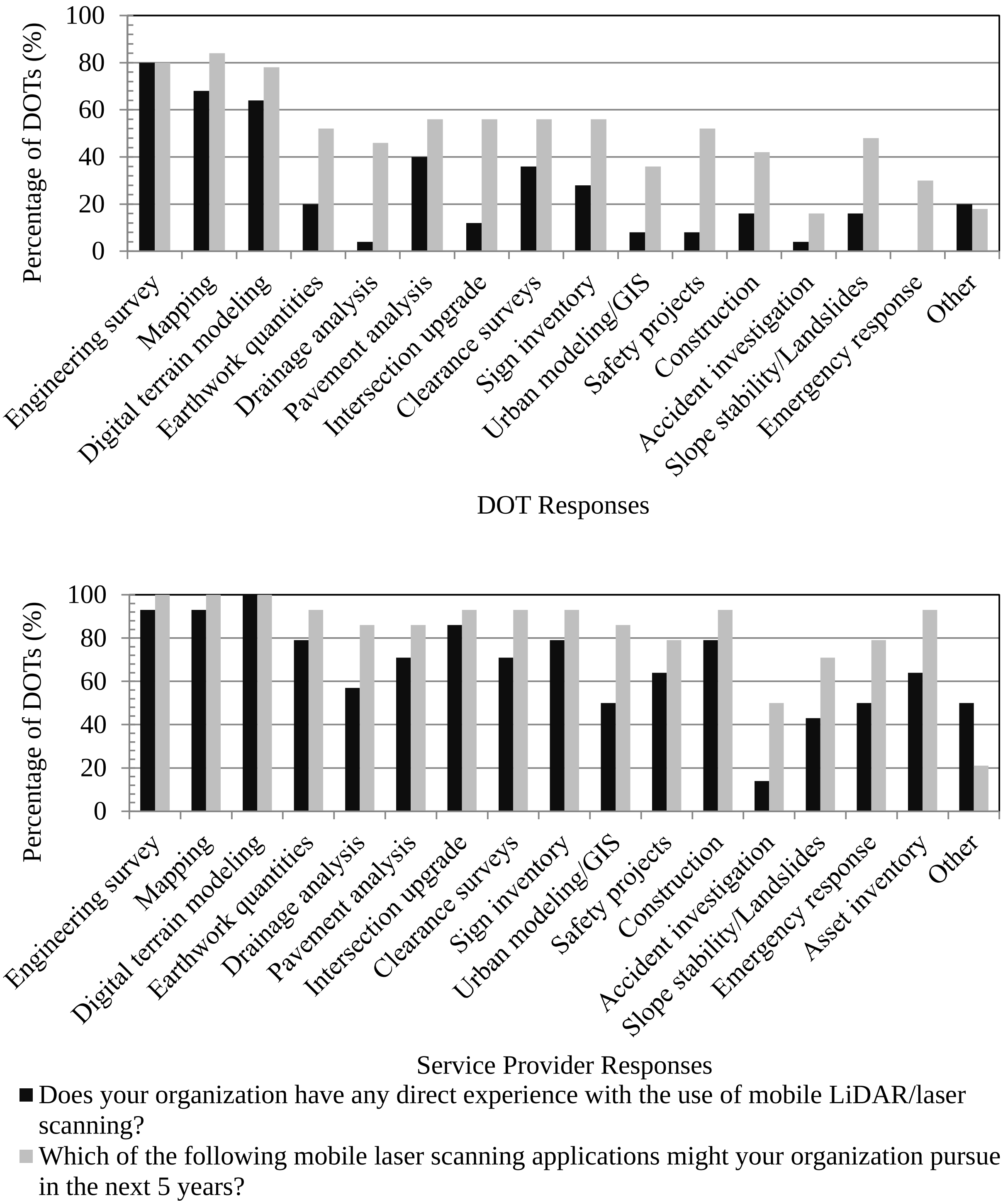



**FIGURE 5 Current and future transportation applications of mobile LIDAR by State DOTs and service providers.**

**Challenges**

One of the most valuable contributions of the state-of-the-practice reviews is the compilation and dissemination of challenges faced by State DOTs regarding the adoption of 3D workflows and the implementation of mobile LIDAR scanning. State DOT and service provider responders were asked to identify the three most significant issues preventing the adoption of 3D workflows by DOTs (Figure 6). When multiple subjects were included from a single DOT, all selections were aggregated into a single response for that DOT. Approximately half of the DOT respondents selected the dataset size/ complexity and the cost as the most significant challenges. Other frequently selected challenges included technical expertise (57%), and organizational challenges (41%).

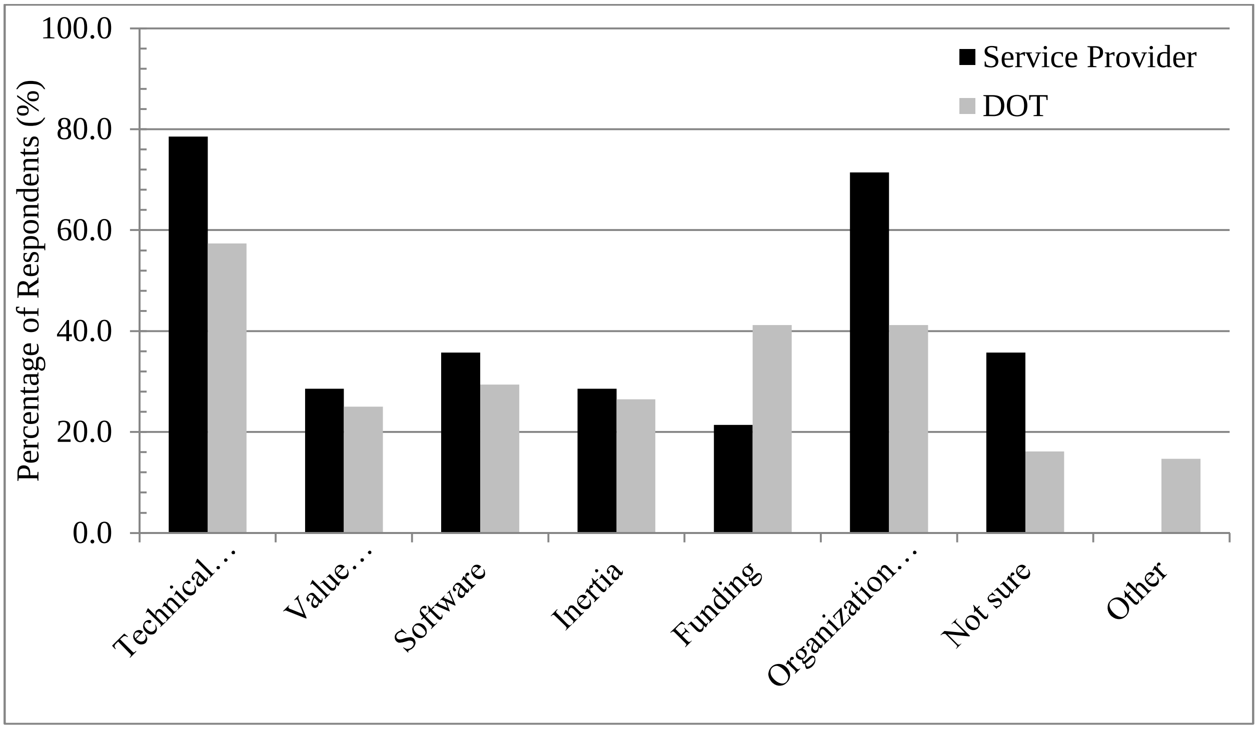



**FIGURE 6 Top three issues preventing the adoption of 3D model-based workflows by DOTs, according to State DOT and service provider responders.**

Regarding implementation challenges of mobile LIDAR scanning by State DOTs, service provider and State DOT responders showed some consistencies. Service providers identified technical expertise (79%) and organizational issues (71%) as the most important challenges. "Other challenges" included reluctance to accept the new technology, concerns with replacing tried and tested mapping methodologies and training, and a rigid procurement policy. Additionally, value proposition and inertia were each identified by 29% of service provider responders.

**Accuracy and Resolution Requirements**

Two of the most important factors impacting geospatial data are accuracy and resolution. Respondents were asked to identify the levels of accuracy and resolution that were required to support their department's daily workflow. The largest request occurred at the centimeter level (71% of department responses for accuracy and 57% for resolution), as shown in FIGURE 7.

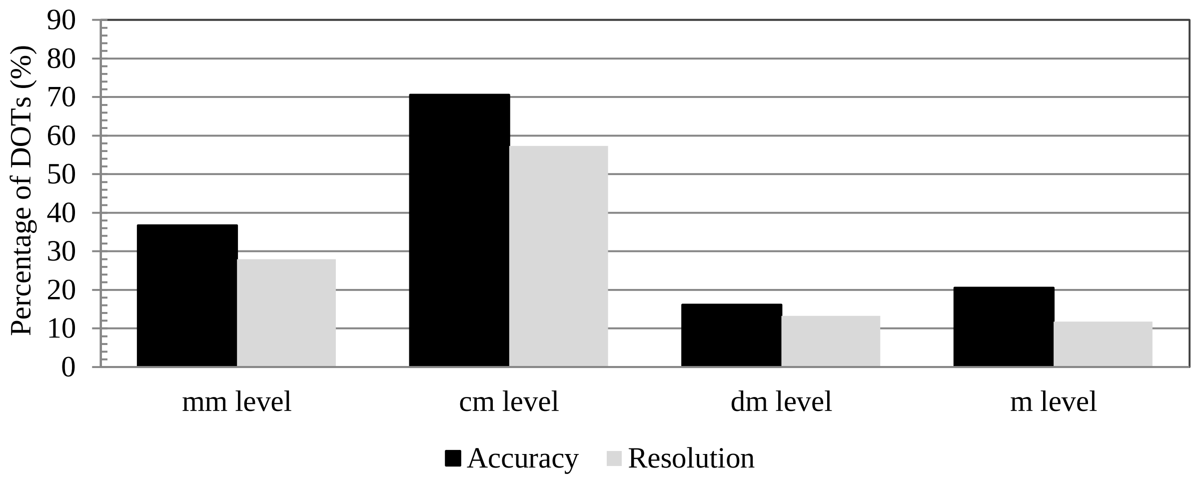



**FIGURE 7 Accuracy and resolution levels required to support daily workflows, according to State DOT responders.**

Service providers were asked to provide the level of accuracy that their company would specify as being required for specific applications, such as engineering survey and pavement management (Table 2). Some of the greatest accuracy discrepancies were reported for asset inventory and sign inventory, with a range of 90 to 56 cm respectively. Table 3 shows the best horizontal and vertical accuracy (in cm) that the service providers specified as achievable with mobile LIDAR. The results from the responding service providers were transcribed into ranges, from the smallest accuracy required to the largest. The service providers provided responses in both SI and US customary units; however, all values were converted to SI units for ease of comparison.

**TABLE 2 Accuracy ranges service provider responders specified as being required for applications.**

| Application | Maximum (cm) | Minimum (cm) | Range (cm) |
|---|---|---|---|
| Engineering survey | 1 | 5 | 4 |
| Bridge clearance | 1 | 9 | 8 |
| Paving | 1 | 5 | 4 |
| Drainage | 1 | 6 | 5 |
| Utility | 1 | 30 | 29 |
| Pavement | 1 | 30 | 29 |
| Sign inventory | 5 | 61 | 56 |
| Highway construction | 2 | 5 | 3 |
| Bridge construction | 1 | 5 | 4 |
| Asset inventory | 10 | 100 | 90 |

**TABLE 3 Achievable horizontal and vertical accuracies indicated by service provider responders.**

| Direction | Maximum (cm) | Minimum (cm) | Range(cm) |
|---|---|---|---|
| Horizontal | 0.6 | 5 | 4.4 |
| Vertical | 0.6 | 5 | 4.4 |

The service providers were also asked what order of survey control was needed to achieve the desired accuracy. Three service providers said that the control varied and was condition-dependent, whereas one service provider said that no control was needed. Two service providers mentioned that under good GPS conditions, ground control points should be every 200 m (approximately 660 ft). One of these service providers also indicated that under poor GPS conditions, control points should be set every 100 m. A few service providers discussed the quality rating of the survey control used. One service provider stated that he/she only used first-order control; another stated that second-order control was acceptable; and a third stated that "high" order control was needed. Two service providers said that the recent Caltrans (2011) mobile LIDAR specifications govern the survey control they use (*4*).

### Considerations for Adoption and Procurement

The DOT respondents indicated that guidelines were needed to help enable further adoption of the technology. Regarding the development of national standards, two service provider respondents felt that each DOT should develop their own static or mobile LIDAR standards, whereas 11 service provider respondents felt that a single standard should be adopted by all DOTs. One service provider did not respond. Comments from service provider respondents to this question included the following:

- Best practices or guidelines would be preferred over rigid standards. Standards may stifle innovation and can be confining. Flexibility is needed for projects and technology.
- Standards could be like licensure requirements, in which there is a national standard with state supplements. New standards should be integrated into existing DOT standards.

- Existing photogrammetry and survey standards could be adopted. Standards should focus on deliverables, not methodology.

The DOTs mentioned several strategies to streamline adoption of scanning technology, including:

- Convince "non-design users to accept this tool as viable".
- Work with asset management and GIS professionals, who have been hesitant to accept this technology. (However, one DOT mentioned that their organization uses the technology for asset management but not for engineering/design work.)
- Create a professional network, through which information and procedures could be shared.
- Create flexible guidelines to address the varying needs of end users for their many applications.

When asked what DOTs could do to streamline the adoption of mobile LIDAR, the responses from service providers included the following:

- Exchange knowledge between DOTs.
- Build from experience with airborne photogrammetry.
- Hire an expert consultant.
- Focus on deliverables/ end products rather than data acquisition.
- Develop standards or adopt guidelines. Use the recently developed Caltrans specifications.
- Adopt standards and develop good quality Requests for Qualifications (RFQs), to avoid being disappointed with the results.
- Be willing to experiment.
- Understand how mobile LIDAR can be used for multiple projects rather than narrowly defining it by project. Learn how the data may be used by multiple divisions within an organization.
- The determination of cost recovery in contracts must allow for new technology.
- Calculate cost savings from mobile LIDAR.
- Realize the safety benefits of mobile LIDAR.
- Realize the changes in workflow from field to office.

Similarly, the service providers were asked what DOTs can do to streamline the procurement process for mobile LIDAR, which has been a challenge for many DOTs. Responses included:

- Exchange knowledge between DOTs.
- Have a clear scope of the work, consistent with standards.
- Focus on deliverables, not data collection.
- Understand that most of the work for scanning is done in the office, not in the field.
- Use qualification-based criteria (*e.g.*, pilot projects for demonstration) rather than lowest bid.
- Implement more prequalified Indefinite Delivery Indefinite Quantity (IDIQ) projects.
- Relax procurement guidelines that are locked into old procedures.
- Establish new rates for mobile LIDAR services.

**Deliverables and reporting**

Most service providers agreed that the type of deliverable varies depending on the needs of the particular project and DOT. Potential deliverables identified by the service providers included the following:

1. Point clouds (raw, geo-referenced, or classified LAS file)
2. Viewing software
3. Calibrated imagery
4. Reports (methods, procedures, data quality achieved, control fit)
5. CAD or geodatabase files of extracted features
6. Planimetrics
7. DTM
8. Control surveys
9. Lineage documents
10. Corrected trajectory files
11. Check points
12. Ortho-photographs
13. Metadata

Some service providers expressed the belief that DOTs own the data from the mobile LIDAR services they pay for; however, some were concerned that the DOTs would be unable to use the full datasets. It was also mentioned that data ownership should be determined as part of the contract.

In addition to accuracy certification, many service providers agreed that reporting on the survey methodology was an important part of the project deliverables. Many mentioned that this information was critical to ensure that the results could be reproduced. However, three of the 14 service providers indicated that they should only be required to certify the final accuracy. These service providers felt that reporting the methodology would reveal proprietary information in some cases.

## ADDITIONAL TRANSPORTATION AGENCIES

Of the 74 responses to the DOT questionnaire, six were from transportation agencies that were not State DOTs. The data provided by these agencies were analyzed separately; however, the relatively small sample size limits the statistical comparisons that may be made with the 50 State DOTs. Many of the following comparisons are aggregated into the same groups (familiarity, work-flows, direct experience, and accuracy and resolution) from the DOT questionnaire section.

Respondents from the non-DOT agencies had a similar familiarity with LIDAR, with means of 7.2 for non-DOT agencies and 6.4 for State DOTs. Based on the small population, non-DOT agencies seemed to be more familiar with mobile LIDAR than State DOTs (mean of 6.8 vs. 5.4, respectively). However, both groups valued these technologies as very important to future operations, with means of 8.5 (non-DOTs) and 7.8 (DOTs).

The top three applications that the non-DOT agencies have had direct experience with were the same applications selected by the DOTs: engineering survey, mapping, and digital terrain modeling. These three applications were also the most selected applications to be pursued in the next 5 years by both groups. With regards to the transition from 2D to 3D workflows, non-

DOT agencies reported that they are primarily in the transitioning stage (67% of non-DOTs vs. 34% of DOTs).

Top challenges for the non-DOT transportation agencies included software interoperability/ data exchange (also a top challenge for State DOTs) and dataset size/ complexity. Compared to the State DOTs, non-DOT agencies considered data management guidelines to be less helpful (33% for non-DOTs vs. 76% for DOTs vs. 86% for service providers), whereas guidelines on survey accuracy were indicated to be more beneficial (83% vs. 78% vs. 43%).

Although the number of other transportation agencies is too small for a full comparison, it appears that the accuracy and resolution supported by the responding departments daily workflows were very similar to those of the State DOT respondents, requiring centimeter level accuracy. However, the management of data was different between the two groups, with five out of the six non-DOT agencies managing the data centrally and updated by each department. For State DOTs, 53.7% of the respondents said that data was managed separately within each department, compared to 16.7% for non-DOT agencies.

## CONCLUSIONS

The DOT and service provider questionnaires provided valuable insights into the current and future plans of DOTs for the use of mobile LIDAR. These questionnaires established a technology adoption baseline that can be used to measure future progress. The DOT questionnaire included responses from all 50 State DOTs in the U.S., plus a few other transportation agencies. The service provider questionnaire included results from 14 highly experienced mobile LIDAR service providers.

Many personnel within the DOTs appear to be very interested in the use of scanning technology and feel that it will become a critical part of their operations in the next 5 years. The DOTs identified several applications for which they currently use mobile LIDAR and stated that they foresee expanding the use of the technology into numerous transportation applications over the next 5 years. The level of expertise related to mobile LIDAR among the DOTs showed substantial variability, particularly as compared to static scanning. Interestingly, more DOTs have used mobile than airborne LIDAR within the last year, even though mobile LIDAR technologies are comparatively less established.

Responders cited many challenges, both organizational and technical, that must be addressed before the DOTs can optimize the use of mobile LIDAR and completely integrate it into their workflows. One of the most significant challenges identified regarding the adoption of mobile LIDAR by DOTs was cost. This finding indicates that the respondents are not clear where savings come from and what the return on investment is from mobile LIDAR. Additional education and evidence may be required to overcome this hurdle.

Comparison of the DOT and service provider questionnaire results highlighted key differences between the perceptions of DOTs and service providers on the utility of 3D data. Most significantly, many service providers felt that DOTs were far from a transition to 3D workflows. However, most DOTs stated that they had transitioned or were well into the process of transitioning. These data reveal an important disconnect between the people responsible for acquiring LIDAR data and those responsible for the design workflows. As Mobile LIDAR usage expands, it becomes increasingly important for both DOTs and service providers to understand how 3D data can be integrated into DOT workflows. All responders agreed that there are many challenges to overcome for a complete transition to 3D within DOTs.

The insights provided by this questionnaire form a framework to understand the key issues currently faced by DOTs and service providers in adopting mobile LIDAR in transportation applications. These insights will be incorporated in upcoming national guidelines, which will assist DOT personnel in utilizing mobile LIDAR effectively for a variety of applications.

**AKNOWLEDGEMENTS**

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