



## Introduction

In the winter of 2011–12, Utah participated as a pilot state to evaluate the Federal Highway Administration (FHWA) INVEST tool for Operations and Maintenance. In addition to providing comments on the content and format of the tool, an evaluation of the current practices of UDOT was performed and scored using the criteria outlined in the pilot version of INVEST. INVEST 1.0 has incorporated the suggestions provided by UDOT. In our opinion, the revised tool better fits the needs of agencies looking for sustainability guidance. Specific recommendations for potential improvements to increase its sustainability were also prepared for UDOT.

INVEST 1.0 was made available for general use later in 2012. UDOT decided to perform a new self-evaluation in the summer of 2014 using the new tool to measure progress and to identify deficiencies. The following are included in this report based on the reevaluation:

- leaf Comparison of the new results to the previous marks.
- leaf Progress measurements toward the goals outlined in the earlier recommendations.
- leaf Recommendations for future actions based on information gathered during the evaluation.
- leaf Case studies of how UDOT used previous recommendations to improve their benefit cost.

## Brief Overview of UDOT's 2011-2012 Study

The following are areas where UDOT demonstrated competence and scored well in sustainability.

*Environmental Commitment Tracking* – ePM is used to document and track commitments made during the environmental phase.

*Pavement Management* – An extensive pavement management system is in place to recommend improvements that benefit the system as a whole.

*Maintenance Management System* – The OMS is implemented to plan, schedule, budget, and perform maintenance activities. MMQA guides the overall funding decisions.

*Highway Infrastructure Maintenance* – UDOT has a systematic pavement and bridge preservation program based on the available funding.

*Roadside and Facility Maintenance* – UDOT uses OMS and MMQA to budget and perform maintenance activities outside the pavement shoulders.

*Snow and Ice Control* – UDOT has a proactive snow removal operation.

*Work Zone Traffic Control* – UDOT has implemented routine traffic control methods and has an aggressive innovative contracting program to limit the time motorists are exposed to impacts from construction.

*Transportation Management and Operations* – UDOT has implemented and is operating and ITS program. Operational strategies are implemented in program/project decision making.

*Safety Management* – UDOT is maximizing the safety of the existing roadways through its State Highway Safety Program.

*Fuel Efficiency* – UDOT and State Fleet have implemented fuel conservation practices and measurements. Lower emission vehicles are also established in the fleet.

## Results from INVEST 2014 Reevaluation

To accurately score UDOT using INVEST 1.0, the responsible managers for each of the categories were interviewed and participated in the scoring. Meetings with several UDOT Senior Leaders were held to discuss overall sustainability strategies. Many were involved in the Pilot evaluation. All participants were very open and readily acknowledged both strengths and short comings. The following UDOT personnel were involved in the assessment:

- Brandon Weston, Environmental Director\*
- Carmen Swanwick, Chief Structural Engineer\*
- Josh Sletten, Bridge Management Engineer
- Cheryl Simmons, Structures Design Manager
- Rob Clayton, Traffic Management Director\*
- Rob Wight, Director of Construction & Materials
- Scott Jones, Safety Programs Engineer\*
- Kevin Griffin, Director of Maintenance\*
- Lloyd Neeley, Engineer for Maintenance\*
- Shana Lindsey, Deputy Maintenance Engineer\*
- Stan Burns, Asset Management Director\*
- Gary Kuhl, Pavement Management Engineer\*
- Jeff Casper, Equipment Operations Manager
- Jason Davis, Director of Operations
- Becky Bradshaw, Finance Director\*
- Shane Marshall, UDOT Deputy Director

\*Participated in INVEST Pilot Evaluation

For comparison it is best to look at each criteria individually. The Pilot tool had fifteen criteria, instead of the current fourteen. Some of the original criteria were eliminated and/or combined into other categories. Some questions and scoring measures have also changed as a result of comments provided by UDOT during the Pilot evaluation. The results indicated that UDOT had improved in four criteria in two years and decreased in two. The overall percentage (70%) stayed nearly the same. As in the earlier evaluation, UDOT is doing very well at executing sustainable practices as it relates to its core business functions. UDOT is still lagging in regards to overall "strategic" sustainability plans such as, internal sustainability, electrical energy efficiency, and recycle and reuse.

The following table is a comparison of the scores from 2012 and 2014.

2014 Criteria	2012 Score INVEST Pilot	2014 Score INVEST 1.0	Change
OM-01 Internal Sustainability Plan	3	4	1
Comment: UDOT added support for alternative (electric) vehicles.			
OM-02 Electrical Energy Efficiency	N/A	2	N/A
Comment: New criteria in INVEST 1.0.			
OM-03 Vehicle Fuel Efficiency	15	15	0
Comment: UDOT continued best practices.			
OM-04 Recycle and Reuse	0	0	0
Comment: Little progress made in documenting practices.			
OM-05 Safety Management	15	14	-1
Comment: New question added to criteria. UDOT still working on analysis of how projects performing after implementation.			
OM-06 Environmental Commitment Tracking	8	13	5
Comment: Implemented environmental commitment tracking.			
OM-07 Pavement Management	15	15	0
Comment: Enhanced existing best practices.			
OM-08 Bridge Management	5	12	7
Comment: UDOT implemented Bridge Management System.			
OM-09 Maintenance Management System	11	11	0
Comment: UDOT working on linking MMS to vehicles and Project Management Systems.			
OM-10 Highway Infrastructure Preservation	9	11	2
Comment: New lidar data provided an accurate feature inventory.			
OM-11 Traffic Control Maintenance	8	8	0
Comment: UDOT working on traffic sign and ITS preventive maintenance plans.			
OM-12 Road Weather Management	15	15	0
Comment: Enhanced existing best practices.			
OM-13 Transportation Management & Operations	15	15	0
Comment: Enhanced existing best practices.			
OM-14 Work Zone Traffic Control	15	12	-3
Comment: UDOT working on monitoring of progress towards work zone crash goals.			
Total	134	147	13



## Progress on 2012 Sustainability Recommendations

The primary goal of the INVEST tool is to encourage state transportation agencies to consider the three primary principles of sustainability (social, environmental, and economics) as it relates to their mission. Throughout and following the pilot evaluation, participants from Utah Department of Transportation (UDOT) identified opportunities for improved sustainability in a variety of areas. The progress made towards these recommendations are listed and described below.

For each of these opportunities, the following information has been included:

- leaf Recommended action
- leaf Benefit(s)
- leaf Responsible Division
- leaf Relation to sustainability
- leaf Effort/Cost
- leaf Ease of Implementation
- leaf Progress on INVEST Pilot Recommendations

### High Importance

**1. Recommended Action:** Implement collected Lidar data into the Pavement Management System (PMS). (OM-07 Pavement Management System)

**Benefit(s):** The consistency of the pavement condition data will lead to better results from the PMS.

**Responsible Division:** Asset Management

**Relation to Sustainability:** UDOT already has a highly sophisticated PMS. The consistency of the data collected will improve the accuracy and reduce the subjectivity in the current data set.

**Effort/Cost:** Due to the amount of data the effort will be extensive. The Asset Management Division is in the process of doing this.

**Ease of Implementation:** Once data is processed and loaded, the process will be the same as the current process.

**Recommendation Progress - Met:** There were many challenges in integrating the large amount of lidar data into UDOT databases. It took over a year, but the data is now in use by the PMS. The quality of the data is significantly better than previously collected, which leads to better and more reliable results from the PMS. Lidar also provided data for other roadway features that allows the PMS to produce quick cost estimates to complete the entire construction project. For example, the data includes lengths of guardrail (including if it is substandard and requires replacement) and includes the cost estimate for any improvements required along with the pavement solution and other assets.

**2. Recommended Action:** Produce a proactive Bridge Management System (BMS) (OM-08 Bridge Management System)

**Benefit(s):** Maximized bridge life.

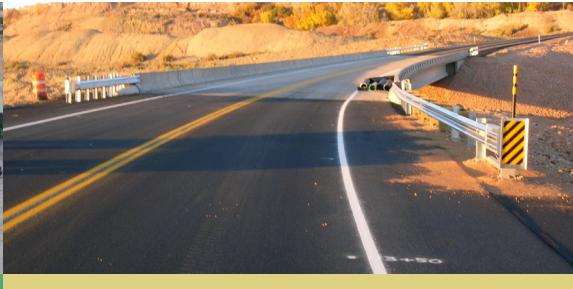
**Responsible Division:** Structures

**Relation to Sustainability:** Fortunately Utah has very few bridges in poor condition. As this number continues to decrease, it will remain important to maintain and extend the lives of these structures through routine and preventative maintenance.

**Effort/Cost:** This is a large effort that the Structures Division is currently undertaking.

**Ease of Implementation:** Will require coordination with Asset Management, Regions, and Maintenance to implement.

**Recommendation Progress - Met:** UDOT has implemented a BMS. The database contains the necessary information to allow for planning and



programming. Different metrics are used for each structure type. It tracks functional and operational items. UDOT attempted to adapt the pavement management software but it wasn't sophisticated enough to model individual elements of the structure – it produced projects that didn't make sense, such as fixing one joint of a structure. UDOT will use PONTIS for BMS when the new version is released this year.

**3. Recommended Action:** Measurement of Innovative Contracting Work Zone Crashes.(OM-14 Work Zone Traffic Control)

**Benefit(s):** Innovative contracting has many societal benefits. The improved safety aspects that result from the shorter exposure times should be measured.

**Responsible Division:** Construction/Traffic and Safety.

**Relation to Sustainability:** The effects of UDOT's innovative contracting methods are dramatic in reducing user costs and improving air quality. The decreased construction time invariably leads to fewer work zone crashes. The benefits of this should be measured.

**Effort/Cost:** This effort will require establishing the baseline for average work zone crashes and determining the reduction factors based on shorter contract times.

**Ease of Implementation:** Once the expected crash reduction factors are established, the summary results could be easily tracked as projects are awarded.

**Recommendation Progress - Partially Met:** UDOT currently tracks fatal and severe crash in work zones. All construction contracts use innovative contracting to reduce time. Crash reduction measures of innovative contracting have not been produced.

**4. Recommended Action:** Produce an overall

environmental commitment tracking list that is readily available within UDOT. (OM-6 Environmental Commitments Tracking System)

**Benefit(s):** Measurement of progress on the commitments.

**Responsible Division:** Environmental

**Relation to Sustainability:** Track the progress of commitments made during the NEPA process. Performance measures could be included.

**Effort/Cost:** Since this information is currently available in the Electronic Program Management System (ePM) for each individual project, it will only need to be compiled, updated as needed, and monitored.

**Ease of Implementation:** Relatively easy since data exists.

**Recommendation Progress - Met:** UDOT has implemented. Central Environmental tracks all long term NEPA commitments.

### Medium Importance

**1. Recommended Action:** Establish and Implement Corridor Performance Measures for Traffic Signal Operations. (OM-13 Transportation Management and Operations)

**Benefit(s):** Improved air quality and reductions in user delay.

**Responsible Division:** Traffic Operation Center (TOC)/Regions

**Relation to Sustainability:** Efficient traffic signal operation through the collector and arterial network reduces carbon emissions, improves air quality, and reduces user delay.

*Effort/Cost:* The TOC is currently performing tests on software designed to measure the effectiveness of signal timing at individual intersections. Once a software package is selected, it is important to refine corridor timing plans, implement them, and measure the overall improvement in delay reduction.

*Recommendation Progress - Met:* UDOT has implemented signal performance measures. They are sharing the software they developed with other states.

**2. Recommended Action:** Prepare a fossil fuel reduction plan. (OM-3 Vehicle Efficiency and Use)

*Benefit(s):* Improved air quality and carbon footprint reduction.

*Responsible Division:* Maintenance/Administration.

*Relation to Sustainability:* Reductions in the use of fossil fuels benefit the environment in emission reductions.

*Effort/Cost:* The renewable energy plan could be a component of this. A large component would be a plan to reduce and measure the amount of fuel used by the UDOT fleet.

*Ease of Implementation:* UDOT is currently measuring many items necessary to prepare the plan. Idling time, fuel consumption, and number of clean vehicles are all collected now. A comprehensive plan could use much of the available data and also add measurements and future goals.

*Recommendation Progress - Partially Met:* UDOT has implemented several carbon reduction tactics, such as, adding clean emission mufflers to ten wheelers, CNG sweepers, hybrid vehicles and idling monitoring. No comprehensive reduction plan has been prepared.

**3. Recommended Action:** Traffic Sign routine maintenance plan. (OM-11 Traffic Control Infrastructure Maintenance)

*Benefit(s):* A routine sign replacement program that enhances the safety of road users.

*Responsible Division:* Traffic and Safety.

*Relation to Sustainability:* The societal costs due to crashes are high. Standard signing improves safety and driver expectancy.

*Effort/Cost:* The collected lidar data will provide an updated comprehensive sign inventory. It will take extensive effort to establish deterioration curves and establish a routine program for sign replacement. The annual costs will need to be established and appropriate funding allocated.

*Ease of Implementation:* After the plan is established and funding all allocated, the program will become routine.

*Recommendation Progress - Partially Met:* UDOT now has an accurate sign inventory. A routine replacement plan has not been prepared.

**4. Recommended Action:** Produce a Snow Removal Decision Support System. (OM-12 Road Weather Management Program)

*Benefit(s):* Best use of resources by using the appropriate amount of material and equipment.

*Responsible Division:* Maintenance

*Relation to Sustainability:* Using the proper amount of material (salt, red salt, etc.) is vital to keeping the roads safe during storms. Excess use wastes resources (material and money) as well as introducing more salt to the environment.

*Effort/Cost:* Although each storm is unique, guidelines regarding best practices (including type and amount of material, use of brine, time between plow passes, etc.) are available and should be implemented. Performance measures should also be established.

*Ease of Implementation:* Measuring snow removal performance has always been difficult. The shed crews take great pride in their plowing efforts. Extensive, continuing education will be required to follow best practices.

*Recommendation Progress - Met:* UDOT now uses real time data from Road Weather Information System (RWIS) sites to measure snow removal performance. Material usage is tracked for each storm. All snow plows have been equipped with



Automatic Vehicle Location (AVL). Supervisors are able to view RWIS data and plow locations in real time. This allows resources to be deployed efficiently. The unique microclimates in Utah provide challenges in producing a "one size fits all" decision support system.

**5. Recommended Action:** Traffic signal and ITS devices maintenance plan. (OM-11 Traffic Control Infrastructure Maintenance)

**Benefit(s):** Decreased travel times will result in lower user costs and reduction of pollution.

**Responsible Division:** TOC/Regions

**Relation to Sustainability:** A highly functioning traffic control system leads to less congestion, lower pollution, and more efficient movement of people and goods. Much of the current maintenance effort is reactive to issues that arise. A proactive maintenance plan will keep the overall system functioning at the highest level possible.

**Effort/Cost:** This will require additional resources to accomplish. The existing staff are kept busy with reactive concerns. A dedicated budget to replace/repair older equipment is required.

**Ease of Implementation:** The TOC and Regions are in the process of adding resources to implement the traffic signal maintenance program.

**Recommendation Progress - Partially Met:** A traffic signal maintenance plan has been implemented. Intelligent Transportation System (ITS) device maintenance is still somewhat reactive but an asset management plan for the devices is currently under development.

### Lower Importance

**1. Recommended Action:** Prepare a Renewable Energy Plan. (OM-01 Internal Sustainability Plan)

**Benefit(s):** Reduction in carbon footprint.

**Responsible Division:** Maintenance/Administration.  
**Relation to Sustainability:** The use of renewable Energy sources improves the environment and reduces costs in the long term.

**Effort/Cost:** UDOT has done a commendable job in

implementing renewable energy at various facilities by taking advantage of opportunities as they arise. A comprehensive strategic plan on location, energy source, and benefit/cost, would allow a more proactive approach.

**Ease of Implementation:** The plan would take several months to prepare. The bigger issue is identifying funding sources for implementation. Maintenance has secured grants from various sources to secure funding for previous projects. The plan should address available sources, including potential internal funds.

**Recommendation Progress - Not Met:** No renewable energy plan has been prepared. Individual projects are implemented when possible.

**2. Recommended Action:** Produce an Overall Internal Sustainability Plan. This document would focus on internal practices of UDOT. It would contain items relating to resource and energy use and pollution generation. It could be general or specific in nature in regards to recycling, etc. Performance measures could be included. (OM-1 Internal Sustainability Plan)

**Benefit(s):** Improve internal awareness and practices concerning energy and resource usage.

**Responsible Division:** Administration

**Relation to Sustainability:** This document would define UDOT's goals relating to sustainability, define measures to improve sustainability, and potentially lay out performance measures to track progress and sustainability.

**Effort/Cost:** The effort could be small to large depending on the establishment and monitoring of performance measures. Limited pilot plan with several key measures that have data currently available would work best initially.

**Ease of Implementation:** Commensurate to the detail in the overall plan. Could range from simple education to an extensive tracking system.

**Recommendation Progress - Not Met:** No plan has been developed. UDOT Senior Management agrees a general plan regarding recycling and energy use would be valuable and will be prepared in the near future.



## Recommendations for Future Action

### High Importance

- 1. Recommended Action:** Implement PONTIS for Bridge Management (OM-08 Bridge Management System)

**Benefit(s):** Ability to model individual structure elements and produce project recommendations with the correct scope, cost and timing.

**Responsible Division:** Structures

**Relation to Sustainability:** Will enhance the ability to maintain and extend the lives of the structures through routine and preventative maintenance.

**Effort/Cost:** As is customary with all newer software programs there will be a learning curve to its functionality. Since PONTIS is currently the structure database, the interface with the new software should be seamless.

**Ease of Implementation:** Will take substantial effort to refine to UDOT's desires.

- 2. Recommended Action:** Measurement of Innovative Contracting Work Zone Crashes. (OM-14 Work Zone Traffic Control)

**Benefit(s):** Innovative contracting has many societal benefits. The improved safety aspects that result from the shorter exposure times should be measured.

**Responsible Division:** Construction/Traffic and Safety.

**Relation to Sustainability:** The effects of UDOT's innovative contracting methods are dramatic in reducing user costs and improving air quality. The decreased construction time invariably leads to fewer work zone crashes. The benefits of this should be measured.

**Effort/Cost:** This effort will require establishing the baseline for average work zone crashes and determining the reduction factors based on shorter contract times.

**Ease of Implementation:** Once the expected crash reduction factors are established, the summary results could be easily tracked as projects are awarded.

### Medium Importance

- 1. Recommended Action:** Traffic Sign routine maintenance plan. (OM-11 Traffic Control Infrastructure Maintenance)

**Benefit(s):** A routine sign replacement program that enhances the safety of road users.

**Responsible Division:** Traffic and Safety.

**Relation to Sustainability:** The societal costs due to crashes are high. Standard signing improves safety and driver expectancy.

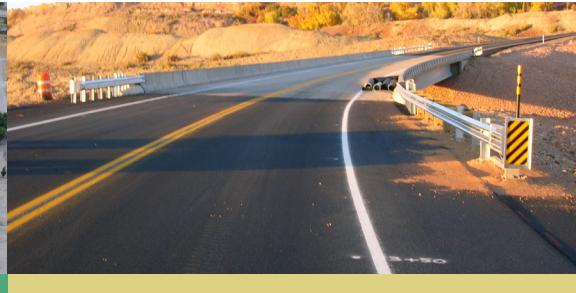
**Effort/Cost:** There is now an accurate sign inventory database. It will take extensive effort to establish deterioration curves and establish a routine program for sign replacement. The annual costs will need to be established and appropriate funding allocated.

**Ease of Implementation:** After the plan is established and funding allocated, the program will become routine.

- 2. Recommended Action:** ITS Devices Maintenance Plan. (OM-11 Traffic Control Infrastructure Maintenance)

**Benefit(s):** Decreased travel times will result in lower user costs and reduction of pollution.

**Responsible Division:** TOC



**Relation to Sustainability:** A highly functioning and reliable ITS system leads to less congestion, lower pollution, and more efficient movement of people and goods. Much of the maintenance effort is reactive to issues that arise. A proactive maintenance plan will keep the overall system functioning at the highest level possible.

**Effort/Cost:** This will require additional resources to accomplish. The existing staff are kept busy with reactive concerns. A dedicated budget to replace/repair older equipment is required. The TOC is in the process of preparing the ITS Device Management Plan.

**Ease of Implementation:** The TOC has implemented a traffic signal maintenance plan, so they are aware of the challenges to incorporate the ITS plan.

### Lower Importance

**1. Recommended Action:** Produce an Overall Internal Sustainability Plan. This document would focus on internal practices of UDOT. It would contain items relating to resource and energy use and pollution generation. It could be general or specific in nature in regards to recycling, etc. Performance measures could be included. One potential option is to provide a general guideline document to the UDOT Employee Committee with instructions to produce guidelines for recycling; energy usage; etc., and performance measures. Assemble existing documents and practices to include that relate to sustainability. (OM-1 Internal Sustainability Plan)

**Benefit(s):** Improve internal awareness and practices concerning energy and resource usage.

**Responsible Division:** Administration

**Relation to Sustainability:** This document would define UDOT's goals relating to sustainability, define

measures to improve sustainability, and potentially lay out performance measures to track progress and sustainability.

**Effort/Cost:** The effort could be small to large depending on the establishment and monitoring of performance measures. A limited pilot plan with several key measures that have data currently available would work best initially.

**Ease of Implementation:** Commensurate to the detail in the overall plan. Could range from simple education to an extensive tracking system.

**2. Recommended Action:** Incorporate Project Development Business System (PDBS) and ePM system into Operation Management System (OMS) (OM-09 Maintenance Management System)

**Benefit(s):** Proper timing of maintenance activities prior to construction projects. The elimination of work that may be replaced in the near term.

**Responsible Divisions:** Central Maintenance/Construction/Project Development/Technology Services

**Relation to Sustainability:** Proper timing of maintenance activities in relation to construction projects leads to longer lasting pavements. The reduction in unnecessary work conserves resources and funding.

**Effort/Cost:** This will require extensive computer programming. Effort is needed to decide what elements of ePM and PDBS are required to provide the necessary data.

**Ease of Implementation:** Central Maintenance is currently investigating the essential phases for implementation.

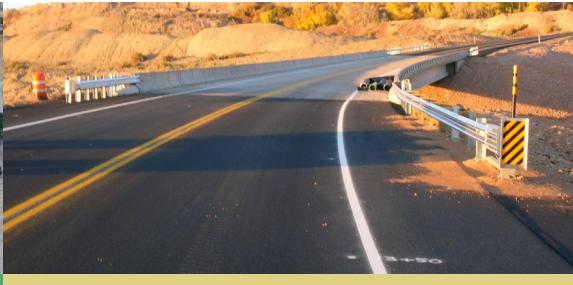


## **Value of Operations and Maintenance INVEST Tool to Agencies (Utah Experience)**

The primary benefit of the INVEST toll is to provoke thoughts about how to incorporate sustainability concepts into our organization and integrate into the daily culture. It also confirms the current processes and practices in place that are performing well. Human nature compels us to want to score well when we measure ourselves. Although the resulting score indicates how we are performing in relationship to sustainability based on the established criteria, the real benefit is how we use the information we attained in answering the questions.

We believe it is vital to analyze the results and prioritize future improvements. The effort required for implementation and its associated benefits need to be considered. Proceeding to implementation is much easier when the ideas relate to UDOT core functions of designing, constructing, maintaining and operating the highway network. Although non-core sustainable practices such as recycling, energy conservation, and reduced vehicle idling are implemented throughout UDOT, the documentation is lacking. Quantifying these benefits would require significant effort. The question becomes: Is accomplishing these practices sufficient or do they need to be measured and quantified?

The following Case Studies demonstrate high reward efforts that UDOT implemented. It is interesting that these are two areas that UDOT was already doing quite well in regards to sustainability in the INVEST Pilot scoring. Both of them relate to UDOT's mission of "Keeping Utah Moving". They both required a significant investment of capital and time. The sustainability benefits derived from these are substantial: improved air quality; reduction in fossil fuel usage; reduced injury crashes; overall economy benefits; reduced user delay; improved employee safety; and maximization of pavement service life.



### Case Study #1

#### Implementation of Mobile Automated System Wide Data Collection (OM-07 Pavement Management System)

Every two years, UDOT collects system wide data on its roadways. This data included photo logging; ride; and manual pavement condition assessment. In 2012, the vendor collected state of the art 3D pavement distress data. Previously pavement condition data was collected manually by inspecting a 0.1 segment at each mile post. This information was used to populate the Pavement Management System (PMS) that recommends the treatment, timing, location and funding levels for pavement projects. The automated collection provided detailed cracking, rut and faulting distress data that is quantified by exact length, width and depth. The Department is now able to recommend specific projects, allocate funding and predict future pavement performance more accurately than before. UDOT has estimated an annual cost savings of \$3.4M in improved pavement management practices and projects.

The vendor also collected system wide LIDAR data concurrently with the pavement distress information. This presented some early challenges due to the large amounts of information contained in the point cloud. UDOT worked with the vendor and outside consultants to refine the data to calibrate the data to improve the accuracy to plus or minus one inch. The uses of the calibrated point cloud continue to expand. UDOT has already identified the following cost savings and uses for this data:

- leaf design projects
- leaf \$125K annually in MMQA data collection and features inventory database
- leaf \$39K annually in field investigation to prepare Concept Reports for design projects
- leaf \$100 K annually in surveying for applicable larger design projects

#### *Relationship to Sustainability*

The implementation of the automated data supports sustainability concepts on many different levels. Much of the cost savings involves reduced time spent by personnel in the field and the associated travel. The reduced travel results in fewer emissions from burning less fossil fuel. The safety of personnel is improved because of their reduction in exposure to traffic. The improved pavement distress data provides better decision making criteria in the PMS. By performing the correct treatments at the right time, paving materials will be utilized to their maximum benefit.

#### *Cost Benefit Analysis*

The cost to collect the pavement distress and LIDAR data was \$2.2M. The identified annual savings to date are \$3.865M. UDOT plans to collect this data every two years due to the inevitable changes in the system. The benefit to cost ratio will use two years of the savings for comparison to the cost.

*Benefit/Cost = 3.51*

- leaf \$85K annually in outdoor advertising inventory and measurements
- leaf \$26K annually in HPMS field measurements
- leaf \$90K annually in field measurements for smaller pavement preservation

## Case Study #2

### Establish and Implement Corridor Performance Measures for Traffic Signal Operations.

(OM- 13 Transportation and Management)

In 2012, UDOT challenged itself to implement a "World Class" signal timing program. The Department committed \$3M annually to accomplish this target. UDOT has successfully implemented the following to meet this lofty target.

Through a partnership with Indiana DOT and Purdue University, UDOT implemented real time performance measurement of traffic signals. This allows UDOT to assess the effectiveness of traffic signal timing and coordination plans in real time. Resources can be directed to address the intersections and corridors in the most need of signal timing adjustments. Savings are estimated at \$3M annually in user costs. These savings will increase as additional signals are equipped to measure their performance.

Dynamic dilemma zone detection was installed on higher speed corridors to reduce crashes. This equipment basically measures the speed and size of approaching vehicles to a signal. If the determined speed is above the established threshold for adequate stopping distance, the signal timing is adjusted to hold the red light a fraction longer for the stopped vehicles. Data has shown this prevents the likeliness of high speed T-bone crashes that often result in severe injuries by over 50 percent. Predicted annual savings are \$495,000 in user cost safety savings.

UDOT has expanded its effort to provide improved traffic signal operations support for events that have regional traffic impacts. Examples of events that are supported include college football and basketball games, events at Energy Solution Arena, Hill Air Force Base Air Show, and various firework shows. This effort includes coordinating with event planners and local jurisdictions, developing traffic signal timing plans, implementing a public involvement plan, and execution during event loading and unloading periods. Annual savings in user costs are greater than \$1.2M.

Corridor responsive ramp metering was installed to allow real time metering rate adjustments to improve

traffic flow on ramps and interstates. This system monitors traffic volumes on both the ramps and mainline and makes appropriate adjustments to the metering rate in real time. Measurements indicate peak hour mainline speeds have increased an average of 18% and volume has increased by 8%. Annual user cost savings are estimated at \$170,000. UDOT is currently performing a study to investigate the feasibility/benefits of enhanced ramp metering and managed lanes.

A traffic adaptive signal system was installed on a major corridor (US-40) in Heber City. Signal timing is automatically adjusted in real time based on current traffic demand. The average daily delay has been reduced by 30% and corridor travel time has decreased by 6%. The user cost savings are \$310,000 annually.

#### *Relationship to Sustainability*

The Wasatch Front (Salt Lake, Utah, Davis and Weber Counties) is a non-attainment area. In the winter, particulates are the problem. Ozone becomes the issue in the hotter summer months. Vehicle emissions are a major contributor in both instances. These implemented improvements reduce traveler delay and idling vehicles. Both of which lead to improved air quality and reduction in use of fossil fuels. Traffic delays also impact the overall economy. Goods and service providers are able to move more efficiently to meet their schedules. Individuals spend less time on the road – allowing them more productive time each day. The safety enhancements reduce crashes and the resulting property damage, injuries, and associated traffic delays.

#### *Cost Benefit Analysis*

UDOT committed an additional \$3M annually to enhance signal coordination. Conservative annual savings are estimated at \$5,175,000.

*Benefit/Cost = 1.73*