3D Engineered Models:
Schedule, Cost and Post-Construction

PROGRAM CASE STUDY

This Program Case Study highlights the transformation of the Utah Department of Transportation's asset management system through the development of an advanced, network-wide asset inventory and its integration with other GIS-based systems and Business Intelligence tools. It is offered as a general aid for those considering starting similar programs or enhancing existing ones. It provides just one example of how state transportation agencies might expand their use of 3D engineered models.

Geospatial 3D As-Found Surveys: A Key Component of Utah's Integrated Asset Management Program

Preserving infrastructure through proactive strategies is, along with improving Zero Fatalities and optimizing mobility, one of the Utah Department of Transportation's (UDOT) top three strategic goals. This strong focus on infrastructure preservation has allowed UDOT to develop an asset management program that maximizes the value of current and future infrastructure investments by capitalizing on rapid advancements in technologies, data, and automation.

UDOT's vision for asset management is a *cradle-to-cradle* approach where asset information requirements in each phase of project delivery drive the way asset data is collected and used, leading to efficient business plans and truly lean asset management. Through cross-divisional synergies and leveraging parallel departmental initiatives, UDOT ultimately initiated an asset data collection program that is organically evolving into the first fully integrated asset management system in the United States, one that is producing results in the form of cost savings and process efficiencies.

UDOT: Organizational Overview

With approximately 2.8 million people, Utah is relatively small in terms of population and is the 34th largest state. However, it is the 11th largest in terms of land area, with close to 85,000 square miles. The state's roadway network includes nearly 40,000 centerline miles, of which UDOT is responsible for about 15 percent. This amounts to around 6,000 centerline roadway miles and over 300 miles of freeway ramps carrying almost 70 percent of the total vehicle miles traveled in the state.

Different divisions from across UDOT's three organizational groups contributed to the asset inventory and condition assessment effort. Namely, the Program Development Group's Asset Management and Planning Divisions, the Project Development Group's Business Information Technologies (BIT) Division, and the Operations Group's Maintenance and Traffic and Safety Divisions. The Department of Technology Services (DTS), while outside UDOT, was also a key player in this process.

Building UDOT's Integrated Data Management System

In 2007, UDOT's Planning Division began developing a data visualization tool to improve their long-range planning process. The tool, called *UPlan*, was meant as an internal platform; however, it soon became evident that *UPlan* would not only improve the planning process, but also change the way the department operated as a whole.

UPlan is a web-based geographic information system (GIS) platform that allows internal and external users to easily customize and share maps of geospatially located data. Data is mapped from an enterprise-wide source (as opposed to mapping from disparate sources) and communicated visually. In essence, *UPlan* improves communication and allows for better information analysis during planning phases and throughout the entire project lifecycle.

As *UPlan* gained nationwide attention, other UDOT divisions were also exploring alternative ways to improve data analysis and management processes. Specifically, between 2009 and 2011, UDOT's BIT Division joined forces with DTS to create *UGate*—UDOT's central GIS data repository. *UGate* pulls data from many different UDOT databases that the divisions then access through portals. With assistance from a consulting firm, they also created *Linear Bench*. *Linear Bench* is a straight-line diagram application that complements *UPlan* in specific cases where there are so many assets in place that a map does not properly communicate the relationship between them (e.g., assets in a roadway). UDOT also leveraged a commercially available data portal (Esri's *Open Data*) to provide easy and transparent access to all public UDOT data in multiple formats, not just in GIS format as *UPlan* does.

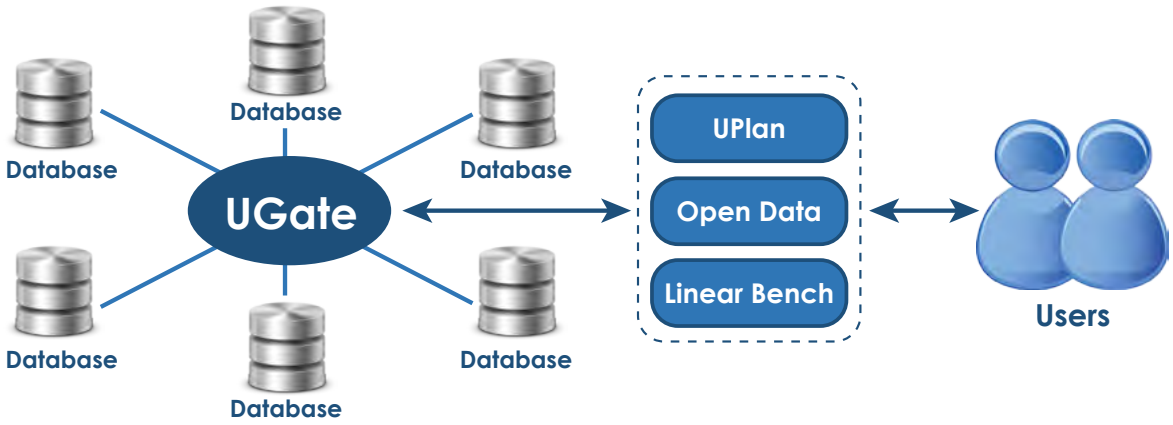


Figure 1: UDOT's Data Integration Model

Prior to *UGate*, data at UDOT was highly fragmented in a siloed environment. Today, all data is integrated in a single web-based location. This improves data accessibility, reduces duplication of work, enhances information sharing, and eliminates the need for UDOT staff to collect data and perform updates. Linked to *UGate*, visualization tools like *UPlan* and *Linear Bench* can access a much wider array of data, significantly expanding their analysis capabilities.

The *UPlan, UGate, Open Data,* and *Linear Bench* initiatives started as independent efforts, but as UDOT realized their combined potential, their missions soon began to align. By 2012, UDOT had the base structure in place for a fully integrated data management system that opened the door to a myriad of possibilities.

UDOT, along with its industry partner, spent a great deal of time and resources developing *UPlan*. As a result, any agency in the country can now commercially procure a platform equivalent to *UPlan* for less than $20,000 per annual license. Developing *UGate* and *Linear Bench*, on the other hand, cost UDOT about $500,000.

"Something visual like UPlan allows key decision makers and stakeholders to understand and share the vision of an integrated data management system."

– Stan Burns, UDOT Director of Asset Management

Key Enabling Technology: As-Found Surveys of Utah's Roads

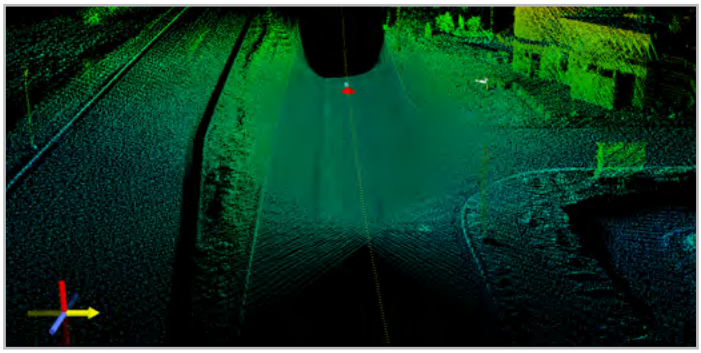
> "Bringing it all into one place—a federated database—opened up countless opportunities."
>
> *– Becky Hjelm, GIS Manager at UDOT*

In early 2011, UDOT's Asset Management Division started investigating new asset data collection technologies to improve its Pavement Distress Survey program, which had been conducted for several years to assess the condition of Utah's roads then prioritize pavement preservation projects and conduct life-cycle analysis of different roadway segments. The research revealed a wide range of modern surveying[1] technologies that not only measured pavement condition but also geospatially captured every single asset within the Right of Way (ROW) cost-efficiently.

The division then engaged in conversations with the Maintenance and Traffic and Safety Divisions, and it became apparent that they were each collecting the same type of data and collaboration could result in huge savings for the department. Moreover, the *UGate* and *UPlan* initiatives were already underway and could provide them with the capabilities needed to store, share, and analyze the great amount of data that would result from such an effort. The three divisions subsequently committed to collect asset data for the entire road network using state-of-the-art collection methods.

As the first U.S. agency to develop such an advanced, network-wide asset inventory, UDOT did not have a reference to follow throughout the process and lacked the necessary experience to structure a Request for Proposal (RFP). Before embarking on the procurement, the Asset Management Division asked other divisions which data they could use to enhance their asset management processes. The goals were to identify a dataset to use effectively across all divisions and to develop a combined data dictionary (information requirements) based on one used by the Maintenance Division. They also invited 11 different vendors to perform live demonstrations on site to help determine what the current state of the practice was and what they could ask for in an RFP.

In October 2011, an RFP was advertised asking potential contractors to geo-locate a limited set of aboveground roadway features over 14,000 driven miles of roadway (referred to as the Roadway Imaging and Inventory Program). The RFP defined a two-step procurement process and a best-value selection approach. After an initial screening, the top three bidders provided a proof of concept-type demonstration on two different types of roadway sections and met for one full day to explain their software and user interface.



UDOT's integrated asset management program capitalizes on rapid advancements in technologies, data, and automation, including mobile LiDAR imaging for roadway asset inventory. (Photo courtesy UDOT)

They selected a vendor in January 2012, expanding the final scope to include collecting almost all aboveground assets within the ROW (e.g., barriers, sign faces, sign supports, walls, lanes, shoulders, pavement markings) and an extensive list of attributes (e.g., geolocation, type, geometry, color, condition).

Additionally, at the vendor's suggestion, they included Light Detection and Ranging (LiDAR) imaging in the deliverables. LiDAR provides datasets in the form of a collection of points or point clouds that record the location and condition of everything within the instrument's field of view. UDOT is currently leveraging this type of information, which can only be captured with LiDAR, the most among different divisions.

1 The term survey is used here in a generic sense and in strict accordance with its use as a verb in the English language. It is used without any implied attribution to the accuracy of the survey itself.

> "We collected everything for everyone."
>
> *– Stan Burns, UDOT Director of Asset Management*

The final contract required the vendor to perform three full collection cycles, one every two years, starting in 2012. Each cycle has four deliverables: a full-feature inventory of extracted assets, LiDAR imaging, ROW digital imaging[2], and an *intuitive* and *easy-to-use* workstation that combines all data in a single place. The vendor is responsible for data post-processing[3] and for hiring an independent firm to provide quality assurance (QA) testing. Depending on the quality of the product, the vendor is eligible for $100,000 in incentives and $50,000 in disincentives[4]. The vendor is also required to meet with the department weekly to further quality check the data. UDOT is conducting independent internal QA, with several divisions contributing to the process.

UDOT agreed to pay $2.5 million for the first collection cycle. The Asset Management Division funded $1 million for the pavement portion (the same amount the division had spent in previous years), and the Maintenance and Traffic and Safety Divisions funded the remaining $1.5 million.

The first data collection cycle began in April 2012. Final delivery was scheduled for October 2012, but given the project's special nature, data handover did not occur until late 2013[5]. The final product included about 25 layers of GIS data stored in UGate and accessible through *UPlan*, *Open Data*, and *Linear Bench*.

Unveiling the Potential of As-Found Survey Data

The result of this asset data collection effort was a comprehensive inventory of every visible feature within the ROW across 6,000 centerline miles of state-owned roadways. With this data in hand, UDOT divisions can now examine roadway features without leaving the office, saving hours and dollars.

UDOT is capitalizing on its investment in federating asset data through a number of uses. Some of these, such as inventory reporting and asset-specific interventions, were expected and are generating labor-related savings[6] of more than $200,000 annually—an 84 percent (approx.) savings over similar efforts using conventional methods (see Table 1).

Prior to UDOT's automated asset data collection effort, these tasks were conducted by teams driving Utah's roads and recording the data on paper, then manually entering it in the pertaining databases. Personnel collecting the data were pulled from their regular duties for days, weeks, or even months, and they had different levels of training and experience. Today, UDOT staff use *UPlan* and *Linear Bench* to perform these inspections in a few minutes and in a much safer environment. Moreover, inventories include data that is more accurate and collected at the same time, using the same method, with uniform assumptions.

UDOT is realizing some of the biggest benefits in cases where they retroactively mined as-found survey data for purposes not anticipated when the collection effort started. Table 2 highlights three such use cases from the Asset Management Division: automatic production of material quantity sheets and cost estimates for pavement preservation and rehabilitation projects (design stage) and preliminary project estimates, safety-

2 Three high-definition images stitched together (2400 X 3200) collected every 26 feet for a total of 200 images per mile.

3 Data post-processing would involve, for instance, examining the ROW images to identify the type of barrier end treatments or explaining the specific condition of a signal (e.g., graffiti drawings).

4 UDOT may revise the incentive/disincentive amounts based on experience from completed data collection cycles to date.

5 The time required to quality check, post-process, and deliver a complete inventory of the state highway system required a greater effort than initially planned.

6 Table 1 represents labor-related savings only. Other savings, such as those derived from improved communication, increased safety, and better decision-making, which could arguably result in two to five times the savings observed in the table, are not considered as part of this analysis. The table also does not factor in the cost of developing *UPlan* and *UGate/Linear Bench*. These costs were distributed among all the divisions benefiting from each of these platforms and the data warehouse. If a department-wide analysis were conducted, the Asset Management Division would account for about 25 percent of the incurred expenditure in developing *UGate* (about $125,000). It would also require a 0.5 Full Time Equivalent (FTE) at $35/hour fully loaded cost (about $35,000/year) to manage the data. **Note:** After up-front costs are incurred, agencies should expect a two- to three-year period before reaching a break-even point from which savings will begin to take off. UDOT is now at this point.

Table 1: Predicted Uses of Asset Data and Associated Annual Savings

Use Case	Prior Time and Cost	New Time and Cost	Labor-Only Savings	Non-Quantifiable Benefits
Billboard inventory and measurements	90 days $144,000	2 hours per region: $400	$144,000	Many billboards are extremely difficult to access in the field
Highway Performance Monitoring System (HPMS) reporting	3,300 hours $55,000	700 hours $35,000	$20,000	Data can now be updated every year, per-diem and overtime costs are saved
Bike corridor inventory	300 hours $15,000	0.5 hours $25	$15,000	This information was not previously available for project planning and bike-friendly state ranking

based prioritization of countermeasure projects, and identification of high-risk locations and prediction of accidents in the state roadway network. These uses are reporting additional labor-related savings of almost $600,000, or 80 percent, per year.

These use cases depend on GIS-based systems like *UPlan* or *Linear Bench* and specific Business Intelligence (BI) tools like *Report Auto Generator, Crash Analysis Tool,* and the *United States Road Assessment Program (usRAP)*[7]. While GIS-based systems help people visualize and better understand raw data, BI tools transform raw data into meaningful information. Specifically, *Report Auto Generator* receives as-found survey data to generate project cost estimates, and *Crash Analysis Tool* and *usRAP* take roadway features and crash location data to produce safety-based investment plans.

Table 2: Top Three LiDAR Use Cases and Associated Annual Savings

Use Case	Prior Time and Cost	New Time and Cost	Labor-Only Savings	Non-Quantifiable Benefits
Create project summary sheets for pavement preservation and rehabilitation projects (75 projects)	6 days/pr. $180,000	1.5 days/pr. $45,000	$135,000	Fewer change orders and more accurate estimates
Develop preliminary project estimates (30 Concept Reports)	100 hours $150,000	10 hours $15,000	$135,000	More accurate estimates, better responsiveness to public due to faster reporting
Identify safety improvements that can be made with projects (40 Operational Safety Reports)	$7,500/proj. $300,000	$2,500/proj. $100,000	$200,000	Higher quality analysis with more recommendation options, able to perform analysis quickly in programming and scoping phase
Assess safety elements and crash conditions using usRAP and BYU Safety Modeling (5,000 miles)	0.5 hr./mile $125,000	40 hours $2,000	$100,000	N/A

Today, UDOT continues to research and develop new ways to leverage its investment in asset data. Among these, using as-found survey data for design surveys, and its combination with 3D engineered models, has proven particularly promising. In 2014, UDOT converted the original point cloud from 1 m absolute accuracy[8] to about 2-3 cm, and then tested using the calibrated point cloud for project design. Additionally, using LiDAR dramatically decreased traffic control needs, which in turn minimized public inconvenience and benefited safety by limiting the exposure of surveyors to high-speed traffic. The potential of this specific use case is particularly relevant because it establishes the first solid connection between asset management systems and design and construction platforms, an essential link to completing UDOT's vision of a *cradle-to-cradle* approach.

7 UDOT expended approximately $150,000 in developing these BI tools.

8 The 2012 point cloud had a relative accuracy that was acceptable for asset management purposes, but an absolute accuracy that made it inappropriate for use in design.

Updating and Upgrading the Dataset

UDOT's end goal is to rely on 3D as-built models to update the asset data, as roadway asset condition and the assets themselves change over time, but neither the department nor the industry is yet ready to take this step. Until this goal is achieved, UDOT will use repetitive collection cycles to keep the dataset current.

> "We are now beginning to answer the question of how to effectively spend the first and last dollar, because we made adequate use of collected data."
>
> *– Carlos Braceras, UDOT Executive Director*

So far, each data collection cycle has resulted in lessons learned that, together with technology improvements, have allowed UDOT and the contractor to improve, accelerate, and reduce costs for the next one. For instance, double counting assets and inadequately identifying barrier end treatments were issues in the first cycle, but not in the second. Similarly, algorithms were developed that allowed collection equipment to recognize system changes.

As divisions made use of asset data and identified new use cases, asset attributes were refined and new assets were added to the initial collection list (i.e., new information requirements). These changes translated into a more comprehensive asset data collection effort. Likewise, technology improvements also allowed for collecting features, such as sign retro-reflectivity, not properly captured in the first collection cycle.

The 2014 cycle collected more data, cost $2.4 million, and took approximately six months for both data collection and data post-processing. The third and final data collection effort on this contract started in September 2015.

Laying the Groundwork for Efficient Asset Management

Three years after formally completing an integrated data management system and launching its first roadway inventory program, UDOT has realized all the predicted benefits and continues to profit from those it never foresaw. More importantly, these benefits will grow as the department continues to institutionalize asset data. The tools at UDOT have changed, and so have the workflows, the training modules, and the hiring requirements. Three years later, and to an extent inadvertantly, UDOT is closer to fulfilling its vision of a fully integrated, standards-based, asset management system.

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Every Day Counts (EDC), a State-based initiative of FHWA's Center for Accelerating Innovation, works with State, local and private sector partners to encourage the adoption of proven technologies and innovations aimed at shortening and enhancing project delivery.

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