Digital Stockpile Management (DSM)

INTRODUCTION

Highway agencies measure the size of stockpiles of materials, such as earthwork, aggregates, salt, and debris. They track their stockpiles of materials for a variety of reasons: inventory management, environmental, compliance, construction, and operations planning. The agencies have traditionally relied on either simple estimating techniques, such as walking wheels, bills of lading, planimetries etc., or resource-intensive survey grade measurements. Nevertheless, the traditional techniques of stockpile measurements are more expensive, less accurate, less efficient, and time-consuming.

Current materials management practices are improving at a remarkable pace due to recent innovations in digital technologies. DSM is a stockpile management process that uses digital technologies to measure and analyze material quantities efficiently, accurately, and consistently in real time.

The available digital technologies include smartphone applications, unmanned aerial systems, fixed wing aircraft photogrammetry, terrestrial laser scanning and mapping, and cloud-based platforms which are used in place of and, in some cases, in conjunction with traditional methods. The digital technologies facilitate capture, transfer and storage of real-time measurements of stockpiles which can be quickly calculated, verified, analyzed, and reported.

STATE OF THE PRACTICE

State DOTs have traditionally measured stockpiles using a variety of tools and methods. According to a survey of 33 DOT staff performed by the Digital Stockpile Management Lead States Team, the most widely-used methods are:

- **Walking Wheel Estimation – 15%**
- **Mobile Devices – 15%**
- **Bills of Lading – 13%**
- **GNSS RTK Rovers and Handheld Devices – 11%**
- **Laser – 10%**

Data from these methods are largely paper-based, however some data is represented as images and electronic or digital files.

Challenges that DOTs face using the traditional methods include accuracy of inventory data, training staff to use systems, inefficient use of time and labor, and keeping staff safe during the measurement process. Due to amount of labor and time involved, stockpiles were measured yearly. Additionally, the accuracy of a surveys and cross sections is very low compared with newer methods of measurement, such as using a point cloud and 3D model to calculate volumes. Furthermore, there is often no inventory system to manage stockpile data.

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BUSINESS CASE FOR IMPLEMENTATION

DSM overcomes many of the challenges associated with traditional methods. DSM is less expensive, safer, and more accurate than traditional methods. The primary benefits of DSM are:

Enhanced Safety — The DOT staff are exposed to various safety hazards during stockpile measures. Examples of such hazards include blind spots, being struck-by or caught in/between heavy equipment and vehicles, falls, slips and trips under snow and frozen conditions. Using DSM reduces the exposure of the DOT staff to potential hazards in the field and in the vicinity of the stockpile. Keeping employees and the public safe also has many secondary benefits, such as employee retention, lower costs and public approval.

More accurate and repeatable measurements — DSM measurement techniques can be more accurate. Some users report measurements are within 2% of the actual pile size when measured with LIDAR or other survey grade sensors. With Lidar Scan as the benchmark, the repeatability of DSM and Global Positioning Systems (GPS) topographic survey measurements are within 2 and 6 percent tolerances, respectively. Lead adopters of DSM, such as Montana and Texas, have made this method as a standard for stockpile measurements due to its accuracy and repeatability.

Digitalization of measurements — The digitalization of stockpile measurements can serve as a management tool. The electronic measurements using alpha-numeric and image data create a more complete picture of the stockpile. DSM collects more information than legacy processes because it creates a 3D (3 Dimensional) model of the stockpile. The historical records of 3D images allow agencies to track changes in both physical forms and quantities of the stockpile more frequently. It further allows periodic tracking of quantities at a higher frequency. This historical data can help track "lost" material caused by many factors, such as spillage, drifts, erosion, and thefts, and reduce write-offs. Digitalization also allows agencies to conduct auditing of stockpile measurements and training remotely.

The digitalized stockpile measurement data is currently used by the agencies for many use cases, such as the following:

- Reporting and auditing
- Inventory planning and management, including forecasting, ordering materials and processing contractor payments.

Lower Costs — DSM makes stockpile management more economical than legacy processes because materials can be measured in less time, requiring less labor. Since DSM makes measurement faster, it can also be done more frequently. In addition, DSM systems facilitate the transfer of measurement data to multiple systems which reduces the amount of labor. DSM systems also feature a user dashboard which makes obtaining up to date measurement data faster.

Various users of DSM, whether field or office staff, can review data remotely. Finally, remote training on DSM systems makes training more cost and time efficient.

The cost estimates for the use of various methods of DSM are summarized in the following table:

Montana DOT Cost Analysis	GPS Topo Survey	Digital Measurement
GPS Survey vs. Digital Measurement iPhone App (using a commercially off-the-shelf DSM solution's average subscription costs)	**Equipment:** GPS or Total Station and Data Collector **Software:** Microstation and GeoPak **Labor Cost:** $400 per Stockpile	**Equipment:** iPhone and subscription for using a commercially off-the-shelf DSM solution **Software:** none **Labor Cost:** $24 per Stockpile **Subscription Cost:** $30 $13 per measurement (Tx) Yearly subscription with unlimited measurements
GPS Survey vs. Digital UAV Measurement (Stockpile Site/ Pit w/ multiple stockpiles, using a commercially off-the-shelf DSM solution's average subscription costs)	**Equipment:** GPS or Total Station and Data Collector **Software:** Microstation and GeoPak **Labor Cost:** $1800 per Site	**Equipment:** UAV, Mobile Device **Software:** none **Labor Cost:** $130 per Site **Subscription Cost:** $30

PLANNING FOR DSM IMPLEMENTATION

Procurement

Vendor-based off-the-shelf products (COTS) are available in the market to enable digital measurement of the volume of stockpiles. The vendors may offer different services, including software-as-a-service, drone rentals, training, and technical support.

The DSM vendor provides a software application, while a DOT user needs only an iPhone or a mobile device compatible with the vendor's software application. The vendor pricing is typically based on the number of stockpiles in inventory on average for the year. This includes unlimited measurements, up to the tier level of your subscription, using an iPhone or drone.

UAS equipment can be used for data collection or in conjunction with an iPhone or other mobile device. Users may use their own drone at no additional cost, or the vendors can source commercial drone pilots.

Business Process Changes

Implementing DSM requires agencies to consider changes to their workflows:

- Establish user hierarchy for the software products to identify administrators, super users, and reviewers based on their roles in the stockpile measurement process.
- Review the agency's IT policies to ensure that the vendor product's security aspects are compliant with the agency's security requirements. Each State might have their own IT protocols and policies for various aspects of software solutions, including user authentication, information security, cloud service etc., to ensure cybersecurity and protection.
- Establish data requirements to ensure compatibility of data fields between the vendor products and the DOT information systems.

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Using the Data

DSM users can download and use measurement data in various file formats, such as Microsoft Excel, CSV, Text and PDF. The PDF formats of measurements can be stored in existing document management systems. These interchangeable file formats allow the users to easily share data with other users, store, archive, and integrate with the agency enterprise information systems.

There are several ways to integrate DSM data into existing information systems. Outputs from DSM can be integrated with various enterprise information systems, including Peoplesoft, maintenance management systems, and AASHTOWare Project.

Training

DSM software vendors provide initial training sessions on the use of their products. Training is most effectively conducted when agencies use a "train the trainer" process. Key users can be trained by the vendor and replicate the training for rolling out the innovation to districts.

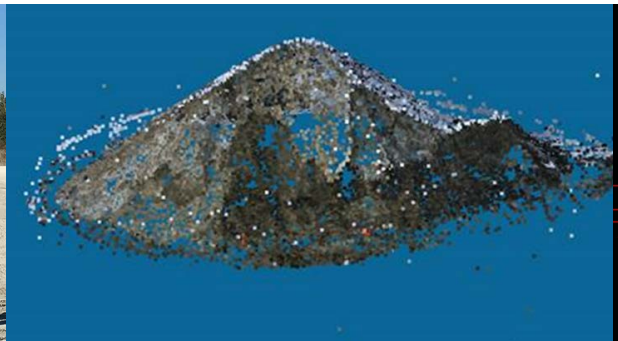
IMPLEMENTATION CHALLENGES

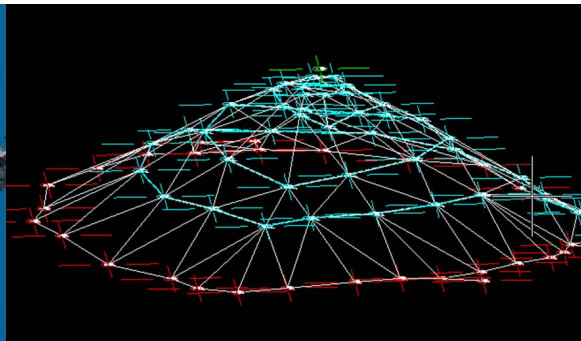
The agencies who seek to adopt DSM should be cognizant of commonly cited challenges that they might encounter during their implementation process:

Integration with Existing Information Systems: DSM produces rich data on the stockpile shapes and quantities, which has many use cases in inventory management, reporting and auditing. However, the agencies have challenges in integrating data with their existing information systems. The agencies should be cognizant of potential interoperability challenges that hinder the ability to exchange stockpile data from different vendor products with information systems. Examples of potential interoperability challenges include incompatible interfaces between a vendor product and an information system, incompatible file formats, data field formats, and unit conventions. Creating data standards will help agencies to ensure the interoperability of data.

Change Management: Staff have been measuring stockpiles using legacy processes for a long time. They may have become set in their ways which increases resistance to new methods (mention user bias, lack of independent verification). Although staff understand and have a level of comfort with existing practices, they know more than most others, the limits of those practices. When staff are engaged during changes, they will see benefits and will be willing to learn new practices. One way to overcome this challenge is to pilot DSM to a small group of staff who are most willing to adopt a new process. Additionally, having strong support from administration staff can signal to staff the importance of adapting to new processes.

Federal Regulations on the Use of Drones: The DOT users should be aware of the Federal Aviation Administration (FAA) regulations on the use of drones for stockpile management. In recent times, the FAA regulations are changing to encourage the use of drones in transportation applications. In Montana, drone data capture of up to two miles can be captured during each flight. The AII DSM Lead States Team is available to share their experience on handling such issues, which can help potential adopters understand the applicable FAA regulations relating to DSM.





Digital Stockpile Management

USER STORY – MONTANA DOT

Montana Department of Transportation (MDT) has moved from completing topo surveys of stockpiles on unsafe snow- and ice-covered slopes in the winter to a much safer and robust cloud-based digital management solution.

Historically, MDT measured stockpiles, at best, yearly and otherwise guessed at our inventory volumes. Agency staff spent a significant amount of labor hours and costs measuring stockpiles and saw minimal benefit. Problems included running out of road products, and over purchasing materials. Due to this, MDT determined improvement was essential. To solve these problems, MDT implemented DMS in 2016. Now, staff can measure stockpiles in minutes, safely, at any frequency needed, and all the data and inventory information is stored in a cloud-based inventory management system. The transformation has yielded many benefits, including:

- Measurements can be completed from a safe location, cost less, are timelier, occur more frequently,
- Users have an inventory history, a map with every stockpile in our inventory, analysis of each measurement, a dashboard with management tools, and
- Data can be exported to other systems.

Currently, MDT is measuring approximately 400 stockpiles containing stone, gravel, sand, salt, reclaimed asphalt millings, riprap and topsoil.

Since implementation at MDT is complete, future plans include continuing to monitor the technology.

Paul Rieger, Construction Reviewer

Digital stockpile management has revolutionized how we manage stockpiles and helped us provide a better, more efficient product to the public.

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USER STORY – TEXAS DOT

TXDOT manages approximately 4,500 stockpiles and bunkers every year containing more than 500 different materials including aggregates, flex base, rip rap, limestone, filter stone and sand. Using legacy stockpile measurement methods, TXDOT experienced issues with inconsistent and varying measuring methods, accuracy concerns and lack of data and reporting resources. To mitigate these issues, TXDOT implemented Digital Stockpile Management in 2016.

Darryl Starkes, Materials Management Section, Director; Frances Fletcher, Inventory Supervisor; and Leighann Heine, Inventory Specialist

Initially, the vendor for TXDOT's DSM system trained agency staff. Since then, TXDOT has created and updated both online and in-person training programs to educate users on correct measuring methods which has resulted in improved user performance and improved stockpile maintenance.

The agency manages stockpile inventory by performing routine cycle counts performed at the local level with random spot inventory checks performed statewide by an Inventory Specialist. The Inventory Specialist performs administrative desk reviews to monitor measurement results and data. When issues arise, training gaps are identified and addressed via email or in-person guidance.

TXDOT staff report DSM is an easy to use, consistent method that was easily implemented statewide that has proven to be a huge benefit in regard to managing the constantly moving large amount of roadway material in Texas. Readily available, exportable statewide data is a great benefit that has contributed to efficiency and accuracy in review and audit tasks. Additionally, with DMS there is improved accountability and greater user 'buy-in'.

An important lesson TXDOT staff learned is that training is important and beneficial, whether in-person or via phone or email. DSM provides the ability to review user measurement videos with users to provide guidance and recommendations. This method has improved measuring methods leading to improved accuracy. Texas also had to learn how to deal with imaging with significant sun flares. Training involves not just how to use the iPhone app, but also best times to measure to avoid sun flares, avoiding camera rotation, and other methods for improving measuring materials based on location, time and other factors.

It is a safe and automated standardized method to measure our roadway material with quick and easy access to measurements for inventory management and oversight.

Digital Stockpile Management

USER STORY – OREGON DOT

In 2016, the Oregon Department of Transportation (ODOT) began using DSM to manage salt and sanding materials during winter operations. The materials teams quickly applied it to crushed aggregates, soils, and asphalt grindings. A few years later a consortium of several agencies participated in a large cinder crushing purchase that needed to be verified. ODOT maintenance staff reached out to survey staff and it was determined that using unmanned aerial systems (UAS) to calculate material volumes would be an effective method. To establish trust in the process, multiple methods for measurement were used including GPS rover, static lidar, and UAS using DSM tools for processing. All measurements fell within tolerance with DSM tools and technologies being the most efficient method. The contractor's belt scale measurements over-represented the amount of material and ODOT was able to resolve the issue quickly with the digital measurements, saving tax dollars for multiple agencies.

ODOT has found with minimal training and the right tools, measurements can be made quickly and accurately which is especially critical during high use periods (winter operations). Also, with documentation for reference, volumes for payment can be verified with confidence.

Chris Harris, Automation Engineer & UAS Program Coordinator

A key lesson learned is that user adoption and training are key parts to making the transition a success. Showing that tools provide value to staff and that the data is trusted are the first steps to working toward a full implementation of a DSM material management program.

At present, DMS measurements are still being used as a tool in the toolbox instead of a primary method for managing materials across ODOT. Compiling stories from staff that regularly use the tools and documenting barriers to implementation from staff that aren't yet using them will help form the roadmap to further implementation.

Nearly everyone in today's workforce takes photos and videos regularly with their cell phones. This is all it takes to make quick, accurate stockpile measurements using DSM. Whether it's verifying a purchase or getting ready for the next winter storm, just a few minutes of work can save money and lives.

Digital Stockpile Management

CONTACT INFORMATION

Paul Rieger (Chair)
Construction Reviewer
Montana Department of Transportation
Phone: 406-208-4363
Email: prieger@mt.gov

Chris Harris
Automation Engineer & UAS Program Coordinator
Oregon Department of Transportation
Phone: 503-302-9390
Email: christopher.harris@odot.oregon.gov

Daryl Starkes
Materials Management Section, Director
Texas Department of Transportation
Phone: 512-658-1367
Email: daryl.starkes@txdot.gov

Leighann Heine
Special Projects Coord/Inventory Specialist
Texas Department of Transportation
Phone: 210-753-1743
Email: leighann.heine@txdot.gov

Frances Fletcher
Materials Management Section
Inventory Supervisor
Texas Department of Transportation
Phone: 903-900-8555
Email: frances.fletcher@txdot.gov

Travis Long
Chief of Surveys
West Virginia Department of Transportation
Phone: 304-414-6457
Email: travis.e.long@wv.gov