The National Academies of SCIENCES · ENGINEERING · MEDICINE

TRANSPORTATION RESEARCH BOARD

Shovel Ready—Using Digital Terrain Models in Construction

November 15, 2021

@NASEMTRB
#TRBwebinar

PDH Certification Information:

- 1.5 Professional Development Hour (PDH) – see follow-up email for instructions
- You must attend the entire webinar to be eligible to receive PDH credits
- Questions? Contact TRBWebinars@nas.edu

The Transportation Research Board has met the standards and requirements of the Registered Continuing Education Providers Program. Credit earned on completion of this program will be reported to RCEP. A certificate of completion will be issued to participants that have registered and attended the entire session. As such, it does not include content that may be deemed or construed to be an approval or endorsement by RCEP.

RCEP

REGISTERED CONTINUING EDUCATION PROGRAM

#TRBwebinar

Learning Objectives

1. Discuss how digital terrain models impact project delivery
2. Identify examples of DOTs leveraging project efficiencies with DTMs

Shovel Ready DTMs:
DOT Experiences with DTM

Hala Nassereddine, Ph.D.

Assistant Professor
University of Kentucky

Research Engineer
Construction Engineering and Project Management
Kentucky Transportation Center

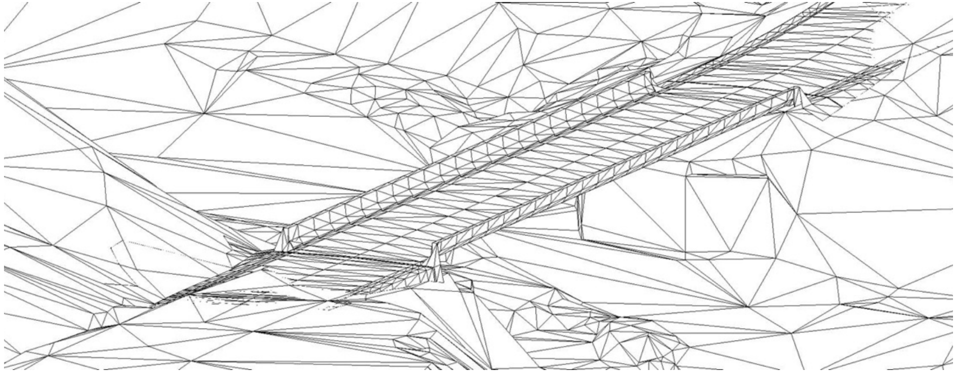
Digital Terrain Models(DTMs)

Definition

Digital Terrain Models

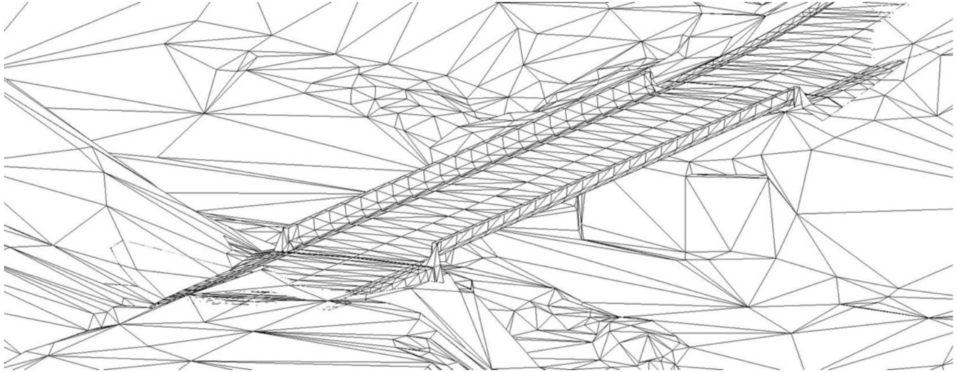
- DTMs are three dimensional (3D) models of the bare ground surface with natural features such as ridges and breaklines

- DTMs can represent:
  - the existing terrain condition
  - the project’s as-designed terrain condition



Digital Terrain Models

- DTMs are three dimensional (3D) models of the bare ground surface with natural features such as ridges and breaklines



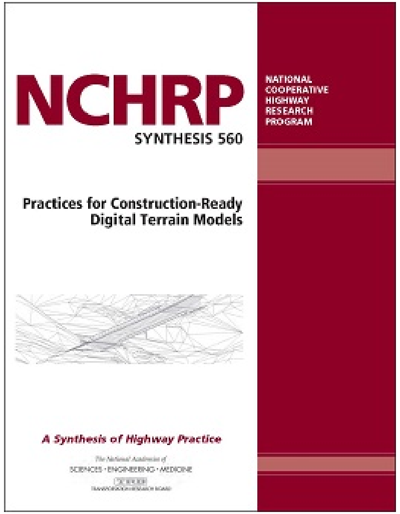
- DTMs can represent:
  - the existing terrain condition
  - **the project's as-designed terrain condition**

Digital Terrain Models

Are DTMs
construction-ready?

Design → Construction

NCHRP Synthesis 560



Practices for Construction-Ready Digital Terrain Models

Gabriel B. Dadi, *University of Kentucky*
Hala Nassereddine, *University of Kentucky*
Rachel Catchings, *Kentucky Transportation Center*
Makram Bou Hatoum, *University of Kentucky*
Melanie Piskernik, *University of Kentucky*

https://www.trb.org/Publications/Blurbs/181735.aspx

Digital Terrain Models(DTMs)

State of Practice

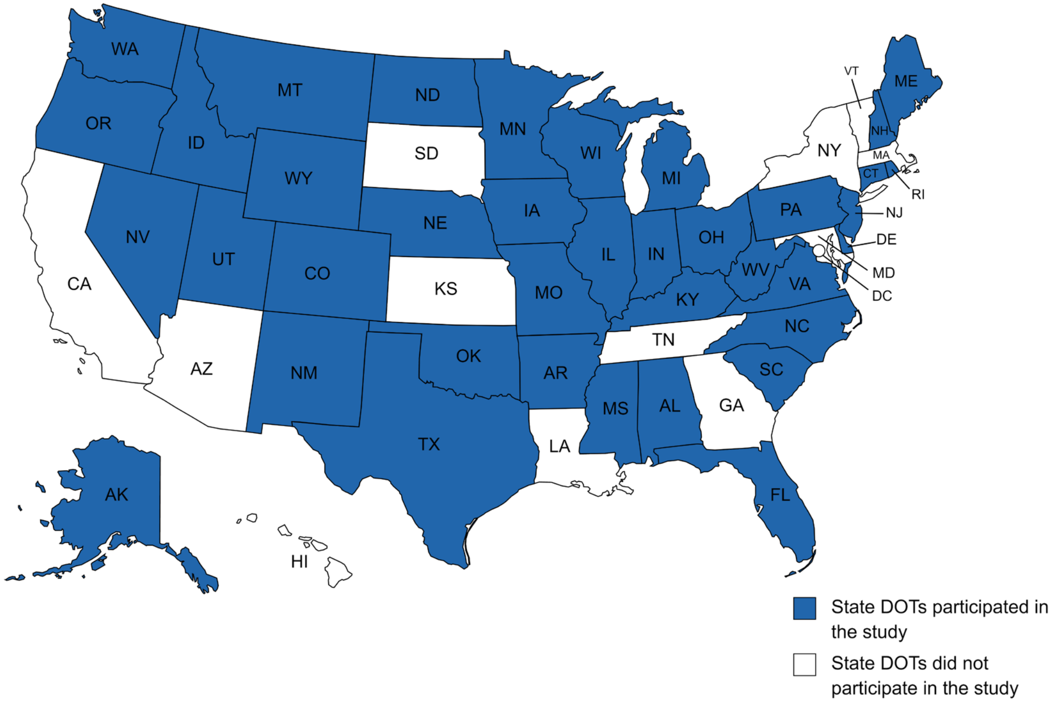
NCHRP Synesis 560

An abbreviated presentation…

- Survey Findings
- Case Studies

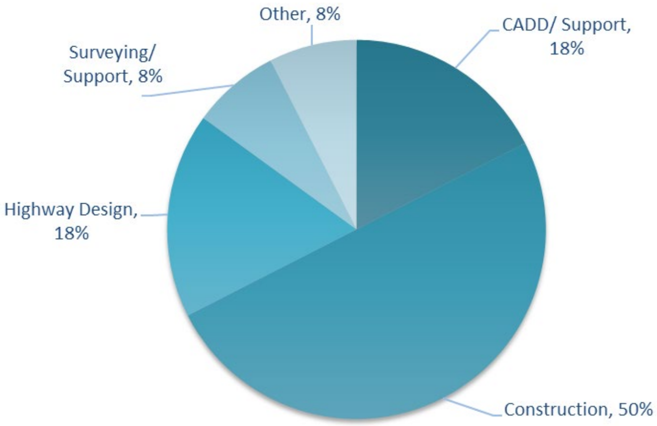
NCHRP Synesis 560

40 responses from 40 state DOTs

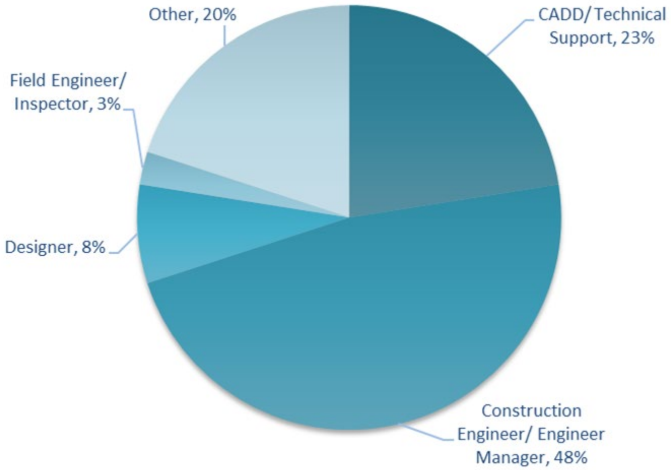


Survey Respondents

Division



Role



Survey Findings

General DTM Use

Project Specific DTM Use

User/Non-User Feedback

Legal Aspects

Designer/ Contractor Interface

Survey Findings

General DTM Use

Project Specific DTM Use

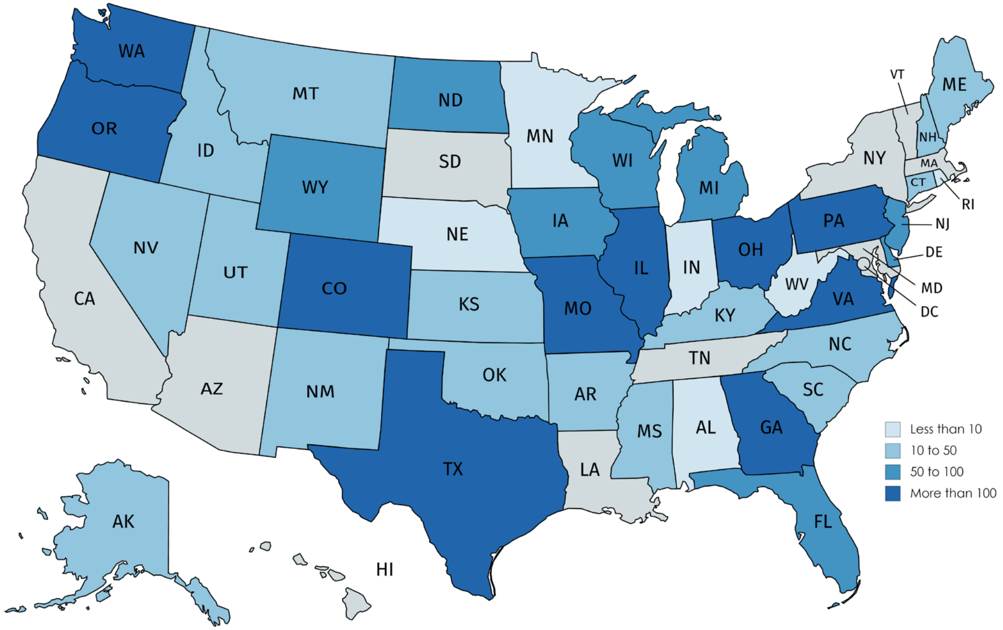
User/Non-User Feedback

Legal Aspects

Designer/ Contractor Interface

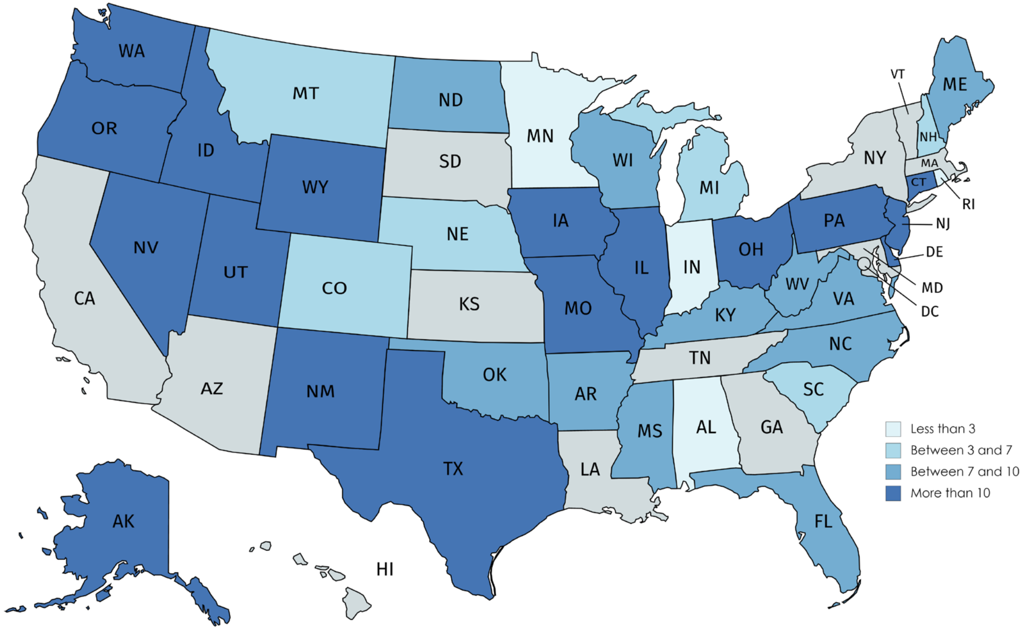
General DTM Use

DTM Usage Frequency



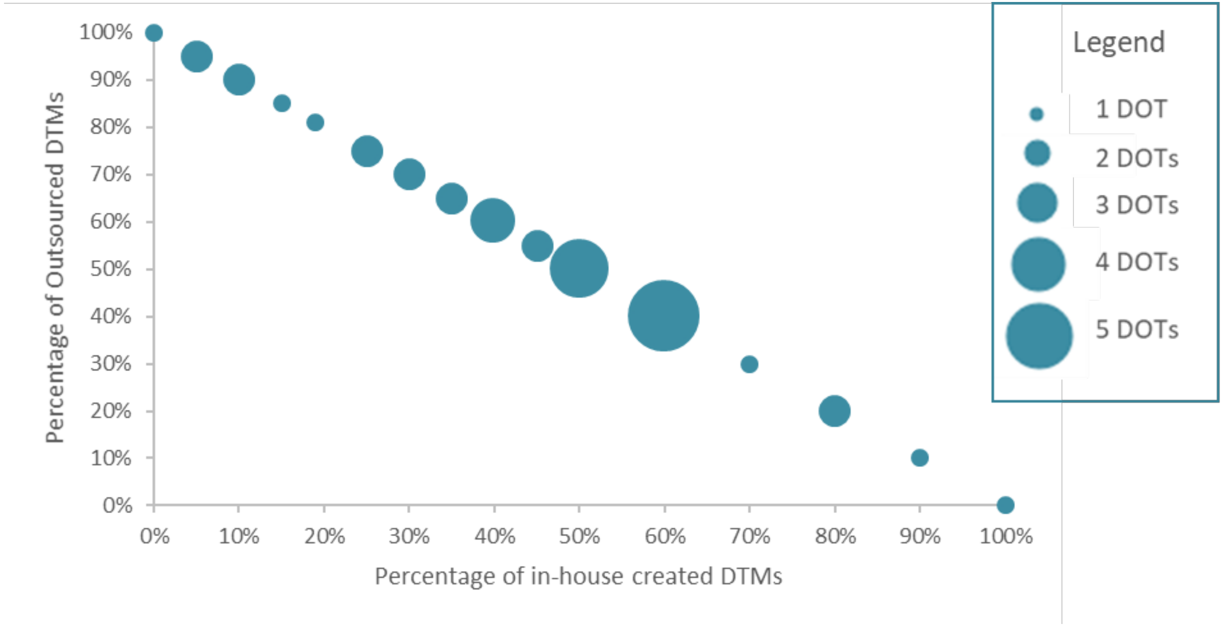
General DTM Use

DTM Usage Timeline



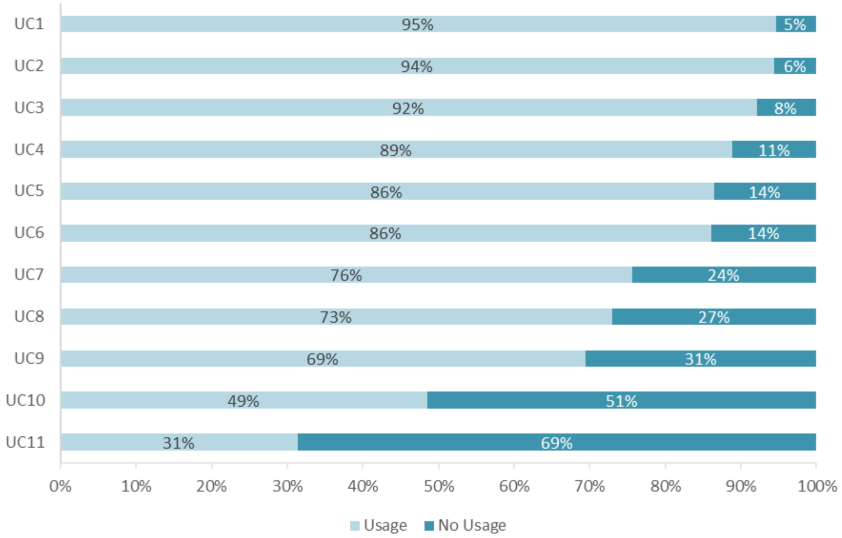
General DTM Use

DTM Source



General DTM Use

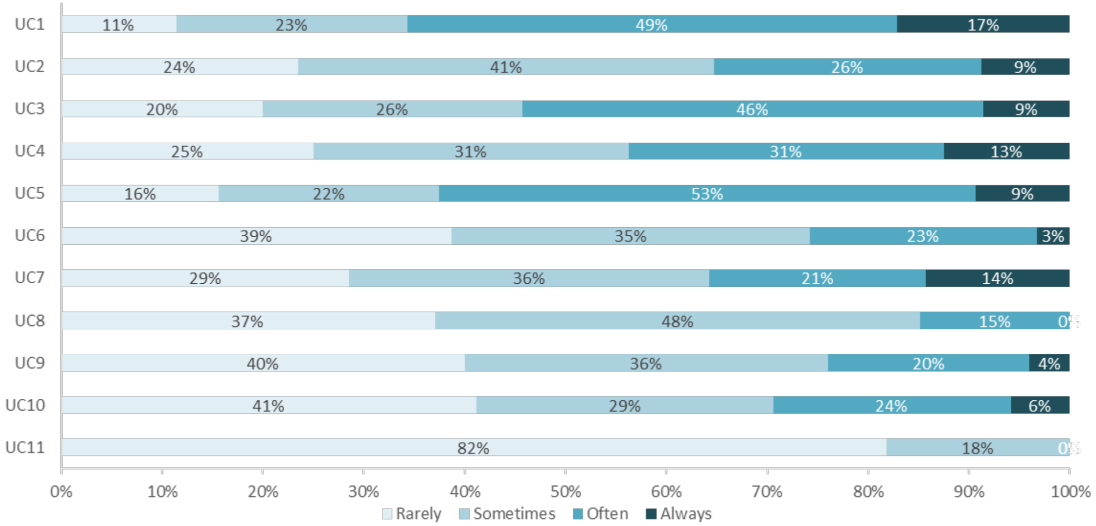
DTM Use-Cases



UC1 Grade Work
UC2 Quality Measurements
UC3 Survey Verification
UC4 Field Staking
UC5 Automated Machine Guidance
UC6 Progress Checks
UC7 Cost Analysis for Initial construction Bid
UC8 QA/QC, Clash Detection, or Reducing Plan Discrepancies
UC9 Pavement Thickness Checks
UC10 Work Planning Productivity, or Efficiency
UC11 Cost Analysis for Future Maintenance

General DTM Use

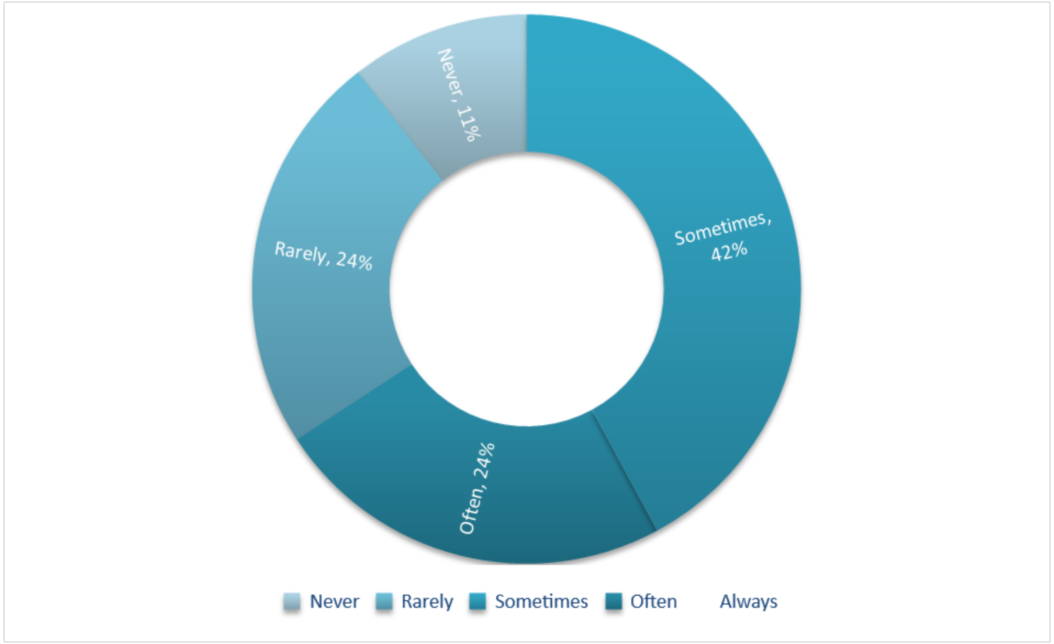
DTM Use-Cases



UC1 Grade Work
UC2 Quality Measurements
UC3 Survey Verification
UC4 Field Staking
UC5 Automated Machine Guidance
UC6 Progress Checks
UC7 Cost Analysis for Initial construction Bid
UC8 QA/QC, Clash Detection, or Reducing Plan Discrepancies
UC9 Pavement Thickness Checks
UC10 Work Planning Productivity, or Efficiency
UC11 Cost Analysis for Future Maintenance

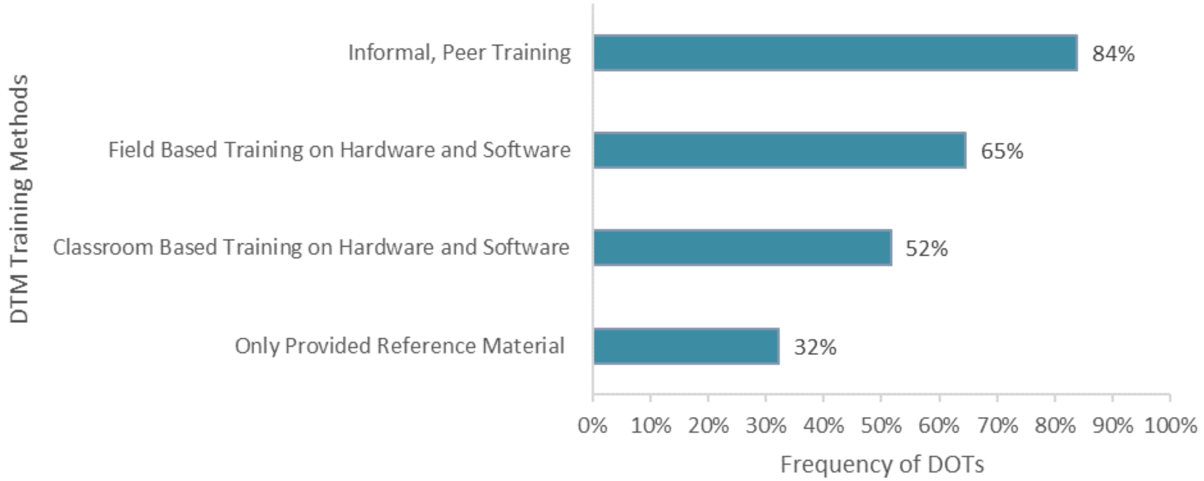
General DTM Use

DTM and Construction Inspection



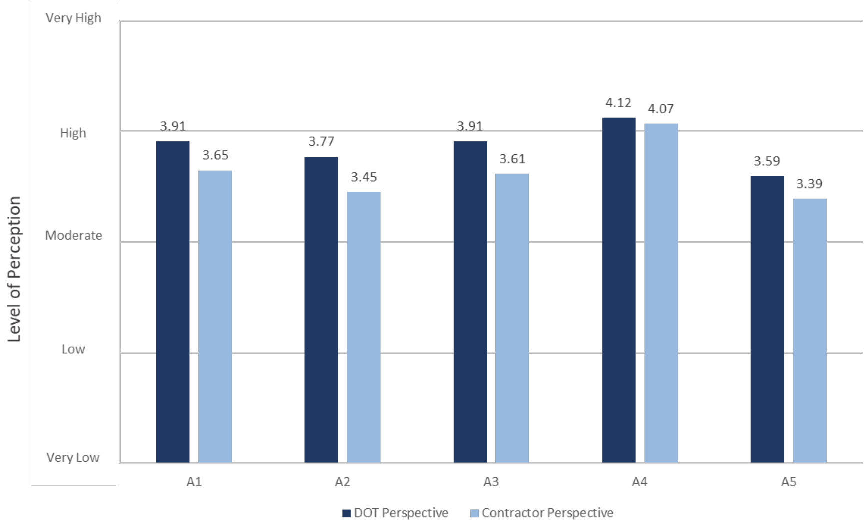
General DTM Use

DTM Training provided to construction staff inspection



General DTM Use

DTM Handover



A1 Accuracy Compared to PDF/Printed (Contract) Plan Information
A2 Interoperable Format (or Usefulness of Data Format)
A3 Level of Detail (Level of Precision Between the Model's 3D Geometry and Real World)
A4 Overall Usefulness
A5 Quality or Completeness

Survey Findings

General DTM Use

Project Specific DTM Use

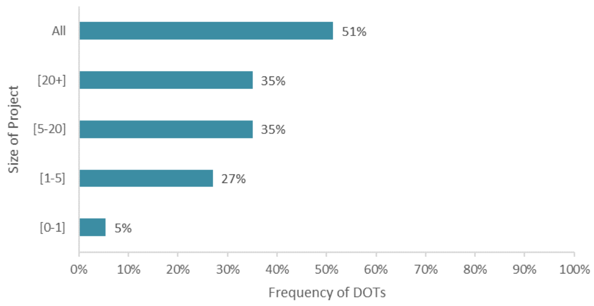
User/Non-User Feedback

Legal Aspects

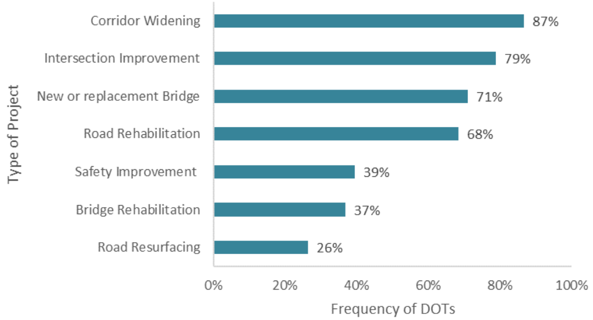
Designer/ Contractor Interface

Project Specific DTM Use

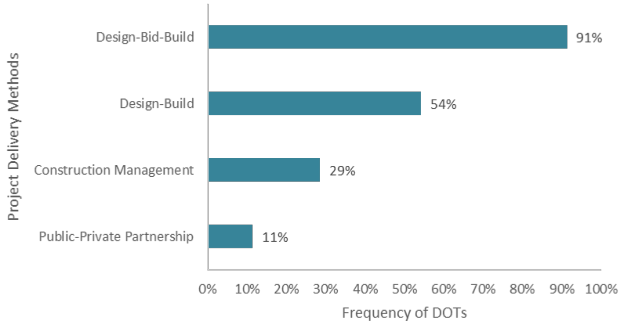
Project Size



Project Type



Project Delivery System



Survey Findings

General DTM Use

Project Specific DTM Use

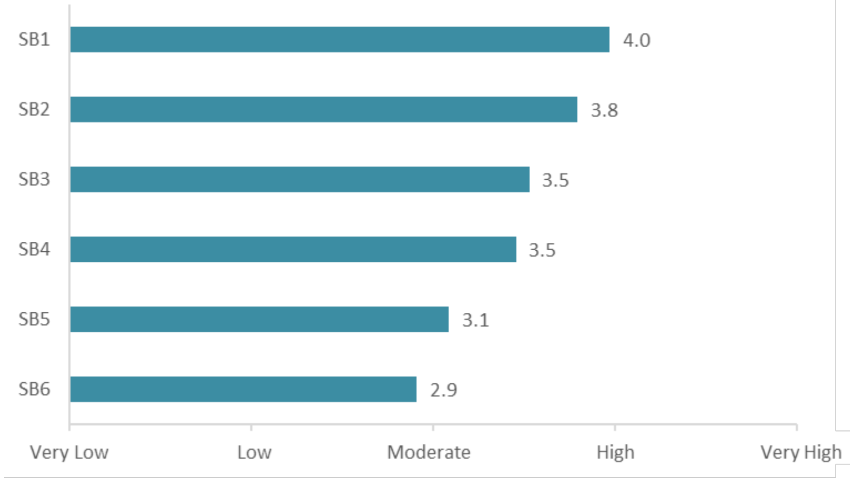
User/Non-User Feedback

Legal Aspects

Designer/ Contractor Interface

User/Non-User Feedback

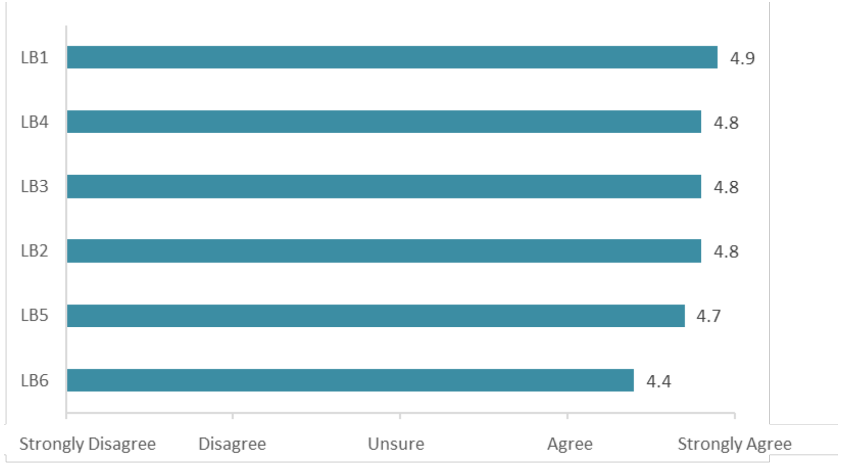
Project-Specific Benefits



SB1 Easier to Calculate Construction Quantities
SB2 Earlier Identification of Plan Discrepancies and Conflicts
SB3 Reducing Risk During Bidding for Contractors and/or DOTs
SB4 Improved Communication on the Project
SB5 Fewer Change Orders or Construction Revisions
SB6 Fewer Project Delays

User/Non-User Feedback

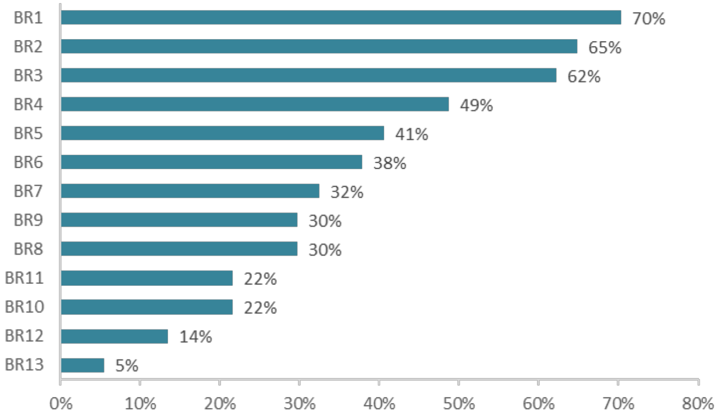
DTM Long-Term Benefits



LB1 Cost Savings
LB2 Improved Accuracy of Plans
LB3 Improved Documentation of Measurements in Database for Future Reference
LB4 Improved Communication
LB5 Improved Efficiency of Project Construction
LB6 Fewer Claims and Litigation

User/Non-User Feedback

DTM Barriers



BR1 Insufficient knowledge or training for inspectors (DOT or CEI)
BR2 Insufficient knowledge or training for office staff
BR3 Insufficient knowledge or training for field survey staff
BR4 DTMs are often incomplete and inconsistent with contract plans
BR5 Designer fear of problems with DTM/lack of confidence
BR6 Insufficient knowledge or training for equipment operators
BR7 High cost for owner to stay current with field technology using DTMs
BR8 Fear of contractor changing terrain model or introducing error into electronic plan files
BR9 High cost for owner for initial software and hardware
BR10 Inadequacy of Information Technology (IT) Infrastructure
BR11 Incompatibility of existing software
BR12 Benefits of using DTMs are unknown. The return on investment (ROI) is unproven.
BR13 Incompatibility of existing hardware

Survey Findings

General DTM Use

Project Specific DTM Use

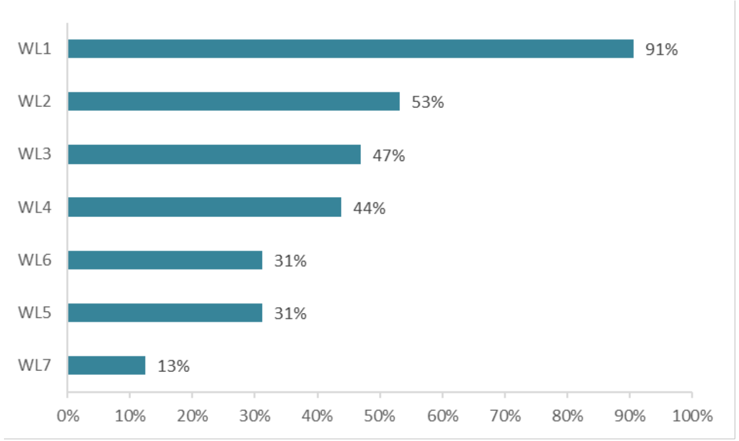
User/Non-User Feedback

Legal Aspects

Designer/ Contractor Interface

Legal Aspects

Written Language in Contract Documents



WL1 DTM (or XML) provided as "For Information Only" for Contractor to Use at their Own Risk
WL2 Extent of DOT's Liability of the Accuracy of the DTM
WL3 Survey Practices
WL4 Extent of DOT's Liability for Use of DTM in the Field
WL5 File Management Protocols
WL6 Model Handover Policy from Designer to Contractor
WL7 Plan Production Methods

Legal Aspects

DTM as a Legal Document

38%
Have not used DTM as a legal document

38%
Have not used DTM as a legal document, but plan to in the next 1-5 years

24%
Have used DTM as a legal document

Legal Aspects

DTM as a Legal Document

38%	38%	24%
Have not used DTM as a legal document	Have not used DTM as a legal document, but plan to in the next 1-5 years	Have used DTM as a legal document

Legal Aspects

DTM as a Legal Document

Document Type	Ranked First	Ranked Second	Ranked Third
Written Specifications	88%	12%	0%
2D Blueprints	12%	50%	38%
3D Model	0%	37%	63%

Survey Findings

General DTM Use

Project Specific DTM Use

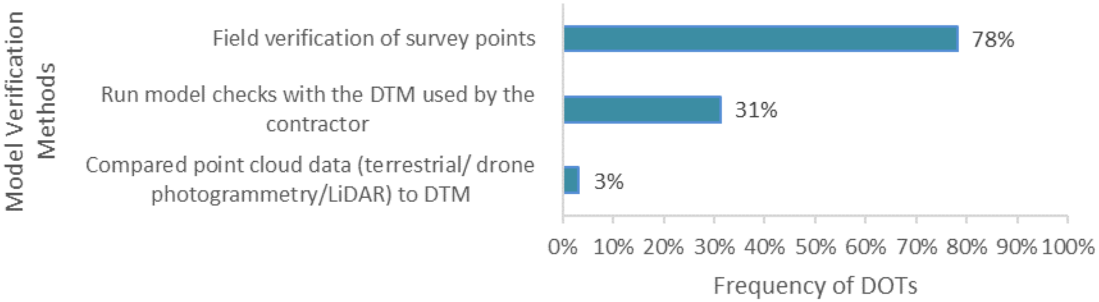
User/Non-User Feedback

Legal Aspects

Designer/ Contractor Interface

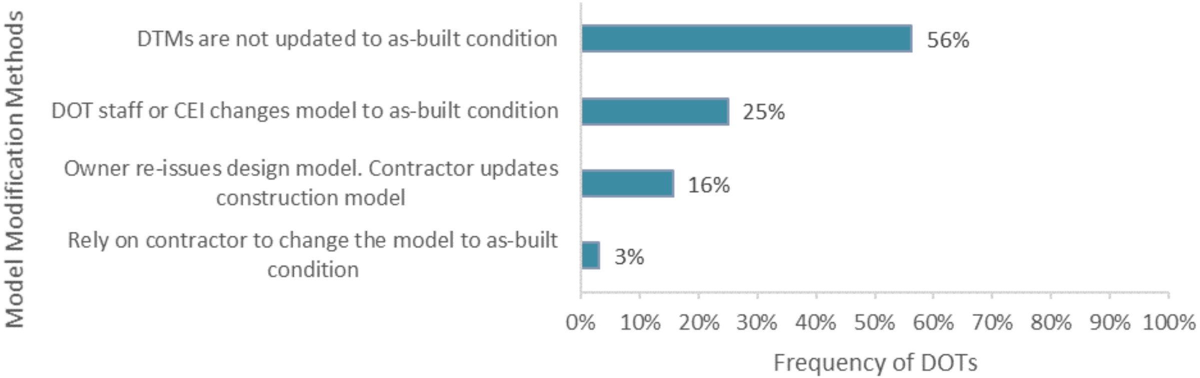
Designer/Contractor Interface

Verifications of DTMs



Designer/Contractor Interface

Modifications of DTMs



Thank You

Q&A after

Shovel Ready DTMs:
DOT Experiences with DTM

Gabe Dadi P.E., Ph.D.

W.L. Raymond and R.E. Shaver Chair

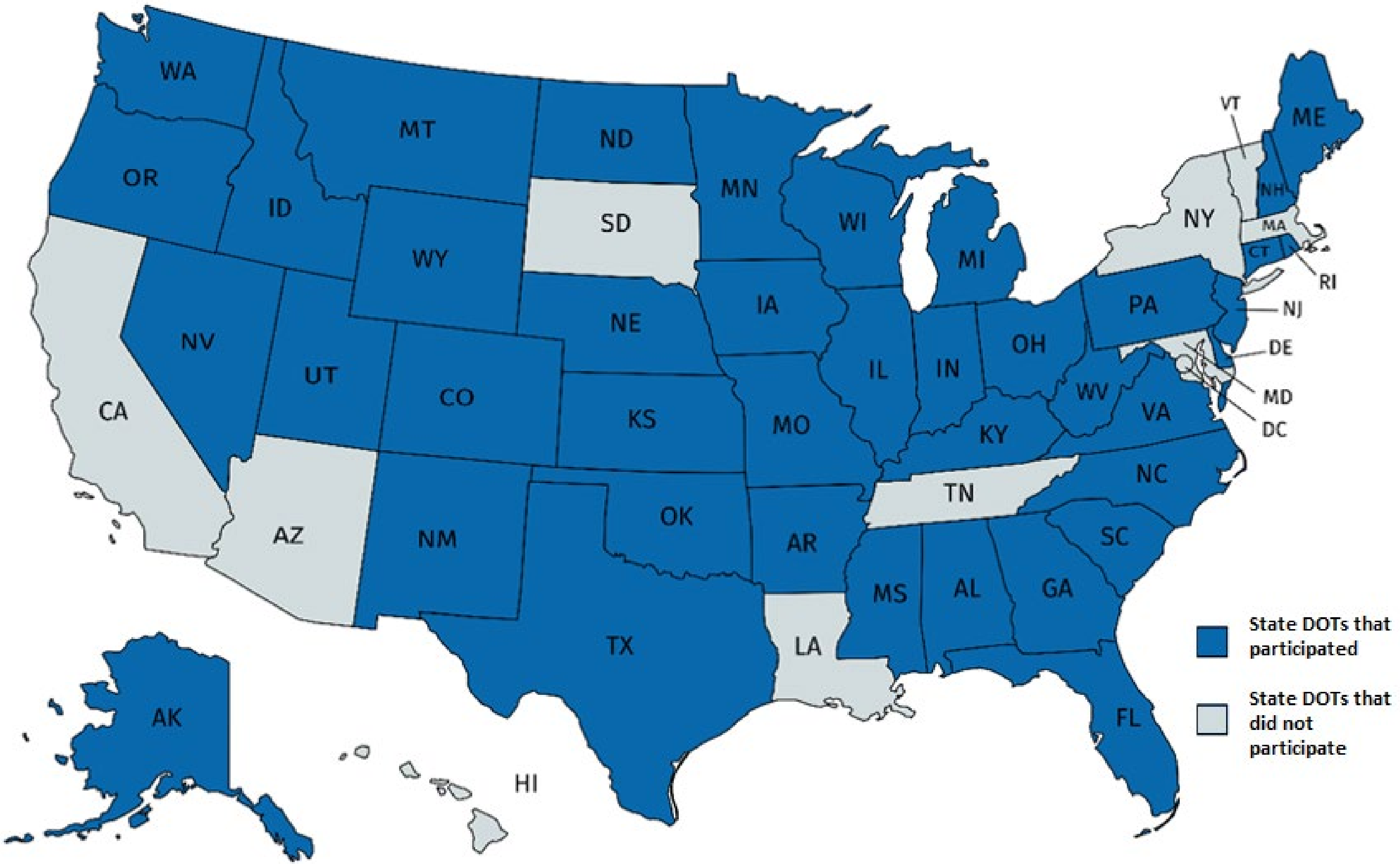
Associate Professor

University of Kentucky

Program Manager

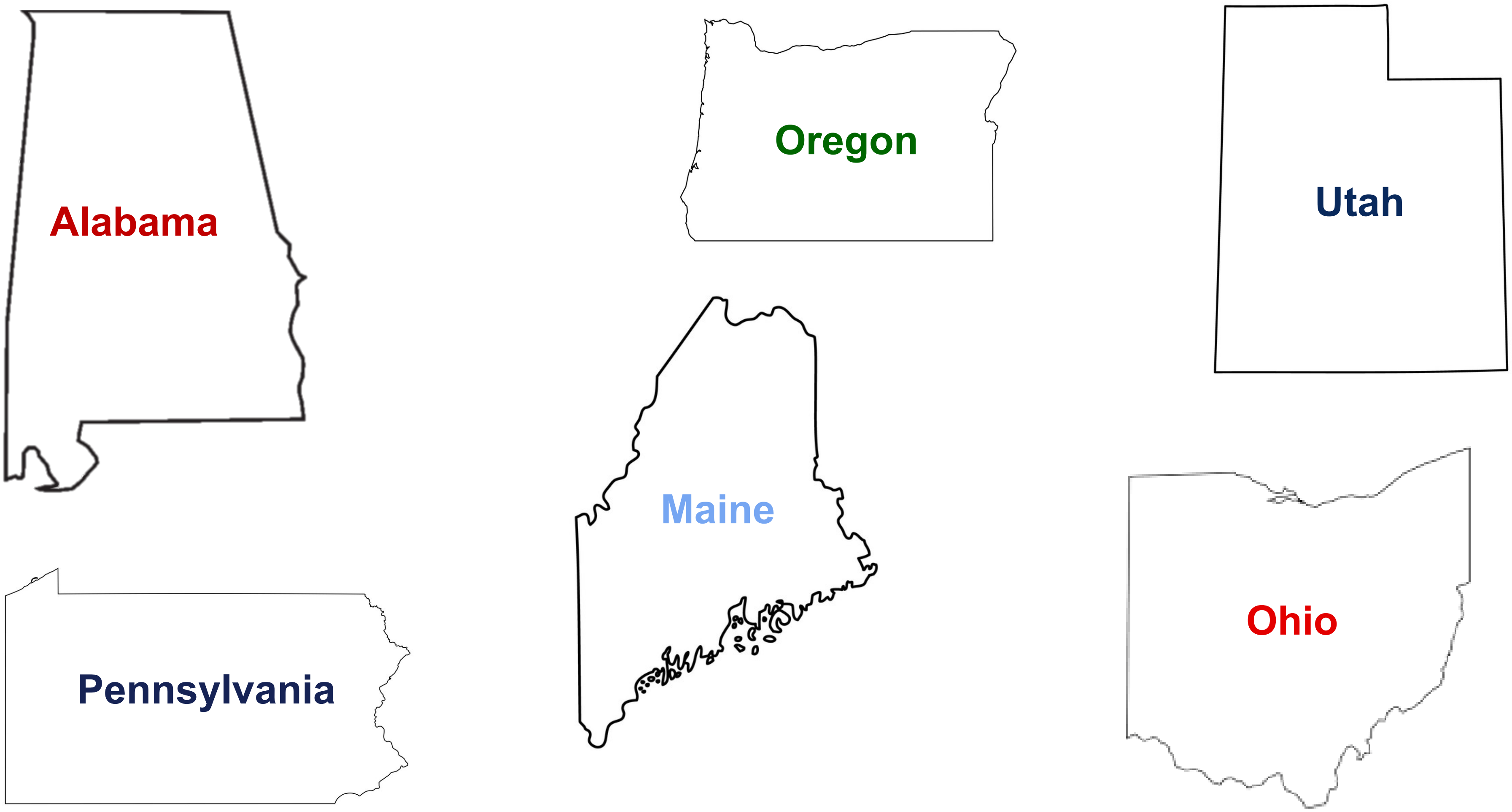
Construction Engineering and Project Management

Kentucky Transportation Center


WA
MT
ND
MN
ME
VT
OR
ID
WY
SD
WI
MI
NY
NH
MA
CT
RI
NV
UT
CO
NE
IA
IL
IN
OH
PA
NJ
DE
MD
DC
CA
KS
MO
KY
WV
VA
AZ
NM
OK
AR
TN
NC
SC
MS
AL
GA
TX
LA
FL
AK
HI
State DOTs that participated
State DOTs that did not participate

Who to Interview?

- 5 of 6 interviews
  - Having 10 or more years of experience with DTMs;
  - Having used DTMs on 100 or more projects; and/or
  - Having executed a project with the DTM as part of the contract documents.
- 1 of 6 interviews
  - Significant e-Construction experience but limited DTM use in construction.


Alabama
Oregon
Utah
Maine
Ohio
Pennsylvania

Maine

- Benefits/Motivation
  - Contractors use of AMG piqued interest
  - If the contractors were building with digital data, the DOT needs to be inspecting with digital data
  - Targeted rollout of DTM use with technologically advanced contracting community

Maine

- Benefits/Motivation
  - Able to track earthwork volume quantities with GPS rovers
  - Grade, centerline, cross-slopes, elevations, and other spatial information
  - Central office provides surveying support for entire state, but regional offices have personnel and equipment

Maine

- Challenges
  - Implementing OpenRoads Designer (ORD), as of Sept. 2020
  - Seeking to have 3D model as part of the bid package but working through regulatory hurdles
  - Often use contractor’s base station

Maine

- Lessons Learned
  - Blending training on how to use the technology vs. what the technology captures
  - Poor satellite conditions in parts of the state
    - Need to hold on to traditional surveying skills
  - Match shots with contractor
    - Found contractors took significantly more data points in the field that led to significant quantity differences

Oregon

- Benefits/Motivation
  - 3D Roadway Design Committee in 2011
  - Required 3D design model as deliverable in 2015
  - Contractors wanted to run AMG. Most turned paper to models
  - Equipped every construction office with hardware, software, and training in 2018
  - Saw 30% schedule savings on one project and more consistent smoothness bonuses
  - Reduced claims over quantities

Oregon

- Challenges
  - Still do not have DTMs and 3D model as part of the contract
  - However the model is used as field verification, so not a push to be in the contract

Oregon

- Lessons Learned
  - First major initiative was to train all the construction offices (8-hour required)
  - After training, every construction office conducted a pilot
  - Have Engineerting Technology Advancement Unit with employees from IT, design construction, surveying, and other end users to evaluate technology

Pennsylvania

- Benefits/Motivation
  - Digital Delivery 2025 – plan to go completely digital
  - Cycle of “double working”
  - Time, cost, and workflow efficiencies as well as improved accuracies

Pennsylvania

- Challenges
  - Lack of available time in construction for personnel to become familiar with technology
  - When construction needs surveying, it’s time critical and in-house surveying isn’t setup for quick turnarounds

Pennsylvania

- Lessons Learned
  - Construction spec (Pub 408) outlines construction surveying procedures and AMG
  - Required 2-day (8 hours per day) training for inspectors and field staff for initial use and 1 day (8 hours) annual refresher
  - Conduct ground truth exercise compared to traditional surveying to demonstrate prove of concept

Utah

- Benefits/Motivation
  - Culture: “not being afraid to fail in the interest of trying things out”
  - Continuity in leadership → consistent messaging and vision
  - Winter Olympics forced design-build legislation in the 1990s
  - Efficiency in data transfer and builds model confidence
  - Emerging technologies (e.g. UAS) will force good DTMs

Utah

- Challenges
  - Leveraging existing software (i.e. model viewers in the field)
  - A software agnostic approach will help meet needs
  - Cost of surveying equipment

Utah

- Lessons Learned
  - Stopped surveying ~20 years ago and lost significant knowledge, now they need them again
  - Contracting method helps facilitate DTM workflows (CM/GC, Design-Build, etc.)
  - D-B-B interferes with dialogue and sharing of information

Alabama

- Benefits/Motivation
  - Just beginning DTM use in construction (as of Fall 2019)
  - Sought to use on projects with significant gradework to maximize benefit of AMG
  - Attended an FHWA EDC 3 Peer Exchange (NYSDOT) where they built confidence in DTM's potential

Alabama

- Challenges
  - Pilots have been difficult to get off the ground
  - Few large earthwork projects
  - Contractor not surveying as frequently as specified

Alabama

- Lessons Learned
  - Leveraged federal resources (FHWA Peer Exchange and STIC) to explore DTMs
  - Sought to have contractor and DOT survey to check measurements and build confidence
  - Early communication with contractor would have improved outcomes

Ohio

- Listen to the next guy

Summary

DOT	Benefits	Challenges	Lessons Learned
Alabama	• Calculating quantities • Learn with contractors • Federal aid to assist pilots	• Setting expectations with contractors • Having sizable projects for equipment resource needs	• Early communication with contractors • Understand capability of contracting community
Maine	• Quick grade checks • Easy quantity comparisons with contractors • Time efficiencies	• Software constantly changing • Legal hurdles (e-signatures, stamps, plan set of record) • Equipment budget	• Peer exchanges helped shared information with adjacent agencies and shared contractors • Formal training program and frequent updates keeps staff ready • E-Construction Implementation team would be beneficial
Ohio	Listen to the next guy		
Oregon	• Inspectors found tools that supported their work • Lower surveying costs • Fewer claims and delays over quantities • Quicker and more accurate payments	• Still have not used the model as part of the contract documents.	• Significant, early, state-wide training effort. • Fully staffed Engineering Technology Advancement Unit with IT, design, construction, surveying, and other end users for trial and support.
Pennsylvania	• Facilitates AMG • No more "double working" the model	• Compressed construction schedules • Getting quantity measurements with high accuracy during construction	• Have a standard specification for surveying practices and training requirements • Have a group that conducts experimental tests of new technology

Thank You

https://www.trb.org/Publications/Blurbs/181735.aspx

CASE STUDY OF DOT’S USING DTM’S

Kyle Ince, P.E., S.I.

AGENDA

- Existing
  - Methods
    - Acquisition
    - Deliverables
      - Hybrid Generated Datasets
      - Accuracy
      - Use Cases
    - Formats and Creation Methods
- Proposed
  - Deliverables
    - Accuracy
    - Formats
  - Legality
  - Current Practice Vs. Future Vision

- Digital Surface Model (DSM)*
  - Less costly, includes vegetation and buildings
- Digital Terrain Model (DTM)*
  - More expensive, edited to only display the terrain

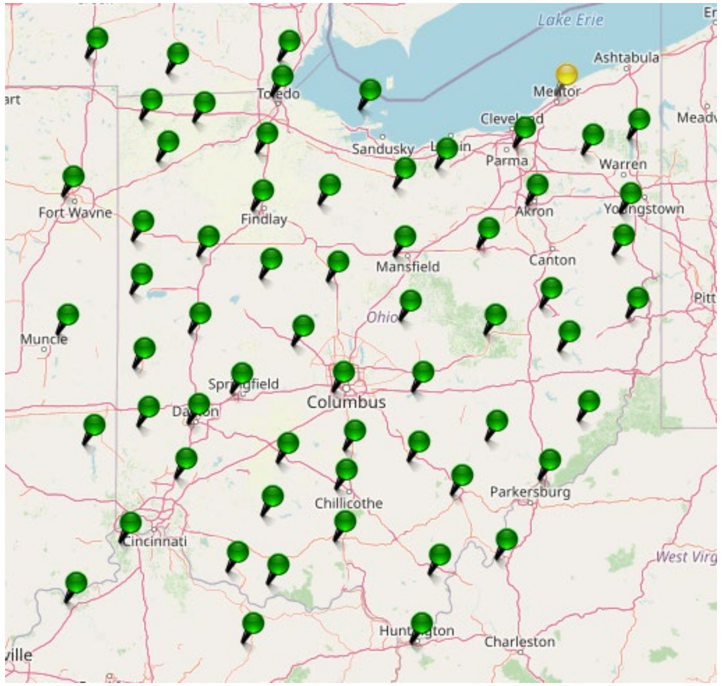
EXISTING

EXISTING (ACQUISITION)

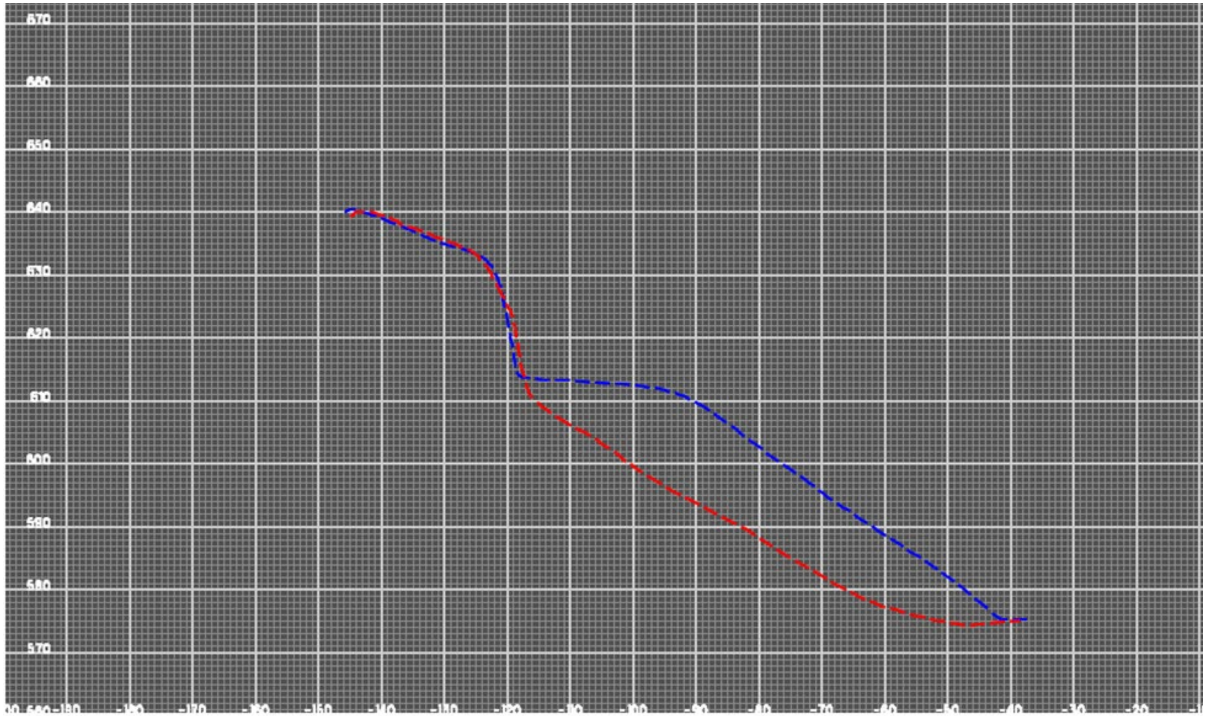
- Remote Sensing: *Technique for measuring, observing or monitoring a process or object without physically touching the object under observation.*
  - 2 Categories
    - Active
    - Passive
- Data Collection Methods
  - Airborne
  - Mobile
  - Terrestrial

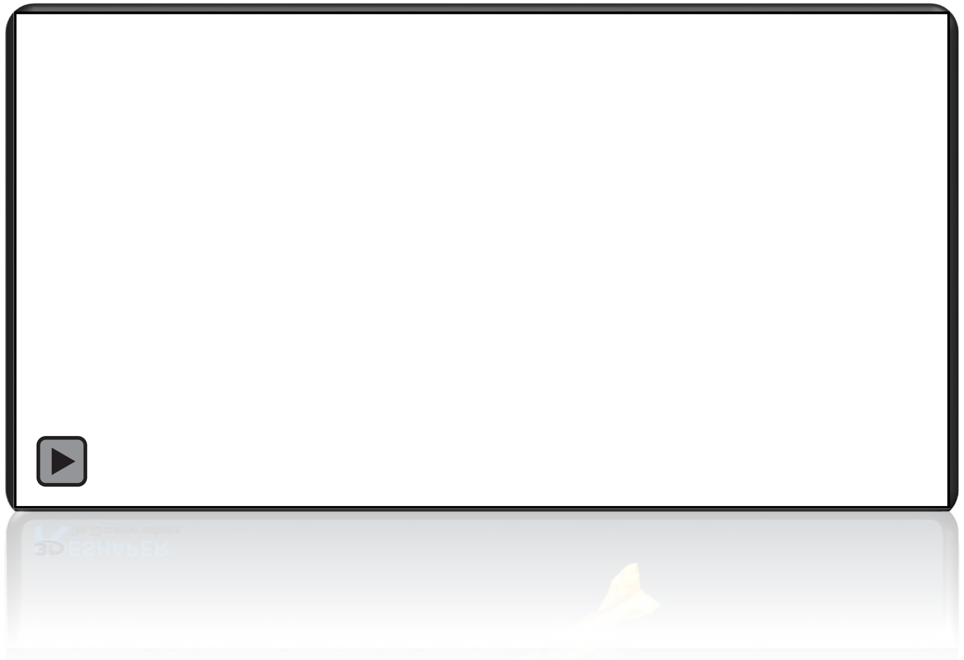
EXISTING (ACQUISITION AT OHIO DOT)

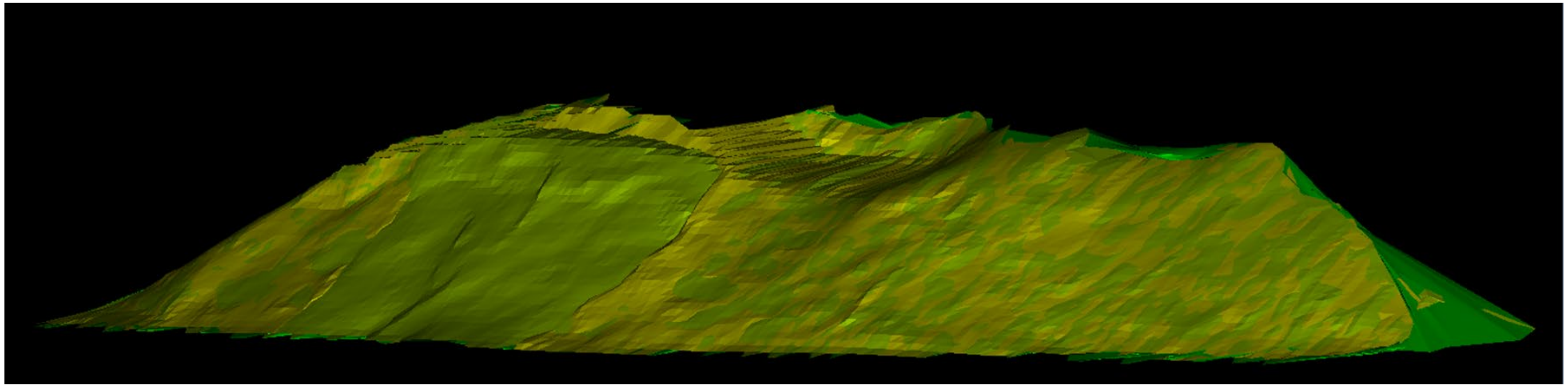
- LiDAR
  - Terrestrial Laser Scanners
    - Total Station and “True” Scanners
  - Aerial (Manned Aircraft Based)
  - Mobile (Consultant Collection (Project by Project Basis))
- Conventional (Field to Finish)
  - GNSS (VRS or RTK)
    - Ohio RTN
  - Total Station and Differential Leveling
- Photogrammetry
  - Crewed and Un-Crewed Aircraft
- Echo Sounding
  - Crewed and Un-Crewed Vessels



EXISTING (COMPLEX HYBRID DATASETS)

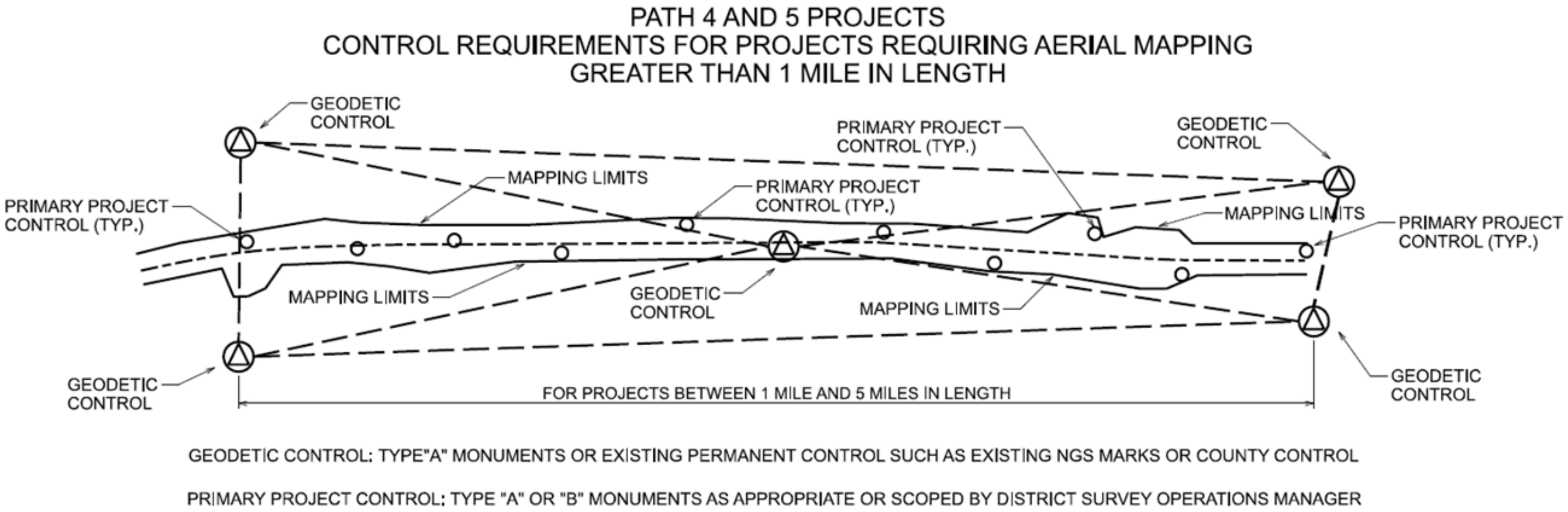






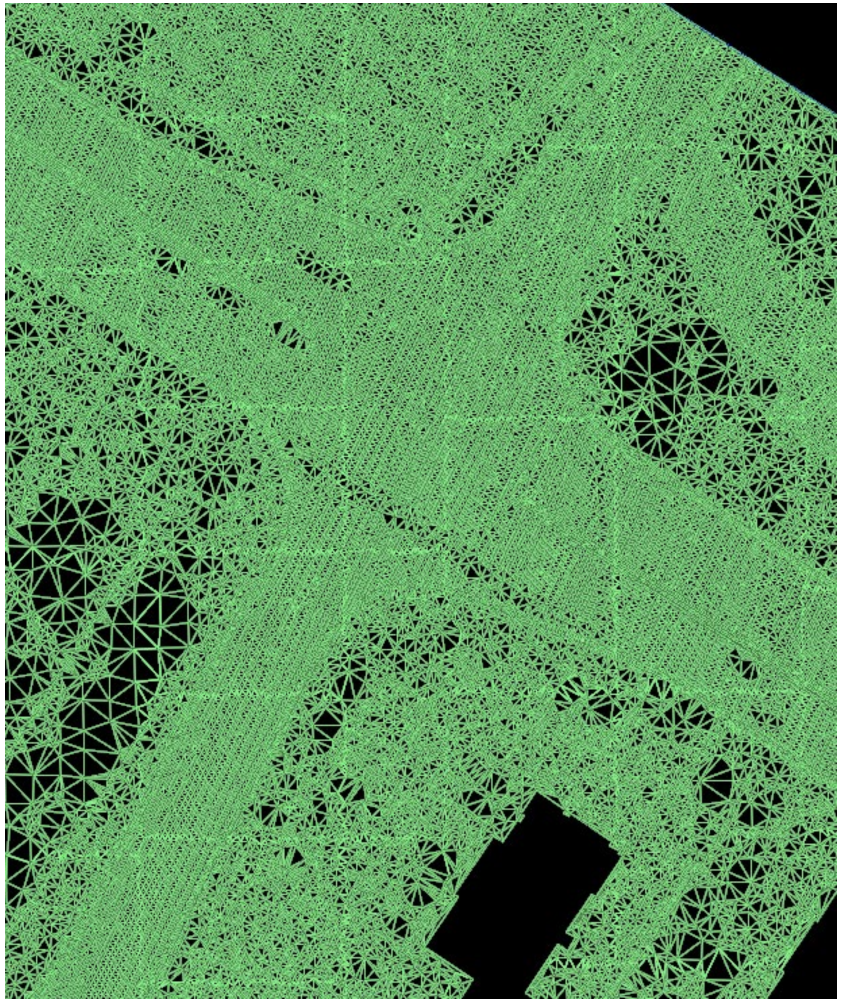
EXISTING (ACCURACY)

- Current Specifications*
  - Update to occur in January 2022

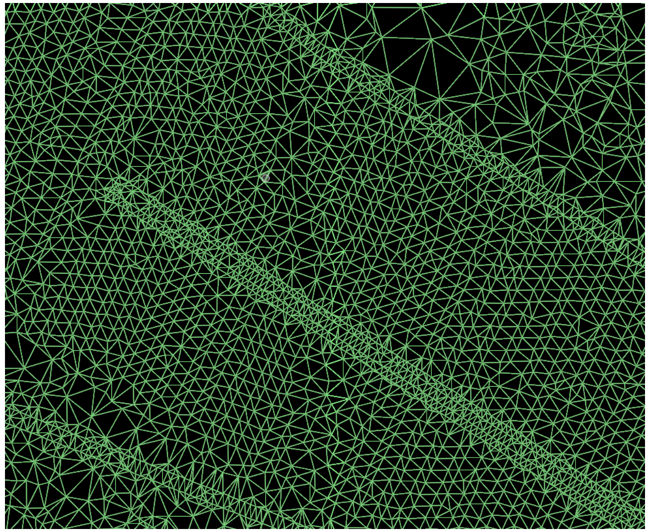


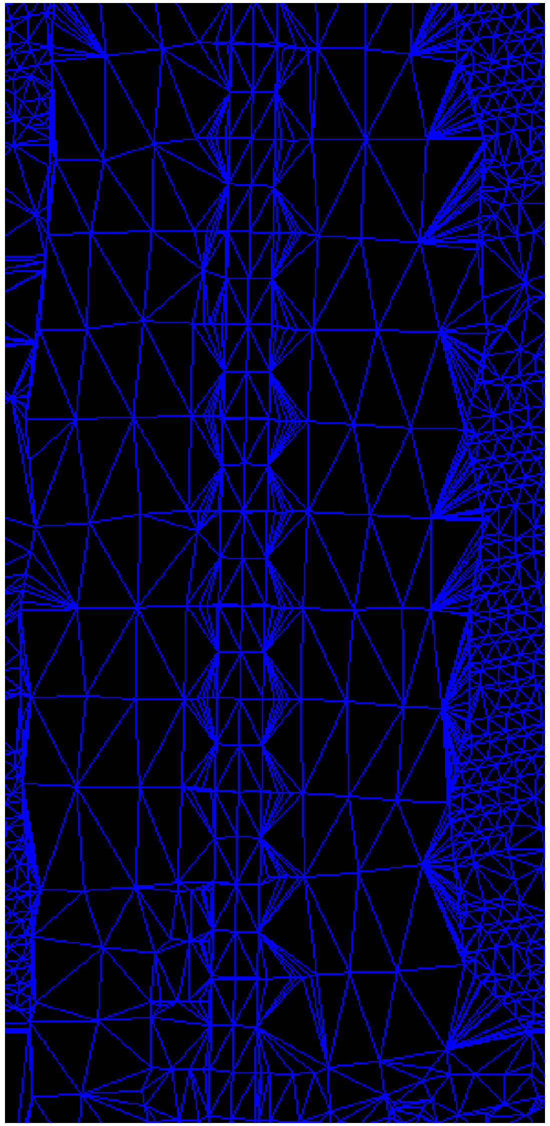
DTM Accuracy Class	Classification Area	Maximum Allowable Average Dz (feet)	Maximum Allowable RMSE (feet)
Class A	Paved areas	± 0.07	0.16
Class B	Vegetated areas outside of pavement that are maintained at a minimum biannual frequency (i.e.: farm fields, residential yards, roadside R/W, etcetera)	± 0.25	0.32
Class C	Vegetated areas that are not maintained	± 0.50	0.50
Class D	Areas where vertical accuracy is not critical or warranted	± 1.00	1.00

EXISTING (COMPLEX HYBRID DATASETS)

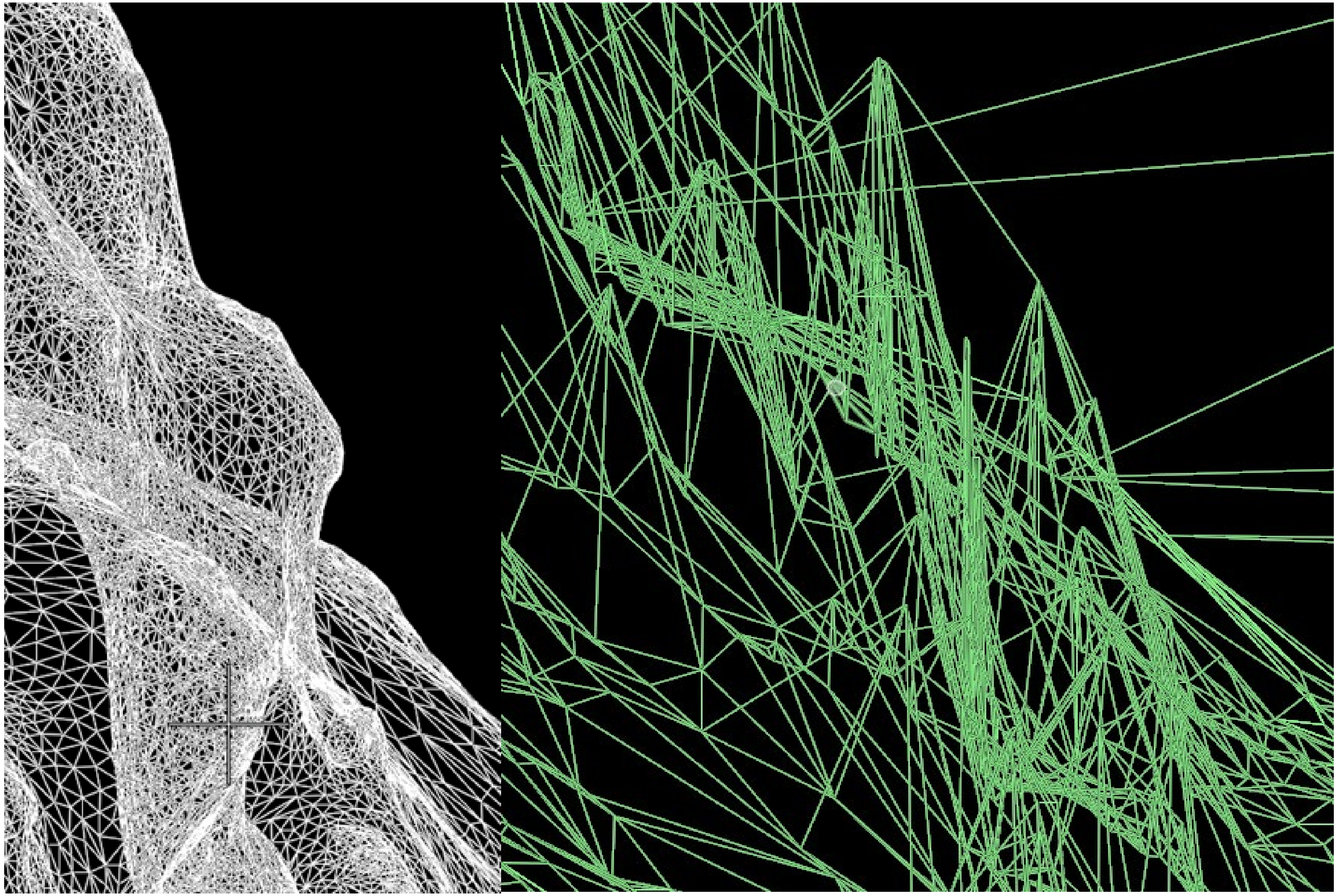


- Generated through a top→down approach





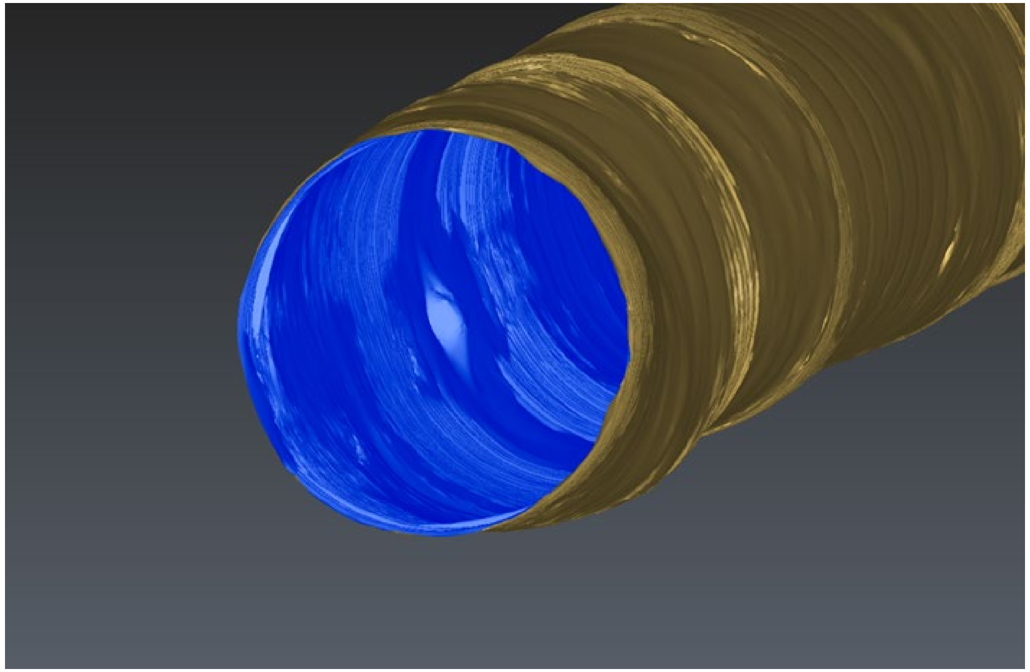
EXISTING (TIN/TERRAIN MODEL) VS. MESH

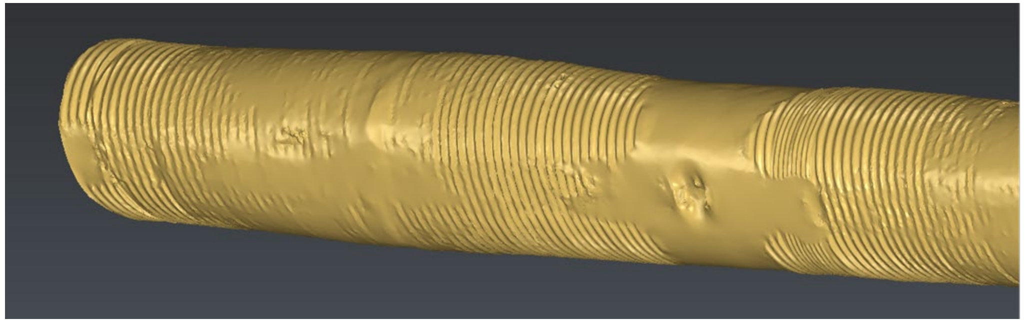


- Mesh Algorithms can have multiple Z (elevation values) for the same X,Y coordinate

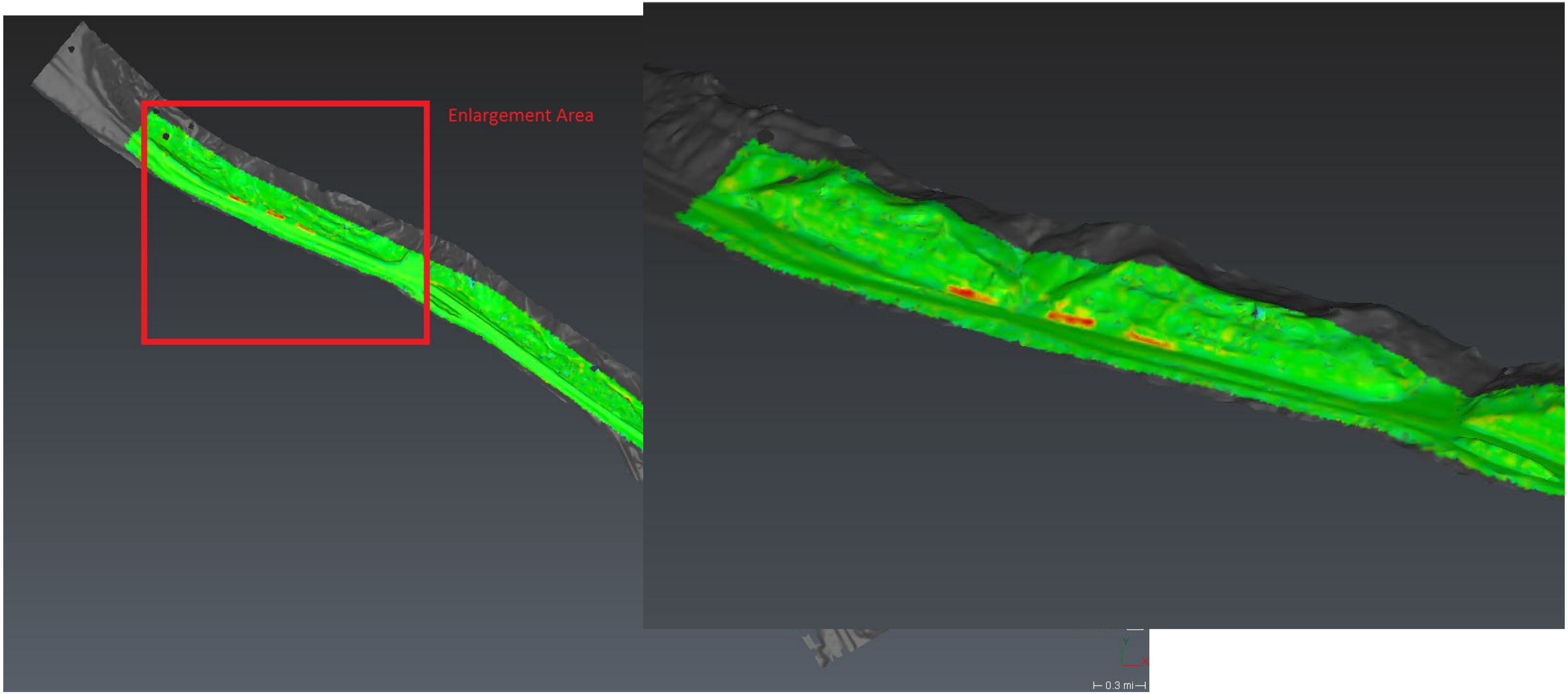
ADVANCED DERIVATIVES

- Examples (sort of terrain models)
  - GAL SR 71 (Southeast Ohio)
  - ASH and MED Culvert Pipes





ADVANCED DERIVATIVES



PROPOSED

PROPOSED (FORMATS)

Current/Past workflow:

- No digital files, plan only, digitized cross sections to make model
  - CADD manual said to provide basemaps, alignments, profiles, cross section staking..all in digital form for the past 10+ years…
- How are we ever going to deliver 3D models if we can’t even get a basemap??

Electronic Cadd Deliverables document

- Brought to light what the CADD Manual always had
- App to help streamline process
- Get people in the mindset, we need this data
- Automated checker to help ensure compliance
- Deliver at bidding…contractors shouldn’t need to digitize from a pdf to get electronic data we already have

PROPOSED (DELIVERABLES)

- Current*
  - Guidelines for what should be modeled and what digital files are needed.
  - Make digital data available for bidding process.

  - *3D Proposed being generated*

PROPOSED (DELIVERABLES)

Provide single open-sourced format of the model

Contractors

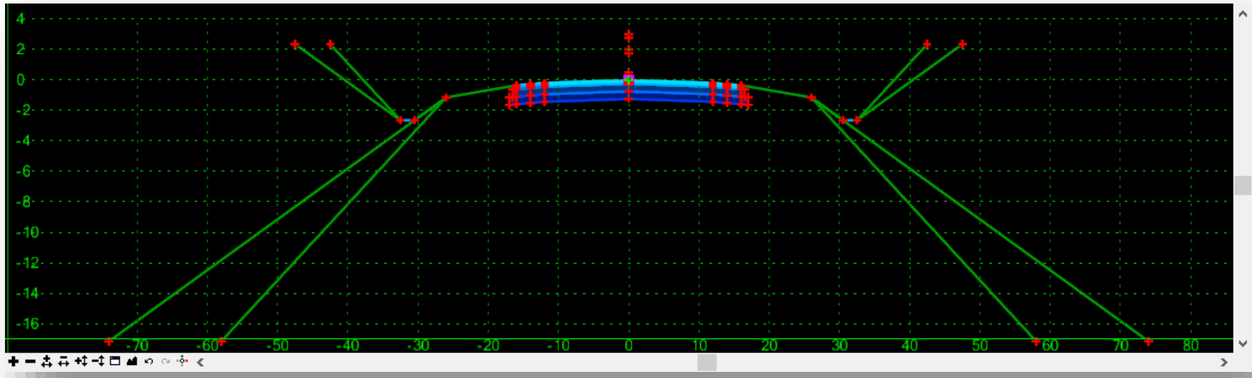
- No more digging though 100s of files

Construction staff

- Pay item data tied to the 3d model
- MetaData

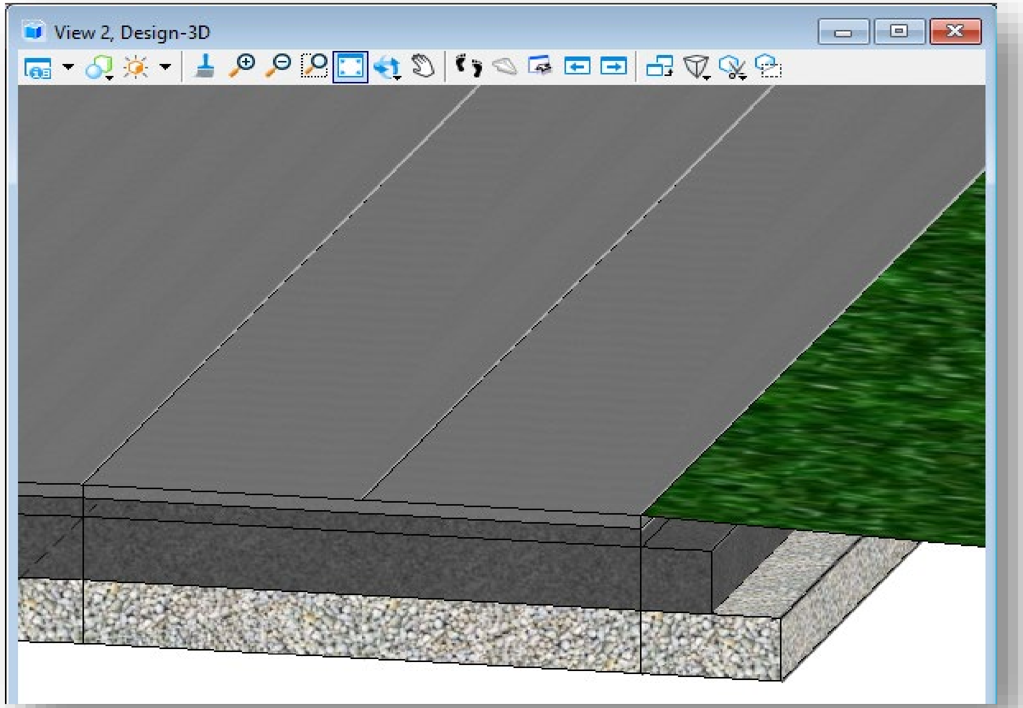
PROPOSED (ACCURACY & LOD)

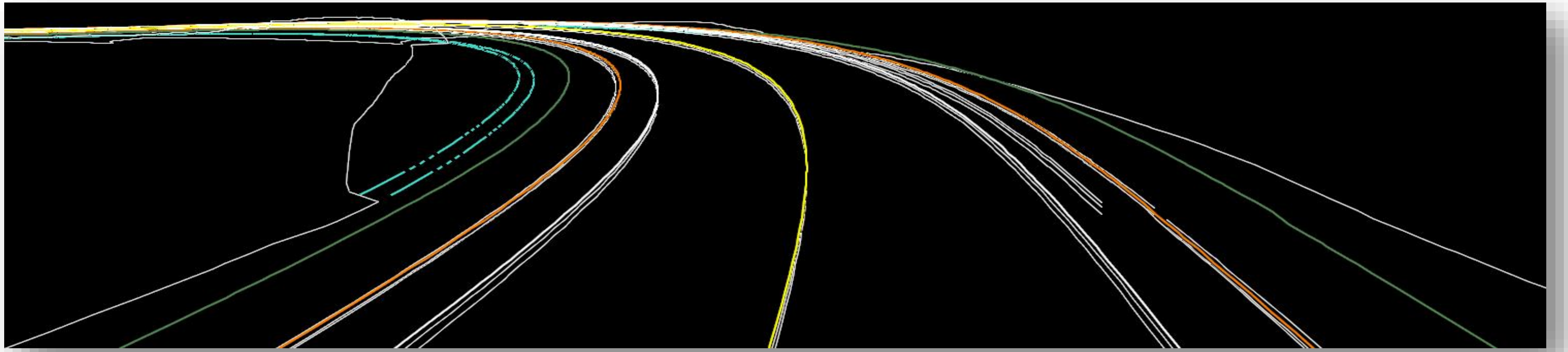
- Level of Detail (LOD)
  - What needs to be modeled? What doesn't?
    - Gutter depressions at curb inlets
    - Seeding areas
    - Grading at headwalls
    - Changes in reports/tables
- Engagement!



PROPOSED (FORMATS)

- Current
  - XML Files
  - 2D and 3D Basemaps
  - Reports
- Future
  - Imodel?
  - IFC?
  - Surfaces and Linestrings?





QUESTIONS

Kyle.Ince@dot.ohio.gov

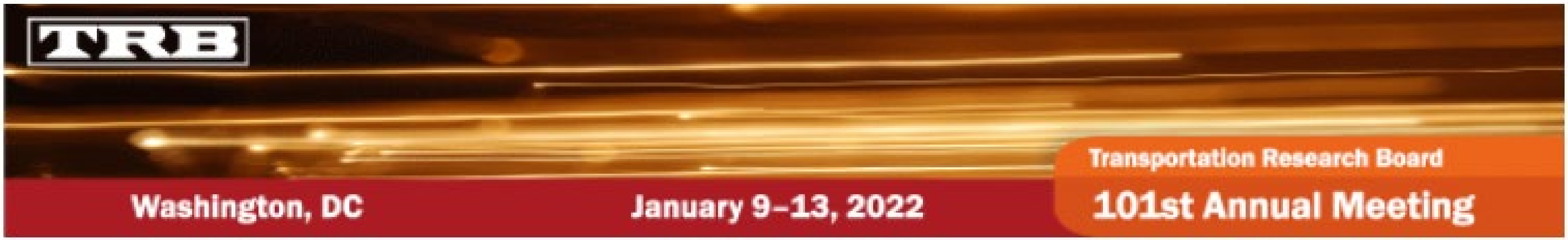
Today’s Panelists

Moderator: Gabe Dadi,
University of Kentucky

Hala Nasserddine,
University of Kentucky

Kyle Ince,
Ohio DOT

Register for TRB's Annual Meeting!



Register now for our January meeting! ***There will be no onsite registration this year.***

#TRBAM

The National Academies of
SCIENCES · ENGINEERING · MEDICINE

TRB
TRANSPORTATION RESEARCH BOARD

TRB Weekly

TRB Weekly covers the latest in transportation research.

- Subscribe to the newsletter for the most recent TRB news & research!

https://bit.ly/ResubscribeTRBWeekly

TRB’s New Podcast!

- Have you heard that we have a new podcast, TRB’s Transportation Explorers?
- Listen on our website or subscribe wherever you listen to podcasts!

#TRBExplorers

Get involved with TRB

- Receive emails about upcoming webinars: https://mailchi.mp/nas.edu/trbwebinars

- Find upcoming conferences: http://www.trb.org/Calendar

@NASEMTRB
@NASEMTRB
Transportation Research Board

#TRBWebinars

Get Involved with TRB

#TRBwebinar

@NASEMTRB
@NASEMTRB
Transportation Research Board

Getting involved is free!

Be a Friend of a Committee bit.ly/TRBcommittees

– Networking opportunities
– May provide a path to Standing Committee membership

Join a Standing Committee bit.ly/TRBstandingcommittee

Work with CRP https://bit.ly/TRB-crp

Update your information www.mytrb.org