DTFH61-13-C-00026

Addressing Challenges for Automation in Highway Construction
Learning Objectives

• Research Objectives
• Research Team
• Introduce Part I: *Implementation Challenges and Success Stories*
• Describe in detail Part II: *Guidelines and Guides Specifications Manual*
Research Objectives
Research Team

The Transtec Group

Dr. George Chang
Mauricio Ruiz
Helga N. Torres

Parsons Brinckerhoff

Richard Duval  
FHWA COR  
Richard.duval@dot.gov

Francesca Maier
Dr. Jag Mallela
Key Automation Technologies

Planning | Survey | Design

Maintenance | Construction

Remote Sensing | Underground Utility Location | 3D Modeling

Field Technology & Inspection | Machine Control & Automation
Remote Sensing

Ohio DOT
Underground Utilities Location

• SHRP2 products address many challenges
• 2015 FHWA Report: *Feasibility of Mapping and Marking Utilities*

Picture: Hatch Mott MacDonald
3D design is a key process for implementing automation in highway construction.
Construction Automation
Field Technology and Inspection

Non-destructive testing (NDT)
Field Technology and Inspection

Field Inspection Tools for Real-time Verification
Which benefits have you experienced?

- Time savings
- Greater detail and accuracy in 3D data
- Detect issues before construction
- Better control of quantities
- Cost savings
- Increased safety
- Increased productivity
- Higher quality subsurface utility information
- More Uniformity and consistency in final...
- Fuel savings
- Fewer destructive tests like cores
Which challenges have you experienced?

- Training needs
- Lack of standards and guidelines
- Cost: Equipment & Software
- Cost: Data collection
- Quality of information
- Allocation of liability and risk
- Data interoperability
Final Report: Part II

DTFH61-13-C-00026
Addressing Challenges in
Intelligent Construction Systems and Technologies

Draft Final Report


Submitted to:
Federal Highway Administration

Submitted by:
The Transtec Group, Inc.

22 May, 2015
Where is your agency investing?

<table>
<thead>
<tr>
<th>Service</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delivering 3D Design CADD files to contractors</td>
<td>70%</td>
</tr>
<tr>
<td>Updating 3D Design CADD requirements</td>
<td>60%</td>
</tr>
<tr>
<td>Purchasing mobile devices for inspectors</td>
<td>40%</td>
</tr>
<tr>
<td>Intelligent Compaction</td>
<td>30%</td>
</tr>
<tr>
<td>Reducing staking/hubbing with AMG construction</td>
<td>30%</td>
</tr>
<tr>
<td>Equipping inspectors with Rovers for QA</td>
<td>20%</td>
</tr>
<tr>
<td>Providing CADD support in Construction</td>
<td>20%</td>
</tr>
<tr>
<td>Higher accuracy topographic survey</td>
<td>20%</td>
</tr>
<tr>
<td>Subsurface Utility Engineering</td>
<td>20%</td>
</tr>
<tr>
<td>Subsurface utility locating technologies</td>
<td>20%</td>
</tr>
<tr>
<td>Ground Penetrating Radar</td>
<td>10%</td>
</tr>
<tr>
<td>Updating the accuracy of control monuments</td>
<td>10%</td>
</tr>
<tr>
<td>Real-time Smoothness profilers</td>
<td>10%</td>
</tr>
<tr>
<td>Infrared profilers</td>
<td>0%</td>
</tr>
</tbody>
</table>
Which policies is your agency revising?

- Construction Manual
- Construction Specifications
- CADD Manual
- Design Manual
- Survey Manual
- Other
Policy Development

1. Define Objectives and Business Requirements
2. Consult with Stakeholders
3. Identify Automation Technologies to be implemented
4. Identify affected Policy Areas
5. Make necessary Investments
6. Implement Policy changes
Implementation Strategies

Refer to Table 4: Sample Resource Assignment Matrix (RAM)
## Enabling Infrastructure

<table>
<thead>
<tr>
<th>Enabling Infrastructure</th>
<th>1 Initial</th>
<th>2 Evolving</th>
<th>3 Defined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statewide CORS Network</td>
<td>Limited access to a CORS network</td>
<td>Statewide CORS network that is asset/GIS-grade only</td>
<td>Limited access to survey-grade CORS network</td>
</tr>
<tr>
<td>Real Time GNSS Network (RTN)</td>
<td>Single Base RTK, requires site localization</td>
<td>Commercial RTN solution, requires site localization</td>
<td>Commercial RTN solution, tied to the NSRS</td>
</tr>
<tr>
<td>Coordinate Reference System</td>
<td>State Plane coordinate system used on all projects</td>
<td>Modified State Plane coordinate system used on all projects</td>
<td>Some projects use custom coordinate systems</td>
</tr>
<tr>
<td>Computer Hardware for Design</td>
<td>All staff have computers</td>
<td>All staff have networked computers</td>
<td>All staff have networked computers that are less than 3 years old</td>
</tr>
<tr>
<td>Computer Software for Design</td>
<td>Email, Internet, PDF and Office software only</td>
<td>CADD design software for designers and technicians</td>
<td>CADD design software for all and limited access to design review software</td>
</tr>
<tr>
<td>CADD Standard</td>
<td>CADD Manual documents minimum requirements for 2D electronic plans</td>
<td>CADD Manual outlines minimum requirements for 3D model used to generate 2D plans</td>
<td>Standardized 3D model format and outputs including standard file naming convention</td>
</tr>
</tbody>
</table>

Refer to Table 4: Capability/Maturity Matrix for Enabling Infrastructure
Setting Control

<table>
<thead>
<tr>
<th>Control Type</th>
<th>Network Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal Control</td>
<td>0.10 ft</td>
</tr>
<tr>
<td>Vertical Control</td>
<td>0.02 ft</td>
</tr>
</tbody>
</table>

Refer to Chapter 6.1
Topographic Survey Accuracies

Refer to Chapter 6.3 and Table 9

Constraint Feature
- $H \pm 0.04$ ft
- $V \pm 0.02$ ft
- 5-ft spacing

Design Feature
- $H \pm 0.1$ ft
- $V \pm 0.04$ ft
- 10-ft spacing

Location Feature
- $H \pm 0.25$ ft
- $V \pm 0.1$ ft
- 25-ft spacing

Planning Feature
- $H \pm 0.5$ ft
- $V \pm 0.5$ ft
- 50-ft spacing
## Remote Sensing

<table>
<thead>
<tr>
<th>Feature Type</th>
<th>Aerial LiDAR</th>
<th>Mobile LiDAR</th>
<th>Static LiDAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constraint Features</td>
<td>not appropriate</td>
<td>not appropriate</td>
<td>suitable</td>
</tr>
<tr>
<td>Design Features</td>
<td>not appropriate</td>
<td>consider</td>
<td>suitable</td>
</tr>
<tr>
<td>Location Features</td>
<td>consider</td>
<td>suitable</td>
<td>consider</td>
</tr>
<tr>
<td>Planning Features</td>
<td>suitable</td>
<td>suitable</td>
<td>consider</td>
</tr>
</tbody>
</table>

Refer to Chapter 6.4 and Tables 11, 12 and 13
Subsurface Utility Location

Scope Project
Evaluate Subsurface Utility Location Records
Identify needs for higher Quality Level data
Select Locating Technologies
Update Subsurface Utility Records

Refer to Chapter 7 and Table 14
Subsurface Utility Data Management

Use color and levels to distinguish between the different quality levels of subsurface utility data.

Refer to Chapter 7.3
Can you access the Survey data you need?

EDC-3 3D Modeling Webinar 9/1/15, 81 unique responses
# 3D Model Standard - Content

## CADD Data Type for Automation

<table>
<thead>
<tr>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>alignment, surface &amp; 3D line strings</strong></td>
</tr>
<tr>
<td>Roadways, interchanges, intersections</td>
</tr>
<tr>
<td><strong>surface &amp; 3D line strings</strong></td>
</tr>
<tr>
<td>Side slopes, gore areas, sidewalks and paths, lane width transitions,</td>
</tr>
<tr>
<td>culvert headwall grading, guardrail berm transitions, benching transitions,</td>
</tr>
<tr>
<td>bridge abutments, storm water ponds, ditches and swales</td>
</tr>
<tr>
<td><strong>3D line strings</strong></td>
</tr>
<tr>
<td>Pavement markings, curbs and gutters, retaining walls, sewer inverts</td>
</tr>
</tbody>
</table>

Refer to Chapter 8.4.1 and Tables 17, 18 & 19
3D models are incomplete and imperfect. Data density must be sufficient to depict the design intent with the fidelity needed for automation technologies.

Refer to Chapter 8.4.2 and Table 20
4D Model Standard

- Identify Usage Cases
- Identify Target Audiences
- Determine 3D Model Content
- Determine Schedule Resolution & Time Step
- Determine Geometric Accuracy and Segmentation
- Define 4D/5D Modeling Products

Refer to Chapter 8.5 and Tables 21 and 22
3D Model Reviews

- Triangles
- Contours (0.1 ft)
- Flow arrows
- Slopes

Refer to Chapter 8.6
### Guide Specifications

<table>
<thead>
<tr>
<th>Section of Standard Specifications</th>
<th>Considerations to Support use of automation technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controlling Work: Plans and Working Drawings</td>
<td>Owner’s provision of 3D data, Review and agreement of electronic plan data, including 3D digital data, Requirements for 4D/5D models, Provision of as-built records</td>
</tr>
<tr>
<td>Controlling Work: Conformance with Plans and Specifications</td>
<td>Standing of 3D data in relation to other contract documents</td>
</tr>
<tr>
<td>Controlling Work: Construction Stakes, Lines and Grades</td>
<td>Verifying control position, accuracy and usage, Agreeing a site localization, Staking requirements</td>
</tr>
<tr>
<td>Controlling Work: Inspection of Work</td>
<td>Provision of equipment for performing inspection, Requirements for notification of work ready to inspect</td>
</tr>
<tr>
<td>Controlling Work: Quality Control Plan</td>
<td>Use of a Work Plan to agree use of automation technology in construction and inspection, including minimum requirements for equipment calibration.</td>
</tr>
<tr>
<td>Measurement and Payment</td>
<td>Means of measurement and payment</td>
</tr>
<tr>
<td>Earthwork, Base Material, Fine Grading, Asphalt Paving, Concrete Paving</td>
<td>Accuracies, tolerances, means of measurement and payment</td>
</tr>
</tbody>
</table>
Field Technology & Inspection

1. Hold Precon meeting
2. Agree roles & responsibilities
3. Develop plans for digital data management, low accuracy positioning and high accuracy positioning
4. Select tools
5. Inspect work
6. Document quantities and tolerances
7. Store digital as-built records

Refer to Chapter 10
Establishing a Model of Record

Refer to Chapter 10.1 and Table 28
Agreeing Control & Site Localization

Refer to Chapter 10.4 and Table 29

<table>
<thead>
<tr>
<th>Element</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Original mapping control</td>
<td></td>
</tr>
<tr>
<td>Survey network diagrams</td>
<td></td>
</tr>
<tr>
<td>Coordinate differences</td>
<td></td>
</tr>
<tr>
<td>New control</td>
<td></td>
</tr>
<tr>
<td>Mapping projection and datum</td>
<td></td>
</tr>
<tr>
<td>Method of RTK correction</td>
<td></td>
</tr>
<tr>
<td>Site Localization</td>
<td></td>
</tr>
<tr>
<td>Surveyor’s seal</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name</th>
<th>H.Error</th>
<th>V.Error</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.01'</td>
<td>-0.04'</td>
</tr>
<tr>
<td>3</td>
<td>0.04'</td>
<td>0.03'</td>
</tr>
<tr>
<td>4</td>
<td>0.04'</td>
<td>-0.03'</td>
</tr>
<tr>
<td>5</td>
<td>0.04'</td>
<td>0.04'</td>
</tr>
</tbody>
</table>
Real-time Verification

Refer to Chapter 10.5 and Tables 30 and 31
Conclusion
Other Resources

- **www.learnmobilelidar.com** (NCHRP 748)
- Feasibility of Mapping & Marking Subsurface Utilities (contact Richard Duval at richard.duval@dot.gov)
- Contact David Unkefer (david.unkefer@dot.gov) about EDC-3 3D Modeling workshop hosting opportunities
- August 19th webinar recording: https://connectdot.connectsolutions.com/p3jndbzwa44/