AUTOMATION IN HIGHWAY CONSTRUCTION: SUCCESS, CHALLENGES, AND GUIDANCE

BY

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PRESIDENT, IICTG

IICTG.org
OUTLINES

• Definition of Intelligent Construction Technologies (ICT)
• FHWA ICT Efforts
• Key ICT – Benefits, Challenges and Solutions
• ICT Integration
• ICT Guidance
• Case Studies
OUTLINES

• Definition of Intelligent Construction Technologies (ICT)
• FHWA ICT Efforts
• Key ICT – Benefits, Challenges and Solutions
• ICT Integration
• ICT Guidance
• Case Studies
AUTOMATION IN CONSTRUCTION

INTELLIGENT CONSTRUCTION TECHNOLOGIES (ICT)
DEFINITION OF ICT

Systems and technologies that collect, store, analyze, and process information, make, and execute an action or decision that results in quality construction.
DEFINITION OF ICT

Collect, Store
Analyze, Process
Decision, Execute

Quality Construction

Focus on Quality
OUTLINES

• Definition of Intelligent Construction Technologies (ICT)
• FHWA ICT Efforts
• Key ICT – Benefits, Challenges and Solutions
• ICT Integration
• ICT Guidance
• Case Studies
Improved Highway Delivery with the use of Intelligent Construction Systems
ICT DEVELOPMENT CYCLE

- Technology
- Concept
- Research & Development
- Field Trials & Demos
- Training
- Spec / Standard
- Deployment
- Maintenance & Updating
TECHBRIEF

3D Engineered Models for Construction
UNDERSTANDING THE BENEFITS OF 3D MODELING IN CONSTRUCTION: THE WISCONSIN CASE STUDY

Introduction

Transportation agencies have used three-dimensional (3D) modeling in building construction (also known as "Building Information Modelling" (BIM)) effectively for many years. In BIM applications, designers are able to identify early in the process potential construction issues, such as clashes in future piping, wiring, and HVAC ductwork.

In recent years, transportation agencies have started to plan and design roadway 3D models because they understand the possible benefits that 3D models offer to constructors. The benefits include improved productivity of operations and worker safety. Using 3D models also enhances the bidding process and allows contractors to use Automated Machine Guidance (AMG) to yield higher quality and less expensive construction. Agencies may provide 3D design data to potential bidders, or contractors may develop their own models for use with AMG during construction.

The Wisconsin Department of Transportation (WSDOT) is at the forefront of this movement toward using 3D modeling in roadway construction. While many States recognize the benefits that 3D modeling can provide in earthwork operations in roadway construction, WSDOT's Return on Investment (ROI) calculation, using actual project data, shows that 3D modeling can result in even more significant gains during construction of roadway structures and features. WSDOT is currently verifying early ROI projections on the Zoo Interchange Project, a roadway interchange on the west side of Milwaukee.

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TECHBRIEF

3D Engineered Models for Construction
CASE STUDY FOR POLICIES AND ORGANIZATIONAL CHANGES FOR IMPLEMENTATION: THE KENTUCKY CASE STUDY

Introduction

The building construction industry began using three-dimensional (3D) engineered models in the 1990s because of the greater efficiency, reduced schedule, and reduced cost offered by this approach. Today, 3D modeling for building construction has become the standard for design and construction of commercial and industrial buildings. Known as Building Information Modeling (BIM), the concept goes beyond planning and design phases of the project and extends throughout the building life-cycle to support cost management, construction management, project management, and even facility operation.

While lagging behind BIM, the use of 3D models for horizontal construction, also known as Civil Integrated Management, represents roadway construction in digital form and has been shown to accelerate construction operations, improve accuracy, reduce cost, and increase safety on job sites.

Highway construction contractors began using 3D modeling for transportation projects in the 1990s. Typically, contractors would "reverse engineer" 2D plans developed by State agencies to use for automated machine guidance. Many State transportation agencies have developed the capability and resources to develop 3D models, with potential for use as legal and bidding documentation. However, State specifications typically are not written to accommodate the nuances associated with the full application of 3D modeling for roadway construction.

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TECHBRIEF

3D, 4D, and 5D ENGINEERED MODELS FOR CONSTRUCTION
EXECUTIVE SUMMARY / MARCH 2013

ABSTRACT

This Technical Brief provides an overview of 3D modeling, including technology applications during design and construction, benefits to stakeholders, resource requirements, current state-of-the-practice, and advanced applications such as adding 4D and 5D components.

- Improved project delivery
- Improved communication
- Enhanced identification of errors
- Improved visualization

Three-dimensional engineered models (3D models) for construction provide transportation agencies, contractors, and consultants a better understanding of design with a virtual representation of project design. 3D models allow for identification of potential conflicts and/or errors in design compared to traditional design and construction techniques using 2D plans and profiles. 3D models illustrate a project in a digital form that can then be analyzed to determine inconsistencies that would normally not be discovered until the construction phase. The model can be edited, rotated, and manipulated to provide various views of the designed roadway path and features. While there are design benefits to using 3D models with visualization capabilities, perhaps a more significant benefit is that the data can be processed and used to automate construction activities.

For the last two decades, the vertical construction industry has used 3D models to improve the process for constructing buildings and other structures. This same process has been applied to several states to the horizontal Highway construction industry. But more work can be done to achieve the same type of benefits for roadway design. Agencies might begin with pilot projects or perform a full transition from 2D to 3D design shops. Often, contractors lead implementation by developing 3D models post bid. 4D modeling allows stakeholders to visualize construction over the project duration to identify potential social/temporal conflicts in schedule. Adding a cost component to the process creates a 5th dimension, making it a 5D model. Such 3D engineered models allow stakeholders to evaluate costs and model clash from the early phase of construction.

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FHWA GUIDE DOCUMENTS

Guide for Using 3D Engineered Models for Construction Engineering and Inspection
Winter 2017

Guide for Creating and Maintaining 4D Models
Fall 2016

Guide for Efficient Geospatial Data Acquisition using LiDAR Surveying Technology
Spring 2016
FHWA EDC 3D WORKSHOPS
### Self-Assessment Tool

#### Project Phase Inputs

#### Applications Matrix
OUTLINES

• Definition of Intelligent Construction Technologies (ICT)
• FHWA ICT Efforts
• Key ICT – Benefits, Challenges and Solutions
• ICT Integration
• ICT Guidance
• Case Studies
KEY ICT TECHNOLOGIES

- Integrated Surveys
- Underground Utilities Location
- 3D Designs and Modeling
- Automation in Construction
- Real Time Monitoring and Inspection
- Civil Integrated Management
INTEGRATED SURVEYS
SURVEY DATA AND INTERACTION

- Surveyor
- Control and Calibration
- Verify
- DOT Inspector
- Inspection
- Contractor
- Model
- Pre-Construction

WisDOT
AIRBORNE, MOBILE & STATIC TERRENTIAL LIDAR
SURVEY PRECISION

• GPS is highly reliable horizontally
• GPS alone limited the vertical control required for the project
• Preconstruction CM team control checks / densification / vertical improvements
• Digital levels run through all primary control to allow tighter calibrations
• Verified control published to all contractors
VERTICAL PRECISION

- Fixed Wing Aerial Photogrammetry: ±6” (15cm)
- Low Altitude Helicopter Photogrammetry: ±1”~2” (2.5 ~ 5.0cm)
- Mobile LiDAR Laser Scanning: ±½”~1” (1.3 ~ 2.5cm)
- RTK GPS: ±½” ~1” (1.3 ~ 2.5cm)
- Static LiDAR: ±¼” ~½” (6.4 ~ 13 mm)
- Total Station: ±¼” ~½” (6.4 ~ 13 mm)
## LIDAR PRECISIONS

<table>
<thead>
<tr>
<th>Method</th>
<th>Network Accuracy (RMS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Wing Aerial LiDAR/Photogrammetry</td>
<td>3” - 6”</td>
</tr>
<tr>
<td>Low Altitude Helicopter LiDAR/Photogrammetry</td>
<td>1” - 2”</td>
</tr>
<tr>
<td>Mobile LiDAR</td>
<td>½” - 1”</td>
</tr>
<tr>
<td>Tripod-Mounted Static LiDAR</td>
<td>¼” - ½”</td>
</tr>
</tbody>
</table>
HIGH PRECISION & LOW DISTORTION - CORS
INTEGRATED SURVEY APPROACH

Mobile LiDAR scan area
Stationary scan area
Proposed Design

WisDOT
LIDAR POINT CLOUD
OPTIMIZE QUANTITY

Data Source:
3D Cloud Point Aerial Imagery

Process:
Add Breaklines and Mass Points Extract Topographic Features

Final Product:
GL2 Bare Earth Point Cloud DTM (Breaklines/Mass Points) CADD Topographic Drawing
# DATA FUSION TO CREATE DTM

<table>
<thead>
<tr>
<th>Derived Product: DTM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>File Types:</strong> Caice, DWG</td>
</tr>
<tr>
<td><strong>Processing Software:</strong> Trimble, Leica Cyclone, Caice, Civil 3D</td>
</tr>
</tbody>
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<td><strong>File Types:</strong> Caice, DWG, DGN</td>
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<thead>
<tr>
<th>Derived Product: DTM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>File Types:</strong> Caice, DWG, DGN, LAS</td>
</tr>
<tr>
<td><strong>Processing Software:</strong> Trimble, Leica Cyclone, Caice, Civil 3D, MicroStation, ArcGIS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reality Capture: DTM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3D Point Cloud with RGB Values</strong></td>
</tr>
<tr>
<td><strong>Survey 3D Features</strong></td>
</tr>
<tr>
<td><strong>File Types:</strong> Caice, DWG, DGN, LAS</td>
</tr>
<tr>
<td><strong>Processing Software:</strong> Trimble, Leica Cyclone, Caice, Civil 3D, MicroStation, ArcGIS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Added Value Product: 3D Survey Grade DTM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3D Elevation and Intensity Values</strong></td>
</tr>
<tr>
<td><strong>File Types:</strong> CADD, and GIS</td>
</tr>
</tbody>
</table>

Caltrans IICTG.org
KEY BENEFITS

Survey data collection time and cost savings
Improved safety

Example:
Utah DOT - Asset Management Mapping Grade LiDAR for Design (Searle et al. 2014)
24% cost savings, 22% time savings, increased safety
KEY BENEFITS

Increased level of **detail**, **accuracy**, and **scalability**

Example:
Alabama DOT: Evaluating Mobile Scanning Data for use within a State DOT (Russell 2012)
improved quantity estimates
rutting and pavement condition, guard rails, bridges, overhead utilities, signs, etc.
CHALLENGES

- Cost is the most significant challenge
- More evidence and education needed regarding the benefit-to-cost comparison

2013 Survey on mobile LiDAR at State DOTs (Hurwitz et al.)

<table>
<thead>
<tr>
<th>Challenges</th>
<th>Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost (Equipment and data collection)</td>
<td>Acquire and share info between agencies; i.e., Oregon LiDAR consortium</td>
</tr>
</tbody>
</table>
## CHALLENGES

<table>
<thead>
<tr>
<th>Challenges</th>
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</table>
| Lack of Standards, Interoperability| • American Society of Photogrammetry and Remote Sensing (ASPRS): LAS format  
• The ASTM E57 committee: format E57 for 3D imaging systems               |
| Data Management                    | • Positions to facilitate data flow between design and construction  
• Dedicated IT staff in design sections to support 3D design efforts       |
UNDERGROUND UTILITIES LOCATION
UNDERGROUND UTILITIES LOCATION

- 3D modeling software + underground location technologies
- 2015 FHWA Report: *Feasibility of Mapping and Marking Utilities* (Hatch Mott MacDonald)
KEY BENEFITS

More accurate information regarding existing utilities is needed, especially in urban environments,

• identify conflicts during design

• avoid guess work and digging during construction which results in significant cost, delays, change orders, claims, and damages.
CHALLENGES

• Agencies/designers work with inaccurate, low quality information from utility companies
• Liability for utility conflicts and relocation is placed on the contractor
## CHALLENGES

<table>
<thead>
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<tbody>
<tr>
<td>Unknown or mistakenly recorded utilities (<em>R01A Technologies to Support Storage, Retrieval, and Utilization of 3-D Utility Location Data</em>)</td>
</tr>
<tr>
<td>Locating underground utilities across a variety of soil conditions (<em>R01B Utility Locating Technology Development Utilizing Multi-Sensor Platforms</em>)</td>
</tr>
<tr>
<td>Locating deep underground utilities (<em>R01C Innovation in Location of Deep Utility Pipes and Tunnels</em>)</td>
</tr>
</tbody>
</table>
3D DESIGN AND MODELS
3D COMPUTER-AIDED DESIGN MODEL

• Real-time field verification with GPS rovers,
• Surface-to-surface accurate volume, and
• Export design information shared by designers, surveyors, and inspectors.
• 3D design is a key process for implementing ICST.
3D MODELING

• 3D design is a key process for implementing automation in construction
  • Transition from 2D to 3D design at DOTs has been driven by contractors using Automated Machine Guidance
• Once transition to 3D design is underway, DOTs benefit of 3D modeling throughout all phases of a highway project
3D SOFTWARE TOOLS

• Civil 3D
  • CM team wanted to use C3D to work within the new approved software platform and help develop the DOT process. Started with the idea of having an independent model to check against contractor model.
  • Software wasn’t ready for a model of this scale.

• Terramodel
  • Changed to Terramodel to integrate and collaborate more efficiently with the contractors model
3D DESIGN AND MODELING

3D Modeling Environment → 2D Design Products → 3D Model Building → GPS Machine Guidance

Design

3D Modeling Environment → 3D Design / Construct Model → GPS Machine Guidance

Construction

a. Current

b. Desired
WORK FLOW COMPARISON

- Horizontal and Vertical Alignment
- Roadway Modeler
- Create DTM To Match Plan Graphics
  - Cross Sections
  - Miscellaneous Tables
  - Estimate
- Profile Graphics

- Horizontal and Vertical Alignment
- Roadway Model and Edit Surface Commands
- Create Engineering Content
  - Cross Sections
  - Plan Graphics
  - Miscellaneous Tables
  - Profile Graphics
  - Design Archive for Estimates, Stackout, and Inspection
3D DESIGN AND VISUALIZATION

Mitchell Interchange I-94/I-43 Corridor
2D DRAWING VS 3D DESIGN/MODEL

Photos

2D Drawing

3D Design/Model
3D MODELING THRU ALL PHASES

Option 1: Stonepile centered Roundabout

Extra Protection Barrier - Truck Apron

Barrier - Style and Material to be determined

Only existing barrier - Historic stone barrier to be left in place
AS-BUILT 4D MODEL AND SITE PHOTOS

Photos

4D Model for Specific date
KEY BENEFITS

• More accurate construction documents and 3D as-built plans
• Visualization for engineering analysis and communication with the public
• Detection of issues before construction, conflict resolution applications (i.e. utilities)
• Automated Machine Guidance (AMG), quantities calculations, etc.
CHALLENGES

- How to quantify implementation cost?
- Direct method to document ROI?

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Solution Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implementation Cost</td>
<td>• Begin with 3D design for mega/large projects, then work agency wide implementation</td>
</tr>
<tr>
<td></td>
<td>• Begin with smaller projects and build on experience</td>
</tr>
</tbody>
</table>
## CHALLENGES

<table>
<thead>
<tr>
<th>Challenge</th>
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</table>
| Lack of Standards, Interoperability           | • Meetings with industry associations and contractors  
• Collaboration with technology vendors, equipment manufacturers, etc. |
| Specialized Training and Software             | DOTs handle transition and training **individually** since it requires organizational and cultural changes |
## CHALLENGES

<table>
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</table>
| Contractual and Legal Issues     | Incremental steps towards this goal, e.g.:  
  • Replaced 2D plans with PDF sealed with a digital signature  
  • Release 3D models for information only, with disclaimers |
| Model Certification/Review       | Design-construction reviews for megaprojects with designers, consultants, construction, and industry personnel |
CONSTRUCTION AUTOMATION
MODEL USE DURING CONSTRUCTION

Model correction to avoid excessive waste

Original Berm Design

Proposed revision to accommodate 33,000 cubic yards of waste
MODEL USE DURING CONSTRUCTION

Model and as built shots used to mediate disputes between contractors
GRADE CONTROL WITH GPS AND UTS

Grade Control System

From 2D to 3D

GCS900

GCS400

UTS

 Courtesy Trimble
3D MILLING

GCS900 Grade Control System
3D UTS HMA PAVING
3D UTS HMA Paving
BENEFITS

• Better control of quantities
• Increased productivity
• Increased accuracy and precision
• More uniform surfaces
• Reduced surveying cost and time
• Fuel savings
• Increased safety
COST AND ROI

• Cost and ROI information is scattered
• Case studies available are at a project level, not representing agency wide figures.
• Direct method to document ROI?
  • DOTs: construction bids
  • Contractors: quantities overruns
## CHALLENGES

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Solutions</th>
</tr>
</thead>
</table>
| Lack of 3D Models          | • Contractors “reengineer” 3D model from 2D plans  
• Pilot projects to evaluate 3D surface model standards and data flows  
• Some DOTs deliver 3D surfaces/models from design and support AMG usage by contractors |
| Lack of Training / Education | • Pilot projects to illustrate utilities and benefits  
• For all parties: designers, inspectors (i.e. GPS equipment calibration), equipment operators, etc. |
**CHALLENGES**

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Solutions</th>
</tr>
</thead>
</table>
| Lack of Specifications and Inspection Procedures | Specification and special provisions have been developed by DOTs, many based on pilot studies.  
  - NCHRP 10-77: This project is to develop AMG guidelines  
  - AASHTO’s AMG Quick Reference Guide |
REAL TIME MONITORING & INSPECTION
REAL TIME MONITORING & INSPECTION
INTELLIGENT COMPACTION

Global Position System (GPS)

Continuous Measurement System

Onboard Report system

Courtesy Bomag
Traditional Compaction Testing Method

1 / 1,000,000

Compaction Testing and Coverage Mapping with AccuGrade

100 % Coverage
Asphalt IC
SOILS IC VS. ASPHALT IC
SINGLE DRUM IC ROLLERS

- Ammann-Case
- Caterpillar
- HAMM-Wirtgen

Soils and Subbase

- BOMAG
- Dynapac-Atlas Copco
- Sakai
DOUBLE DRUM IC ROLLERS

- BOMAG
- Hamm-Wirtgen
- Dynapac-Atlas Copco

Asphalt

- Caterpillar
- Sakai
- Volvo
IC RETROFIT SYSTEM

- CCS900
- CB460
- MS992
- CI310
- IS310
- SNM940
- CM310

Courtesy of Trimble/SITECH
GPS Antenna

MCI-3 and Satel Radio

Accelerometer

Infrared Temperature Sensor

GX-60

Courtesy of Topcon/RDO
ICMV

Intelligent Compaction Measurement Value
DEFORMATION OF MATERIALS DURING COMPACTION

Plastic + Elastic Deformation
ACCELEROMETER-BASED ICMV
VARIOUS ICMV
US NCHRP 24-45 IC STUDY

De-Coupled Layer Moduli

2015 - 2018
DE-COUPLED LAYER MODULI

Layer deformation modulus

- $E_1$
- $E_0$

$E_1$ = Layer modulus of compacted layer
$E_0$ = Subgrade modulus

Equivalent deformation modulus

$E_{Vib}$
$F_B$
$W$

measuring depth effect

deflection $w$
deformation curve

Courtesy of Bomag
LAYER MODULI - FROM THE GROUND UP
IC/TP data

Spot test data

Manual USB

Vendor’s cloud Server

Automatic

Manual

Data Export

USB, email, etc.

VETA

INTELLIGENT CONSTRUCTION
GPR TO MEASURE HMA DENSITY
GOMACO Smoothness Indicator (GSI)

Ames Real Time Profiler (RTP)

REAL TIME SMOOTHNESS
INSPECTION WITH ROVER

- Grade checks
- Structures
  - Wall alignments
  - Sign bridge footings
  - Structure excavation
- Pavement marking layout
- Pay quantity measurements
Pre-Mapping Subbase

Asphalt Compaction

TPF IC MNDOT Project
Premature Failure

Approximate location of subgrade section failed during test rolling (~ Sta. 134+00 to 144+00)

Approximate location of HA+MA non-wearing course layer failure due to construction traffic (~ Sta. 140+12 to 142+61)

Approximate location of subgrade section failed during test rolling (~ Sta. 134+00 to 144+00)

Approximate location of HA+MA non-wearing course layer failure due to construction traffic (~ Sta. 140+12 to 142+61)

HMA Map

Subbase Map
IC IDENTIFIES CAUSES OF FAILURES

- Failed density due to static passes
- Passed density with vib passes
- Aided using IC
IC BENEFITS

Before

After
IC IMPROVES CONSISTENCY

Lift 1 without IC
< 3 Passes: 31 %
≥ 3 Passes: 69 %
COV: 71%

Lift 2 with IC
< 3 Passes: 10 %
≥ 3 Passes: 90 %
COV: 55%

30% Increase in Compaction Efforts

IC IMPROVES CONSISTENCY
BENEFITS

• Less coring of new and existing pavements/structures, labor intensive tests
• Improved materials quality with faster feedback, and continuous and more complete coverage
• Uniformity and consistency
• Fuel/operation savings
BENEFITS

• Increased efficiency and productivity
• Improved communication
• Safety
CHALLENGES

Cost and ROI information associated with these technologies varies widely

• Not used routinely by DOTs
• Still undergoing R&D

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology and Implementation Cost</td>
<td>Education and unbiased publications with project data documenting cost and time savings.</td>
</tr>
</tbody>
</table>
### CHALLENGES

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Solution Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of Awareness</td>
<td>Demonstrations and publications by national agencies such as FHWA, NCHRP, SHRP2, etc.</td>
</tr>
</tbody>
</table>
| Lack of Training / Education | • Pilot projects to illustrate utilities and benefits  
|                            | • Case studies  
|                            | • Customized workshops focusing on advanced technologies for field technicians and inspectors |
OUTLINES

• Definition of Intelligent Construction Technologies (ICT)
• FHWA ICT Efforts
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• **ICT Integration**
• ICT Guidance
• Case Studies
CONSTRUCTION/DATA MANAGEMENT

• Construction Management
  • 3D Modeling
  • 4D Modeling (3D + work progress)
  • Project Visualization
• Automated Data Management
  • Link Field, Office and Material Suppliers
Connected via Cloud

Office Staff

Internet

Connected Community

Internet

Internet

Field Crew

Job Site Trailer

Trimble
DATA INTEGRATION FOR IC

IC/TP data

Spot test data

Vendor’s cloud Server

Manual or Automatic

FTP/HTTP

Data Export

USB, email, etc.

Manual
3D-CENTRIC INTEGRATION
Construction/Data Management

Project Scheduling / Construction Staging
4D MODEL AND DATA MANAGEMENT
CIM - CIVIL INTEGRATED MANAGEMENT
GIS – CIM - BIM
GIS – CIM - BIM
CIM-VDC PROCESS

- The databases, tools & processes use multidisciplinary performance models of design & construction input such as:
  - Building or Civil Information Models (3D),
  - CPM Schedules (4D),
  - Cost Estimates (5D) and
  - Specifications (6D)

To simulate & validate project objectives.
INTEGRATION OF SOFTWARE TOOLS & PROCESSES
BIM-VDC LIFE CYCLE
EFFICIENT ASSET MANAGEMENT
# BENEFITS OF EFFICIENT ASSET MANAGEMENT

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

.....involve with many stakeholders and partners in construction
## IMPLEMENTING AUTOMATION TECHNOLOGY

### Sample Resource Assignment Matrix (RAM)

<table>
<thead>
<tr>
<th>Initiative</th>
<th>Status</th>
<th>Task No.</th>
<th>Description</th>
<th>Start Date</th>
<th>End Date</th>
<th>Sponsor</th>
<th>Committee Chair</th>
<th>Initiative 2 Leader</th>
<th>Initiative 3 Leader</th>
<th>Stakeholder Group 1</th>
<th>Stakeholder Group 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiative 1</td>
<td>green</td>
<td>1</td>
<td>Coordination</td>
<td>1/1/15</td>
<td>ongoing</td>
<td></td>
<td>T</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coordination</td>
<td>green</td>
<td>1.1</td>
<td>Form an Implementation Team</td>
<td>1/1/15</td>
<td>2/28/15</td>
<td>C</td>
<td>A</td>
<td>R</td>
<td>R</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Coordination</td>
<td>green</td>
<td>1.2</td>
<td>Hold quarterly team meetings</td>
<td>3/1/15</td>
<td>ongoing</td>
<td>I</td>
<td>A</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
</tbody>
</table>
Rapid Deployment

a small team with decision-making power
executive sponsor/manage the implementation
<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>
GUIDELINES

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>
GUIDELINES
TOPOGRAPHIC SURVEY ACCURACIES

Constraint Feature
H +/- 0.04 ft
V +/- 0.02 ft
5-ft spacing

Design Feature
H +/- 0.1 ft
V +/- 0.04 ft
10-ft spacing

Location Feature
H +/- 0.25 ft
V +/- 0.1 ft
25-ft spacing

Planning Feature
H +/- 0.5 ft
V +/- 0.5 ft
50-ft spacing
<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>
GUIDELINES

SUBSURFACE UTILITY LOCATION

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

tunnel portal
GUIDELINES

SUBSURFACE UTILITY DATA MANAGEMENT

Use color and levels to distinguish between the different quality levels of subsurface utility data.
### CADD Data Type for Automation

<table>
<thead>
<tr>
<th>CADD Data Type for Automation</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>alignment, surface &amp; 3D line strings</strong></td>
<td>Roadways, interchanges, intersections</td>
</tr>
<tr>
<td><strong>surface &amp; 3D line strings</strong></td>
<td>Side slopes, gore areas, sidewalks and paths, lane width transitions, culvert headwall grading, guardrail berm transitions, benching transitions, bridge abutments, storm water ponds, ditches and swales</td>
</tr>
<tr>
<td><strong>3D line strings</strong></td>
<td>Pavement markings, curbs and gutters, retaining walls, sewer inverts</td>
</tr>
</tbody>
</table>
3D models are incomplete and imperfect. Data density must be sufficient to depict the design intent with the fidelity needed for automation technologies.
GUIDELINES
4D MODEL STANDARD

1. Identify Usage Cases
2. Identify Target Audiences
3. Determine 3D Model Content
4. Determine Schedule Resolution & Time Step
5. Determine Geometric Accuracy and Segmentation
6. Define 4D/5D Modeling Products
GUIDELINES
3D MODEL REVIEWS

- Triangles
- Contours (0.1 ft)
- Flow arrows
- Slopes
### Section of Standard 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>
GUIDELINES

ESTABLISHING A MODEL OF RECORD

<table>
<thead>
<tr>
<th>Name</th>
<th>Size</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>\81-1961-021_E_Files_(DataFiles)\Alignment_Data_Files</td>
<td></td>
<td></td>
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<tr>
<td>hv_dsn_021.xml</td>
<td>275.4 KB</td>
<td>12/12/2014 11:17</td>
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<tr>
<td>\81-1961-021_E_Files_(DataFiles)\Machine_Control_Surfaces</td>
<td></td>
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<tr>
<td>existing_surface_021.xml</td>
<td>21.7 MB</td>
<td>12/12/2014 11:27</td>
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<tr>
<td>existing_surface_Stage2.xml</td>
<td>129.3 MB</td>
<td>12/12/2014 11:27</td>
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<tr>
<td>prop_surf_subgrade_completeA.xml</td>
<td></td>
<td>12/12/2014 11:28</td>
</tr>
</tbody>
</table>
GUIDELINES

AGREEING CONTROL & SITE LOCALIZATION

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

REAL-TIME VERIFICATION

Let Project
Agree Work Plan
Select tools
Define Data Needs
Capture Data
Get real-time Feedback
Perform Data Quality Control
Accept Work
Compute Quantities
Store digital as-built records
OUTLINES

• Definition of Intelligent Construction Technologies (ICT)
• FHWA ICT Efforts
• Key ICT – Benefits, Challenges and Solutions
• ICT Integration
• ICT Guidance
• Case Studies
3D SURVEY AND UNDERGROUND CASE STUDIES

• 3D LiDAR

• Underground facility case studies

Courtesy Russell (2012)
CONSTRUCTION MANAGEMENT CASE STUDIES

- Fleet Management
- AMG for Excavation

Courtesy Jim Preston of TOPCON
<table>
<thead>
<tr>
<th>Machine</th>
<th>Type</th>
<th>Status</th>
<th>Operator</th>
<th>Activity</th>
<th>Surface</th>
<th>Alignment</th>
<th>As-built</th>
<th>Position (nez)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPS_Excavator03</td>
<td>Excavator</td>
<td>Online</td>
<td>PeterW</td>
<td>Cutting grade</td>
<td>TIN, Design1</td>
<td>N/A</td>
<td>Grid Small 732094.500, 292011.910, 66.630</td>
<td></td>
</tr>
<tr>
<td>TPS_Bulldozer01</td>
<td>Bulldozer</td>
<td>Online</td>
<td>Peter</td>
<td>Dozer Push</td>
<td>TIN, Design1</td>
<td>N/A</td>
<td>Grid Small 732073.102, 292069.470, 65.597</td>
<td></td>
</tr>
<tr>
<td>TPS_MotorGrader02</td>
<td>Motor Grader</td>
<td>Online</td>
<td>TonyT</td>
<td>Fine grading</td>
<td>TIN, Design1</td>
<td>N/A</td>
<td>Grid Small 732518.607, 292113.950, 50.161</td>
<td></td>
</tr>
</tbody>
</table>
WISDOT CASE STUDIES

• Zoo Interchange
• Watertown Plank Road Interchange

Courtesy Lance Parve of WisDOT
I 80 INTEGRATED CORRIDOR MOBILITY PROJECT

Courtesy Brendan Hafferty of FORUM8
PATH TO ICT

• Identify More Relevant Technologies
• Quantify the Benefits and ROI
• Identify Challenges and Solutions
• Future Technology Development & Implementation
• Tighter integration
• A Framework for ICT
FHWA IC SUPPORT

- Technical Support Service Center (TSSC)
- Phone: +1 (512) 659-1231
- Email: ICSupport@TheTranstecGroup.com
- 5 days a week (Monday - Friday)
- 8:00am to 5:00pm CST
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Thank You!

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