GPS/GIS Inspection and Analysis Tools for Highway Construction

By
Sastry Putcha\textsuperscript{1}, Dean Bowman\textsuperscript{2}, and John Sobanjo\textsuperscript{3}

\textsuperscript{1} FDOT Construction Office
\textsuperscript{2} Bentley Systems, Inc.
\textsuperscript{3} Florida State University

March 2, 2005
GPS/GIS Inspection and Analysis Tools for Highway Construction:

Project Motivation: The Construction Inspection Process

- Manual Methods Currently Being Used for Field Data Entry and Measurement of Pay Item's Quantities
  - Spatial (Location) Attributes of Constructed Items Not Effectively Documented (Except as Final As-Built Drawing) – Planned vs. Actual Location
  - Field Inspection Typically Done Based on Hardcopy Print of Drawings and Specifications
  - No Electronic Documentation of Inspection History
GPS/GIS Inspection and Analysis Tools for Highway Construction:
Proposed Solutions: The Construction Inspection Process

- **Integrated GPS/GIS Application for Inspection and Analysis**
  - FDOT’s Microstation drawings converted into Geographical Information System (GIS) Basemaps, with correction to the proper projections; Specifications; and Pay Items' Original Quantities.
  - Database to Store Inspection Results: Observed Quality of Construction, Lab. Test Results, etc. and Digital Images
  - GIS Analyses and Database Queries Provide Monthly Display of Construction Progress and Estimate of Quantities, including As-Built Final Drawings and Quantities.
Customization of the Bentley® Construction Handheld for Florida DOT Pay Items

- Access to Design Data While the Inspector Observations Are Recorded at the Most Convenient Time and Location - in the Field While Construction Is Occurring
- Subsequent Manual Calculations in the Office Are Often Not Longer Necessary.
- Incessant Filling Out of Forms and Transcribing Is Reduced.
- A Complete Compendium of All Previous Inspection Activities Is Readily Available to Inspectors While in the Field. Reviews Can Be Stratified by One or More Inspectors, Date Ranges and Type of Inspection Activity.
GPS/GIS Inspection and Analysis Tools for Highway Construction:

Project Objectives

- Integration of Global Positioning System (GPS) and Geographic Information System (GIS) to Model Temporal Spatial Data and Pay Item Attributes on the Construction Site; GIS-Based Analyses to Estimate Quantities, Display As-Builts and Digital Images.

- A Pilot Study Using the Bentley Construction Handheld Software to Perform Certain Specialty Inspections Such As Bituminous Materials, Concrete Placement and Pile Driving Information.

Develop tools, based on modern technologies that can be used by the FDOT for inspection of ongoing roadway and bridge construction projects.
GPS/GIS Inspection and Analysis Tools for Highway Construction:

*Project Tasks:*

- Project Kickoff and Literature Review
- Develop Framework and Methodology of GPS/GIS Tools
- Data Review and Preparation for the Pilot Study
- Develop Computer Programs for Bentley Construction Handheld
- Develop Computer Programs for GPS/GIS Tools
- Conduct Pilot Study
- Analyses of Data and Results
- Final Report
GPS/GIS Inspection and Analysis Tools for Highway Construction:  
*Project Tasks: Details*

- **Project Kickoff and Literature Review**
  - Identify State-of the Art.
  - Visit Project Pilot Site and Collect Preliminary Data.
  - Identify Pertinent Pay Items for Study.

- **Develop Framework and Methodology of GPS/GIS Tools**
  - Selection of GPS Receivers and Accuracy Enhancement (Correction) Methods.
  - Establish Interoperability Between CAD (Bentley’s Microstation) and ESRI’s GIS Formats.
  - Database Structure Based on FDOT Pay Items and Pertinent Attributes: Method of Construction; Unit and Method of Measurement; and Basis of Payment.
GPS/GIS Inspection and Analysis Tools for Highway Construction:  
*Project Tasks: Details*

- **Data Review and Preparation for the Pilot Study**
  - SR 817 University Drive Project.
  - Request for Project Contract Documents (Drawings and Specifications).
  - Review and Transfer of Project Data Files: Microstation Files, GEOPAK Geometry File (GPK), Drainage Database, and Quantity Manager Database.

- **Develop Computer Programs for Bentley Construction Handheld**
  - Custom VB.NET Applications for Standard FDOT Report and Specialty Inspections.
GPS/GIS Inspection and Analysis Tools for Highway Construction:
Project Tasks: Details

- **Develop Computer Programs for GPS/GIS Tools**
  - Computer Programs to Customize the GIS Software, Enabling Both Data Capture With the GPS Receivers and Also Conducting Analyses to Generate Tabular and Graphic Reports.

- **Conduct Pilot Study**
  - GPS Data Capture of Constructed Pay Items.
  - Use of Bentley’s Construction Handheld to Inspect Constructed Pay items.

- **Analyses of Data and Results**
  - Processing of GPS Data and GIS Analyses.
  - Integration of GPS/GIS Tools and Bentley’s Construction Handheld.

- **Final Report**
GPS/GIS Inspection and Analysis Tools for Highway Construction:

Pilot Project Site:

- **State Road:** 817 (University Drive)
- **Financial Project:** ID 228079-1-32-01
- **County/Section:** Broward / 86220
- **Limits:** North of SR-84 to just South of Broward Blvd (SR-842)
- **Description:** Milling and Resurfacing
GPS/GIS Inspection and Analysis Tools for Highway Construction:
Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida
Meeting with Resident Engineer:
- Project Overview, and Overall Progress Update.
- Site Tour With Resident Engineer.

Collection of GPS Data at Broward Blvd. End of Project
- FDOT Survey Control Point; Point Feature Pay Item; Line Feature Pay Item; and Area Feature Pay Item.

Preliminary Data Transfer and Display
- Microstation – GIS Basemap Conversion; GPS Data Correction Process; Integration of GPS Data with GIS Basemap; Observed Accuracies and Discrepancies.
GPS/GIS Inspection and Analysis Tools for Highway Construction:
Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida

Trimble GeoXT GPS Receiver ($4,000)

Compaq Pocket PC ($300) with Pharos GPS Receiver ($150)

Project Drawing Converted to GIS Basemap
GPS/GIS Inspection and Analysis Tools for Highway Construction:

Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida

**Variation in (X,Y) Data at FDOT Survey Control Point (HBLC6)**
*To be used for Vertical Control Only*
GPS/GIS Inspection and Analysis Tools for Highway Construction:

Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida

Evaluation of Pay Items for Spatial Location Data Relevance

- ROADWAY (89)
- SIGNING (14)
- LIGHTING (19)
- SIGNALIZATION (50)
- LANDSCAPE / PERIPHERAL (14)

Percent Relevance of GPS Data

NEED LOCATION FOR PAY ITEM? % (YES)
GPS/GIS Inspection and Analysis Tools for Highway Construction:

Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida

Evaluation of Pay Items for Spatial Data Relevance

Pay Item Category

- ROADWAY (85)
- SIGNING (14)
- LIGHTINGS (19)
- SIGNALIZATION (60)
- LANDSCAPE / PERIPHERAL (14)

Percent Relevance of GPS Data:
- NEED LOCATION FOR PAY ITEM? % (YES)
- SPATIAL DATA NEEDED FOR QUANTITIES? % (YES)
- DATA NEEDED FOR LOCATION % (X,Y)
- DATA ADEQUATE FOR QUANTITIES % (X,Y)
- QUANTITY IN DIRECT PAY ITEM UNITS? % (YES)
GPS/GIS Inspection and Analysis Tools for Highway Construction:  
Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida

![Evaluation of Pay Items for Spatial Data Relevance](chart)

- **Pay Item Category**
  - ROADWAY (60)
  - SIGNING (14)
  - LIGHTINGS (19)
  - SIGNALIZATION (50)
  - LANDSCAPE / PERIPHERAL (14)

- **Percent Relevance of GPS Data**
  - NEED LOCATION FOR PAY ITEM? (%YES)
  - DATA ADEQUATE FOR QUANTITIES (%(X,Y))
  - QUANTITY IN DIRECT PAY ITEM UNITS? (%YES)
GPS/GIS Inspection and Analysis Tools for Highway Construction:
Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida

<table>
<thead>
<tr>
<th></th>
<th>SPATIAL DATA RELEVANT FOR LOCATION? (%(YES/NO))</th>
<th>SPATIAL DATA NEED FOR LOCATION (%(X,Y)/(X,Y,Z))</th>
<th>SPATIAL DATA RELEVANT FOR QUANTITIES? (%(YES/NO))</th>
<th>SPATIAL DATA NEED FOR QUANTITIES (%(X,Y)/(X,Y,Z))</th>
<th>DIRECT PAY ITEM UNITS (%(YES/NO))</th>
</tr>
</thead>
<tbody>
<tr>
<td>0001 SUMMARY OF ROADWAY (83)</td>
<td>92.8</td>
<td>100.0</td>
<td>92.8</td>
<td>90.9</td>
<td>77.9</td>
</tr>
<tr>
<td></td>
<td>7.2</td>
<td>0.0</td>
<td>7.2</td>
<td>9.1</td>
<td>22.1</td>
</tr>
<tr>
<td>0002 SUMMARY OF SIGNING (14)</td>
<td>100.0</td>
<td>100.0</td>
<td>92.9</td>
<td>92.9</td>
<td>92.9</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>7.1</td>
<td>7.1</td>
<td>7.1</td>
</tr>
<tr>
<td>0003 SUMMARY OF LIGHTINGS (19)</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>94.7</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>5.3</td>
<td>0.0</td>
</tr>
<tr>
<td>0004 SUMMARY OF SIGNALIZATION (50)</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>0005 SUMMARY OF LANDSCAPE / PERIPHERAL (14)</td>
<td>78.6</td>
<td>100.0</td>
<td>90.9</td>
<td>90.9</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>21.4</td>
<td>0.0</td>
<td>9.1</td>
<td>9.1</td>
<td>0.0</td>
</tr>
</tbody>
</table>
GPS/GIS Inspection and Analysis Tools for Highway Construction:
Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida

Following Slides Show Microstation Drawings for Some Pay Item Locations
* Sidewalk/Bus Stop Concrete Slab
* Traffic Signs
* Curb and Gutter
GPS/GIS Inspection and Analysis Tools for Highway Construction: Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida
GPS/GIS Inspection and Analysis Tools for Highway Construction: Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida
GPS/GIS Inspection and Analysis Tools for Highway Construction: Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida
GPS/GIS Inspection and Analysis Tools for Highway Construction: Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida
GPS/GIS Inspection and Analysis Tools for Highway Construction: Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida
Following Slides Show Some Pay Item Locations on the GIS Basemaps, Including Trimble GeoXT GPS Differential-Corrected Locations Relative to the Original Drawings’ Locations

* Sidewalk/Bus Stop Concrete Slab
* Traffic Signs
* Curb and Gutter
GPS/GIS Inspection and Analysis Tools for Highway Construction: Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida
GPS/GIS Inspection and Analysis Tools for Highway Construction: Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida
GPS/GIS Inspection and Analysis Tools for Highway Construction: Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida
GPS/GIS Inspection and Analysis Tools for Highway Construction: Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida
GPS/GIS Inspection and Analysis Tools for Highway Construction: Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida
GPS/GIS Inspection and Analysis Tools for Highway Construction: Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida
GPS/GIS Inspection and Analysis Tools for Highway Construction: Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida
GPS/GIS Inspection and Analysis Tools for Highway Construction: Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida
GPS/GIS Inspection and Analysis Tools for Highway Construction: Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida
GPS/GIS Inspection and Analysis Tools for Highway Construction: Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida
GPS/GIS Inspection and Analysis Tools for Highway Construction: Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida
GPS/GIS Inspection and Analysis Tools for Highway Construction: Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida
GPS/GIS Inspection and Analysis Tools for Highway Construction: Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida
Following Slides Show Site Photographs of Some Pay Item Locations Indicated on the GIS Basemap.

* Sidewalk/Bus Stop Concrete Slab
* Traffic Signs
* Curb and Gutter
GPS/GIS Inspection and Analysis Tools for Highway Construction: Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida
GPS/GIS Inspection and Analysis Tools for Highway Construction: Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida
GPS/GIS Inspection and Analysis Tools for Highway Construction:

Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida
GPS/GIS Inspection and Analysis Tools for Highway Construction: Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida
GPS/GIS Inspection and Analysis Tools for Highway Construction: Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida
GPS/GIS Inspection and Analysis Tools for Highway Construction: Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida
GPS/GIS Inspection and Analysis Tools for Highway Construction: Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida
GPS/GIS Inspection and Analysis Tools for Highway Construction: Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida
GPS/GIS Inspection and Analysis Tools for Highway Construction:

Site Visit and Preliminary Data Collection at SR 817 University Drive, Fort Lauderdale, Florida

Following Slides Show Screen Captures of the Trimble GeoXT GPS Receiver
GPS/GIS Inspection and Analysis Tools for Highway Construction: GPS Receiver Data Collection
GPS/GIS Inspection and Analysis Tools for Highway Construction: GPS Receiver Data Collection
GPS/GIS Inspection and Analysis Tools for Highway Construction:
GPS Receiver Data Collection
GPS/GIS Inspection and Analysis Tools for Highway Construction:

GPS Receiver Data Collection
GPS/GIS Inspection and Analysis Tools for Highway Construction:

Following Slides Show Proposed Applications of the Bentley's Construction Handheld
GPS/GIS Inspection and Analysis Tools for Highway Construction: 
Bentley’s Construction Handheld

In-field Automation via Handheld Devices – Easy to Use

Feature Query

Spatial Query
GPS/GIS Inspection and Analysis Tools for Highway Construction: 
*Bentley’s Construction Handheld*

**In-field Automation via Handheld Devices – Location Assistance**
This is what’s there now; this is what I want to build

Background graphics added to graphical display
GPS/GIS Inspection and Analysis Tools for Highway Construction: 
*Bentley’s Construction Handheld*

**In-field Automation via Handheld Devices – Info Feature**
Everything you want to know about the design

Drainage structure data provided by Info Command
GPS/GIS Inspection and Analysis Tools for Highway Construction:
Bentley’s Construction Handheld

Construction Inspection

Inspect by selecting graphical entities
- Graphical reference to all inspection activities
- Final project rectification easier

Support for wide range of automated measuring techniques: GPS, Atlanta Laser...
Paperwork reduction: Keep inspectors in field rather than in office filling out forms
Spec Book, Special Provisions, Standard Drawings and Standard Inspection Procedures Accessible on Handheld
- Tied directly to graphics/pay items

Support for Visual Basic to customize for specific agency procedures and output formats
- Summary Reports
- Specialized Inspections

Feeds Business-side systems such as AASHTO SiteManager

As-builts will be created during typical Inspection measurements with emergence of VRS/CORS
GPS/GIS Inspection and Analysis Tools for Highway Construction: Bentley’s Construction Handheld

Inspection

Graphical based: If a picture is worth a thousand words...

Graphical layout of all inspection activities filtered by inspector, date, pay item, spatial area
Construction Inspection

Spec Book, Special Provisions, Standard Drawings and Standard Inspection Procedures Accessible on Handheld

- Tied directly to graphics/pay items
GPS/GIS Inspection and Analysis Tools for Highway Construction:  
*Bentley’s Construction Handheld*

Creating As-builds with a Future

As-builds via Inspector-ready Rovers:
- Trimble – VRS
- Leica - CORS

*Courtesy of Trimble*
GPS/GIS Inspection and Analysis Tools for Highway Construction: Bentley’s Construction Handheld

Input to Business Systems

Streamline Input to Business Systems: Graphical identification of the project component negates the need to manually transcribe onto forms.
Construction Management

Summary of all inspection and stake out activities:

- Maintained in comprehensive database that acts like an electronic field book
- Graphical overlays provide comprehensive summary on current inspection and stake out status
- Queries:
  - By date range, personnel, activity
  - Review field generated RFIs, ordered services
- Any type of customized report available
- For Resident Engineers, District Construction Engineer, etc.
GPS/GIS Inspection and Analysis Tools for Highway Construction: Bentley’s Construction Handheld

IDR and Other Reports

VB.NET interface available for comprehensive customization

- Design Archive
  - Geometry
  - DTM
- Field Product Database
  - User
  - Operation
  - Time Frame
  - Pay Item
GPS/GIS Inspection and Analysis Tools for Highway Construction:

THANK YOU!

ANY QUESTIONS?