GIS and Transportation

Fall 2011
Edward McCormack

Washington State Transportation Center
Civil and Environmental Engineering
GIS for Transportation (GIS-T)

• Applications
  – Traffic Engineering
  – Transportation Planning
  – Technology / Intelligent Transportation Systems (ITS) Applications

• Sources of GIS data
What is Special about a GIS-T

- Reliance on network data
- Many GIS polygons (areas or zones) are defined by roads—which in transportation are features in themselves
- Require variable data along a network (pavement type, traffic volumes, crashes)
- Multiple lanes in a link (arc)
- Planar vis non-planar (intersection or overpass?)
GIS-T Software

- ArcView has a growing number of transportation functions
- Other specialized GIS-T packages such as TransCAD, Intergraph are available

A Powerful GIS for Transportation

TransCAD is a state-of-the-art GIS that you can use to create and customize maps, build and maintain geographic data sets, and perform many different types of spatial analysis. TransCAD includes sophisticated GIS features such as polygon overlay, buffering, and geocoding, and has an open system architecture that supports data sharing on local- and wide-area networks.
GIS and Traffic Engineering
Traffic Safety Studies

- Crashes are recorded on an accident report form
- Location of crash is recorded
- Simple to use GIS to locate crash on roadway and then analyze by crash type, cause, severity, etc.
Crashes Involving Domestic Animals

Washington State (east)
Crashes Involving Wild Animals

Washington State (east)
Ice Warning Sign

WATCH FOR ICE
Ice Warning Sign Policy

[Map showing coverage of ice warning signs across the United States]
WSDOT Maintenance Areas
Many GIS Based Safety Applications
GIS-T Data Needs

• Point data: sign location, crash site
• Length data: shoulder width, number of lanes
• Time data: new pavement in 2003
• Route data: I-90, Milepost 29.02, intersection of Brooklyn and 45th Street
• Zone Data: In the City of Seattle
Solutions to GIS-T Data Needs?

- Unique roadway database
- Change segment for each data change
- Fixed segments

Or

- Dynamic Segmentation
**Dynamic Segmentation Approach**

- **Lane Widths**
- **AADT**
- **Sufficiency Ratings**
- **Bridges**

- Data are maintained in individual tables, limiting data redundancy.
- Attributes describe varying extents along a section of roadway.
- Graphic representations of attribute data are generated “on the fly.”
Dynamic Segmentation Analysis

Speed Limit
35 45 55

AADT Values
30000 22000

Pavement Type
Asphalt Concrete Asphalt

Skid Values
34 30 32

GIS Query Results
where: Speed => 45
AADT < 25000
Pavement = Asphalt
Skid Value =< 30
Dynamic Segmentation

- Events (crashes, pavement type, etc) are related to a route segment where the segments are not pre-defined.
- The extent of the segments change based on the criteria used to define segments.
Dynamic Segmentation

- Uses a series of cross referenced tables to that link each type of information to the appropriate street segments.
- Uses a **linear or distance referencing** system such as mileposts
- GIS converts mileposts to lat-long and turns data into a “layer”
Why You Need Linear Referencing

- Where are you on the roadway?
- A method to location attribute or events along a line (a road)
- A number of linear referencing methods
Route 0023

<table>
<thead>
<tr>
<th>ROUTE_ID</th>
<th>BEGIN_DISTANCE</th>
<th>BEGIN_SECID</th>
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</table>
WSDOT - Mileposts and Accumulated Route Miles (ARMS)

New roadway alignment
Crash Data into a GIS

**Crash Data**
Located by milepost (in the field)

**Calculation Process**
Converts Mileposts to Accumulated Route Miles (ARMs)

**ArcView**
Maps crash locations to state routes using ARMds
GIS and Transportation Planning
GIS and Transportation Data Inventory

- GIS are used to keep databases of physical elements and characteristics of transportation systems
- Many possible data elements
  - Streets and highway
  - Signal and signs
  - Pavement
  - Vegetation
  - Traffic volumes
  - Many more
Transportation Planning and Zones

2000 Population by TAZ
POP_2000
- 0 - 953
- 954 - 2129
- 2130 - 3472
- 3473 - 5326
- 5327 - 10461

[Map showing population distribution by TAZ in 2000]
Different Scales of Zones

Regional Zone Structure

County Zone Structure

Local Zone Structure

WRCOG. 1
Network Conflation
Suburban
New Urbanism
New Urbanism
compact
high density
sidewalk
pedestrian
Main Street
5 minute walk
buildings close to street
parallel street parking
grid streets
mixed use land use

Suburbs
spread out
low density
highway
car
shopping mall
car trip
buildings set back
parking lots
cul-de-sacs
segregated land use
TYPICAL STREET HIERARCHY VERSUS TND NETWORK PATHS

A. Typical Street Hierarchy

B. Dense Gridded Network

The Seattle Area Travel Diary

- Respondents contacted using random dialing
- Respondent asked for address of trip start and trip end
- Covered the travel of 900 households over two day
Geocoding

• Conversion of an address into a point specified by a latitude and longitude
Queen Anne Survey Household
Queen Anne Trip Origins and Destinations
Queen Anne Regional Origins and Destinations
Shortest Path Trips
Average Daily Travel Mileage

- Queen Anne
- Wallingford
- N. Seattle
- Kirkland
- Inner
- Outer

Average Miles per Day
GIS and Technology - Intelligent Transportation Systems (ITS)
GIS and ITS

- GIS interface between Internet user and spatial data
- GIS used with global positioning system (GPS) data
Interactive GIS Map

7: Turn SLIGHT LEFT onto 5TH AVE NE. 0.06 miles
8: Turn LEFT onto NE 45TH ST. 0.29 miles

Total Estimated Time: 16 minutes
Total Distance: 9.32 miles

Need a place to stay?
Find a local hotel!
GIS for real-time information on traffic conditions
GPS is an important source of transportation GIS data

- GPS data increasingly common
- GPS data increasingly accurate

Examples:
  - Handheld GPS with barcode reader for sign inventory
  - Pavement conditions
  - Fleet management for trucks
  - Many other sources of GPS data
Global Positioning Systems Use Triangulation
WSDOT Roadside Feature Inventory

- GPS data collection in clear zone
- Locate objects to one foot accuracy

Roadside Feature Inventory Program

On January 29, data from the Roadside Features Inventory Program (RFIP) was made available to WSDOT users. This includes roadway feature data, such as guardrail, culvert ends and sign supports, etc., from Olympic Region, Southwest Region, and Eastern Region, with the remaining regions data becoming available shortly. Recently collected data is being made available first, followed by the backlog of data since data collection began in June of 2006.

In the absence of a statewide inventory roadside feature program, you will find at WSDOT many individual business areas have and are collecting roadside feature information (i.e., utility poles, signs, guardrail, tree groupings, slope information...). These efforts have all been independent of one another and have caused duplicate effort and expense. Data is not consistently stored in a corporate standard format that would allow shared use and maintenance of the data.

Because of the advancements in technology such as GPS mapping grade equipment business areas have the potential to collect roadside feature data quickly and accurately. WSDOT's new GIS Workbench is but one example of new tools recently developed or being developed that allow the business area the opportunity to analyze and work the data efficiently and effectively. These two elements combined have caused an exponential increase in data gathering within the department.
GIS used to crunch GPS data

- GPS from Probe vehicles
  - Travel time
  - Travel speeds
  - Identify roadway bottle necks
  - Check loop accuracy
- GPS from Fleet Management System
Identify Bottlenecks

Area of Recurring Delay
GPS and GIS in Trucks
GIS Process GPS data

Vendor A
Vendor B
Vendor C

Database Server
Vendor A Database
Vendor B Database
Vendor C Database

O/D Trip Information Generator
GIS Processing

Combined Freight Performance Measure Database
GIS to Analyze Ramp & Interchanges

One week of GPS data on the I-5/Corson Interchange (September 2009)
Identifying truck bottlenecks
Step 1 - Code truck Global Positioning System (GPS) data to Washington State’s freight corridors.

We have data from 6,000 trucks each day
Centerline Database Problem

- Many agencies improving their network data with centerline surveys
- Air Photo
- GPS in vehicles
GIS and Roadway Segmentation
Identifying truck bottlenecks

Step 2 – Pre-determine segments to analyze on the state’s major truck corridors

We divided the state highway system into segments according to:

- location of ramps and major (signalized) intersection,
- speed limit changes, and
- Urban/rural boundaries.

22,000 segments in Washington
Identifying truck bottlenecks

Step 3 – Automatically pull GPS data from trucks traveling for each segment.
Identifying truck bottlenecks

Step 4 – Determine each segment’s reliability by analyzing truck speed data by time-of-day

**AM Peak**
Speed distribution for SB I-5 (Snohomish County between 220th SW and 236th SW)

![AM Peak Graph](attachment:image1.png)

**PM Peak**
Speed distribution for SB I-5 (Snohomish County between 220th SW and 236th SW)

![PM Peak Graph](attachment:image2.png)

The diagram on the left shows a highway segment that is unreliable in the AM peak. The diagram on the right shows that trucks reliably travel at 50 to 65 miles per hour in the PM peak on the same segment.
Identifying truck bottlenecks
Step 5 – Define and apply criteria to rank the highway bottlenecks

We developed four criteria to identify and rank truck bottlenecks:

1. Truck speed below severe congestion threshold, which WSDOT has defined as 60 percent of posted speed (35 miles per hour on urban freeways),
2. Average speed,
3. Speed distribution (reliability), and
4. Truck volume.

Percentage of truck speeds falling below severe congestion threshold on southbound I-5

<table>
<thead>
<tr>
<th>Segment Location</th>
<th>6AM-9AM</th>
<th>9AM-3PM</th>
<th>3PM-7PM</th>
<th>7PM-6AM</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>NE 63rd St and NE Pacific Ave E</td>
<td>53.9%</td>
<td>51.7%</td>
<td>80.1%</td>
<td>6.9%</td>
<td>48.2%</td>
</tr>
<tr>
<td>NE Pacific St and Eastlake Ave E</td>
<td>39.9%</td>
<td>41.8%</td>
<td>78.3%</td>
<td>7.7%</td>
<td>41.9%</td>
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<tr>
<td>NE 75th St and NE 63rd St</td>
<td>43.2%</td>
<td>43.9%</td>
<td>69.4%</td>
<td>8.1%</td>
<td>41.2%</td>
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<tr>
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<td>37.4%</td>
<td>41.1%</td>
<td>66.6%</td>
<td>7.1%</td>
<td>38.0%</td>
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<tr>
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<td>56.3%</td>
<td>2.0%</td>
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<td>Eastlake Ave E and SR 520</td>
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<td>82.8%</td>
<td>4.1%</td>
<td>31.6%</td>
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<tr>
<td>SR 520 and I-90</td>
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<td>22.4%</td>
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<td>2.8%</td>
<td>17.9%</td>
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</table>
Truck Bottlenecks on the Strategic Freight & Goods Transportation System

Filters:
- Truck speed less than 60 percent of Posted Speed Limit (Top 40 segments in Puget Sound and the rest of the state for a total of 80)
- Length of grade greater than 1.00 mile where grade is 3.5 percent or greater
- Truck AADT less than 250

Washington State Department of Transportation

Legend:
- Truck Bottleneck
- City Limits
Severe truck bottleneck in Central Puget Sound:
SR 99 northbound

- Location: SR-99 northbound, north of SR-519, SeaTac, WA
- Length: 0.28 mile
- Daily Truck Volume: 3,100
- Average truck travel speed: 21 mph
- Percentage of travel speed below 60% of posted speed limit: 72%

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Reliability</th>
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<td>AM</td>
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<tr>
<td>Midday</td>
<td>Unreliable</td>
</tr>
<tr>
<td>PM</td>
<td>Unreliable</td>
</tr>
</tbody>
</table>
We Can Locate Problem Areas

Truck GPS Data Points
- Red: Truck Speeds Less Than 25 MPH
- Green: Truck Speeds More Than 25 MPH
GIS-T in the Future

- Expansion beyond use by transportation professionals (911, yellow pages, travel planning, vehicle tracking, etc)
- New interfaces (3D, voice activation, virtual GIS)
- Better GPS (Russian and European systems)
- More linked to remote sensing (satellites) - Google Earth
- Better interoperability with other data systems
- More on the Internet and real-time
GIS-T Data Sources on the Internet
Transportation Agency GIS/spatial data

- All state DOTs have road center line database
- Many agencies maintain geo-spatial database (layers)
  - railroads
  - political boundaries
  - Etc.
- Sometimes web-based
http://www.gis.fhwa.dot.gov/

State/Local GIS Practices Database

Visit the database to learn more about GIS applications and practices in transportation being currently implemented across the nation.

- Explore Practices
- Submit Your Agency's Practices

Upcoming Events

October 2009:
GIS Tools for Strategic Conservation Planning

November 2009:
2009 GIS in Transit Conference

December 2009:
International Workshop on GIS for Transportation

February 2010:
GIS: The Geographic Approach for the Nation Conference

April 2010:
AASHTO GIS for Transportation Symposium

What is GIS?

Geographic Information System (GIS) is a collection of computer software, hardware, data, and personnel used to store, manipulate, analyze, and present geographically referenced information. Spatial data and associated attribute information can be layered on top of one another for viewing and analysis.
Welcome to DPD GIS
All DPD GIS users are subject to the Terms of Use

DPD GIS allows you to create custom interactive maps that you can use to perform permit and property data queries.

Getting started
1. Generate a map: In the Search Tools area, click a tab and type the address, intersection, or place name. Click Map This Address.
2. Add features to the map: Select layers (data such as address points and building outlines) in the Legend and Layers area and click Refresh Map.
3. Get data using the map: Use the Selection Query Tools to select the type of data you want. Choose Property Datasheet to get zoning and King County Assessor data; choose Address Activity for permit and project information.
 Pick a tool to use and click a point or draw a rectangle on the map with your mouse.

Need more help?
Click in the Search Tools or Selection Query Tools area for step-by-step procedures for using DPD GIS
King County

Spatial Data Catalog

The Spatial Data Catalog (SDC) is the metadata resource for the King County enterprise GIS.

**KCGIS Vector Data**
Point, line, and polygon data in shapefile format.
See also: KCGIS Vector Data: Metadata Format

**KCGIS Raster Data**
Cell-based data, including imagery, lidar-derived elevation data, and landcover themes.

**Non-KCGIS Vector Data**
Data acquired from non-King County agencies and organizations; for internal King County use only.

Not sure what you need or where to look?
Check out our Data Format Primer.
See also: What Is Metadata?

E-mailing county contact persons:
To e-mail an individual, use the King County address format: firstname.lastname@metrokc.gov
National Transportation Atlas Database

2009

NOTE: All titles found on the NTAD DVD are available here for download. These data are provided in ESRI shapefile format. For your convenience and to improve your download performance, datasets that are larger than 20 mb are also available for download by smaller US DOT regions. There are 10 US DOT Regions, with each region being composed of 3 to 8 states.

<table>
<thead>
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Puget Sound Regional Council

GIS and Maps

Map Catalog
Catalog of PSRC map products.

GIS Shapefiles
Index of GIS shapefiles, including census geographies and PSRC forecasting zones.

Equivalency Tables
Equivalency tables for correlating various geographic boundary systems (e.g., census tracts to TAZ, FAZ to TAZ).

Puget Sound LiDAR Consortium
Devoted to developing public domain high-resolution LiDAR topography for the Puget Sound region.

WA-Trans: Washington State Transportation Framework
WSDOT-sponsored interagency collaboration to build a statewide transportation spatial data structure.
WSDOT Geodata Catalog

The **WSDOT GeoData Distribution Catalog**, maintained by the Office of Information Technology, is a centralized distribution site for geographic information system data produced at the Washington State Department of Transportation. Data provided here is used by WSDOT’s transportation partners, government entities, schools, private businesses, and the general public. The WSDOT GIS Community actively promotes inter agency data exchange and resource sharing; therefore, data on this site is available for download free-of-charge. Our data is provided in [ESRI](http://esri.com) shapefile, georeferenced .jpg, and [Mr. SID](http://www.mrsid.com) formats. See the sidebar to the left for more details. If you do not have a GIS solution to view this data, you can download free of charge open source software for Windows, Macintosh, or Linux from [Quantum GIS (Qgis)](http://qgis.org) or [Refractions Research (uDig)](http://udig.refractions.net).

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**Geospatial Data Available for Download**

**TRANSPORTATION FEATURES**

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<tr>
<th>Description</th>
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Washington State Transportation Framework

Welcome to the Washington State Transportation Framework for GIS web site. In short, we're called "WA-Trans". This site provides news, announcements, and related links about our project, and is sponsored by the Washington Geographic Information Council, the Framework Management Group, and the Washington State Department of Transportation. Our project mission is to provide the best up-to-date data on roads, railways, ferries, aviation, ports, and non-motorized transportation infrastructure. This data can be used in geographic information systems (GIS) across the state for a variety of purposes—from emergency management and homeland security to transportation functions to environmental analysis and management.

Collaborative Planning and Building

Building a statewide transportation database is a collaborative effort that will be continuously improved. It will include location-based transportation data available from all levels of government, including tribal nations. The WA-Trans data or "transportation layer" will seamlessly connect between jurisdictions, boundaries, and other framework layers. For more details, see the Executive Summary (pdf). We encourage other State DOTs to become involved in this effort through the Transportation Pooled Fund.

To be successful, WA-Trans must be supported by well defined, documented, repeatable processes. Initially, a business needs assessment was made by the Washington Transportation GIS Framework, which identified the need for a data user portal. This was intended to be a "front-end" to the framework, allowing users to access the needed data through a web interface.

Project News

- The One-Road Pilot Data User Portal Prototype is installed; Final User testing will begin in November.
- The One-Road Pilot Data Provider Portal Prototype is installed; Unit testing has begun and change/errors are being corrected.
- Welcome Idaho as a new Transportation Pooled Fund Member. Current members are California, Idaho, Nebraska, Ohio, Oregon and Tennessee.
- To help maintain data over the long term, Change Detection and Change Management process are being developed and tested. Change detection is 95% complete. Some QA/QC data reports are being reviewed by providers.
Questions?

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edm@u.washington.edu
[ Linear Referencing Methods ]

Example LRM - Reference Marker Offsets

Route 0023  RM1 (1.2)  RM2 (2.4)  RM3 (5.2)

<table>
<thead>
<tr>
<th>ROUTE_ID</th>
<th>BEGIN_MARKER</th>
<th>BEGIN_OFFSET</th>
<th>BEGIN_SECID</th>
<th>END_MARKER</th>
<th>END_OFFSET</th>
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Truck Data vs. Car Data

GPS Speeds (Trucks) vs. Freeway Loop Speeds (Cars)

<table>
<thead>
<tr>
<th>Road</th>
<th>Mile Post</th>
<th>Time</th>
<th>GPS Speed</th>
<th>5-Minute Loop Data</th>
<th>20-Second Loop Data</th>
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<td>14:38</td>
<td>23.9</td>
<td>60</td>
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</tbody>
</table>

• Which is right?
• It turns out trucks have different travel patterns and speeds than cars
We Can Quantify Network Problems

Westbound
Average Truck Speed: 47mph.
Average All Vehicles Speed: 57mph
18% Difference

Bottleneck

Eastbound
Average Truck Speed: 40mph.
Average All Vehicles Speed: 58mph
31% Difference

(Data from September 2008 to September 2009)
We Can Evaluate Construction Impacts

I-90 Eastbound Average Truck Speeds by Time Period

- Two Weeks Before Construction
- Three Weeks During Construction
- Two Weeks After Construction

Truck speeds were 8 mph slower during construction.
Wireless GPS Data
## Geocoding Results

### Table 3: Geocoding Results

<table>
<thead>
<tr>
<th>Category</th>
<th>Addresses</th>
<th>Intersections</th>
<th>Places</th>
<th>All Data</th>
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<tr>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Total</td>
<td>12,631*</td>
<td>3,882*</td>
<td>825*</td>
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<td>% Computer Matched</td>
<td>72.8%*</td>
<td>57.3%*</td>
<td>0%</td>
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<tr>
<td>All Data</td>
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<tr>
<td>Matched by Computer</td>
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<tr>
<td>or Manually</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Shopping by Walk Trips

Distance from Commercial Street

Percent of Trips

0% 20% 40% 60%

Kirkland Wallingford Queen Anne

Distance Bands

> 0.4 mile
0.3 - 0.4 mile
0.2 - 0.3 mile
0.1 - 0.2 mile
0.1 mile
0.3 - 0.4 mile
Truck Data

- Truck ID
- Latitude and Longitude
- Time/ Date Stamp
- Ping at engine start/stop and every $\frac{1}{2}$ to 15 minutes
- Privacy protected
# GPS data from trucks

<table>
<thead>
<tr>
<th>GPS Vendors</th>
<th>Average Total Daily Records</th>
<th>Total Trucks</th>
<th>Frequency of reads (minutes)</th>
<th>Data type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vendor A</td>
<td>94,000</td>
<td>Approx 2,500 per day</td>
<td>5-15</td>
<td>In-vehicle GPS with a cellular connection</td>
</tr>
<tr>
<td>Vendor B</td>
<td>12,000</td>
<td>25</td>
<td>0.5</td>
<td>In-vehicle GPS with a cellular connection</td>
</tr>
<tr>
<td>Vendor C</td>
<td>3,000</td>
<td>60</td>
<td>1-5</td>
<td>GPS cell Phone</td>
</tr>
</tbody>
</table>
Geocoding
Average Daily Travel by Mode

Average Miles of Travel per...