Network Analyst
Creating Network Datasets
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Agenda

• Preparing street data for use in network dataset
  - Oneway streets
  - Hierarchy
  - RoadClass attribute

• Using turns, signposts, and historical traffic data

• Creating a multi-modal network dataset

• Parameterized Attributes

• Evaluators tips and tricks

• Support & Resources

• Questions
Do I need to create my own network dataset?

- **StreetMap network datasets available**
  - SDC format
  - Ready to use
  - Network dataset already created

- **StreetMap data on Data & Maps**
  - Comes with ArcGIS
  - Data for North America

- **StreetMap Premium data**
  - Data is more current
  - Data for North America or Europe
Know Your Street Data

- What information can be used as a setting in the network dataset?
Review – what is in a Network Dataset?

- **Sources**
  - Line features
  - Point features
  - Turn features

- **Connectivity**
  - End Point / Any Vertex
  - Z-Elevation fields
  - Connectivity groups

- **Attributes**
  - Cost
  - Descriptor
  - Restriction
  - Hierarchy

- **Directions**
  - Primary street names
  - Alt. street names
  - Highway shields
  - Boundary field
  - Signpost data
Know Your Street Data

- View data – geometry and attributes
- Read the documentation for data
- How is street geometry represented?
  What street information is provided?
  In what layers is this information located?
  How is this information formatted?
- What information can be used as a setting in the network dataset?
Coincident Geometries

- To enable network connectivity to be modeled
  - Points of coincidence should exist where line features cross or intersect

Case 1

Case 2
Creating coincident geometry

- Include sources in a Topology
- Use the Geoprocessing Integrate Tool
- Both methods compare features and makes vertices within the cluster tolerance coincident
  - Inserts vertices where features intersect
  - Snaps features that are not coincident
# Common fields for street data

<table>
<thead>
<tr>
<th>Field</th>
<th>Data type</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation</td>
<td>Integer</td>
<td>Ensures proper connectivity</td>
</tr>
<tr>
<td>Oneway</td>
<td>Text</td>
<td>Helps determine one way streets</td>
</tr>
<tr>
<td>Length</td>
<td>Double</td>
<td>Calculate shortest route</td>
</tr>
<tr>
<td>Travel time</td>
<td>Double</td>
<td>Calculate fastest route</td>
</tr>
<tr>
<td>Hierarchy</td>
<td>Integer</td>
<td>Ranking of streets for routing on large network datasets</td>
</tr>
<tr>
<td>Speed</td>
<td>Integer</td>
<td>May be used to calculate travel time</td>
</tr>
<tr>
<td>Road class</td>
<td>Integer</td>
<td>Classification of roads – used for formatting directions text</td>
</tr>
<tr>
<td>Street name or address data</td>
<td>Text</td>
<td>Helps generate network locations and directions</td>
</tr>
</tbody>
</table>
Connectivity using Elevation Fields

- Attribute that enables network dataset to represent multiple “levels” for line features
- Applied to line features with coincident endpoints
- Planar and non-planar features are supported
- Commonly called z-elevation or z-levels

<table>
<thead>
<tr>
<th>NAME</th>
<th>F_ZLEV</th>
<th>T_ZLEV</th>
</tr>
</thead>
<tbody>
<tr>
<td>State St</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Elevation fields – Overpass/underpass scenario

- Four lines with coincident endpoints

Junction
Endpoint

0-1 lines do not intersect 0-0 lines at the same junction
Oneway field – Most common method

- Text field containing values: FT, TF, < >, N
  - “FT” – one-way in digitized direction
    - FT = traffic only allowed in this direction
  - “TF” – one-way against digitized direction
    - TF = traffic only allowed in this direction
  - <empty> – two-way street
    - “N” – No travel

If other field values, change expression
Hierarchy

- Minimizes impedance while favoring higher order roads
- Basic assumption:
  - Higher order roads are “faster” (time), not necessarily “shorter” (distance)
- Hierarchy classifies network edges into multiple levels when the network dataset is built
  - Levels: lower number = higher order road
Hierarchy Considerations

- Highest level needs to be connected to each other
  - Take restrictions into consideration
- Composition of highest level hierarchy dictates **performance vs. accuracy** of route returned
  - Larger: more optimal routes, but is slower
  - Smaller: faster performance, but route is less optimal
- Values derived from road classification (e.g., CFCC)
- Edges per hierarchy guide:

<table>
<thead>
<tr>
<th>Hierarchy</th>
<th>Regional % of edges</th>
<th>National % of edges</th>
<th>Edge count better guide</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5%</td>
<td>3%</td>
<td>~100,000 max</td>
</tr>
<tr>
<td>2</td>
<td>15%</td>
<td>17%</td>
<td>Percentage of total</td>
</tr>
<tr>
<td>3</td>
<td>80%</td>
<td>80%</td>
<td>Percentage of total</td>
</tr>
</tbody>
</table>
RoadClass attribute

- Used for formatting the text of driving directions
- Has no effect on network analysis
- Descriptor attribute, five possible integer values:

<table>
<thead>
<tr>
<th>RoadClass Value</th>
<th>RoadClass Description</th>
<th>Driving Directions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Local road</td>
<td>“Turn left on Main St”</td>
</tr>
<tr>
<td>2</td>
<td>Limited access highway</td>
<td>“Go East on I 44”</td>
</tr>
<tr>
<td>3</td>
<td>Ramp</td>
<td>“Take ramp and go on US-7 N”</td>
</tr>
<tr>
<td>4</td>
<td>Ferry</td>
<td>“Take Lake Expy ferry”</td>
</tr>
<tr>
<td>5</td>
<td>Roundabout</td>
<td>“Take roundabout and proceed South on Main St”</td>
</tr>
</tbody>
</table>
Dissolve Network (new at ArcGIS 10)

- Input: Network dataset
- Output: New network dataset with fewer line features
  - North America: 43.8M lines → 15.7M lines

- Fewer line features – Faster network analysis
Dissolve Network

- Speeds up network analysis for large networks
- Geoprocessing tool in Network Dataset toolset
- Creates a new dissolved network dataset
  - Original network dataset is unedited
- Only fields used by network dataset are present in dissolved data
  - Use dissolved dataset for network analysis
  - Keep original data for maintenance and other work
Demonstration
Adding fields for routing to TIGER/Line® street data
Turns in the Network Dataset

- Describe transitions between two or more edges
- Used to model cost and/or restrictions in the network
- Incorporating turn elements – more realistic network solver results
- Two options:
  - Turn features
  - Global (default) turns
  - Or Both
Turn Feature

- Polyline geometry
- Turn references edges by:
  - Feature class ID
  - Feature ID
  - Position
- Turn elements built by edge references

<table>
<thead>
<tr>
<th>Field</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ObjectID</td>
<td>1</td>
</tr>
<tr>
<td>Shape</td>
<td>Polyline</td>
</tr>
<tr>
<td>Edge1End</td>
<td>Y</td>
</tr>
<tr>
<td>Edge1FCID</td>
<td>42</td>
</tr>
<tr>
<td>Edge1FID</td>
<td>104</td>
</tr>
<tr>
<td>Edge1Pos</td>
<td>0.5</td>
</tr>
<tr>
<td>Edge2FCID</td>
<td>42</td>
</tr>
<tr>
<td>Edge2FID</td>
<td>102</td>
</tr>
<tr>
<td>Edge2Pos</td>
<td>0.6</td>
</tr>
<tr>
<td>Edge3FCID</td>
<td>42</td>
</tr>
<tr>
<td>Edge3FID</td>
<td>103</td>
</tr>
<tr>
<td>Edge3Pos</td>
<td>0.4</td>
</tr>
</tbody>
</table>
Editing Turn Features

- Create and edit turn features in the ArcMap Editor
- Edit as you would any other line feature
- Snap geometry to each street in turn
- Network dataset must be built before editing turn features
Global Turns

- For example – adding a penalty for all left turns
- Consist of:
  - All implied two-edge turning sequences in network
  - No need to create a turn feature for every two-edge sequence in the network
- Specify attribute values for global turns
  - VB Script evaluator; or
  - Global Turn Delay evaluator
Sample VB Script Code for Global Turn Penalty

Pre-Logic VB Script Code:

```vbnet
a = Turn.Angle
If a > 210 And a < 330 Then
    turnTime = 0.5
Else
    turnTime = 0
End If
```

Expression:

```vbnet
turnTime
```

Diagram:
- **Left turn**
- **Right turn**
- **U-turn**
- **Straight**
...or use the Global Turn Delay evaluator

<table>
<thead>
<tr>
<th>Direction</th>
<th>Width (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green Straight</td>
<td>60</td>
</tr>
<tr>
<td>Red Reverse</td>
<td>60</td>
</tr>
<tr>
<td>Yellow Right</td>
<td>120</td>
</tr>
<tr>
<td>Blue Left</td>
<td>120</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Direction</th>
<th>Description</th>
<th>Seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight</td>
<td>From Local To Local Road Across No Roads</td>
<td>0</td>
</tr>
<tr>
<td>Straight</td>
<td>From Local To Local Road Across Local Road</td>
<td>2</td>
</tr>
<tr>
<td>Straight</td>
<td>From Local To Local Road Across Secondary or Primary Road</td>
<td>15</td>
</tr>
<tr>
<td>Straight</td>
<td>From Local To Secondary Road</td>
<td>3</td>
</tr>
<tr>
<td>Straight</td>
<td>From Local To Other Road</td>
<td></td>
</tr>
</tbody>
</table>
Converting Existing Turn Data

- **ArcView 3.x or ArcInfo Workstation data**
  - Convert streets with **Feature Class To Feature Class** geoprocessing tool
  - Convert turn table with **Turn Table To Turn Feature Class** geoprocessing tool

- **Commercial data with multi-edge turns**
  - Use the **Create Turn Feature Class from Multi-Edge Turn Table** script from the Resource Center
Signposts

- Text seen on highway signs
  - Typically includes exit number, street name, and/or destination
- Has no effect on network analysis
- Enhances text of driving directions:
  - “At exit 73B, take ramp to US-421 North toward N Wilkesboro”
Signpost Data – Two tables

- Signpost feature class
  - Actual text on sign
    
    | Exit number | 73 B |
    | Street name(s) | US-421 |
    | Direction | North |
    | Destination(s) | N Wilkesboro |

- Signpost streets table
  - Streets traversed when following the sign
    
    | Feature class ID | 12 |
    | Feature ID | 41 |
    | Positions | 0.0 to 1.0 |

For Vendor data use
“Import Signposts”
.NET SDK Developer sample
Adding Signposts to the Network Dataset

- Signpost tables specified in Directions Settings

![Network Directions Properties window showing signpost tables](image)
Historical Traffic

- New at ArcGIS 10
- Travel time varies by time of day and/or day of week
  - Travel at 8am:
    ![Diagram of traffic at 8am]
  - Travel at 5pm:
    ![Diagram of traffic at 5pm]
- Used by Network Analyst when a Start Time is specified for the route
Historical Traffic Data – Two tables

- **Traffic Profiles table**
  - Contains free-flow speed multipliers by time of day

<table>
<thead>
<tr>
<th>Profile</th>
<th>1 am</th>
<th>5 am</th>
<th>9 am</th>
<th>1 pm</th>
<th>5 pm</th>
<th>9 pm</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>1.0</td>
<td>1.1</td>
<td>2.3</td>
<td>1.2</td>
<td>1.4</td>
<td>1.1</td>
</tr>
</tbody>
</table>

- **Streets-Traffic Profiles join table**
  - Specifies free-flow travel times and profiles to use

<table>
<thead>
<tr>
<th>Feature class ID</th>
<th>Feature ID</th>
<th>Positions</th>
<th>Free-flow travel</th>
<th>Sunday Profile</th>
<th>Monday Profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>41</td>
<td>0.0 to 1.0</td>
<td>10 seconds</td>
<td>Profile 10</td>
<td>Profile 16</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
Historical Traffic in the Network Dataset

- Specify when creating the network dataset

**New Network Dataset**

Do you want to use historical traffic data with this network dataset?

- No
- Yes

**Historical Traffic Tables:**

<table>
<thead>
<tr>
<th>Traffic Profiles Table</th>
<th>Streets - Traffic Profiles Join Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table</td>
<td>Streets_DailyProfiles</td>
</tr>
<tr>
<td>First Time Slice Field</td>
<td>FreeFlowMinutes</td>
</tr>
<tr>
<td>Last Time Slice Field</td>
<td>Minutes</td>
</tr>
<tr>
<td>Minutes Per Time Slice</td>
<td>Sunday ProfileID Field</td>
</tr>
<tr>
<td>First Time Slice Start Time</td>
<td>PROFILE_1</td>
</tr>
<tr>
<td>Last Time Slice Finish Time</td>
<td>PROFILE_2</td>
</tr>
<tr>
<td></td>
<td>Base Travel Time Field</td>
</tr>
<tr>
<td></td>
<td>Base Travel Time Units</td>
</tr>
<tr>
<td></td>
<td>Sunday ProfileID Field</td>
</tr>
<tr>
<td></td>
<td>Monday ProfileID Field</td>
</tr>
</tbody>
</table>
Demonstration

Using Turns, Signposts, and Historical Traffic Data
Connectivity for Multi-Modal Network Dataset

- Connectivity groups “connect” at transfer points
  - Example: Rail stations
- Non-connecting edge sources in separate connectivity groups
Multi-Modal – considerations for Road & Rail

- Road & Rail example – two common scenarios:
  - Railroad station not on rail track
  - Railway station entrance along middle of road
- For Railroad stations not along the road
  - Create “transfer edges”
- For station entrances not at the road ends
  - Create junction with Override policy at entrance
  - Insert vertex on street feature at station entrance
Network Attributes – Multi-Modal Network Dataset

- Create a cost attribute for each scenario you are modeling
  - Automobile
  - Pedestrian (walk only)
  - Pedestrian using light rail
  - etc.
- Create restriction attributes to prevent invalid traversals
  - Example: Restrict driving on the rail lines
Demonstration:

• A multi-modal network dataset

- Streets
- Walking paths
- Railway
Parameterized Attributes

- Network attribute that accepts a parameter
- Used to model dynamic aspect of an attribute’s value

Parameterized attribute

Input Parameter value(s)
(Optional) Other Network Attribute(s)
Example – implementing a height limit

- Requires both a Descriptor and a Restriction attribute
- Descriptor attribute
  - Specifies height limits for each road
- Restriction attribute
  - Stores vehicle height parameter
- Performs the appropriate restriction
- May use Function evaluator or VB Script evaluator
  - Function evaluator – faster & easier

Bridge clearance: 12'6"

Restriction evaluates to True (Restricted) if vehicle height exceeds 12 ft, 6 in
Using Height restriction during solve

• When using solver:
  - Set attribute restriction on Analysis Settings tab
  - Specify actual vehicle height on Attribute Parameters

• Solver Result:
  - Street is restricted when the actual Vehicle Height is greater than street’s MaxHeight attribute value
Evaluators – review

- A function that determines attribute values for network elements in a network dataset
- Six different types available with ArcGIS:
  - Field
  - Constant
  - Global Turn Delay
  - Function
  - Edge Traffic
  - VB Script
- Example usages:

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Evaluator(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td><em>Field</em> – assign the [meters] field</td>
</tr>
<tr>
<td>TravelTime</td>
<td><em>Edge Traffic, Global Turn Delay</em> – use historical traffic, turn delays</td>
</tr>
<tr>
<td>TurnRestriction</td>
<td><em>Constant</em> – “true” (implies all turns restricted)</td>
</tr>
<tr>
<td>MaxHeight</td>
<td><em>Field</em> – assign the [Height_Limit] field</td>
</tr>
<tr>
<td>HeightRestriction</td>
<td><em>Function</em> – specify MaxHeight attribute &lt; VehicleHeight parameter</td>
</tr>
</tbody>
</table>

- Custom evaluators can be developed
Efficiency of calling evaluators

- **Field evaluator (including Field Expressions)**
  
  Fast: Attribute values stored when network is built; Retrieved at solve time

- **Constant, Function, & Global Turn Delay evaluators**
  
  Fast: Attribute values generated at solve time using precompiled logic

- **Edge Traffic evaluator**
  
  Fast: Multipliers & free-flow values stored when network is built; Travel time determined during solve

- **VB Script evaluator**
  
  Can be slow: Invokes scripting at solve time

- **Custom evaluator**
  
  Depends on implementation
Evaluators – Tips and Tricks

• Field evaluator
  - Read in values from a field; and/or
  - Perform calculations using multiple field values
    - Example attributes: Length, DriveTime, Oneway

• Constant evaluator
  - Same attribute value across all network elements
    - Example attribute: TurnRestriction

• Custom logic
  - Initial prototyping with VB Script evaluator
  - Final implementation using Custom evaluator
    - Better performance
Esri Support Center

- Online portal to technical information

- Knowledge Base
  - Technical articles
  - White papers
  - System requirements

- Downloads
  - Patches, service packs
  - Data models
  - ArcScripts and samples

- User forums
  - Discussion groups
  - E-mail lists

http://support.esri.com
For more information

- **Network Analyst Product Page**
  - Links to Demos, Brochures/White Papers, Success Stories

- **Free webcast**
  - Using Network Analyst in ArcGIS Desktop 10

- **Free Podcasts – Instructional Series**

Network Analyst Technical Workshops – Tuesday

• Network Analyst – An Introduction
  8:30AM~9:45AM   Room 3

• Network Analyst – Performing Network Analysis
  10:15AM~11:30PM   Room 3

• Performing Network Analysis with ArcGIS Server
  3:15PM~4:30PM   Room 3

• What is ArcGIS Network Analyst and Why Should I Use It?
  4:05PM~4:25PM   Room 6B
Network Analyst Technical Workshops – Wed/Thu

- **Network Analyst – Automating Workflows**
  - Wednesday 8:30AM~9:45AM   Room 9

- **Network Analyst – An Introduction (Offering II)**
  - Wednesday 1:30PM~2:45PM   Room 9

- **Network Analyst – Performing Network Analysis (Offering II)**
  - Thursday 8:30AM~9:45AM   Room 9
Network Analyst Demo Theater Presentations

- Modeling Real-World Problems with the VRP Solver
  - Tuesday 1:00PM~2:00PM  Spatial Analysis Island

- Routing Inside Buildings with 3D Networks
  - Wednesday 3:00PM~4:00PM  Spatial Analysis Island

- Location-Allocation and Accounting for competition in site selection
  - Wednesday 4:00PM~5:00PM  Spatial Analysis Island
Thank you for attending!

• Please complete the Session Evaluation:

• Questions?