Development of Opportunity Zones

Utilizing Transportation Assets

Final Report
Dr. Gregory Washington
Dr. Carolyn Merry
Kyle Van Volkinburg

for the
Ohio Department of Transportation
Office of Research and Development

and the
Federal Highway Administration

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16. Abstract

Transportation, traditionally, is an afterthought when dealing with company site selection. This way of thinking results in two broad problems: the state's transportation network is not marketed as an asset and desired infrastructure improvements might not be feasible.

The purpose of the study was to develop a framework that, with regard to attracting and retaining companies, enables ODOT to identify ideal job sites around the state. The developed framework considers the needs of a company to optimally locate the company with sufficient existing transportation infrastructure.

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Authors:
Dr. Gregory Washington
Dr. Carolyn Merry
Kyle Van Volkinburg

The Ohio State University

June, 2012

Sponsoring Agencies:
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"*Prepared in cooperation with the Ohio Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration*."

Table of Contents

List of Figures

List of Tables

Introduction

The challenge that spurred this project, along with the creation of the Jobs and Commerce Office within the Ohio Department of Transportation (ODOT), is that transportation is traditionally an afterthought when it comes to economic development (i.e., company attraction, company site selection, etc.). This lack of upfront consideration yields three primary problems:

1. Ohio's expansive transportation network (ex. roads, rails, ports, and airports) and associated facilities (ex. intermodal facilities) are marketable assets when compared to other states and are not leveraged properly
2. Companies contact ODOT with transportation infrastructure enhancement requests after they settled at a site that, sometimes, are not feasible
3. The existing transportation infrastructure supporting the company's logistical network degrades more rapidly than projected, if it was not designed to handle the new loading associated with receiving and shipping goods

The creation of the Jobs and Commerce Office provided the opportunity for greater impact in economic development, primarily in the site selection process[1] for incoming/expanding companies. The goal of this research project was to fulfill this need with the creation and development of the Opportunity Zone Identification Program or "OZ Program" for short.

In general, the OZ Program uses existing GIS (Geographic Information System) data to compare candidate job sites by conducting projected routing analysis, keeping in mind the companies specific transportation needs. The goal is to determine which candidate site is better suited for the company; for example: offered shortest travel to destinations, required fewer infrastructure enhancements, or utilized fewer lane miles of lower classed roads[2].

ODOT has many divisions and offices that each create and maintain data sets unique to their job functions. The first stage in creating the OZ Program was to understand what data existed, both in GIS format and other data sets, understand how the data were being used and maintained, and decide whether or not the data would be useful. Next, a gap analysis led to discussions centered on data sets that would be useful, but that did not exist at ODOT. These included data sets that could be obtained from outside sources or data that ODOT should be collecting and maintaining. Next, desired software functionality was discussed with user groups. The final step was the development of the Opportunity Zone Identification Tool.

Research Objectives

Ohio Department of Transportation (ODOT) RFP 2011-11 originated from the desire to use the state's assets, specifically ODOT's assets including roads, facilities, and right of ways, as

[1] Working in collaboration with agencies like JobsOhio

[2] Based on a hierarchical ranking by Federal Functional Classification numbers

catalysts for economic development. This stemmed from the fact that Ohio is strategically located within 600 miles of 59.5% of US population, has an expansive transportation network, is fourth in the nation in airports, active rail lines, maritime tonnage moved, sixth in interstate highways, and has a balanced industry portfolio [1].

The proposal in response to this RFP, entitled *Development of Opportunity Zones Utilizing Transportation Assets*, used broad language to allow OSU researchers and ODOT technical liaisons (the team) to examine multiple approaches to solving the question:

> How can ODOT support the economic development activities taking place around the state by leveraging its assets to attract and retain corporations to catalyze the expansion of emerging technologies and to spur regional economic growth via new company formation?

Initially, the team felt the research objective that needed to be answered was along the lines of:

> Can one develop an infrastructure management framework that will better enable ODOT to utilize the land it owns for economic development? More specifically, can tools be developed that will enable ODOT to prioritize future potential projects based on future opportunities?

However, through the realignment of the division of ODOT within which this project was housed, an effort to collaborate with Ohio Department of Development (ODOD), as well as the discovery of existing tools that ODOT is/was considering adding to its suite of economic development software programs, the team agreed to provide ODOT with the most useful product. The problem statement to be addressed was refined to:

> Can one develop a framework that, with regard to attracting and retaining companies, enables ODOT to identify ideal job sites around the state that both realize and meet the needs of a company and optimally locate the company around sufficient existing transportation infrastructure?

The research tasks were defined as follows:

1. Prepare a comprehensive literature review.
2. Performa a gap analysis of provided data sets to determine if they provide sufficient information and make suggestions for additional data sets.
3. Develop geospatial-based tools and models using GIS software that will allow ODOT researchers to quickly match assets with opportunities.
4. Develop an infrastructure management framework to identify Opportunity Zones.

General Description of Research

In addition to performing its desired functionality, a chief concern in the design environment of the OZ Project was to give the user a friendly and intuitive GUI (Graphic User Interface) to work in. The OZ Program, in short, is a bi-language software tool combining Python and Microsoft

Excel VBA, which rely on ODOT data sets and ESRI ArcGIS geoprocessing functions, to find the optimal company location through the examination of supporting transportation properties along projected travel routes among a set of candidate sites.

Data Sets

As a result of the gap analysis, it was determined that the required data sets are the three road inventory files (state, local, and municipal level) that are maintained by ODOT's GIS group, TIMS (the Transportation Information Management Section), and a bridge dataset. Augmenting the road inventory files, where the data are available, are road segment congestion values, specifically the volume to capacity ratio, from ODOT's modeling group.

In addition, the following data sets were used to populate possible origin and destination lists for easy selection:

- List of Ohio Businesses (from Harris Data)
- Intermodal Facilities (ODOT generated/maintained)
- Airports (ODOT generated/maintained)
- ODOT Future Projects (ODOT generated/maintained)
- Available Job Sites (Jobs Ohio data dump/converted to GIS format)
- Points of Interest (researcher created general list of destinations/no maintenance)

General Program Methodology

The OZ Program determines the best job site (from ODOT's perspective) from a list of candidate job sites based on the following logic: when comparing candidate job sites, the route that taxes ODOT infrastructure the least between candidate site and destination is correlated with the preferred candidate site.

The general flow of the program is as follows:

- Select a set of roads to be eligible for routing purposes. This set could be every road in the state or a subset based on anticipated constraints. For example, if anticipated shipping loads were 80 kips or larger all road segments containing bridges with a load rating less than 80 kips would not be considered.
- Specify starting and ending points using either points from the possible origin and destination list or by entering latitude and longitude coordinates.
- Specify guiding points (optional). This step offers the possibility to override the default routing algorithm by adding points that the route must follow along its path from origin to destination, based on user specific knowledge.
- Specify flags and costs (optional). This step allows for users to specify, from a list of options, which road properties they want to use in determining the preferred route. For example, if it was desired to avoid local roads (by Federal Functional Classification), the user would choose to flag and apply a cost per mile of local roads along the projected route. The route between candidate sites and destination that used the fewest miles of

local roads (and thus accumulated the lowest cost) would be the preferred route and correlate to the preferred candidate site. Note that if these options are not selected, then the output is a route, not a declaration of a preferred site.

- The OZ program then solves the specified problem and outputs a map and excel table showing relevant results.

Results

The Opportunity Zone software was developed for this research project. The GUI welcome screen is shown in Figure 1. The software will be illustrated through a series of case studies. For further documentation detailing use of the OZ Program see the Appendix.

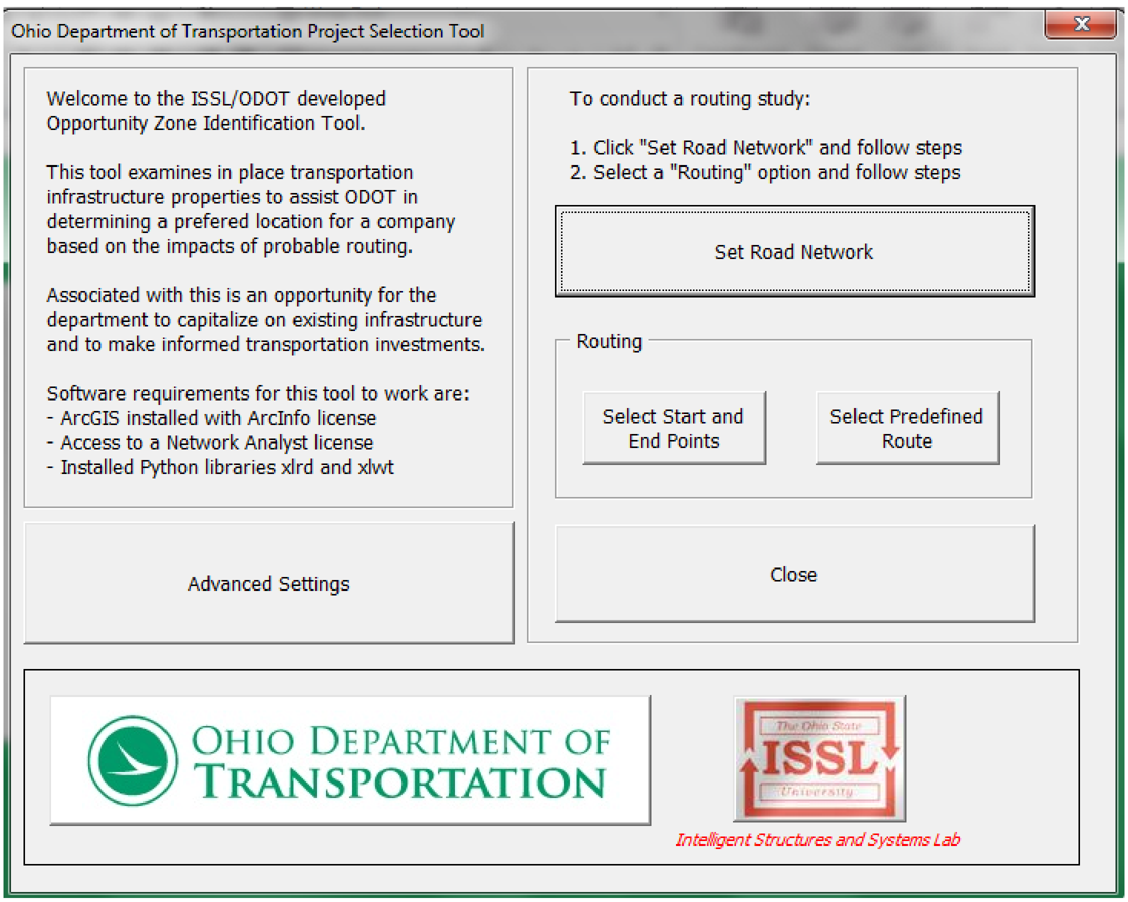

Figure 1. Opportunity Zone Program Welcome Screen

Case Study 1

Scenario: A company is considering a site for the location of their new plant and request ODOT's assistance in developing routing plans to help estimate logistical costs. At the same time, ODOT wants to verify that there are no major transportation infrastructure related problems associated with this site, given that the company plans to ship everything using freight to predefined fixed locations (customers).

Results: The following figures show relevant information obtainable from the output map file, created by the OZ Program using ArcMAP, through turning on and off respective layers as well as the associated excel workbook. Figure 2 shows how the results will appear within the ArcMap GUI.

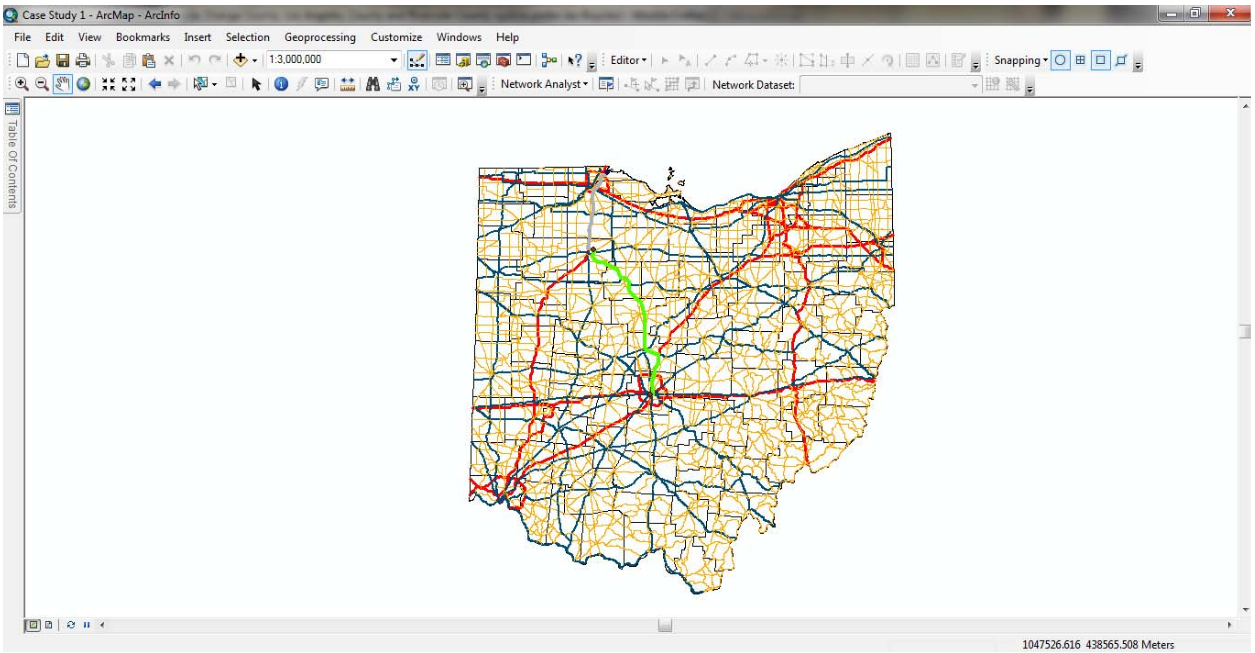

Figure 2. ArcMap GUI displaying results

Figure 3 shows the routing plans from the proposed site to the two prospective destinations; route 1 is represented by the grey line and route 2 by the green line. Table 1 shows the starting, guiding, and ending points used for this case study all in latitude and longitudinal format.

	Route 1 Points	Route 2 Points
Start	41.080645, -83.602334	41.080645, -83.602334
Guiding Point	41.087826,-83.659787	41.087826,-83.659787
End	41.68147,-83.47739	41.157486,-83.395995

Table 1. Case Study 1 recreation points

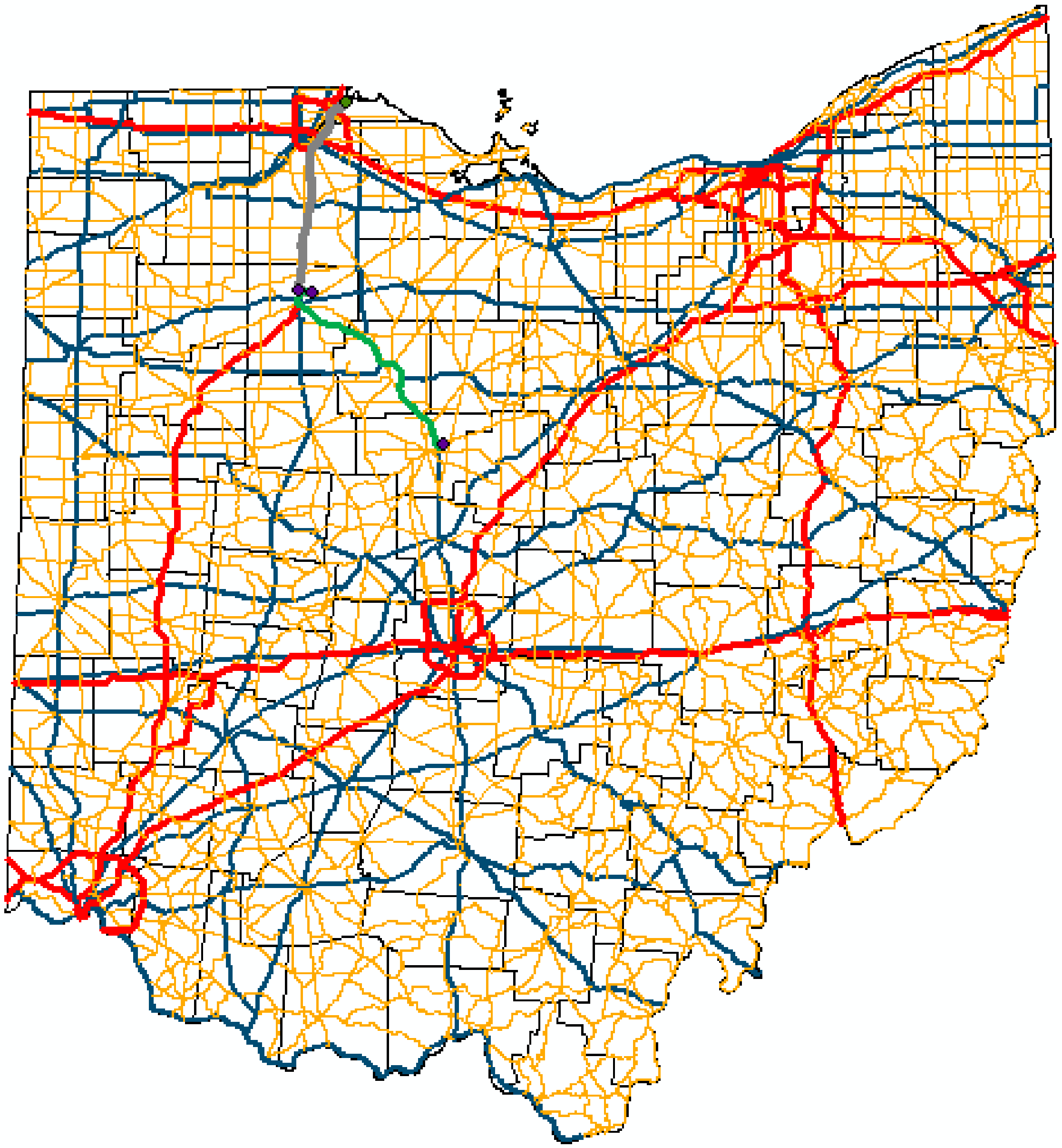

Figure 3. Routing study results, one origin two destinations (whole state)

Figure 4 and Figure 5 show routes 1 and 2 “zoomed in,” respectively.

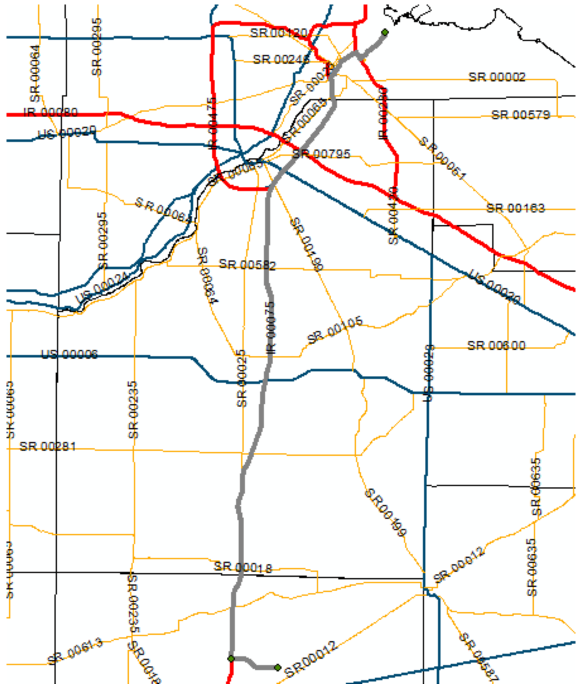

Figure 4. Route 1, zoomed

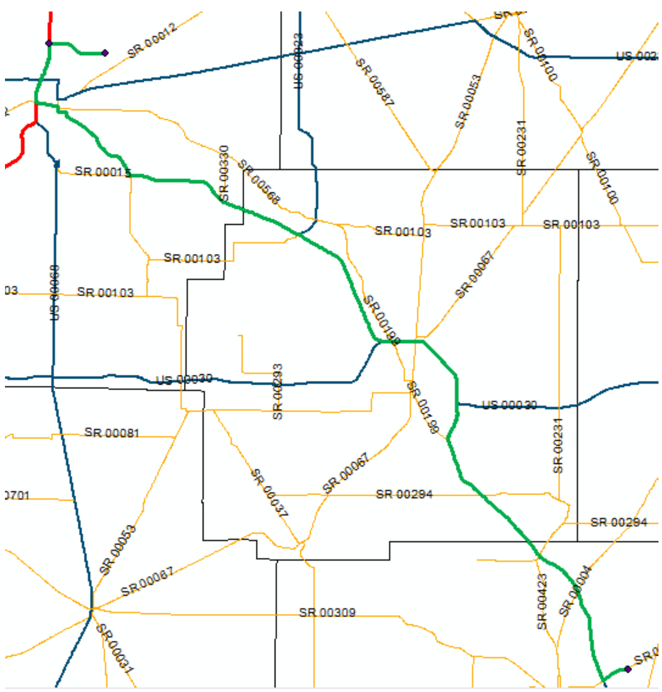

Figure 5. Route 2, zoomed

As an example of how route property information is displayed, Figure 6 and Figure 7 show existing ares of congestion along route 1 and associated tabular data from Excel.

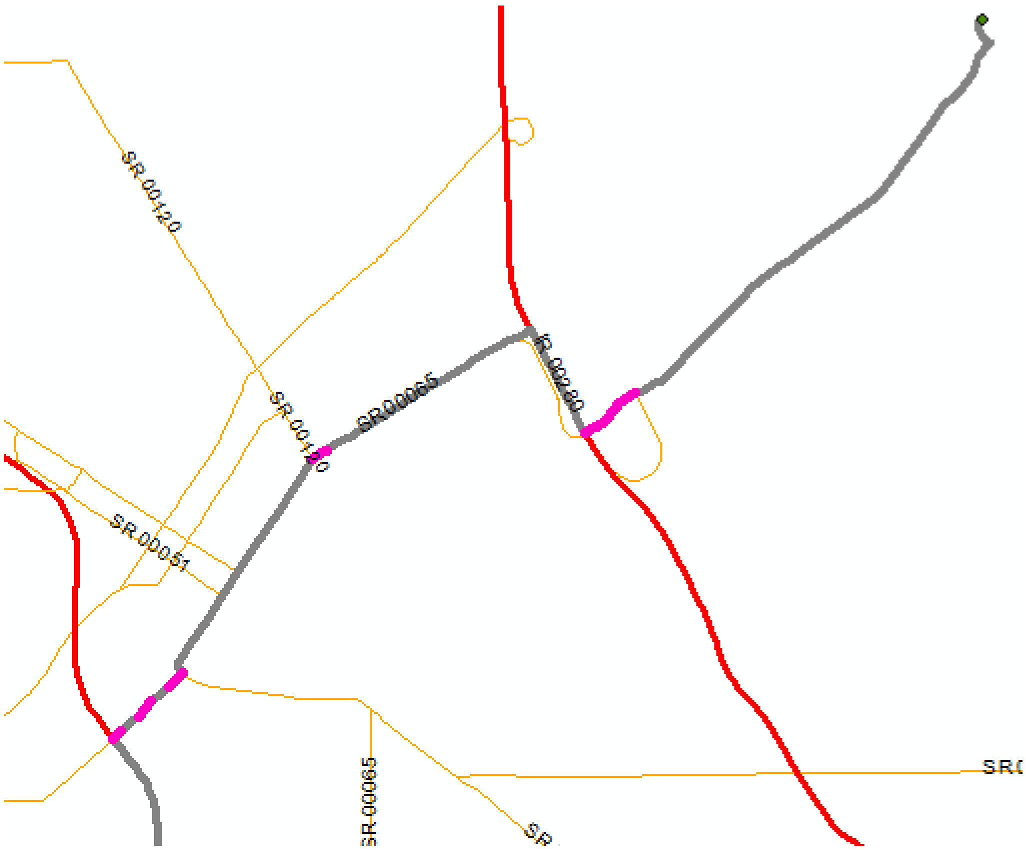

Figure 6. Segments along Route 1 that are congested (magenta lines)

		Destination:	Port_of_Toledo
File	zzzinvs	zzzinvs	zzzinvs
FC Export Field	OBJECTID	NLF_ID	CVCRATIO
Values	1	SLUCSR00002**C	0.920000017
	2	SLUCSR00002**C	1.210000038
	3	SLUCSR00002**C	0.99000001
	4	SLUCSR00065**C	0.970000029
	5	SLUCSR00065**C	0.980000019
	6	SLUCSR00065**C	0.980000019

Figure 7. Route 1 congested road segment tabular data. The higher the CVCRATIO, the higher the vehicle congestion along a segment of road.

Interpretations: Neither of the routes has any limiting transportation infrastructure concerns and the selection of this site should not be opposed.

Case Study 2

Scenario: A company is considering a site for the location of their new plant and request ODOT's assistance in developing routing plans to help estimate logistical costs. This time, the company is able to provide ODOT with their supplier locations and products destination (ex. customer or intermodal facility). At the same time, ODOT wants to verify that there are no major transportation infrastructure related problems associated with this site given that there will be, in this instance, heavy inbound and outbound freight exceeding 120% of the maximum Ohio legal load. Table 2 shows the latitude and longitudinal coordinates for the start, guiding, and end points used to create this case study.

	Route Points
Start	39.099264,-84.536556
Guiding Point	41.087826,-83.659787
Guiding Point	41.080645, -83.602334
Guiding Point	41.087826,-83.659787
End	41.68147,-83.47739

Table 2. Case Study 2 recreation points

Results: Figure 8 shows relevant information obtainable from the output map file, created by the OZ Program using ArcMAP, through turning on and off respective layers as well as the associated excel workbook. The full impact route (supplier to potential new company location to customer) is shown in grey. Bridges that violate the strength criteria are depicted using the maroon dots along the route.

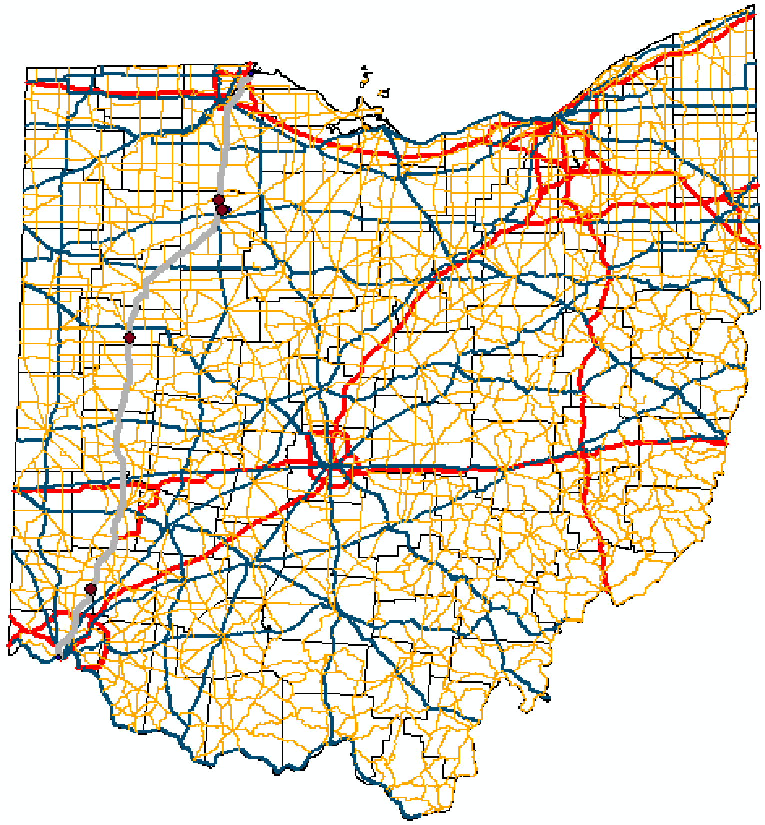

Figure 8. Full transportation impact example showing bridge violations (single supplier and single customer)

The tabular data for the bridges in violation of the strength criterion are shown in Figure 9.

File	Bridges10	Bridges10	Bridges10
FC Export Field	OBJECTID	NLF_ID_INV	**LOAD_RAT_P**
Values	1	SAUGIR00075**C	**115**
	2	SBUTIR00075**C	**105**
	3	SHANIR00075**C	**115**
	4	CHANCR00212**C	**100**

Figure 9. Full impact bridge tabular data

Interpretations: It should be noted that this route does in fact have bridges (4) in violation of planned shipping weights. This finding, however, is not a 'show stopper' and does not mean that the selection of this site should be opposed; rather, it is information that is advantageous for ODOT to know in advance of discussions with the permitting office.

Conclusions and Recommendations

A strong supporting argument for the OZ Program is made through the words of the ODOT report entitled "Impacts of Permitted Trucking on Ohio's Transportation System and Economy":

> Pavement thickness design is based on the projected loading the pavement is expected to carry over a certain time period. New pavements are designed to carry 20 years of traffic loading. Twenty year traffic loading is the cumulative effect of all trucks expected to traverse the pavement in a 20 year period [2].

This speaks directly to the level and type of analysis of the OZ Program. In summary, if a company is located such that the surrounding infrastructure is insufficient to handle the new loads associated with the company doing business (both from suppliers coming in and shipments departing), then the infrastructure will deteriorate in quality more rapidly than projected. This will accelerate the need and possibly the frequency for planned repairs and maintenance, directly resulting in higher monetary costs. Therefore, it is recommended that the OZ Program be utilized as a filter during the planning phase in the site selection process for companies that are relying on freight transportation for receiving and shipping goods.

Implementation Plan

Target users of the OZ Program are persons whose job duties include providing information or making suggestions during the site selection process. Users should be comfortable with Microsoft Excel, as well as ESRI ArcGIS (ArcCatalog and ArcMap). It is recommended that this program be implemented immediately for maximum effectiveness.

The steps for implementation are to have all supporting software installed and the required data available. A user's manual is provided. Required supporting software consists of:

- Microsoft Excel
- ESRI ArcGIS 10 suite with ArcInfo license and Network Analyst extension (comes with Python)
- Python XLRD and XLWT libraries

Specifics are detailed in the appendix, but in general, required data should exist on the local hard drive and includes:

- Augmented copy of the three road inventory files (with congestions and lane width)
- Road network for the Network Analyst
- Files containing common starting and ending points (optional)

The OZ Program offers a wide range of benefits depending on the level of similar work a group is already doing and how results are used. For groups already performing the functions of the program by hand this will be a time saver. For groups not considering their transportation infrastructure when making site recommendations, the program offers the potential for reducing expenses associated with the location of the company.

This tool is a modeling program. The results should be interpreted with caution (manual checking of results). One concern is the completeness and accuracy of the required data (such as non-continuous road segments affecting travel path). Specific examples have been documented in the appendix and shared among the project team. The data sets can improve through continuous data accuracy improvement efforts, facilitated by good communication between OZ Program users and data administrators.

Since ODOT already has concurrent use licenses for ArcMap10 (including ArcInfo licenses and Network Analyst extensions) and currently collects and maintains all required data, the cost of implementing the OZ Program is the time required to become familiar with the program.

References Cited

1. Ohio Means Business. http://www.ohiomeansbusiness.com/why-ohio/the-ohio-promise/ohio-facts.php. Accessed 8/25/201.
2. Impacts of Permitted Trucking on Ohio's Transportation System and Economy, 1/30/09, pg 7. http://www.dot.state.oh.us/Divisions/Operations/Maintenance/Permits/Documents/Impacts%20of%20Permitted%20Trucking.pdf. Accessed 9/6/2011

Appendix: Introduction

This appendix is written with the intent of being an instructive document on how to use, update, modify, and maintain the software aspect of the Development of Opportunity Zone Utilizing Transportation Assets project,[3] which shall be referred to from this point forward as "the OZ Program" or simply "the program".

Users and GIS Data Administrators

This document contains information useful for two groups: the program user and a geographic information system (GIS) data administrator. A user is a person who will be using the program to derive results while the GIS data administrator is a person who will assist in the creation of geodatabases (gdbs), feature datasets (FDs), updating and creating GIS files, as well as updating the Network Datasets. It is therefore expected that a user has a good understanding of Microsoft Excel and a basic understanding of how to navigate the ESRI ArcMap 10 interface. Further, it is expected that the GIS data administrator has a good understanding of Excel and an advanced understanding of the ArcMap 10 interface and ArcCatalog 10.

General Warnings and Possible Errors

This program can be easily "broken" if certain precautions are not observed:

- Read the file structure section to understand why files cannot be moved from their default location or renamed.
- All pages in the Excel file exist for a reason. **DO NOT** delete any of them.
- Do not have multiple instances of the OZ Program running at the same time. For safety, until the user understands how the OZ Program affects concurrent instances of Excel, only have one instance of Excel running.
    - Note that at the completion of running an analysis using the OZ Program an output Excel file is created and will be running at the same time as the program. This is OK. Just close the output Excel document prior to running a new analysis.
- Do not have any ESRI application running while running the program.
    - Note that at the completion of running an analysis using the OZ program an output ArcMap 10 file is created and will be running at the same time as the program. This is OK. Just close the ArcMap 10 document prior to running a new analysis.
- Create local copies of the gdb with all relevant FDs and feature classes (on C drive). This will avoid schema lock errors that will not allow the program to run.

[3] Nuances of the Python and VBA code are not included in this document, but rather as comments in the respective scripts and modules.

Program Components

The OZ Program is actually a combination of multiple programs and scripts that reference and call each other including an Excel document, an Excel VBA GUI (within the Excel document), supporting VBA code, Python scripts, an ArcMap 10 output file, and an Excel output file. Opening the Excel document "ODOT OpZone Identifier Tool" (.xls) will cause the GUI to initiate (Figure 10). Without going into details at this time, upon reaching the last screen of the GUI the user will click on the "Solve" button. This will subsequently launch the Python command prompt (Figure 11) where text will be generated on the screen (the user does not need to do anything). When the Python portion of the code is complete, the Python command prompt will go away and an instance of ArcMap 10 will launch (Figure 12), as well as an output Excel file. When both these programs launch, all code is done running and the outputs can be examined.

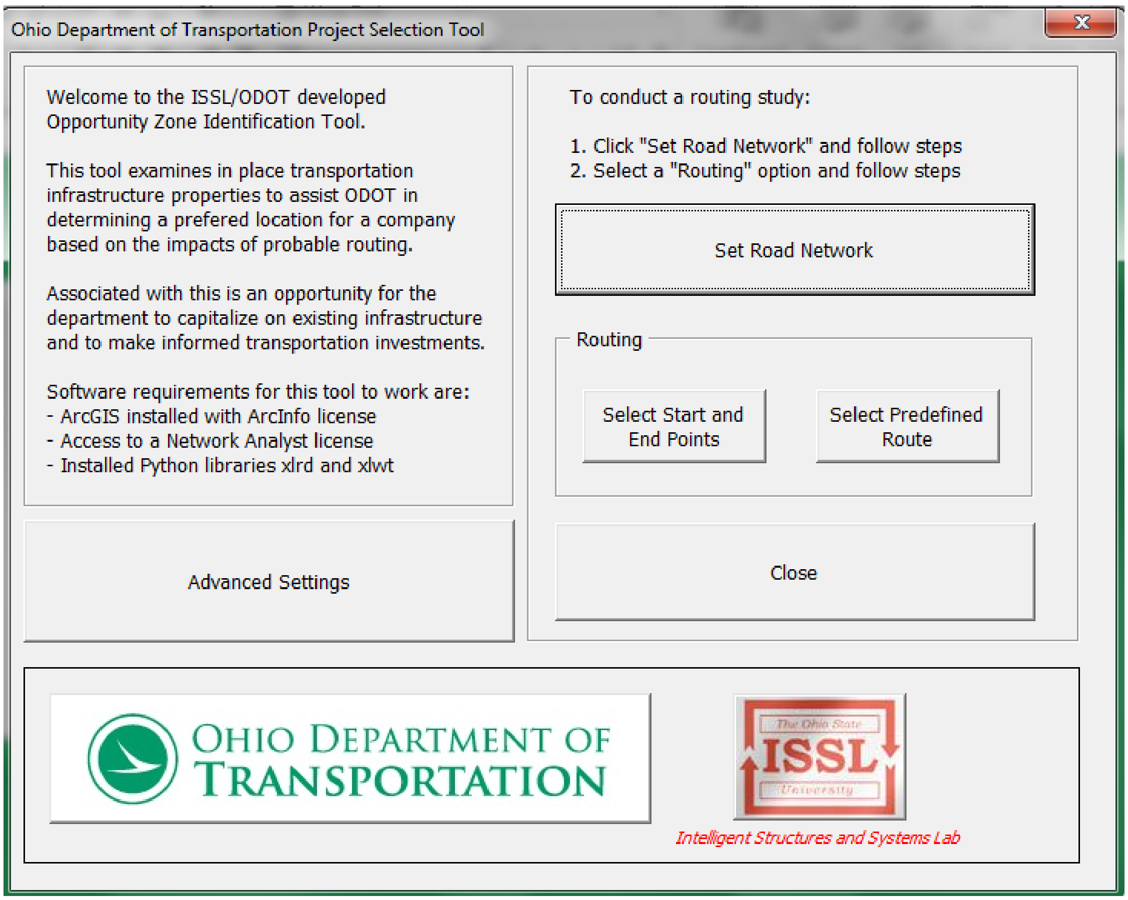

Figure 10. The Program's GUI Welcome Screen

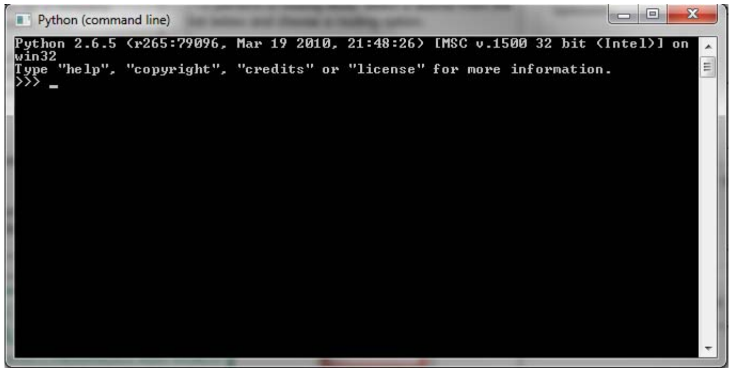

Figure 11. Python Command Prompt

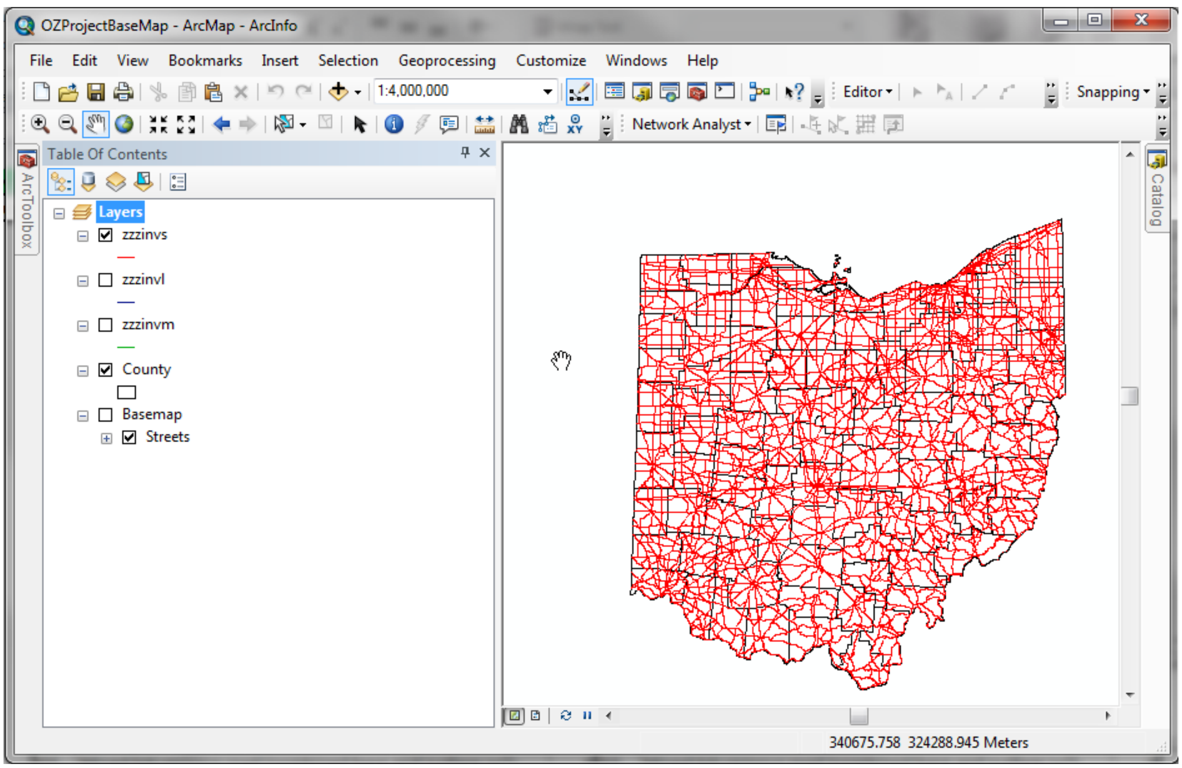

Figure 12. ArcMap 10 Interface

Software Requirements

As can be inferred from the previous section, there are some requirements that need to be met in order for the program to work. Omission of any one of these criteria will cause the program to fail.

- Installation of Microsoft Excel (version 2003 or later) with the ability to run macros (macros enabled)
- Installation of ESRI's ArcDesktop 10

    - Available ArcInfo license and Network Analyst extension
- Proper installation of Python xlrd and xlwt libraries (Figure 13). Python itself is installed as part of ArcDesktop.
    - xlrd and xlwt installations files are included on OZ Program on disk, but if need to re-download:
        - http://pypi.python.org/pypi/xlrd (win32.exe download)
        - http://pypi.python.org/pypi/xlwt (win32.exe download)
    - Default file path: C:\Python26\ArcGIS10.0\Lib\site-packages (Figure 13)
- Available hard drive space (project dependent, multiple gigabytes to be safe)

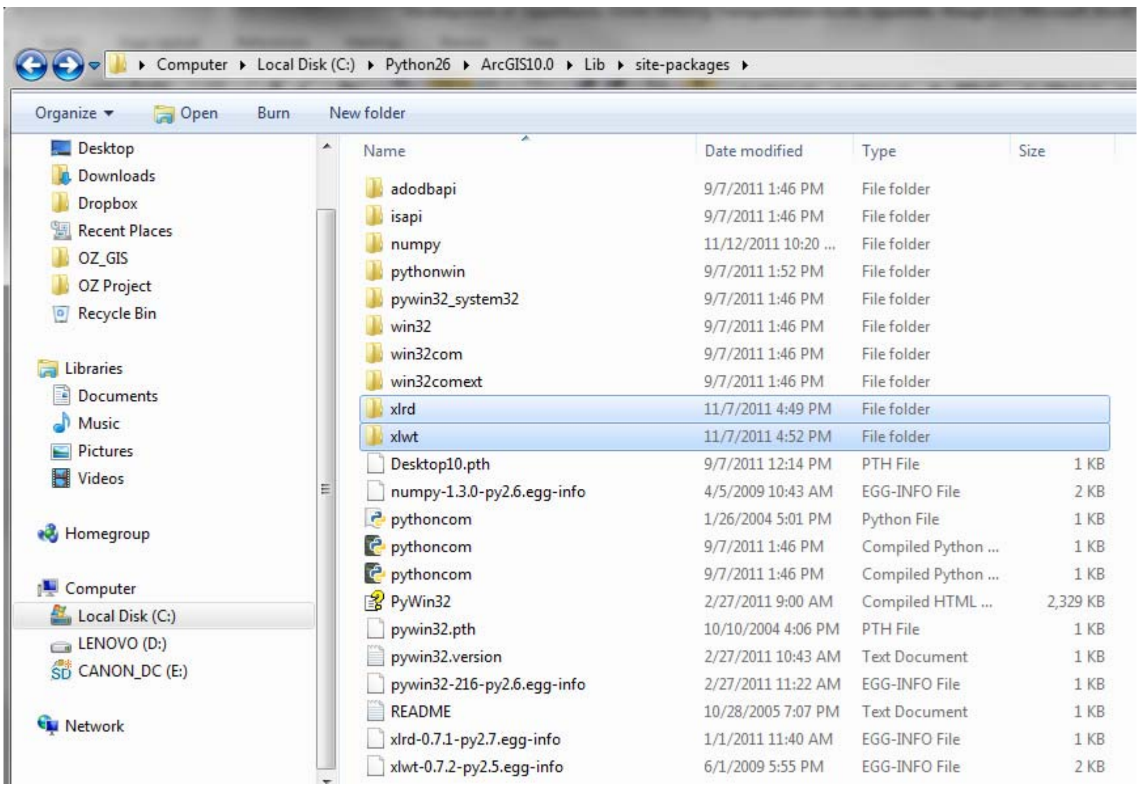

Figure 13. Installed xlrd and xlwt location

Appendix: Nonstandard ODOT files and how to recreate (GIS DATA)

The majority of the data contained in the OZProject.gdb folder was obtained in GIS format from ODOT. The following gives details on those data sets in OZProject.gdb which are either novel non-ODOT data sets or modified ODOT data sets.

POI (Points of Interest) Feature Class

This data set can be used in the origin and destination selection process. It serves as a quick reference point to guide the route to a general area.

Name	**Location**
Indiana-Fort Wayne	Junction Ohio Border and US-30 W
Indiana-Indianapolis	Junction Ohio Border and I-70 W
Indiana-Montpelier	Junction Ohio Border and I-80/90 W
Kentucky-Cincinnati	Junction Ohio Border and I-71/75 S
Kentucky-Portsmouth	Junction Ohio Border and US-23 S
Michigan-Ann Arbor	Junction Ohio Border and US-23 N
Michigan-Detroit	Junction Ohio Border and I-75 N
Ohio-Akron	Junction of I-76 & I-77
Ohio-Cincinnati	Junction of I-75 & 126
Ohio-Cleveland	Junction of I-71 & I-90
Ohio-Columbus	Junction of I-70 & I-71
Ohio-Dayton	Junction of US-35 & I-75
Ohio-Findlay	Junction of US-224 & SR-12
Ohio-Lima	Junction of SR-65 & SR-81
Ohio-Marysville	Junction of US-33 & US-36
Ohio-Toledo	Junction of I-75 & I-475
Ohio-Youngstown	Junction of I-680 & US-62
Pennsylvania-Erie	Junction Ohio Border and I-90 E
Pennsylvania-Pittsburgh	Junction Ohio Border and I-76 E
Pennsylvania-Youngstown	Junction Ohio Border and I-80 E
West Virginia-Charleston	Junction Ohio Border and US-35 E
West Virginia-Marietta	Junction Ohio Border and I-77 S
West Virginia-Wheeling	Junction Ohio Border and I-70 E

Table 3. List of POIs

JobsOhioAvailable Feature Class

The JobsOhioAvailable feature class is a point file listing of all available job sites in Ohio as classified by Jobs Ohio and submitted for use in the Ohio InSite tool[4]. A cvc file (data dump) was obtained through contact with Matt Cybulski[5] of Jobs Ohio. Once the cvc file was obtained, it was manipulated in the following manner and resulted in the included feature class file; future data dumps can be manipulated in the following manner.

Derivation of the JobsOhioAvailable Feature Class

1. Open Data Dump File in Excel and check given latitude(y) and longitude(x) coordinates to make sure they fall within the state of Ohio boundaries[6]
   - Latitude (North to South, Y coordinate): 38° 24′ N to 41° 59′ N → 38.4 to 41.9833
   - Longitude (East to West, X coordinate): 80° 31′ W to 84° 49′ W → -80.5167 to -84.8167
2. Format Latitude and Longitude column entries as Numbers with 8 decimal places
3. Delete unneeded columns to shrink file size (columns in the cvc file translate to columns in the attribute table)
4. Delete sites (rows) not classified as "Future" or "Available" in "status" column
5. Sort alphabetically by the "name" column
   - Make sure the entire sheet is selected and not just "name" column
6. Add a new first column (insert a new A column) named "ID" and number all entries sequentially starting with the number 1 in row 2 using integer formatting
7. Convert .csv to .xls file (save as) with no spaces in file path or file name
8. In ArcMap 10, start a new document and click: add data button (Figure 14) → select .xls document (Figure 15) → select sheet (Figure 16)

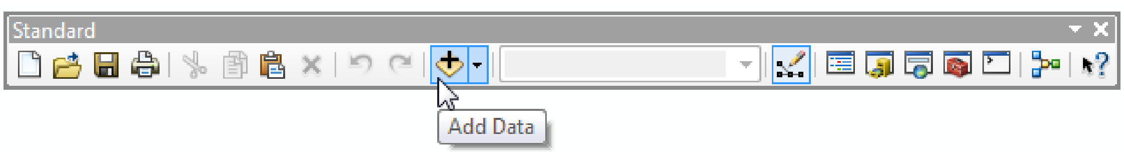

Figure 14. Add Data button found in the standard toolbar

[4] http://www.ohiomeansbusiness.com/site-selection/ohio-insite.php, developed and maintained by ATLAS
[5] mcybulski@ohiomeansbusiness.com
[6] 20,892 out of 22,067 lat/long entries "valid" as of 2011-9-15 data dump

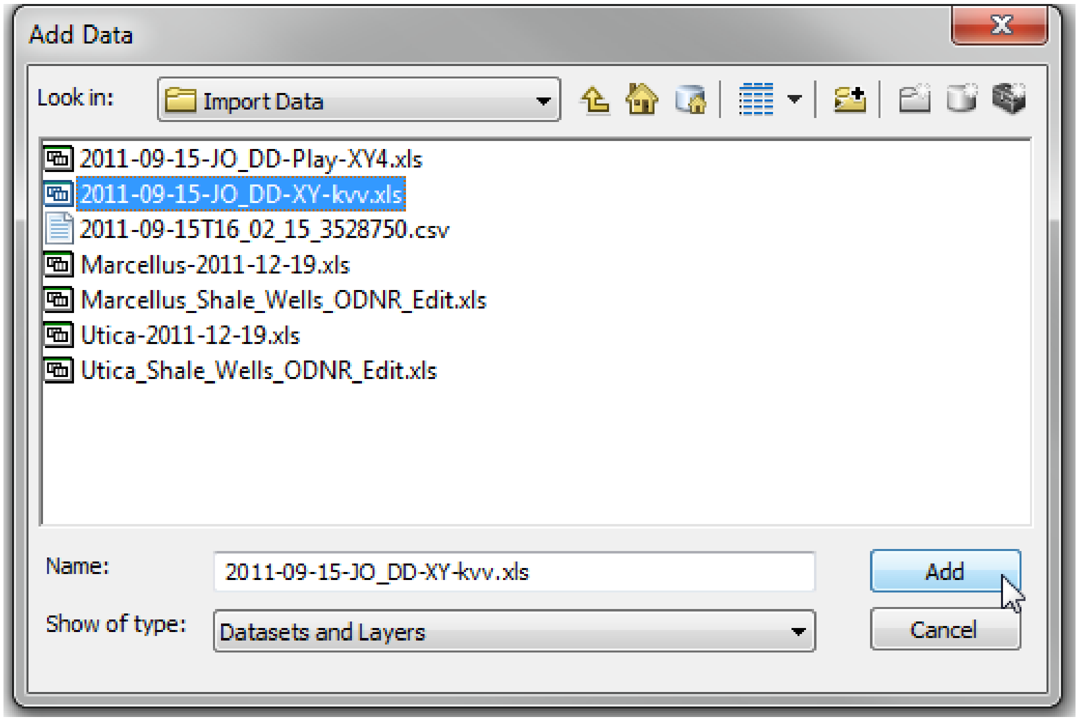

Figure 15. Select relevant xls document

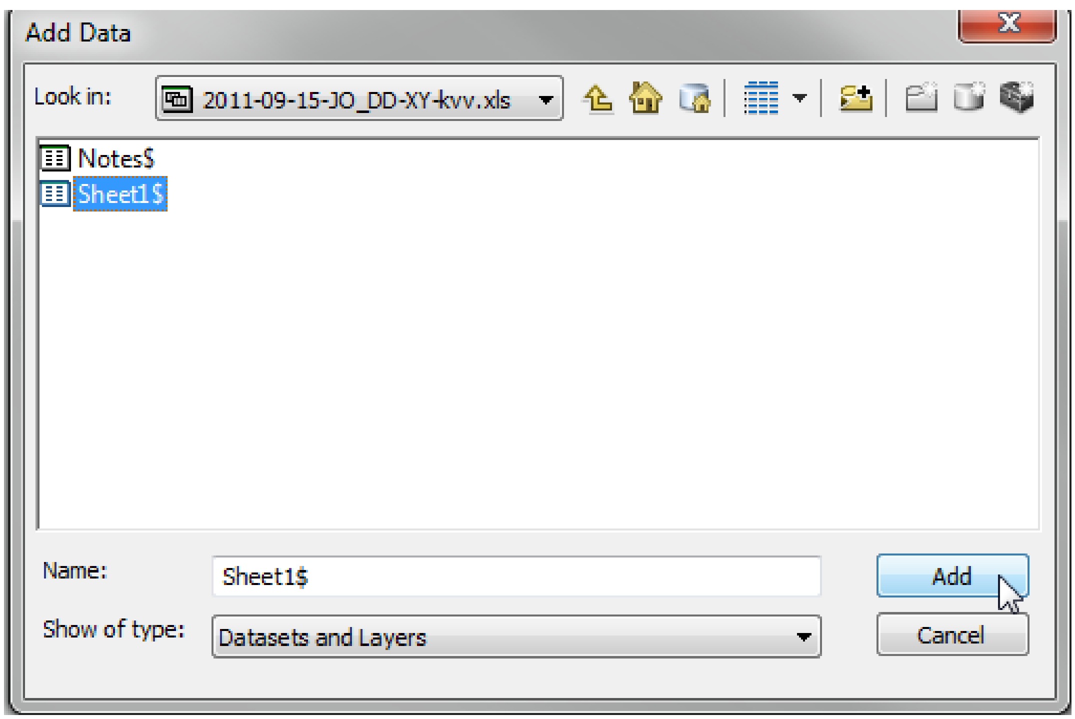

Figure 16. Select relevant sheet

9. Once loaded in the table of contents, right click on added sheet name → click “display xy data” (Figure 17)

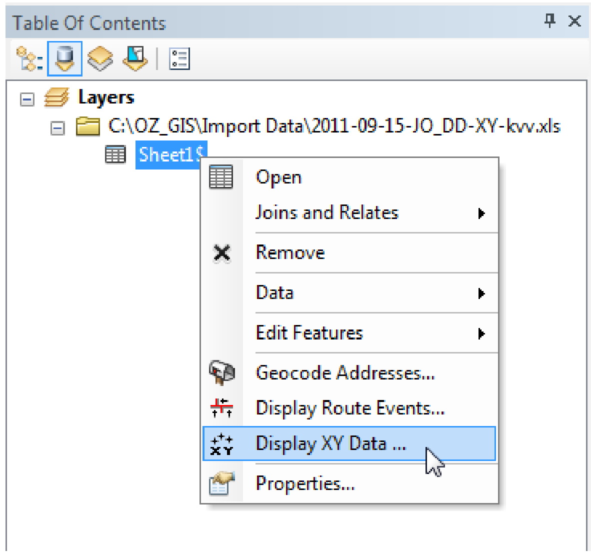

Figure 17. Display XY Data

10. Set x and y fields to match longitude and latitude fields, respectively, with z=none (Figure 18)
11. Click “Edit…” to set coordinate system (Figure 18) → Select (Figure 19)→ Geographic Coordinate Systems (Figure 20) → World (Figure 21) → WGS 1984.prj (Figure 22) → “Add”→ “Apply” → “OK” → ”OK”

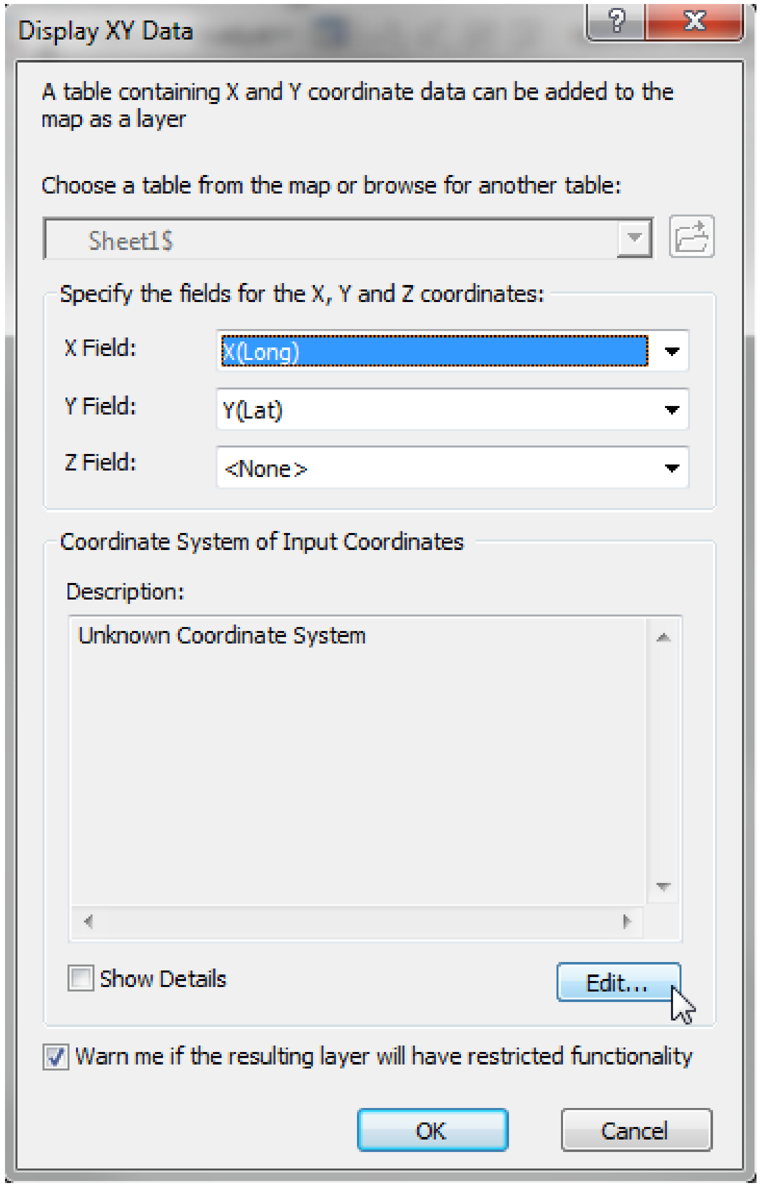

Figure 18. Setting X Field to longitude column and Y field to latitude column

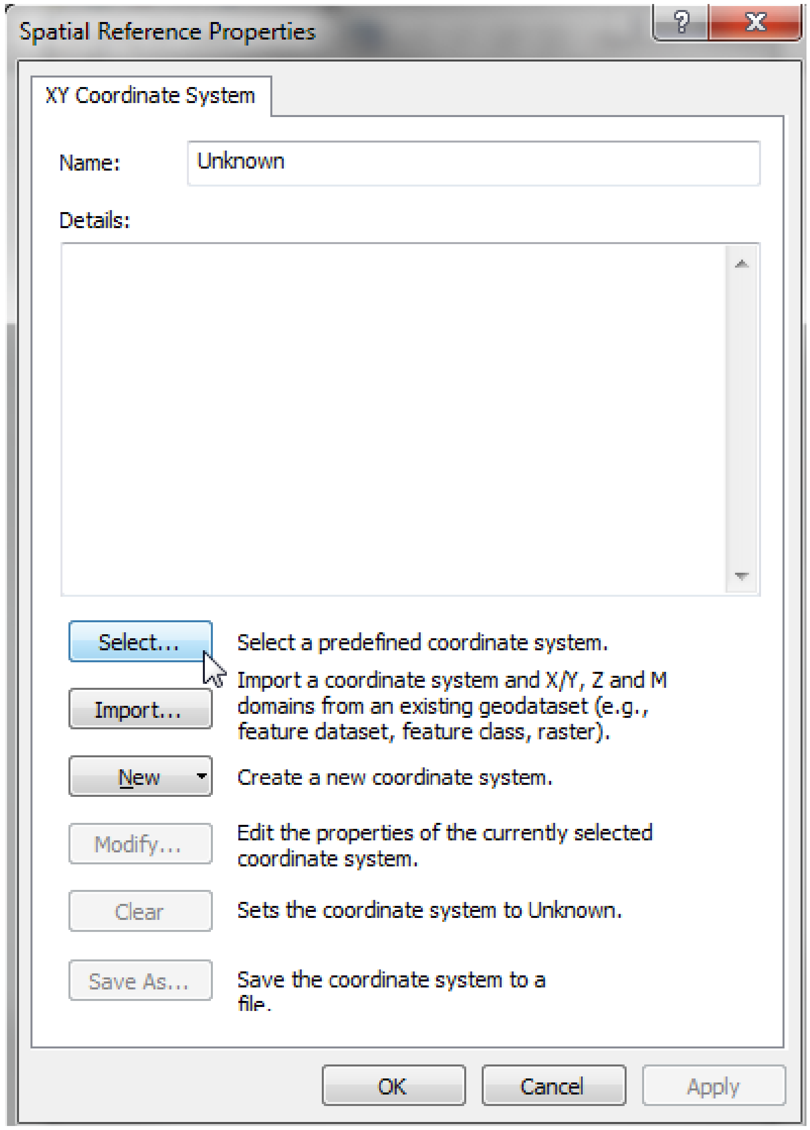

Figure 19. Select a predefined coordinate system

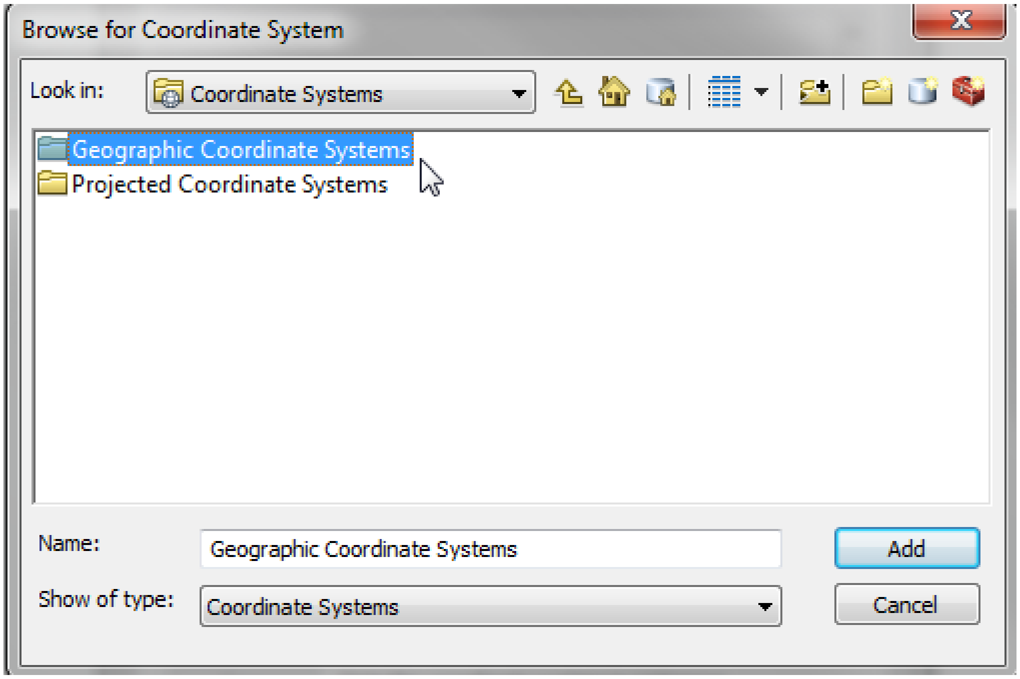

Figure 20. Geographic coordinate systems

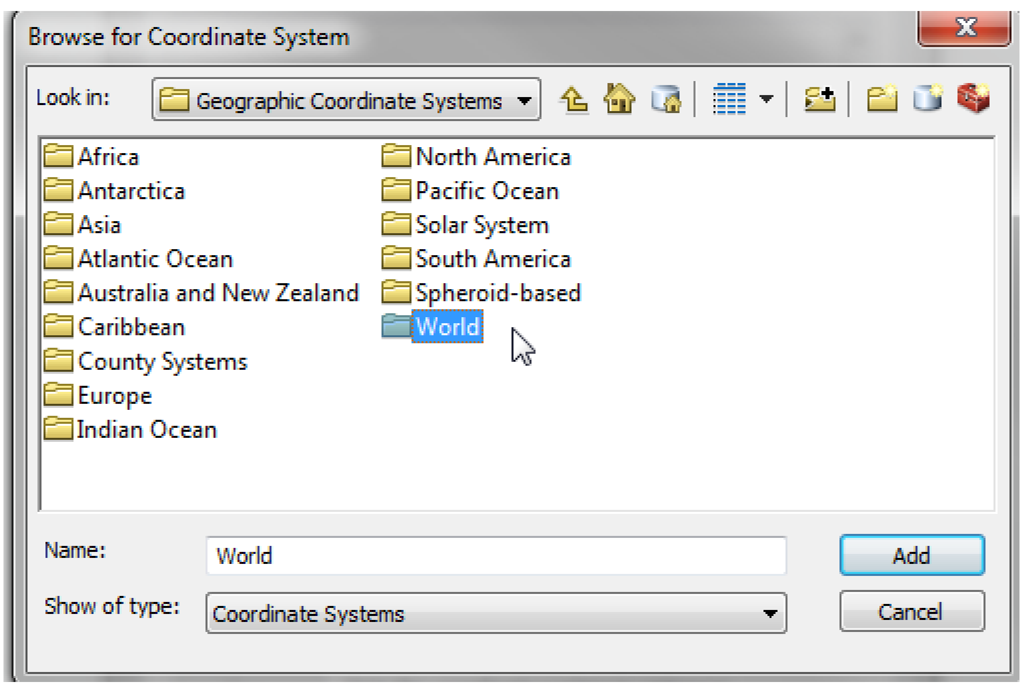

Figure 21. World set of geographic coordinate systems

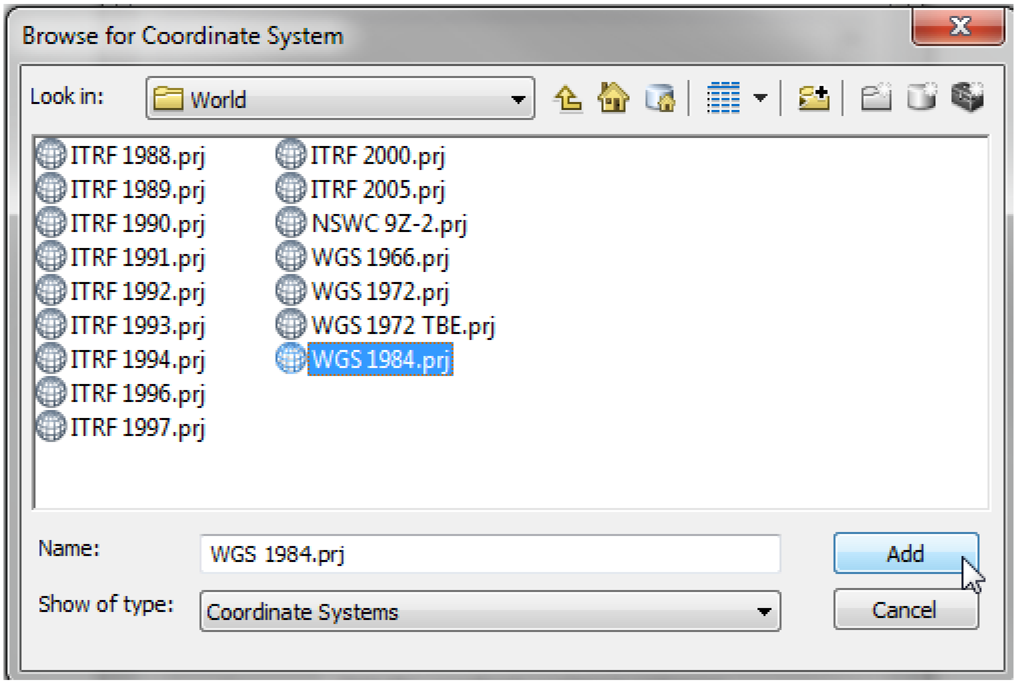

Figure 22. World WGS 1984.prj (associated with latitude and longitude)

12. Will get the message displayed below in Figure 23. Click OK

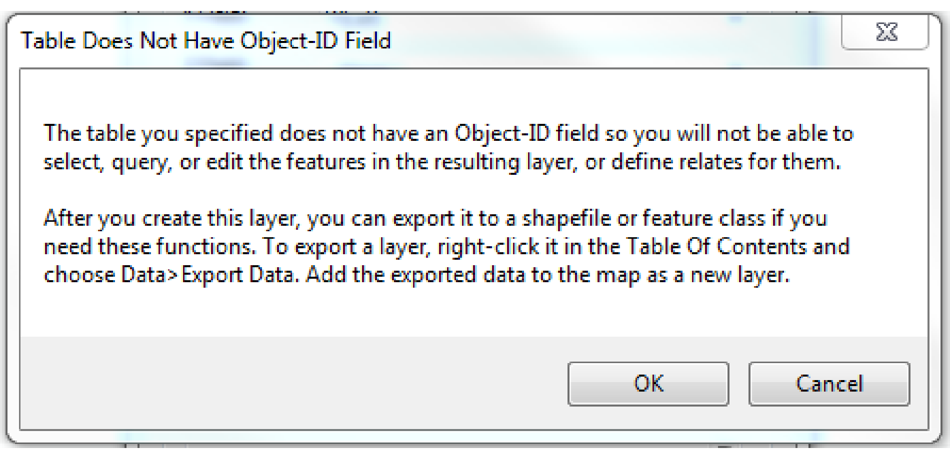

Figure 23. Object-ID prompt

13. Points displayed will be in a “stretched” Ohio (Figure 24), this is OK for now

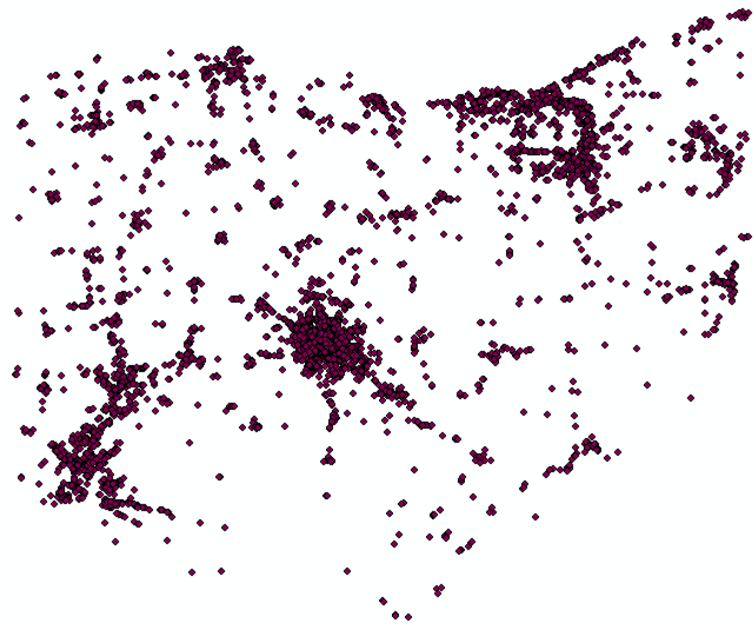

Figure 24. 'WGS 1984.prj' plotted points (appears 'stretched')

14. Right-click "sheet name" &" Events" (Figure 25) in file tree → Data → Export Data… (Figure 26) → Click browse icon in Export Data screen (Figure 27) → Navigate to Sites FD in OZProject.gdb (Figure 28)→ Enter a relevant name (Figure 29) → Save → Make sure the 3rd radio button is selected on the Export Data screen and click OK (Figure 30). You can choose to import the results, but they will not appear any differently than the 'stretched' points.

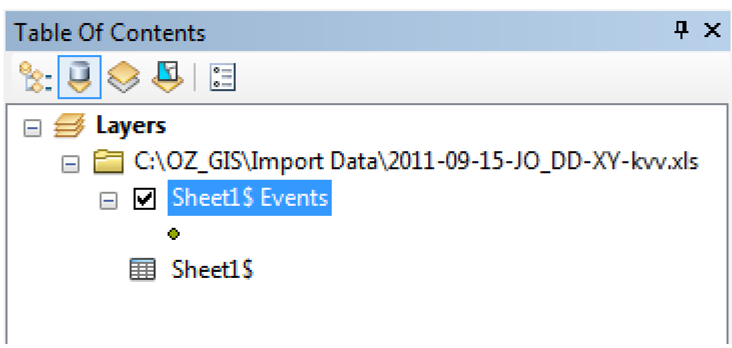

Figure 25. Imported sheet displaying XY points

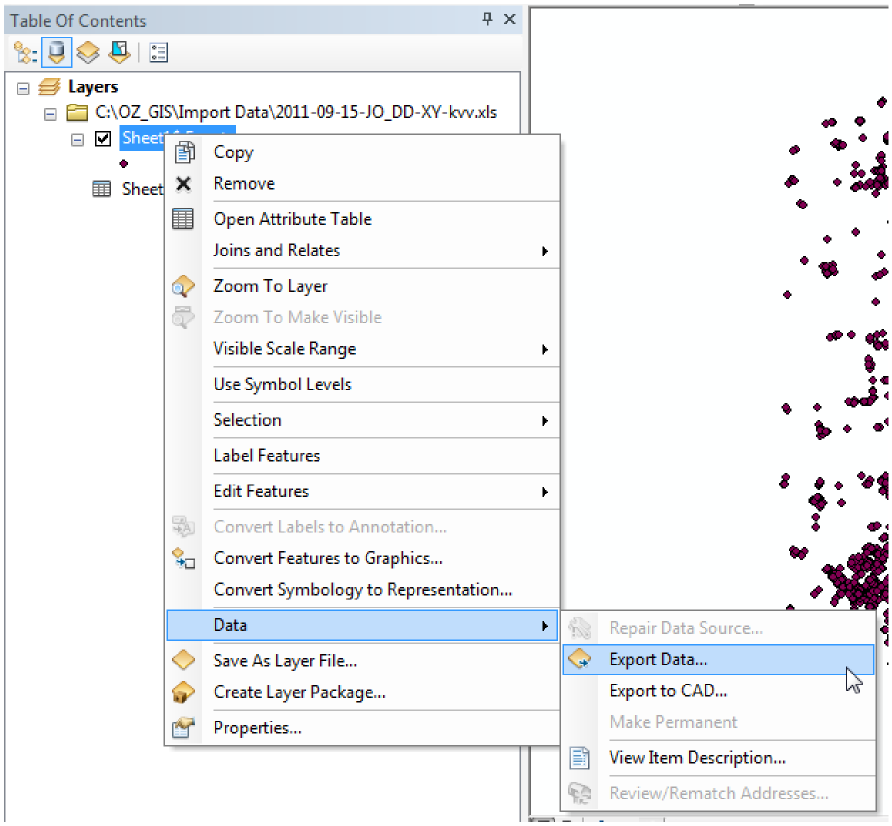

Figure 26. Export Data

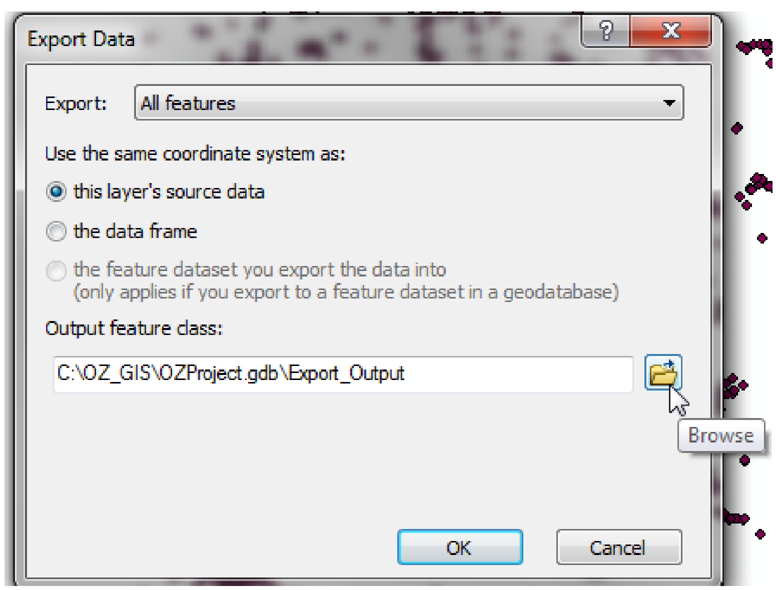

Figure 27. Export Data prompt (click Browse icon)

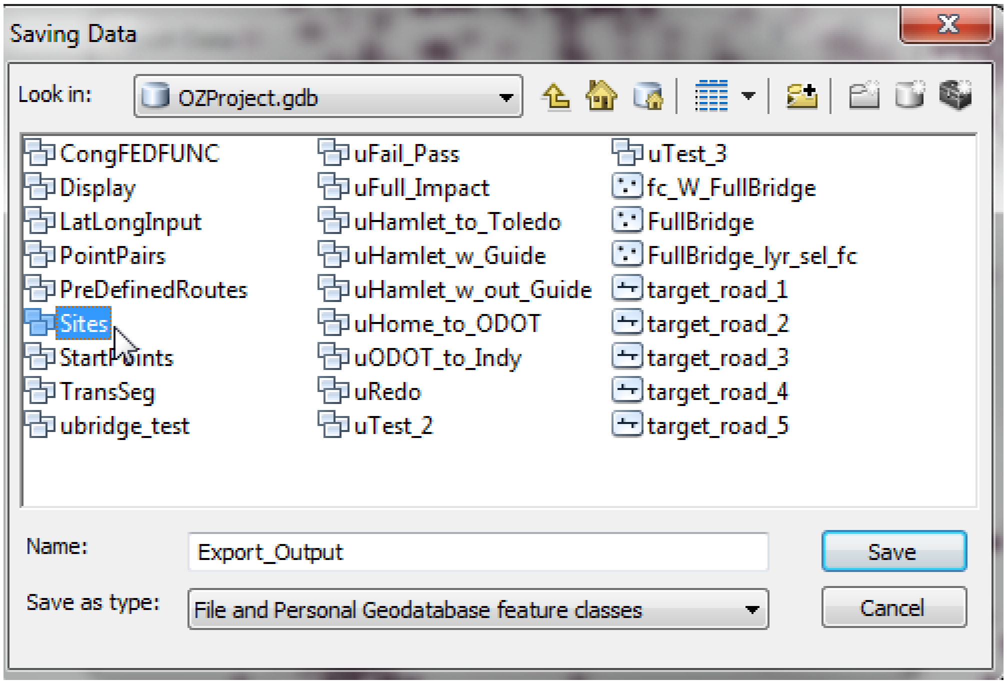

Figure 28. Save to Sites FD

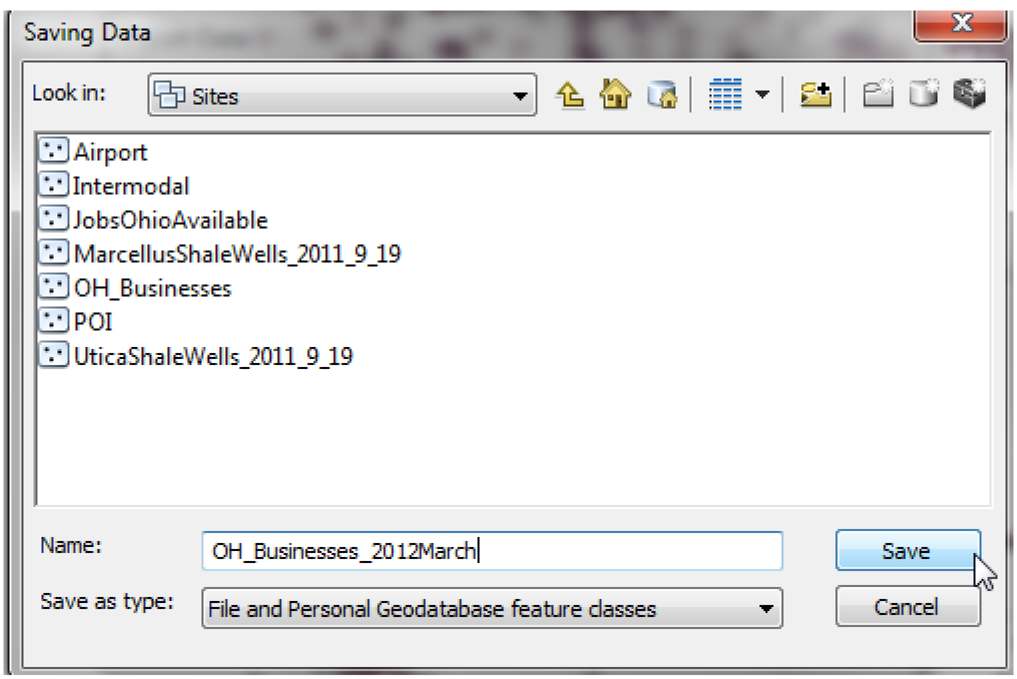

Figure 29. Enter relevant name

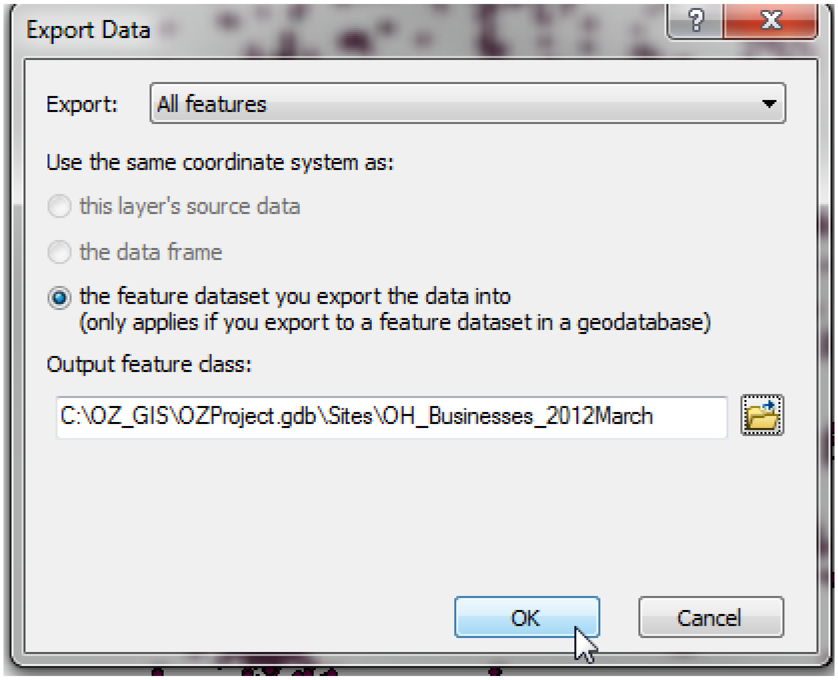

Figure 30. Completed Export Data screen

15. Start a new map document and import the new feature class you just created. The points should now appear to fit a narrower Ohio shape, shown in Figure 31, because we assigned them the same projection as the Sites FD (NAD 1983 StatePlane Ohio South - Meters)

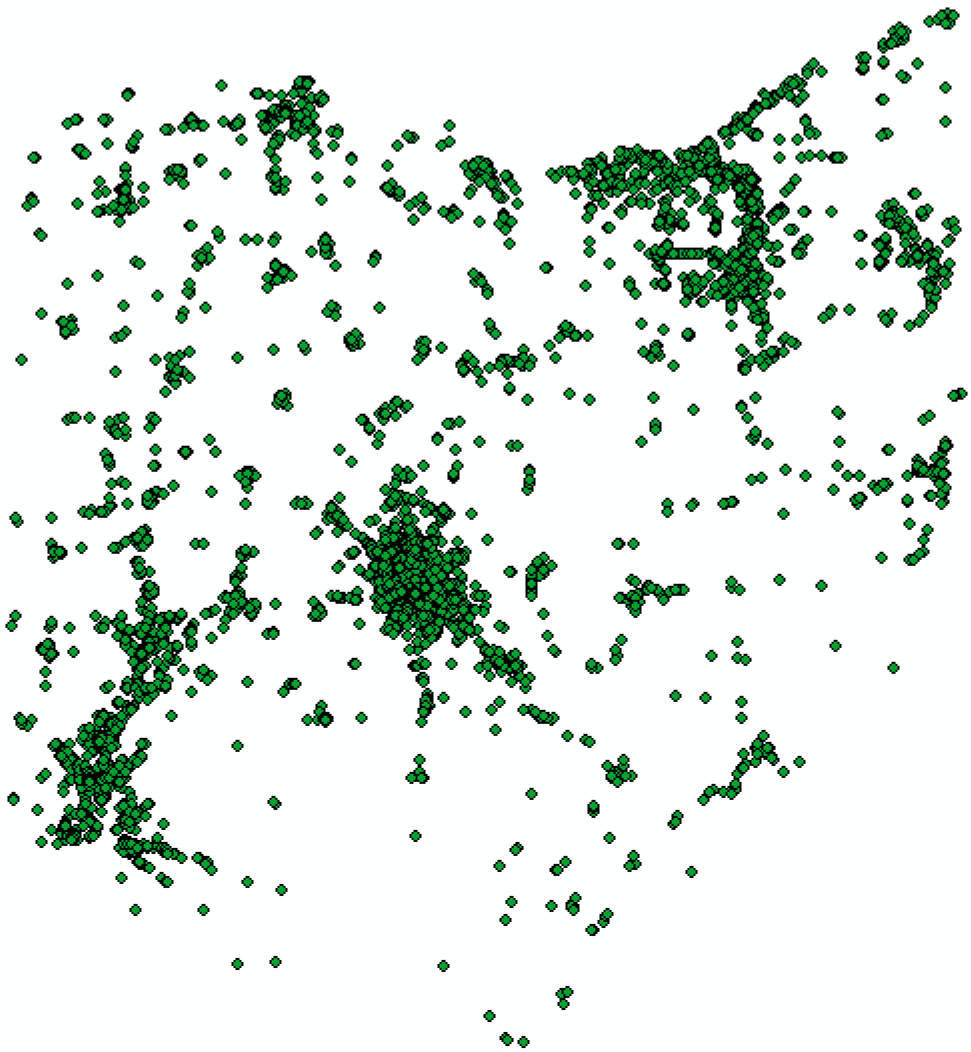

Figure 31. Ohio State Plane South projection of points

Marcellus and Utica Wells

A list of well activity from the Division of Mineral Resources Management in excel tabular format is available from

http://www.dnr.state.oh.us/geosurvey/pub/openfile/biglime/tabid/23014/Default.aspx

for both the Marcellus and Utica wells. Once downloaded, they can be converted to GIS file format using the same technique detailed above for JobsOhioAvailable using relevant file naming.

zzzinvs and zzzinvl congestion columns

The state inventory files do not have any information detailing congestion. Congestion information, specifically the VC (volume to congestion) ratio was obtained from ODOT's Modeling and Forecasting section. Unfortunately, the modeling group's road network does not directly correlate with the state inventory road network. To attribute congestion from the modeled state roads to the state inventory roads, the following manipulation was required.

- Separate the entire modeled network into new feature classes by FFC (Federal Functional Classification) through a "Select by Attributes" query. To read more about FFCs, see the following section entitled The Federal Functional Classification.
- Separate the road inventory files with respect to state and local classification into feature classes by FFC.
- For each FFC feature class derived from the modeled network, create a new feature class by turning the line segments into midpoints (FeatureToPoint_management geoprocessing command).

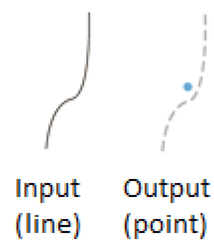

Figure 32. Illustration of line to point manipulation[7]

- Do a near analysis between similar road inventory FFC feature classes and modeled FFC point feature classes (use the Near_analysis command); for example, modeled FFC 11 feature class and state road inventory FFC 11 feature class. The result of this analysis is the correlation between road inventory road segments and modeled road segments (specifically the midpoint, but all attribute data is maintained which is the key) as shown in Figure 33.

[7] http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#/Feature_To_Point/00170000003m000000/

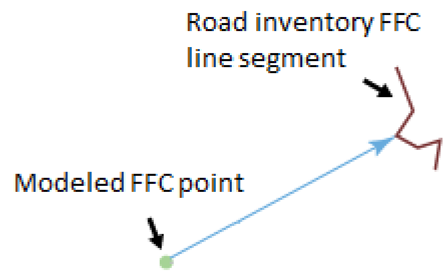

Figure 33. Illustration of near analysis correlating a point to nearest line[8]

- o For unmatched road segments, manual examination and matching of the data are required
- A table join using the unique id generated from the near analysis allows the addition of the modeled "CVCRATIO" attribute data to the road inventory FFC feature classes (JoinField_management command).

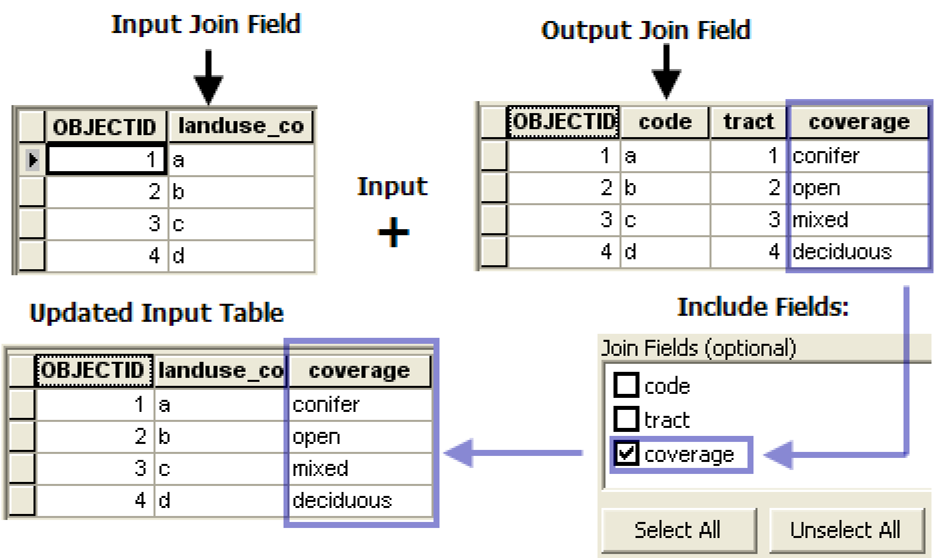

Figure 34. Illustration of Join[9]

For future updates the above (and additional tasks) have been programmed into the Python script titled "RI_TS_Update" and can be accessed by clicking the "Update Network Files" button on the 'Advanced Settings Screen' (refer to section Update Network Files on page 60).

[8] http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//00080000001q000000.htm
[9] http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//001700000065000000

The Federal Functional Classification System

Roads are classified, in an effort to capture the ratio between land access and mobility in which they offer, through the assignment of a Federal Functional Classification (FFC) number. All road inventory file road segments are assigned an FFC that has an associated description, per ODOT's TIMS group, detailed in Table 4. A graphical depiction capturing the land access versus mobility relationship is shown in Figure 35.

Federal Functional Classification Number	Description
1	Principal Arterial Interstate (Rural)
2	Principal Arterial – Other (Rural)
6	Minor Arterial (Rural)
7	Major Collector (Rural)
8	Minor Collector (Rural)
9	Local (Rural)
11	Principal Arterial Interstate (Urban)
12	Principal Arterial – Other Freeways and Expressways (Urban)
14	Principal Arterial – Other (Urban)
16	Minor Arterial (Urban)
17	Collector (Urban)
19	Local (Urban)

Table 4. Road inventory system Federal Functional Classification number summary

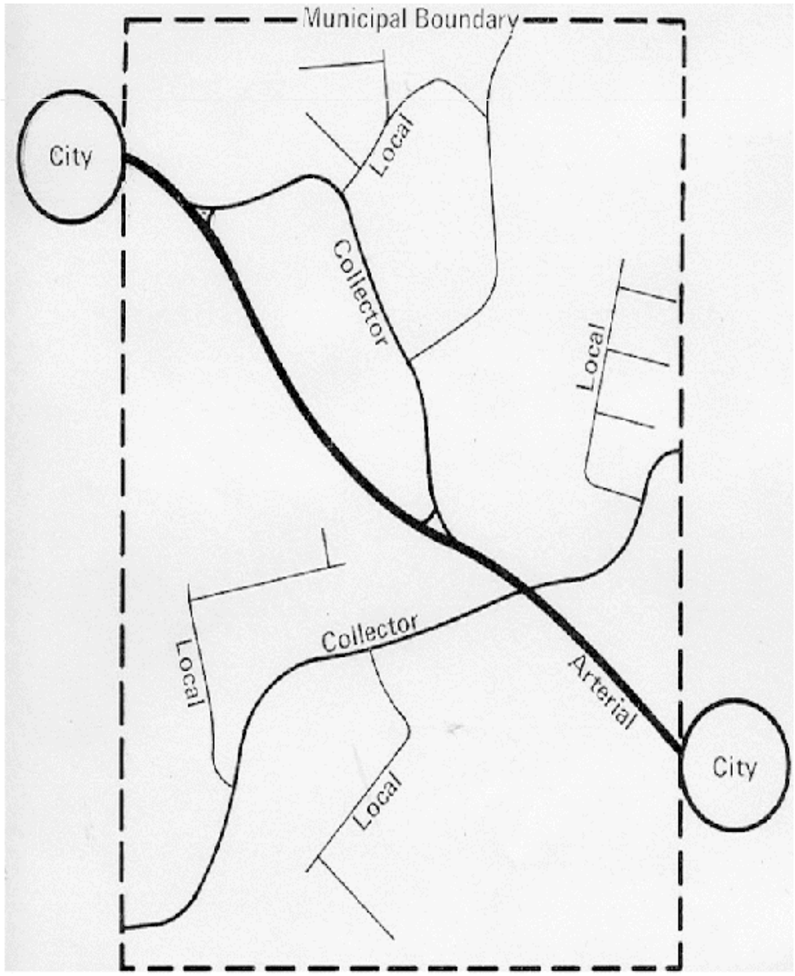

Figure 35. Illustration of FFC mobility[10]

[10] http://www.maine.gov/mdot/maines-transportation-systems/classification-highways%20.php

Appendix: Setting up the Road Network to Solve the Routing Problem

The road network, or network dataset, is the general term that will be used to describe the file that, in short, combines road feature classes with routing logic. The network takes the road inventory files as allowable paths for a route to get from ‘point a’ to ‘point b’ and incorporates additional information, such as road hierarchy, road cost or impedance, intersection turning restrictions, and road connectivity.

Network Analyst Extension

As has been mentioned repeatedly, access to a Network Analyst extension is necessary for the OZ Program to function. The Network Analyst extension is where the capability to build networks and solve the routing problem (among other things) is housed.

Required datasets

The required datasets are the road inventory files discretized by Federal Functional Classification (FFC), as shown in Figure 36. Note that TranSeg_ND and TranSeg_ND_Junctions are creating from building the network dataset, discussed in the Building the Network Dataset section on page 36, and will not exist prior to doing so.

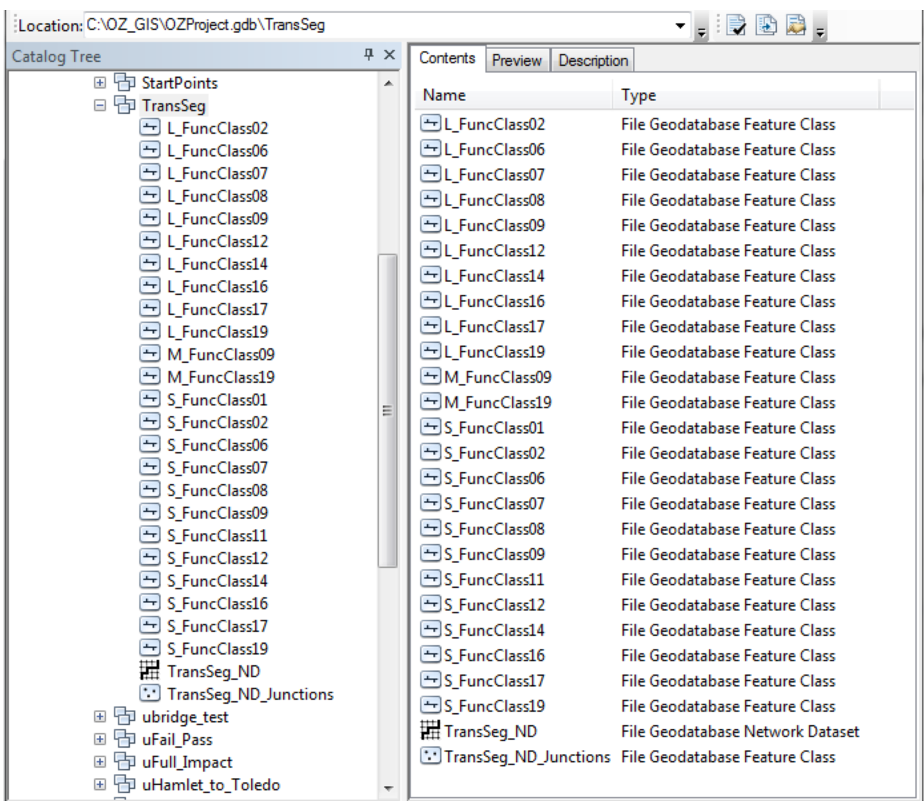

Figure 36. TranSeg required files

Aside from the TranSeg feature dataset are the NetDatasetFull and NetDataset Default feature datasets that also contain network datasets; the network dataset in the TranSeg feature dataset is the active network dataset. Changing which road network to use in the OZ Program, discussed in the Setting the Road Network section on page 61, will dictate which network dataset is in the TranSeg feature dataset.

Building the Network Dataset

The following is the step by step method used to create the TranSeg_ND network dataset file.

1. Right-click on the feature dataset containing the feature classes that will comprise the network, click 'New' and then 'Network Dataset' as is shown in Figure 37.

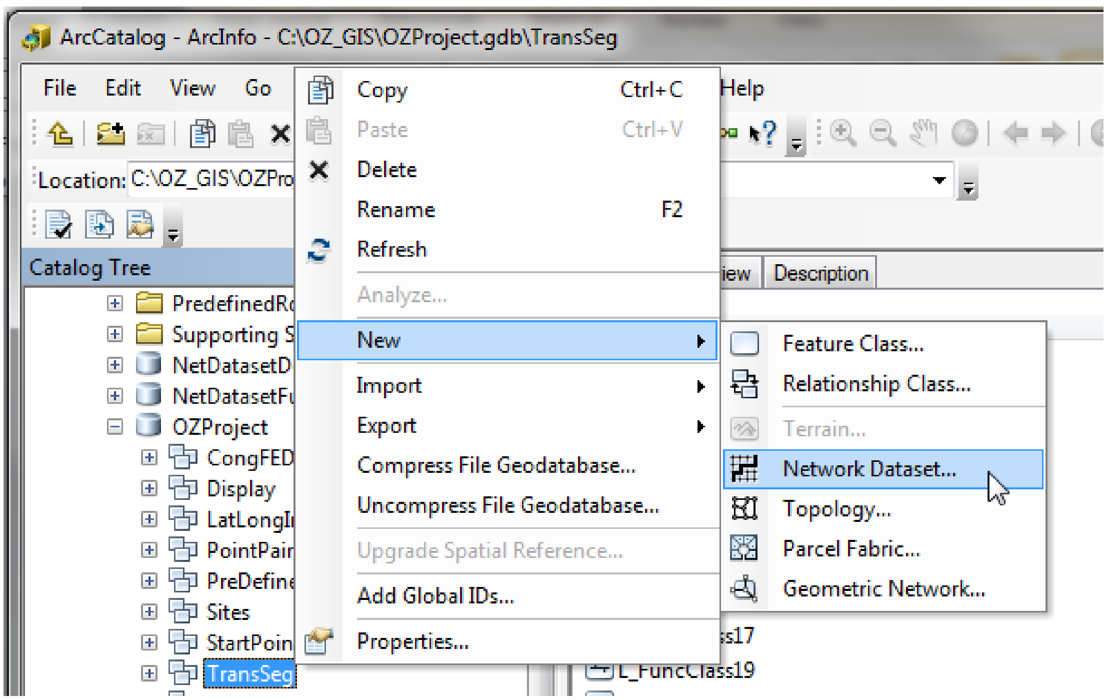

Figure 37. Creating a new Network Dataset in a feature dataset

2. Enter a valid name and click 'Next' → put a check next to all the feature classes that will be included in the network, so that what you have matches Figure 38 and click 'Next' → Select 'No" to modeling turns and click 'Next'

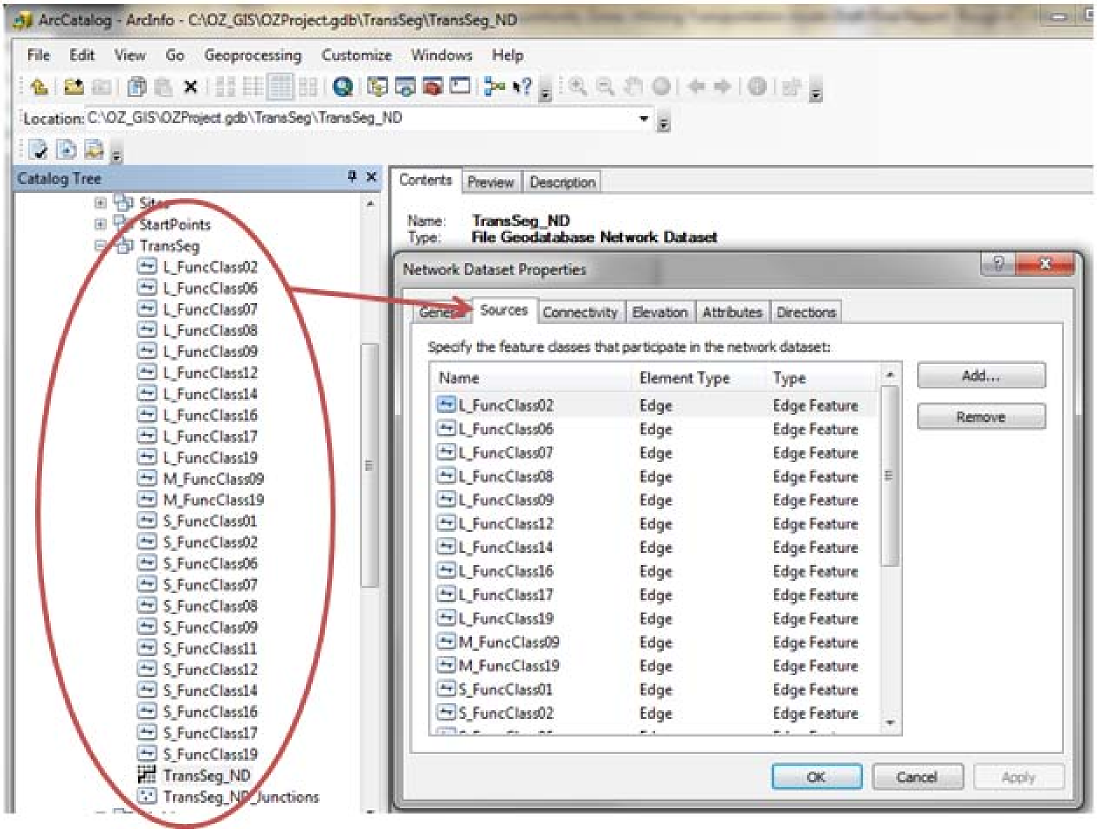

Figure 38. TranSeg Source feature classes

3. Set up the connectivity page so that the 'Connectivity Policy' is 'Any Vertex' and that there is only one 'Group Column' matching what is shown in Figure 39 and click 'Next'. For more information on connectivity, see the Aside on Connectivity section on page 46.

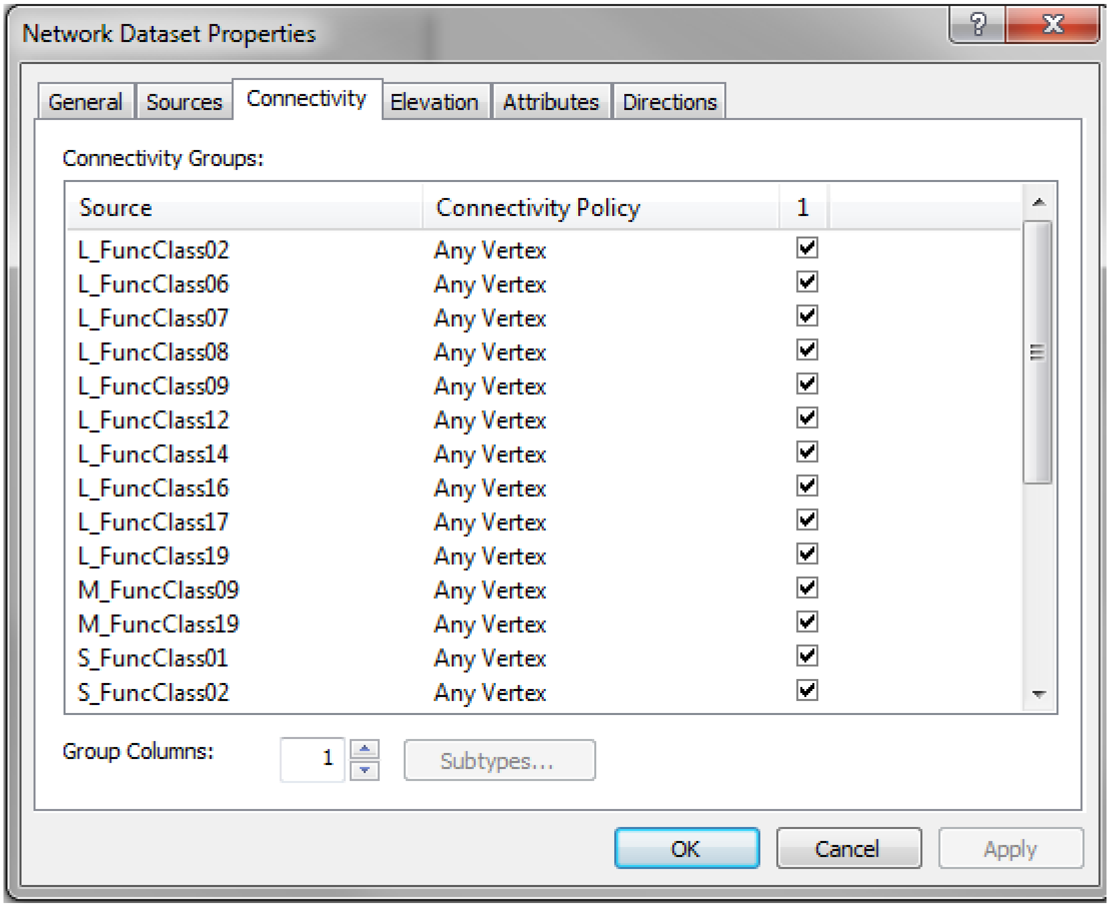

Figure 39. Connectivity settings

4. Select 'None' on the elevation page, matching Figure 40, and click 'Next'

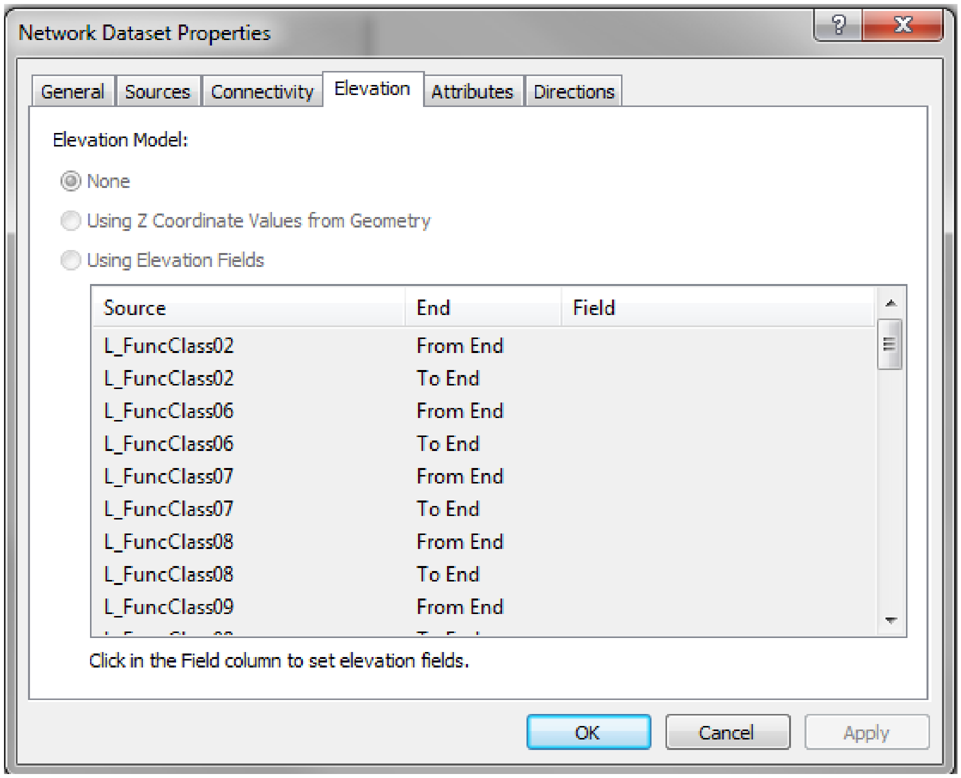

Figure 40. Elevation

5. Set up the Network attributes screen to look like Figure 41

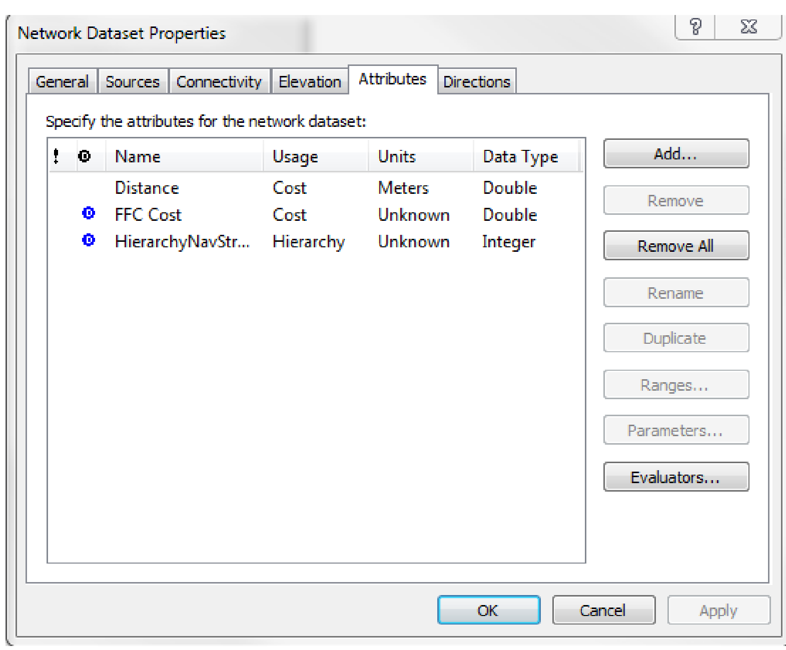

Figure 41. Attributes

6. Select ‘HierarchyNavStreets’ and click the ‘Ranges…’ button and make sure the ‘Hierarchy Ranges’ screen matches what is shown below in Figure 42, then click ‘OK’.

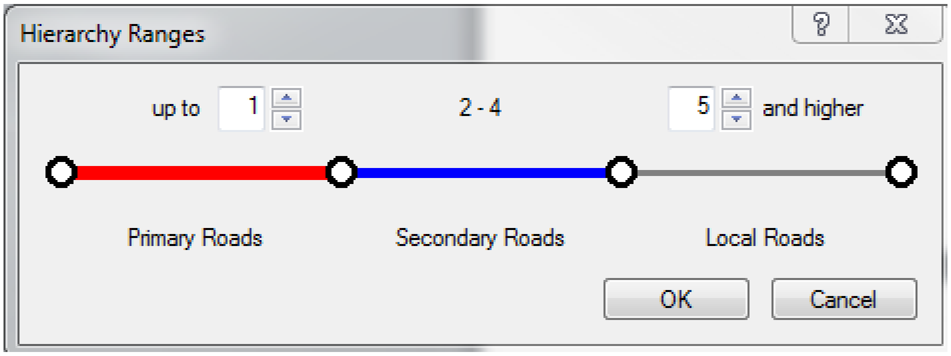

Figure 42. Hierarchy ranges screen

7. Click the ‘Evaluators…’ button. Make sure ‘HierarchyNavStreets’ is the active ‘Attribute’, set the ‘Type’ to ‘constant’, and set the appropriate values according to Figure 43 and Table 5. For more details on how the values in Table 5 were derived, see the Aside on Attributes-Hierarchy section on page 47.

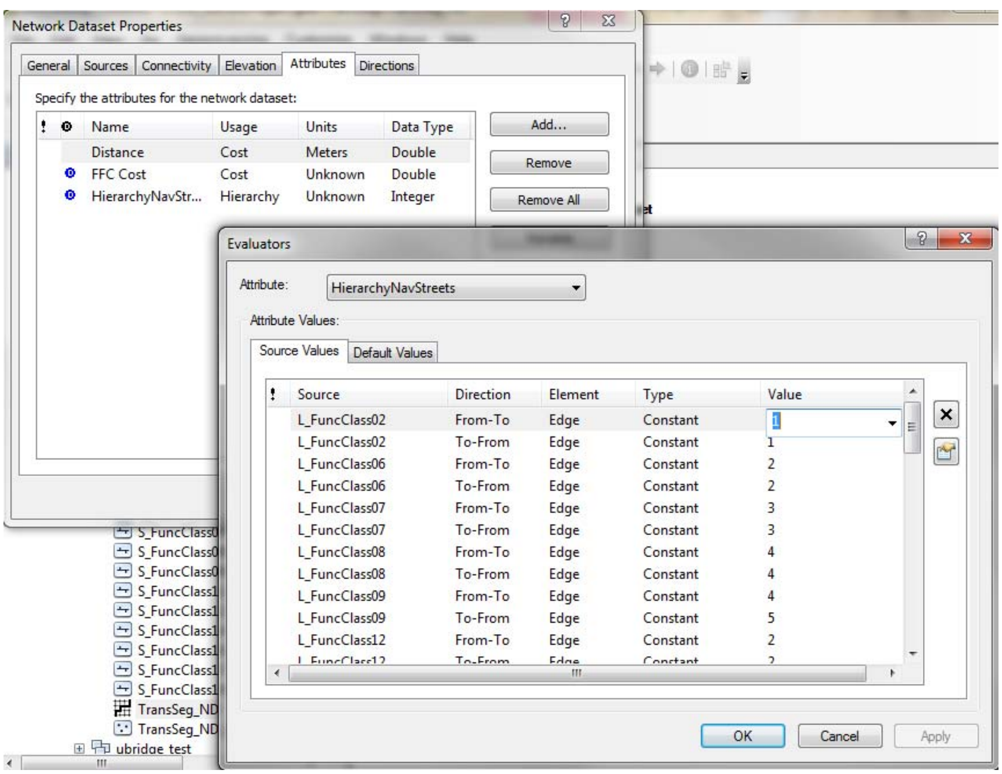

Figure 43. HierarchyNavStreets attributes

State FFC	Hierarchy	Local FFC	Hierarchy	Municipal FFC	Hierarchy
1	1	-	-	-	-
2	1	2	1	-	-
6	2	6	2	-	-
7	3	7	3	-	-
8	4	8	4	-	-
9	5	9	5	9	5
11	1	-	-	-	-
12	1	12	2	-	-
14	1	14	3	-	-
16	4	16	4	-	-
17	4	17	4	-	-
19	5	19	5	19	5

Table 5. HierarchyNavStreets values

8. Change the active ‘Attribute’ to Distance, set the ‘Type’ to ‘Field’, and set the values to the ‘Shape_Length’ field (Figure 44).

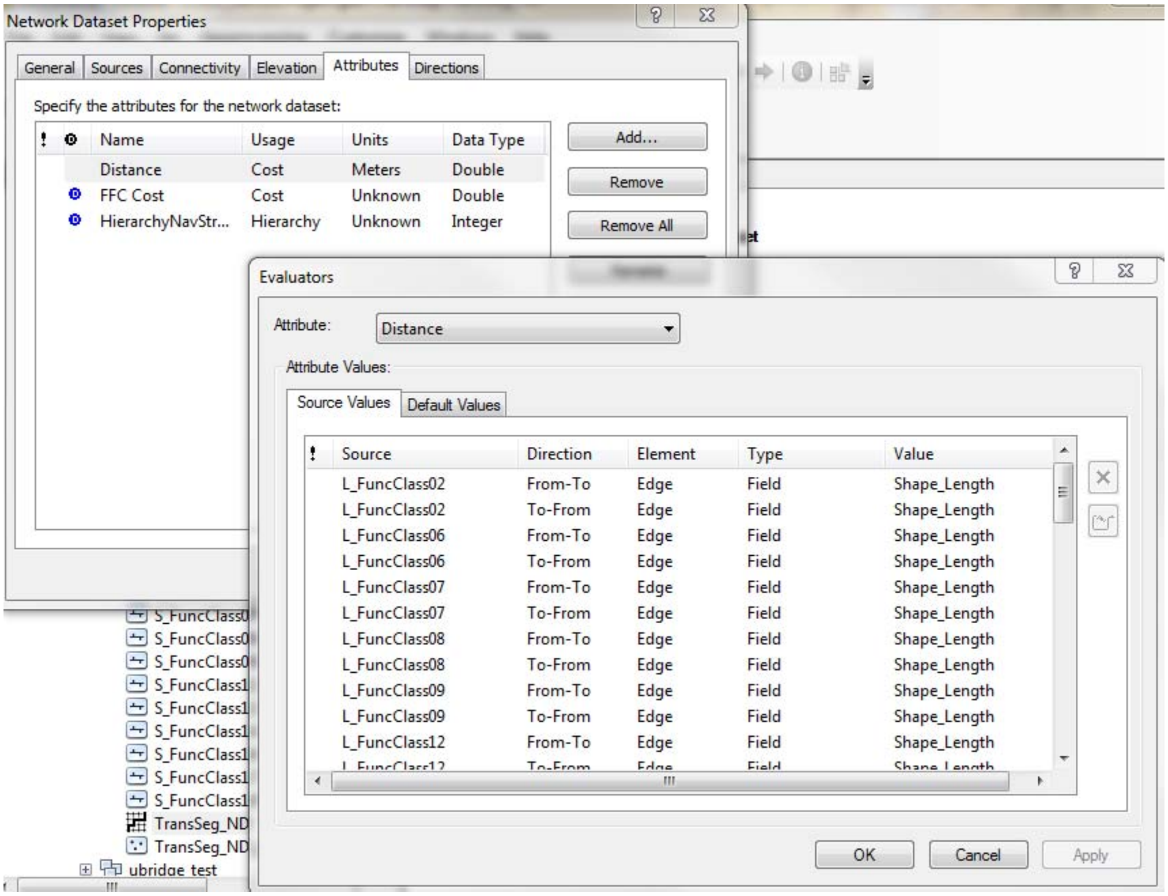

Figure 44. Distance attributes

9. Change the active 'Attribute' to 'FFC Cost', set the 'Type' to 'Function', set the appropriate values according to Figure 45. FFC attributes and Table 6, click 'OK' to exit the 'Evaluators' screen and click 'Next'. For details on how the values in Table 6 were derived, see the Aside on Attributes-Cost section on page 47.

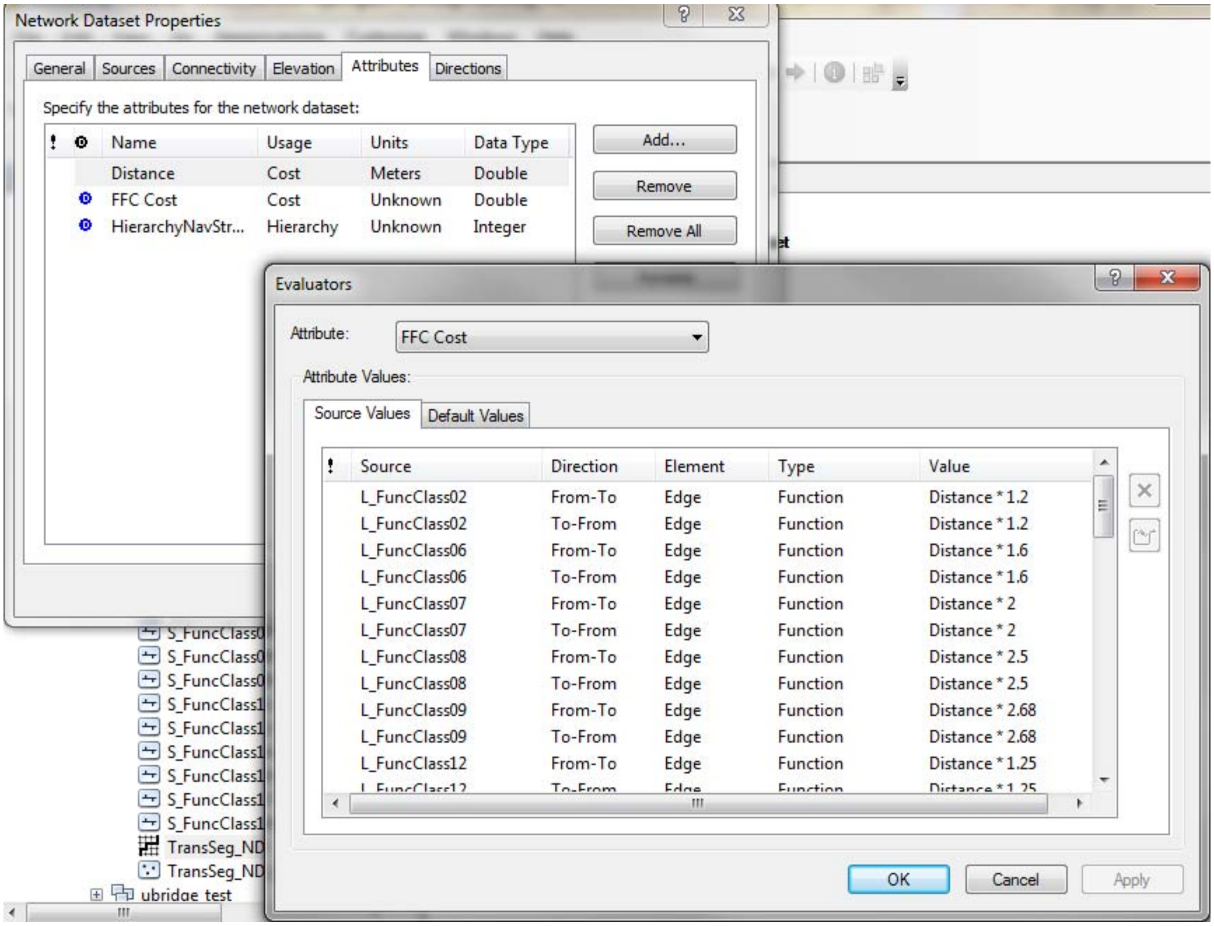

Figure 45. FFC attributes

State FFC	Cost	Local FFC	Cost	Municipal FFC	Cost
1	1.00	-	-	-	-
2	1.05	2	1.20	-	-
6	1.60	6	1.60	-	-
7	2.00	7	2.00	-	-
8	1.69	8	2.25	-	-
9	2.68	9	2.68	9	2.68
11	1.05	-	-	-	-
12	1.25	12	1.25	-	-
14	1.50	14	2.17	-	-
16	2.37	16	2.37	-	-
17	2.49	17	2.49	-	-
19	2.68	19	2.68	19	2.68

Table 6. FFC attribute values*Distance

10. On the driving directions screen select 'Yes' and click the 'Directions…' button. Set up the directions screen to match what is shown in Figure 46 and Figure 47. You will need to set the 'Display Length Units' to Miles, 'Length Attribute' to Distance, 'Prefix' to ST_PREFIX, 'Name' to ST_NAME, and 'Suffix' to ST_NME_SFX for each source file. Note this is assuming the user is using the discretized road inventory files of which ST_PREFIX, ST_NAME, and ST_NME_SFX are populated attribute columns. When finished, click 'Next', review the summary page, and click 'Finish'.

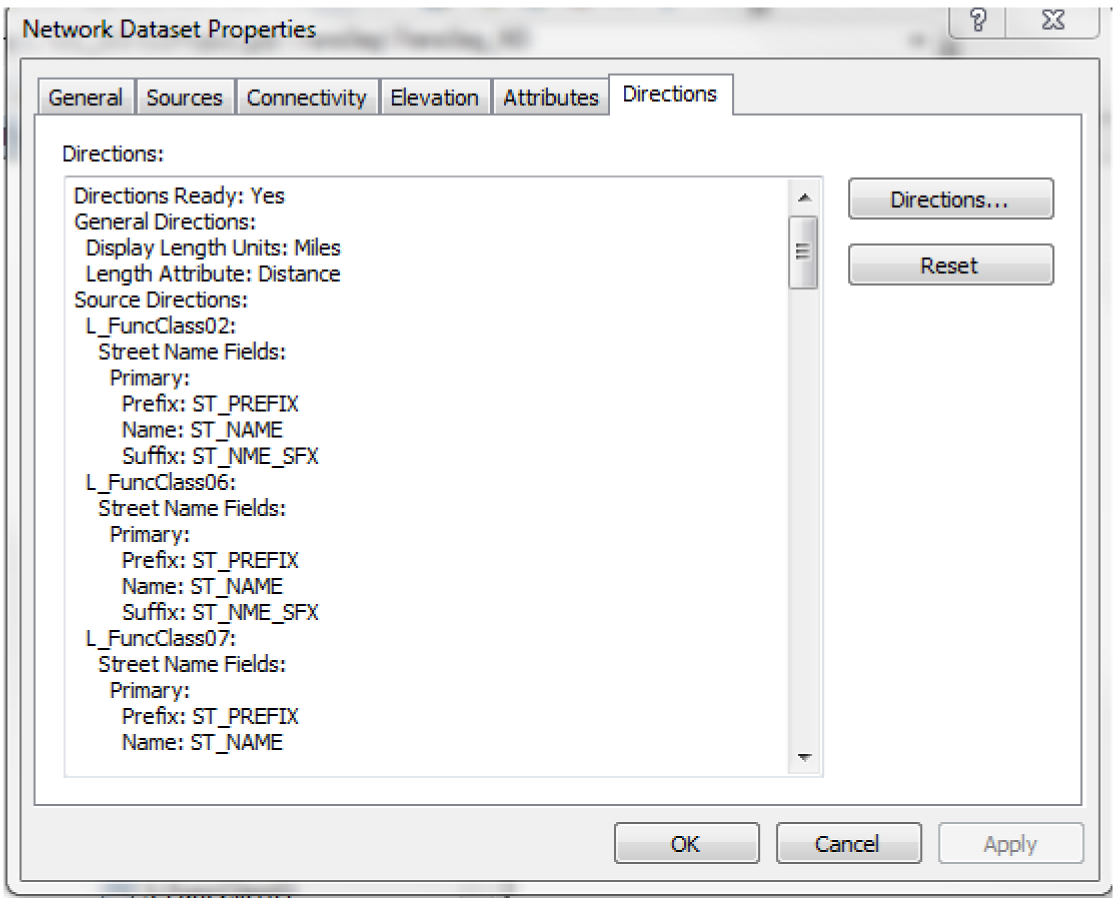

Figure 46. Directions summary

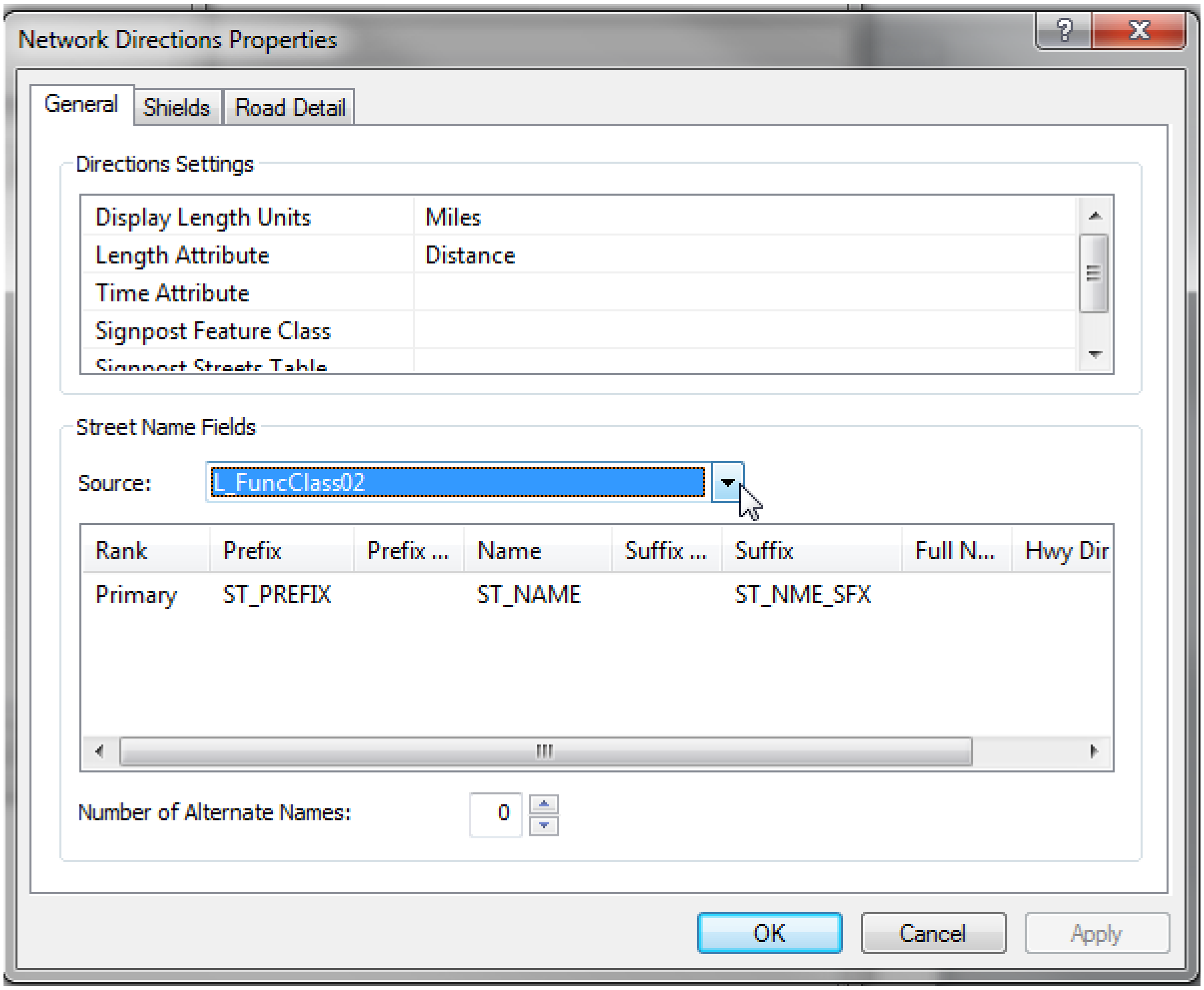

Figure 47. Directions details

Aside on Connectivity

In short, the connectivity feature allows the user to dictate whether or not line segments connect at intersection points as illustrated in Figure 48 with metro lines, streets, and metro entrances. Basically, by setting up the metro lines and streets in different connectivity groups it makes it illegal for a route to jump from a road to a metro line even if they appear to intersect when looking at a 2-d representation.

This level of information is what is lacking in the road inventory files when it comes to non-accessible overpasses. An example is shown in Figure 49, and is elaborated on in the Routing Limitations section on page 85.

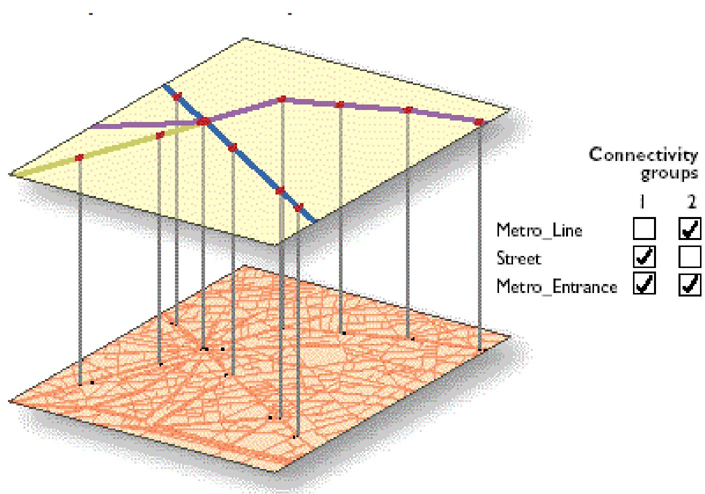

Figure 48. Street and Metro Line connectivity illustration[11]

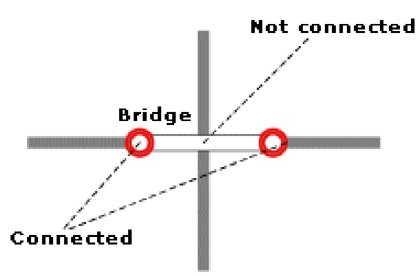

Figure 49. Bridge connectivity illustration[12]

[11]http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#/Understanding_connectivity/004700000009000000/

[12]http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#/Understanding_connectivity/004700000009000000/

Aside on setting up Network Attributes

At this point it is hopefully more obvious to the user why we bothered separating the road inventory files by FFCs. By separating the road inventory files into subsets by their FFC property, we are able to make assumptions about each FFC subset that are more accurate than assumptions that would be made about the full state, local, and municipal road inventory file sets. The following two sections elaborate on assumptions made and how they relate to network hierarchy and network cost (or impedance) values.

Aside on Attributes-Hierarchy

Discretizing the road inventory files by FFC allowed for the resulting files to be assigned a hierarchy value based on the description of each FFC as detailed in Table 4 on page 33, in terms of the mobility versus land access property they possess, as illustrated in Figure 35 on page 34 and summarized here:

- Arterial roads provide longer through travel between major areas
- Collector roads collect traffic from smaller areas and roads and direct to arterial roads
- Local roads allow for access to low volume areas

The hierarchy value, in short, assigns a preference of, when traversing from 'point a' to 'point b', which roads to take; the lower the value, the higher the preference as shown in Figure 42 on page 40.

Aside on Attributes-Cost

When people drive, in general, they take what they perceive to be the fastest route to reach their destination. The cost or impedance attribute of the network attempts to capture this same principal.

The first step was to discretize the modeled road file from the modeling group by FFCs (the same file that was used to capture congestion data). Next, through python scripting, each line segment's free flow speed (a modeled property) and distance was extracted to an excel file. Based on the following equation, the average time to traverse a unit distance was calculated for each line segment (where time/distance is the inverse of the free flow speed)

$$\left[\frac{time}{distance}\right] \times [distance] = [time]$$

These times were averaged for each FFC and normalized with results shown in Table 7.

FFC	Normalized Inverse FFS
1	1
2	1.326
6	1.508
7	1.732
8	1.690
9	1.761
11	1.054
12	1.170
14	2.170
16	2.367
17	2.485
19	2.677

Table 7. Normalized time to traverse unit distance per FFC derived results

Readers will notice that Table 6, the values being used, and Table 7, the values calculated, do not match. There are two interrelated reasons for this:

1. The modeled road network did not differentiate between roads on the state, local, or municipal system, but rather lumped them together. For this reason, Table 7 had to first be expanded to all FFC files (state, local, and municipal).
2. Through case studies, the derived results simply did not yield what were deemed to be the appropriate results and therefore the values were altered accordingly; this is believed to be a consequence of the state, local, and municipal roads being lumped.

Appendix: First Time Use

The following steps detail general requirements, how to 'install' the OZ Program, and how to ensure the program is ready to use.

Installation

The 'installation disk' contains all necessary non ArcGIS files required. It is assumed that the user already has ArcGIS 10 installed with an ArcINFO license and access to a Network Analyst extension. If this is not the case then the OZ Program will not work.

1. Insert the disk and copy the OZ_GIS folder to the C drive (Figure 50)

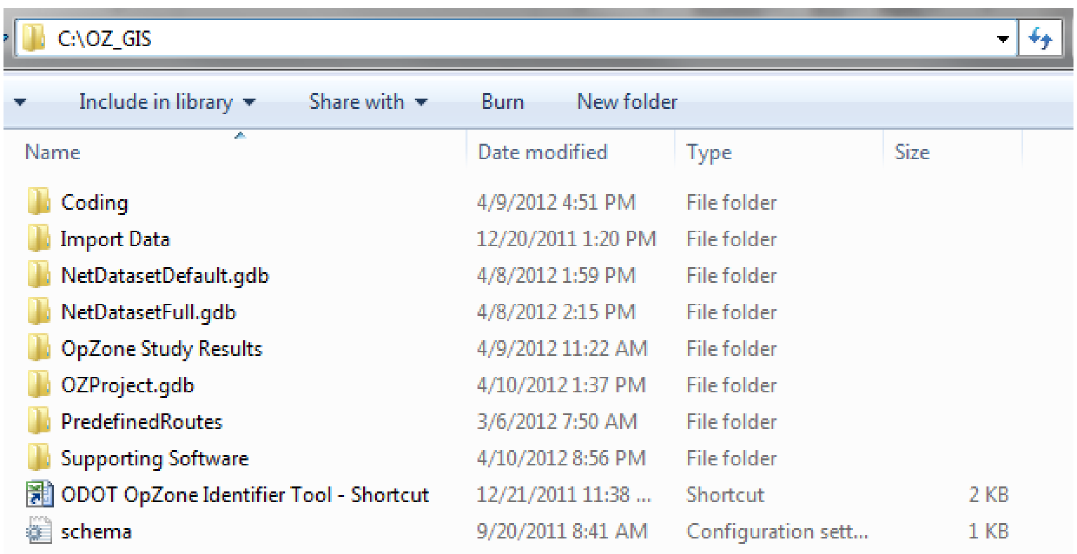

Figure 50. Contents of OZ_GIS

2. Navigate to the C:\OZ_GIS\Supporting Software folder and install the three application files accepting default installation locations (proper installation location for Python library add-ons shown in Figure 51)
   - pywin32-216.win32-py2.6 – Python text editor
   - xlrd-0.7.1.win32 – Python library add on that allows Python to read values from an Excel .xls document
   - xlwt-0.7.2.win32 – Python library add on that allows Python to write values to an Excel .xls document
3. Move the shortcut entitled "ODOT OpZone Identifier Tool – Shortcut" to a convenient location for future use. **IMPORTANT:** Do not move or delete any other default files. New geodatabases can be added, new files can be added to existing geodatabases, and new files with the exact same naming and attribute column headings can update in place files, but no original files are to be deleted.

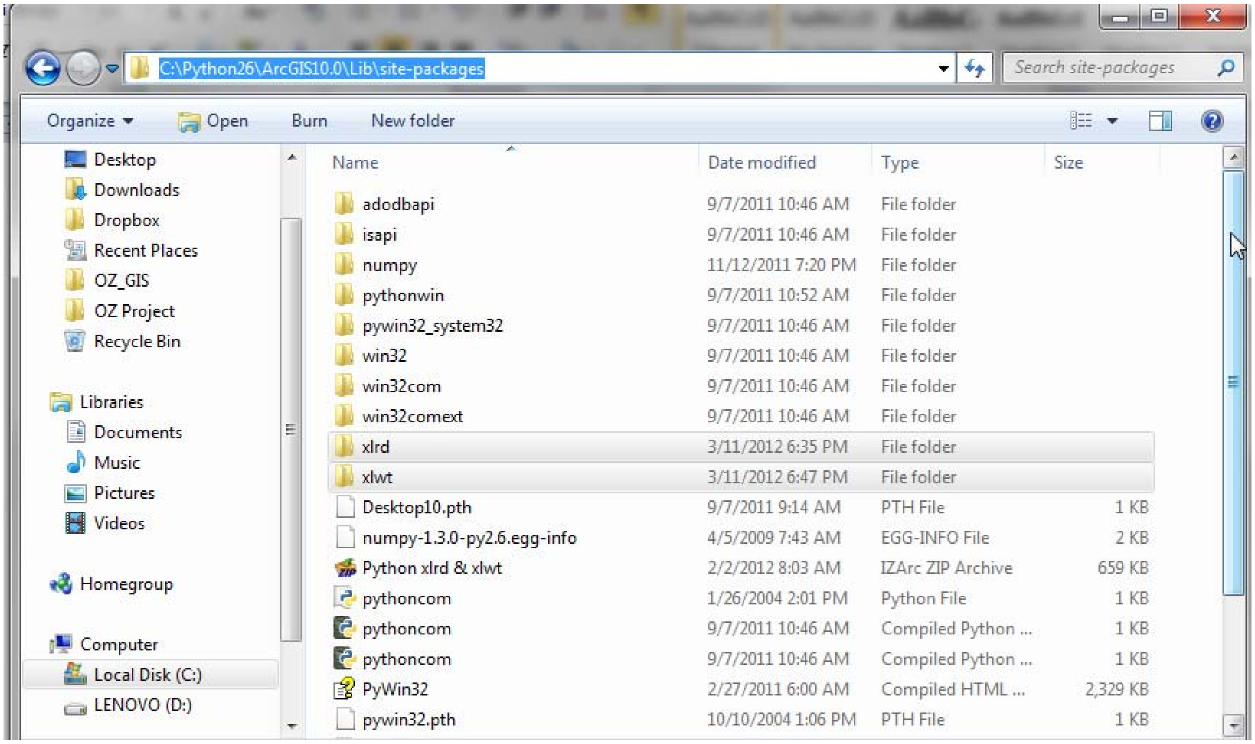

Figure 51. xlrd and xlwt Python library add-on installation location

4. Open the OZ Program
5. Navigate to the ‘Advanced Settings’ screen and click the “Setup Test” button
6. When prompted with the screen shown below in Figure 52 click “OK”

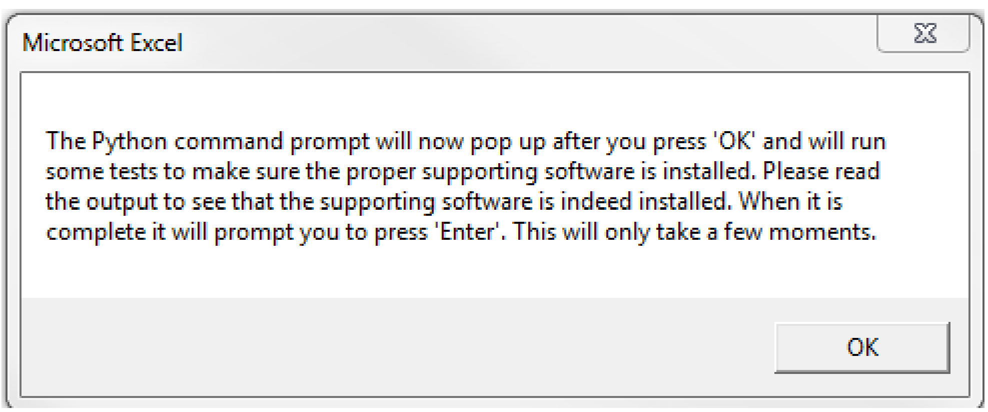

Figure 52. Run Setup Test prompt

7. The Python command prompt will initialize. If your screen matches what is shown below in Figure 53 then the OZ Program is ready to use, press Enter to close the screen. If not, address the error stated in the Python command prompt window.

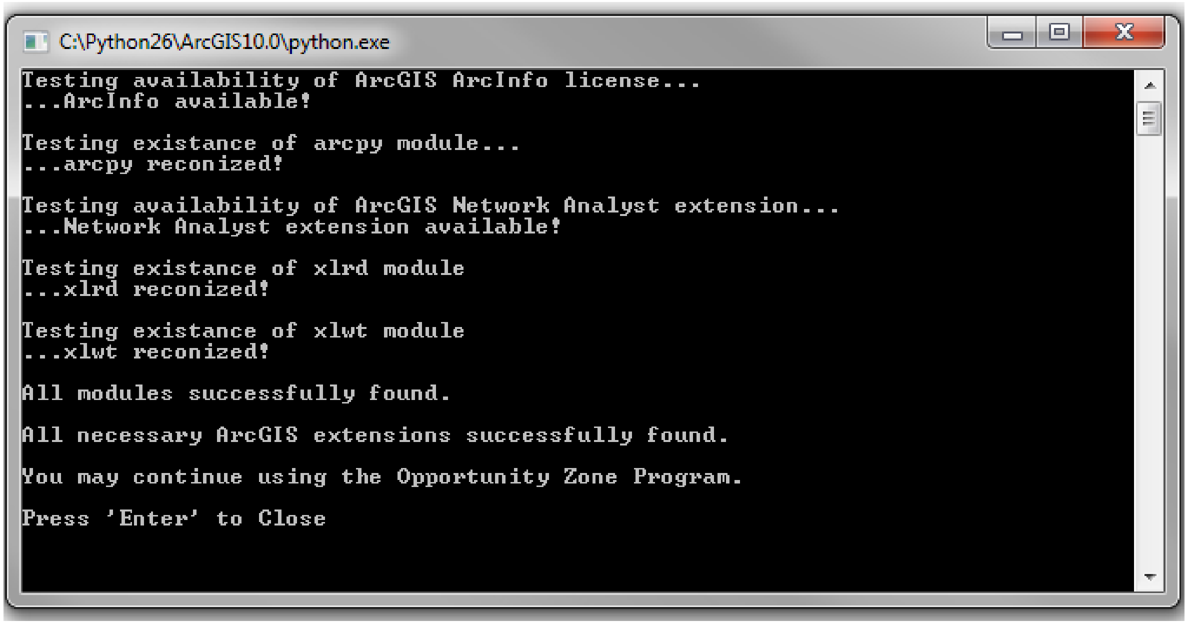

Figure 53. Successful Setup Test Python command prompt

Appendix: User's Guide

The OZ Program software is a compilation of VB and Python scripts that are accessed through an Excel GUI. The excel workbook (ODOT OpZone Identifier Tool.xls) and Python scripts must remain in their default locations. The workbook shortcut is allowed to be moved to a convenient user defined location (such as the desktop).

- Excel workbook file location (fixed): C:\OZ_GIS\Coding\ ODOT OpZone Identifier Tool.xls
- Shortcut location (movable): C:\OZ_GIS\ODOT OpZone Identifier Tool.xls

In general, program flow is as follows. The user specifies the problem to be solved in Excel, using the directions laid out in the following manual and the VB portion of the code takes the user's inputs and writes them to the excel sheet. The VB script then calls Python, and Python solves the problem using ArcGIS geoprocessing functions. Therefore:

- No ArcGIS application is allowed to be open when using the OZ Program
- All datasets should be local (on C drive in default location) to avoid schema lock errors

When Python is running a command prompt style window will be present (Figure 54) and the OZ Program Excel screen will be locked. For this reason, the OZ Program should be run from an instance of Excel independent of already open Excel files. If other Excel files are running, start a new instance of Excel through the start menu and open the OZ Program within the new instance of Excel as opposed to using a shortcut, opening the workbook from an already running instance of excel, or double-clicking the file in windows explorer; doing so would result in the locking of the workbook the OZ Program was opened from. If no other instances of Excel are running, call the workbook in the most convenient manner.

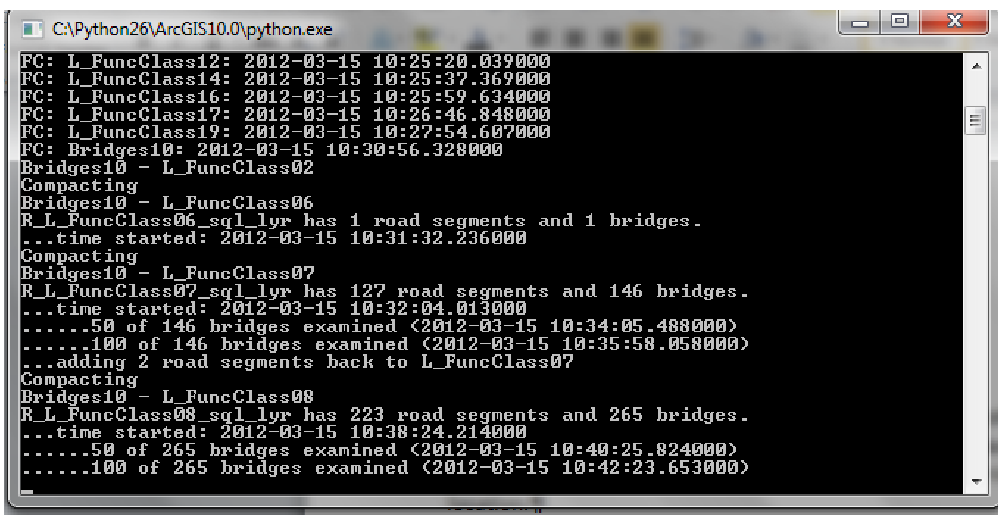

Figure 54. Python window

When Python is finished running, geographic results will be displayed in ArcMap (Figure 55) with geographic property results being displayed in a new Excel workbook (if this option is selected). There will also be a text file, saved in the user specified location, accessible either through the catalog window in ArcMap or through Windows Explorer giving turn by turn directions for the route shown in ArcMAP (note that the text file does not self-initiate meaning you have to manually open it).

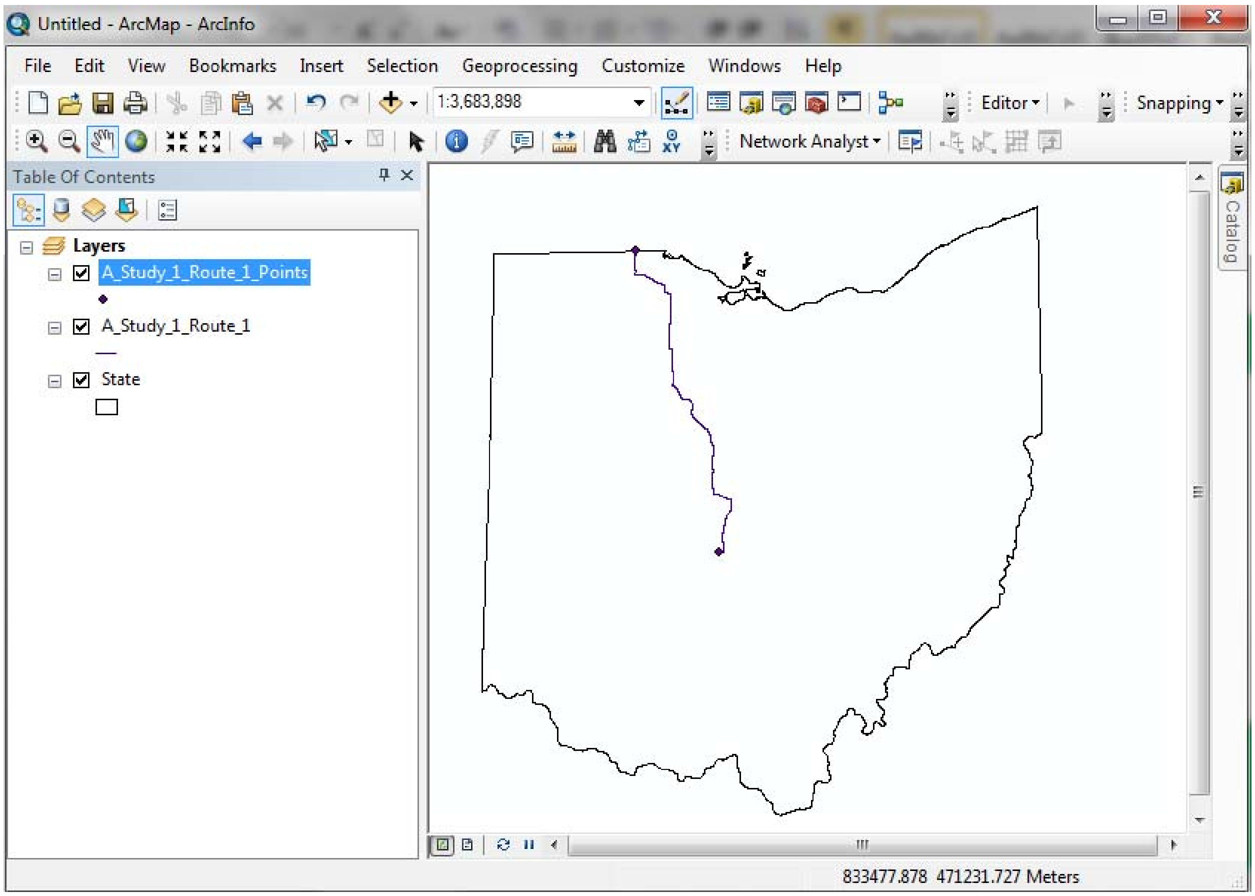

Figure 55. ArcMap interface

From this point on, it is assumed that ArcGIS, with an ArcINFO license and Network Analyst extension, is being used, Python library add-ons xlwt and xlrd are installed correctly, and all data is in place. If this is not the case, go back to the Software Requirements section on page 16 contained within the Introduction Appendix.

A Quick Word on Program Unresponsiveness

As mentioned above, the OZ Program utilizes both Python and Excel VBA scripts, sometimes running at the same time, and, despite extensive error testing, the possibility for either or both to become unresponsive exists. The most probable situation for the OZ Program to become unresponsive is for the Python script to crash (for any number of reasons) and the VBA script to be “stuck in an infinite loop” searching for the expected Python output.

To terminate an unresponsive Python script, open Windows Task Manager (Figure 56), navigate to the Processes tab, find ‘python.exe*32’, click it, and then click the ‘End Process’ button. Note that depending on which version of Windows the user is running, the Task Manager window might have a different appearance.

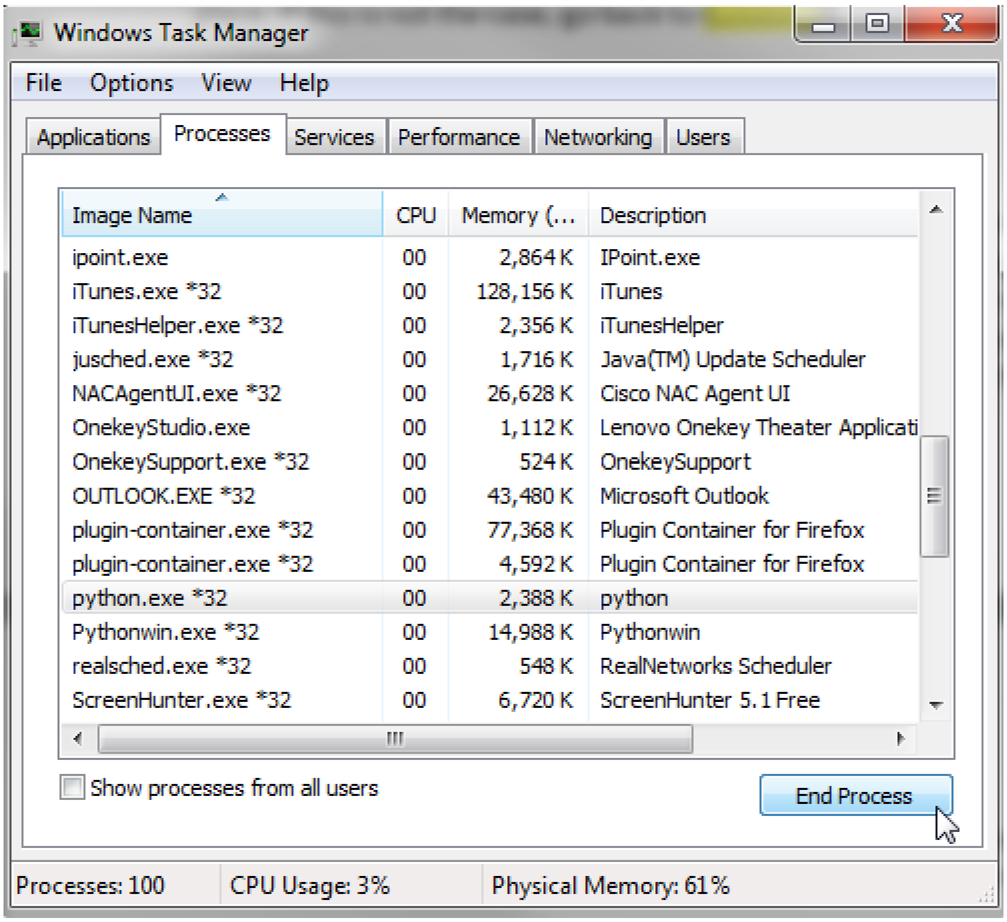

Figure 56. Terminate unresponsive Python script

To cancel an unresponsive VBA script, while the Excel window is active, press the control and break keys at the same time (Ctrl+Break); keyboard dependent, the user might need to press the control, function, and break keys at the same time (Ctrl+Fn+Break). If indeed the VBA script is unresponsive a dialog box like the one in Figure 57 will appear. For users unfamiliar with VBA, click the ‘End’ button, save all work, and exit Excel. For those familiar with VBA or planning on submitting an error report, click the ‘Debug’ button and proceed with caution. If Excel is still unresponsive, go to the Task Manager and terminate Excel; doing so will result in the loss of all unsaved work and is recommended as a last resort.

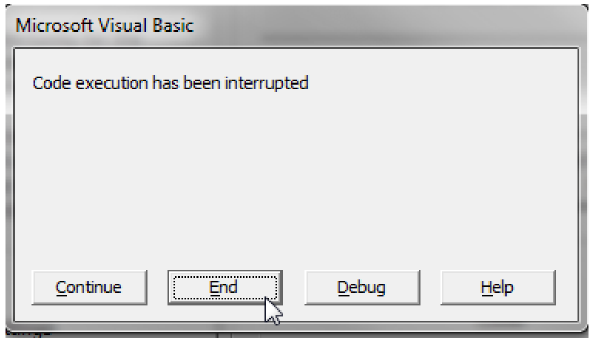

Figure 57. Unresponsive VBA script

Another possibility is that the program is simply taking a long time to solve the prompt. This could be attributed to a number of factors, including user's computer speed, the number of routes the program is solving for, the length of the combined routes, and so on. There is a built in time-out function that, if the program is taking longer than a preprogrammed amount of time, a dialog box will initialize (from VBA) asking the user if they want to terminate the running Python script. Deciding to do so will have the same effect as canceling Python from the task manager and will result in the user having to restart the prompt. If they python script does not appear to be stuck, it is advised to dismiss the timeout option and let the Python script continue to run. The timeout dialog box is shown in Figure 58 where the result of clicking either button is detailed below:

- OK: Terminates the running Python script and VBA module. Some files will likely have been written already to the output folder.
- Cancel: Dismisses timeout dialog box and lets the Python script continue to run.

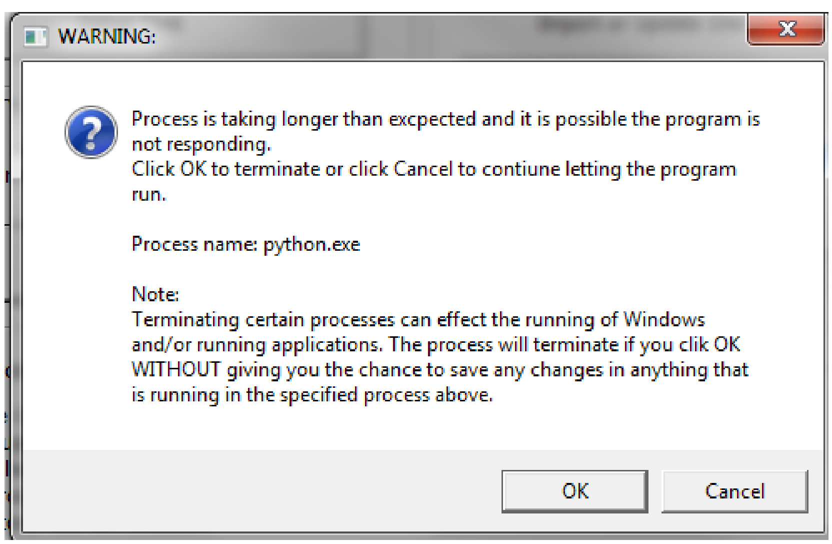

Figure 58. Time out dialog box

Getting Started

When the workbook is opened, the welcome screen will appear (Figure 59). If this is not the case or the screen was closed, it can be accessed by clicking the “Launch Wizard” button from the ‘Hard Prompt’ worksheet (Figure 60).

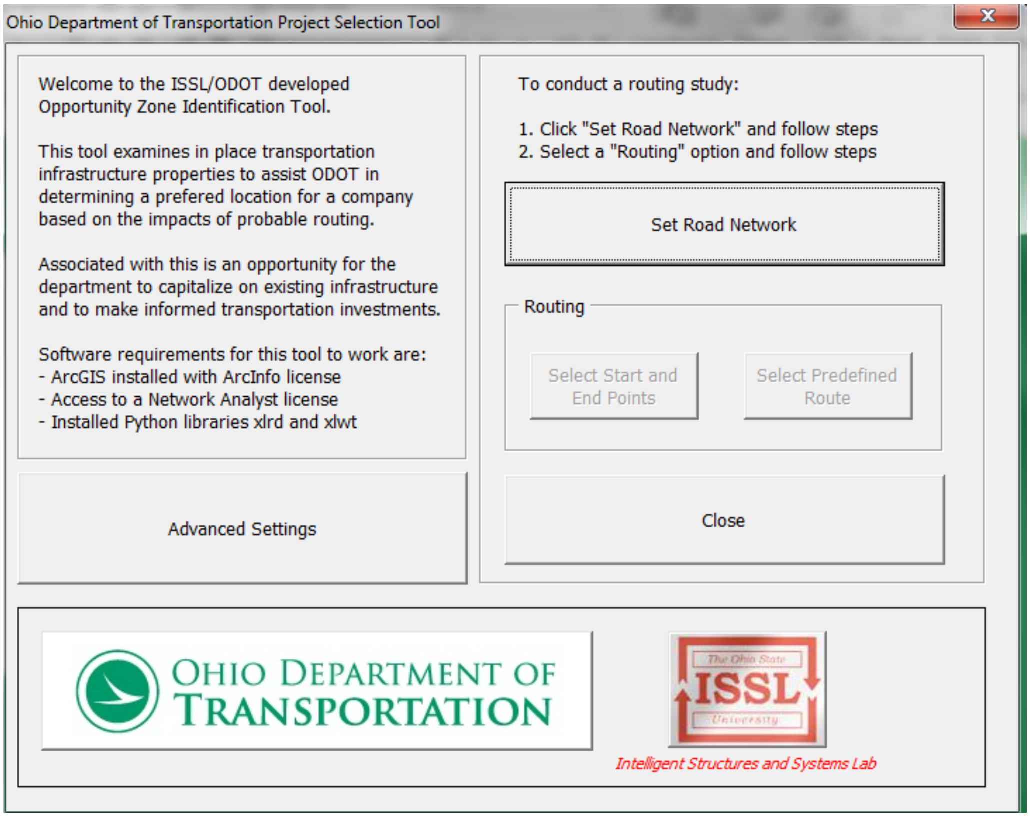

Figure 59. Welcome screen

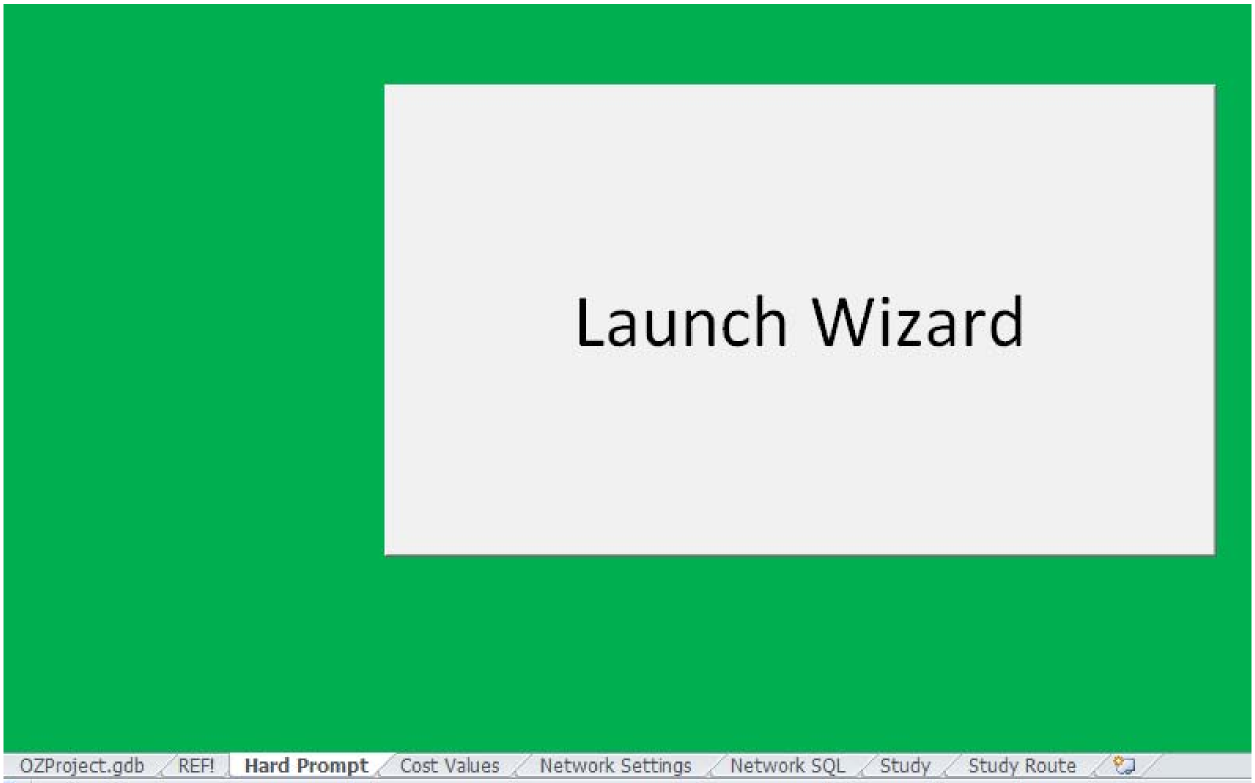

Figure 60. Launch the welcome screen from the Hard Prompt worksheet using the launch wizard button

Advanced Settings

Non-route creating options, such as updating the data, are accessible by clicking the "Advanced Settings" button on the welcome screen.

Setup Test

When the OZ Program is being used for the first time, it is recommended running the setup test accessed by clicking the "Setup Test" button on the 'Advanced Settings' screen (Figure 61). This launches a Python script which verifies that ArcINFO and Network Analyst are available and that the Python library add-ons xlwt and xlrd are installed correctly.

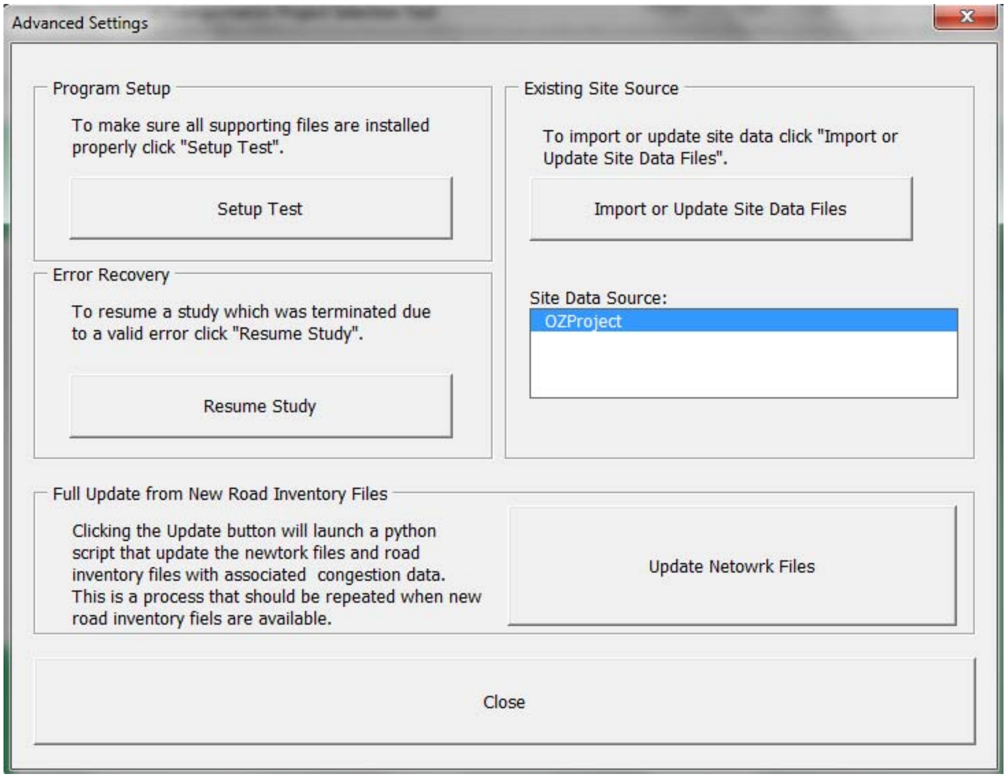

Figure 61. Advanced Settings screen

Import or Update Site Data Files

The “Import or Update Site Data Files” button allows the user to update or create a new list of existing sites (see appendix section titled ‘Specifying Starting and Ending Points’ on page 67). Clicking the button will launch the dialog box shown below in Figure 62. The user is instructed to select a geodatabase (gdb) that contains a feature dataset (FD) entitled “Sites”. The OZProject.gdb folder contains the default “Sites” FD whose contents are shown in Figure 63.

Once the appropriate gdb has been selected, clicking the “OK” button will launch a Python script that imports the names of each point from the point features classes within the FD for use when selecting starting and ending points. If the user has created a new “Sites” FD with new point feature classes, they must amend the Python script titled GenFCList (located in the Coding folder) as follows:

- Open GenFCList in PythonWin
- Navigate to line 74
- Default line 74:
    - field_target = ["OBJECTID", "AIRPORT_NA", "FACILITY", "name", "WellName_Number", "BUSINESS", "LOCATION"]
- Add the name of the attribute column in the feature class that will be used to identify the new points following the existing formatting.

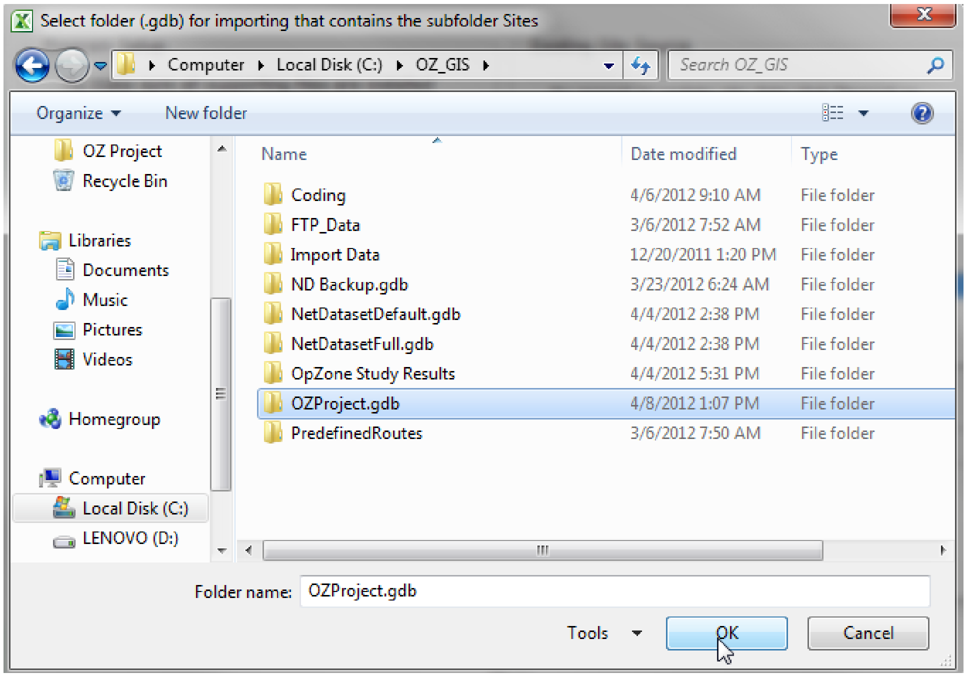

Figure 62. Import or update site data files dialog box

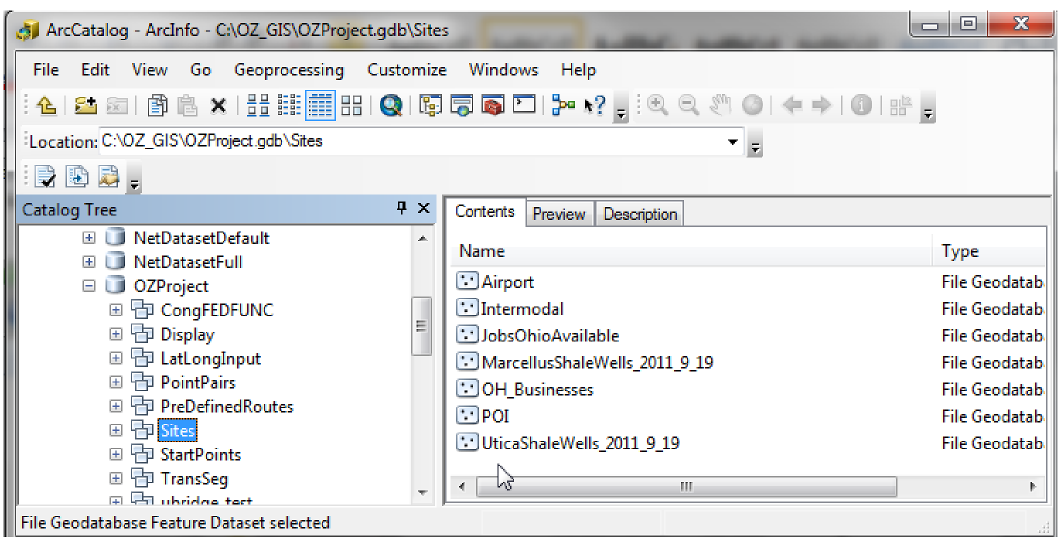

Figure 63. Contents of default "Sites" FD

Site Data Source

The "Site Data Source" list box contains the list of all gdbs that a set of points was imported from. If the user desires to use a source other than the default, OZProject, they must select it; if they plan on using the default option or not using existing sites (manually entering latitude and longitude coordinates), then no action is required.

Resume Study

The "Resume Study" button exists to resolve a prompt that either failed or was aborted prior to completion; one valid error that may exist that will not be recurring is a schema lock error (user has the data open). This button requires specific excel sheets to exist in the workbook. If the "Resume Study" button is inactive, then the necessary excel sheets are not present and the prompt must be restructured.

Update Network Files

Clicking the "Update Network Files" button launches a Python script that performs all necessary updates to the files that comprise the full network and default network data sets (and leaves the full network as the active network). This is a tedious process and as a result the script can take upwards of 8 hours while locking the active instance of Excel; it is recommended running this script at the end of the day. Updating the network files only needs to be done when new road inventory files (zzinvs, zzzinvl, zzinvm) are available. This script assumes that new road inventory files have replaced the old ones in the proper location: C:\OZ_GIS\OZProject.gdb\Display (shown in ArcCatalog in Figure 64).

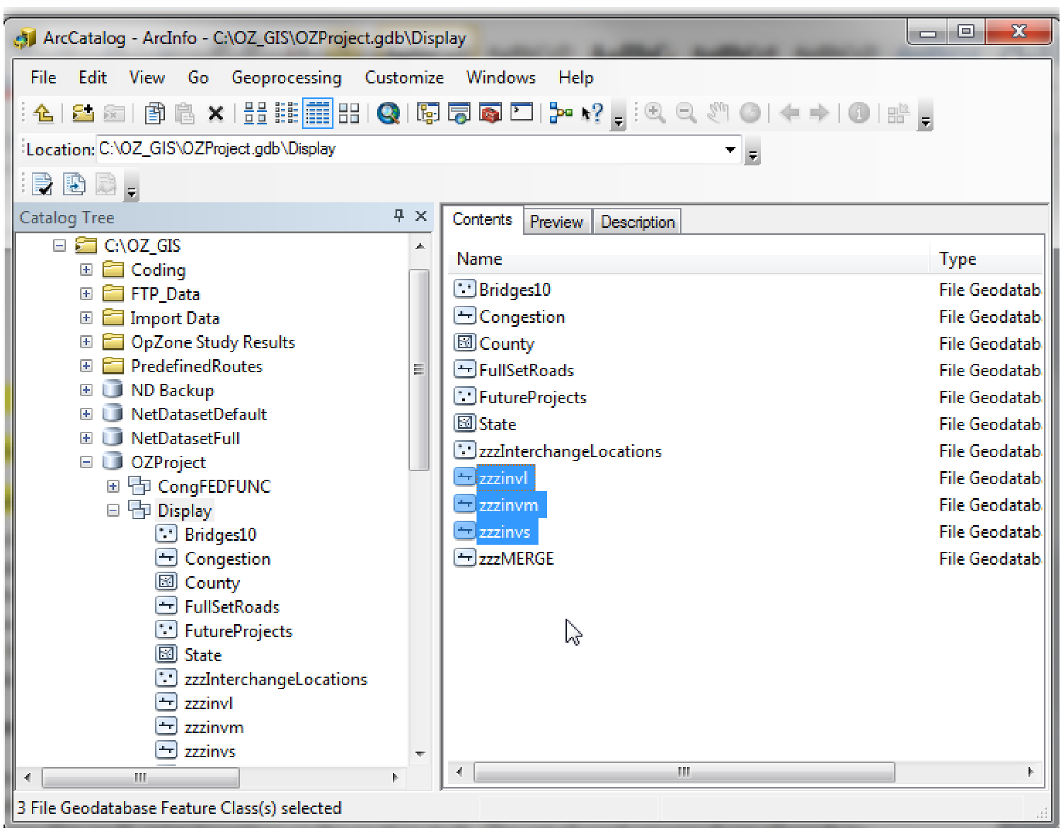

Figure 64. Proper location of the road inventory files

For unknown and unresolvable reasons, this process occasionally results in python.exe crashing as shown below in Figure 65; note that this is not a “code problem” as this is a sporadic occurrence. Through testing, this error seems to only occur during the “Updating Network Files” operation but occurs at inconsistent points in the script. The user has no choice other than to click the ‘Close Program’ button and then, while in excel, press the control and break keys as detailed in “A Quick Word on Program Unresponsiveness” on page 53 to end the VBA script. If the prompt is available, end the VBA script using the timeout dialog box as shown previously in Figure 58.

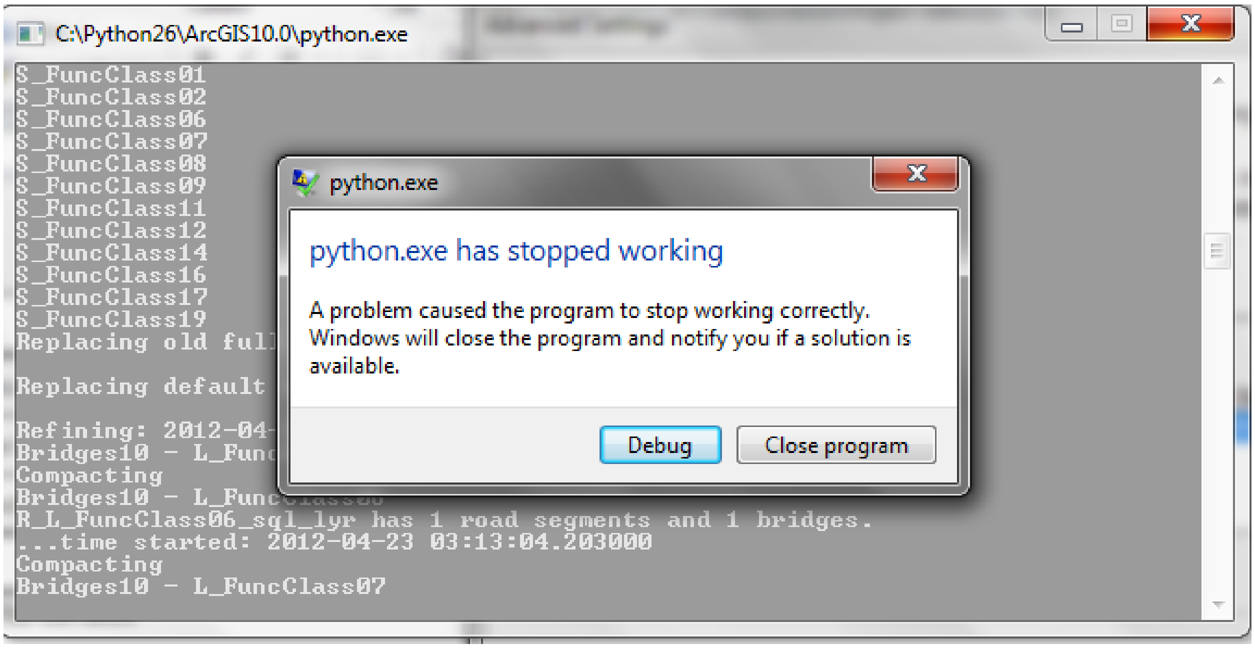

Figure 65. python.exe crashing

Setting the Road Network

This step has the user define the set of roads that are eligible to be used to solve the routing problem and must be completed, by clicking the "Set Road Network" button on the welcome screen (Figure 59), prior to setting up the routing study. The set of roads can vary from all roads in the state (the full-set) to only those roads that have properties that meet or exceed the user specified threshold (some sub-set).

There are two general options on the 'Select Road Network' screen (Figure 66); "Use Currently Loaded Road Network" and "Select Different Road Network".

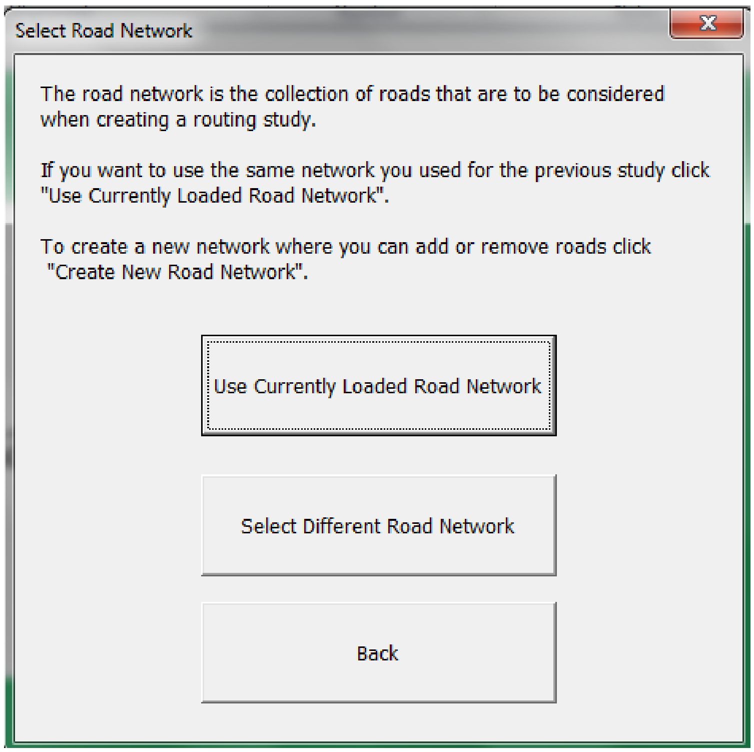

Figure 66. Select road network screen

The "Use Currently Loaded Road Network" option keeps the road network currently loaded (the one used previously). Note that this option assumes that a road network exists. If this is the first time running the OZ Program or the previously loaded network has been deleted and this option is selected, an error will occur during the solving process.

Clicking the "Select Different Road Network" button leads to a screen with three options (Figure 67).

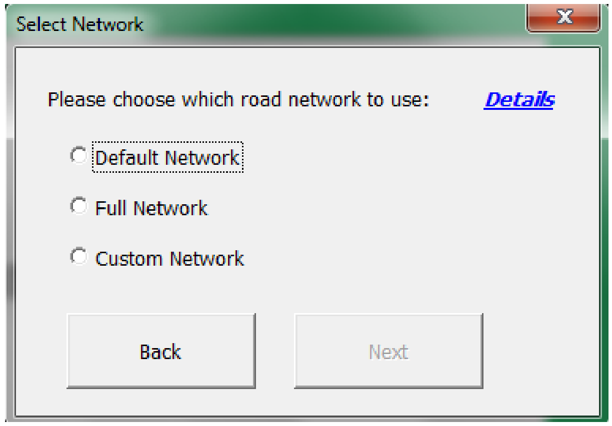

Figure 67. Select network screen

The “Default Network” option copies over an existing network that has been pre-filtered using the following thresholds:

- All interstates are included (excluded from the following constraints)
- Road segments associated with bridges that have a general appraisal rating (GA) less than 5 are removed
- Road segments associated with bridges that have a load rating less than 100% of maximum Ohio legal load (80 kips) are removed
- Road segments with the following surfaces are removed
    - Brick
    - Open graded road mix or pugmill mix
- Road segments with the following compositions are removed
    - Primitive road
    - Unimproved road
    - Graded and drained earth road
    - Gravel road
    - Bituminous (surface treated)
    - Brick
    - Block
- Road segments (state and local) that are one way or contain a one way structure are removed
- Road segments that are classified as the following are removed
    - National forest development roads and trails
    - National park service parkway
    - National park roads and trails

The “Full Network” option copies over the full network; all roads in the state are eligible for use. Note that if this option is not selected and, during the course of the routing analysis, Python alerts the user that no solution can be found, the user should repeat the analysis switching to the full network. The likely cause of the error was that the solver could not connect the origin(s) and destination(s) using the in place set of roads (in place network).

The “Custom Network” option takes you to the “Network Settings” excel tab where the user can make their own specifications and create their own network (Figure 68). Once all selections have been made, the clicking of the “Apply Settings and Resume Study” button will create the custom network. The creation of the custom network can take up to five hours. If the custom network is to become the new default network, then it is advisable to delete the in place default network from the “NetDatasetDefault” gdb (contents of C:\OZ_GIS\NetDatasetDefault.gdb\TransSeg) and copy over the custom network by copying and pasting the network dataset in the OZ_GIS gdb (C:\OZ_GIS\OZProject.gdb\TransSeg\TransSeg_ND).

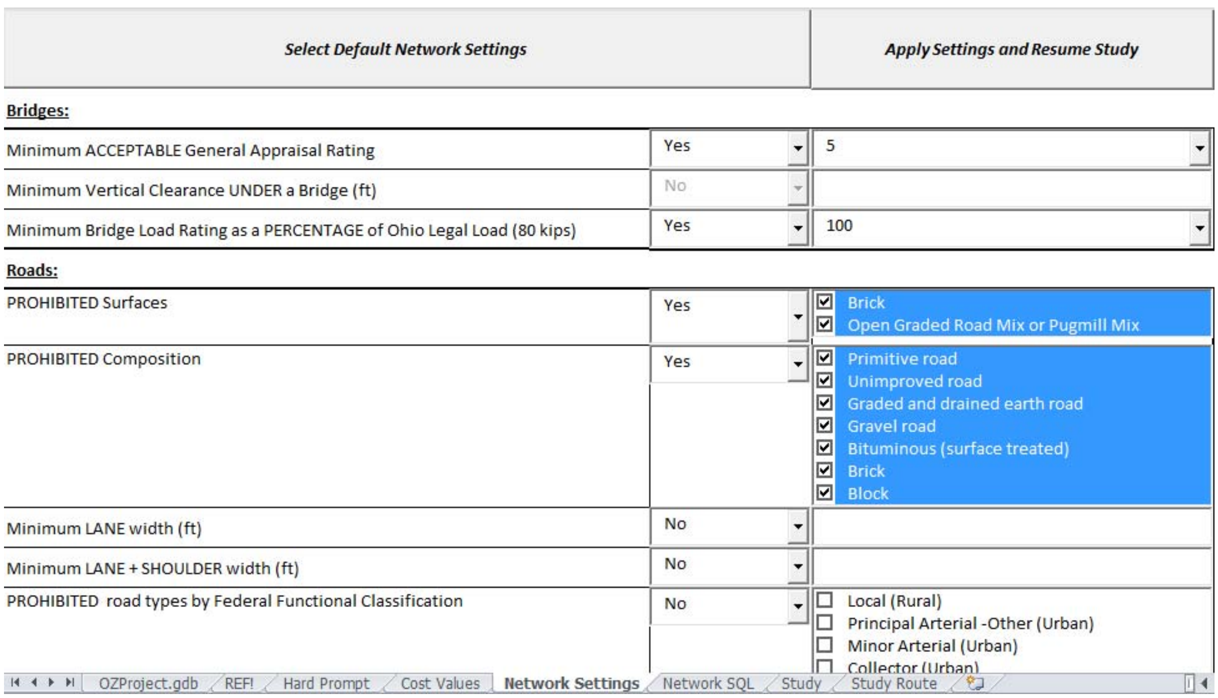

Figure 68. Network settings page

ODOT Note: It is recommended to use the full network with the flagging features which will be discussed. This will eliminate the opportunity for missing road segments to prevent python from finding a path.

Create Route Using Points

To create a routing study select the origin(s) and destination(s) by clicking the “Select Start and End Points” button on the welcome screen (Figure 59). Doing so will present the user with the ‘Specify Number of Studies’ screen (Figure 69) where the user will specify the number of routing studies they wish to perform.

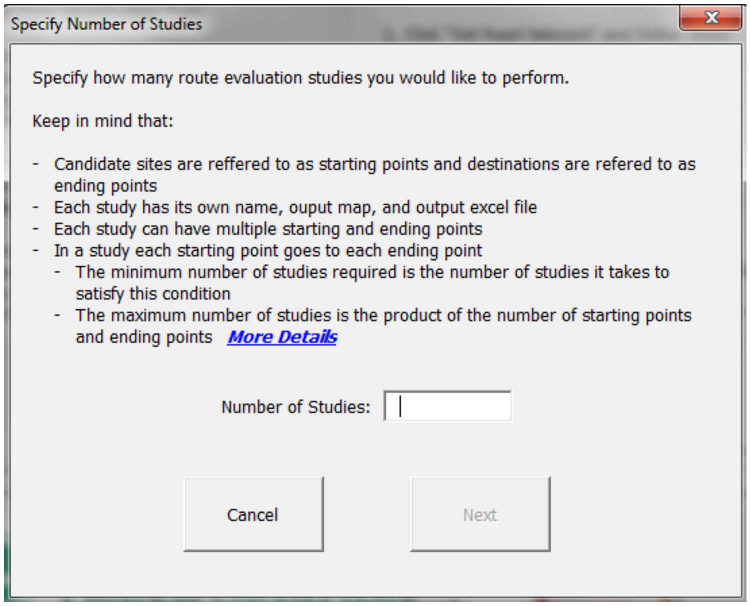

Figure 69. Number of studies screen

Number of Studies

Each study assumes that each starting point goes to each ending point, or each origin goes to each destination, with each starting point being a candidate job site and each destination being a likely shipping destination; an illustrative example is shown in Figure 70. The minimum number of studies required is the number of studies it takes to satisfy this condition. The maximum number of studies is the product of the number of starting points and ending points; this will result in one starting point and one ending point (and one route) per output map. Additionally, each study has its own output map, directions text file, and excel file.

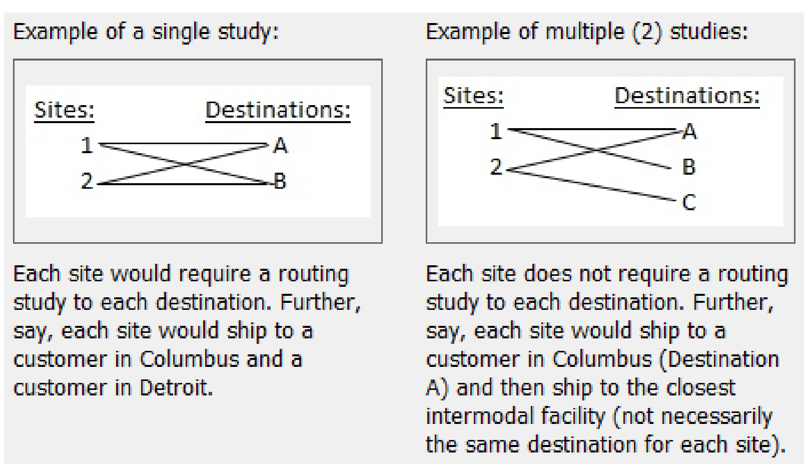

Figure 70. Number of studies diagram

Output File Naming and Location

Once the number of studies has been specified, the user needs to enter a name for the study (Figure 71); each study will have its own name. Valid characters for naming are alphanumeric characters and the underscore character. The first character must be alphabetical. If the name the user entered is invalid, a message box will prompt the user to enter a different name. No two studies can have the same name.

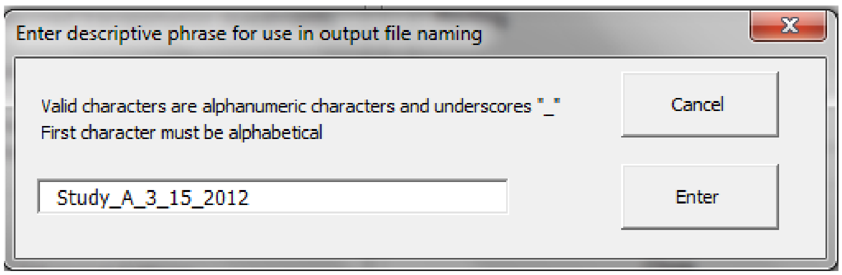

Figure 71. Study naming

Once a valid name has been entered, the user needs to specify a folder for the output layer and excel files (Figure 72). All studies will have the same output folder, thus the criteria that each study must have a different name. The user can create a new folder or use an existing folder. Any folder, following Windows naming convention rules, which is not a geodatabase, is allowed. Note that all non-layer GIS files will be stored in a feature dataset in the OZProject geodatabase following the naming convention 'u_*n*' where *n* is what the user entered as the study name in the naming dialog box (Figure 71).

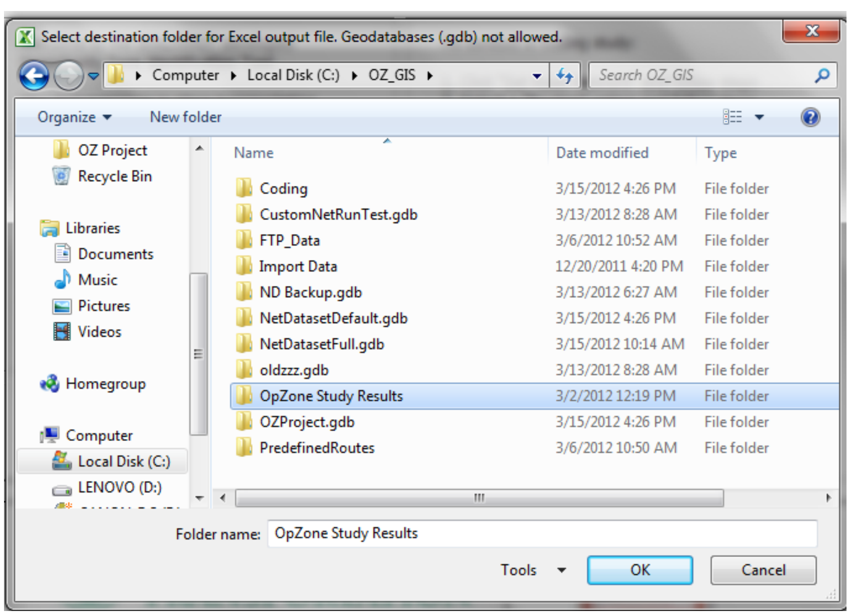

Figure 72. Study output file folder

Specifying Starting and Ending Points

Starting and ending points can either be selected from a prepopulated list or entered using latitude and longitudinal coordinates by clicking the appropriate button in the 'Starting Point Selection Method' screen (Figure 73). If more than one starting or ending point is being entered, a mixture of the two is allowed.

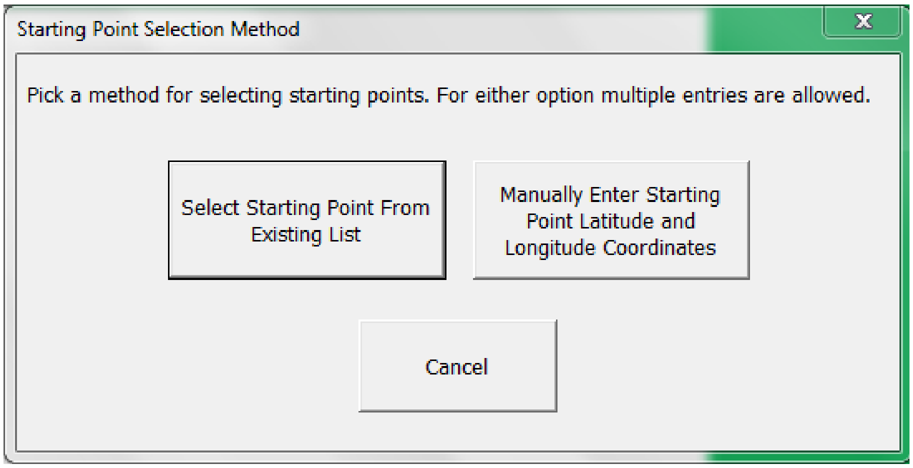

Figure 73. Starting point selection method screen

Select Start Point from Existing List

This method allows the user to select a point from a prepopulated list. The sources of these points are the point feature classes within the Sites FD in the OZProject gdb (Figure 74) or user added gdb. The user has the option to specify the set of points to use in the "Site Data Source" list box in the "Advanced Settings" screen (page 59).

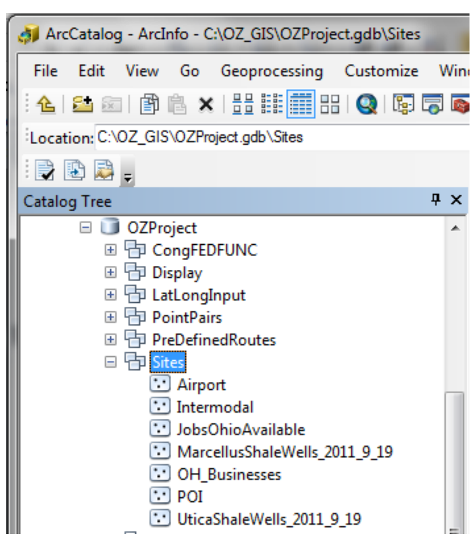

Figure 74. Existing point source files

Once the user selects the category, or feature class, containing the starting point they want to locate, they click the "Select Points" button on the 'Existing Start Point File Selector' screen (Figure 75) to launch the 'Start Point Selector' screen (Figure 76).

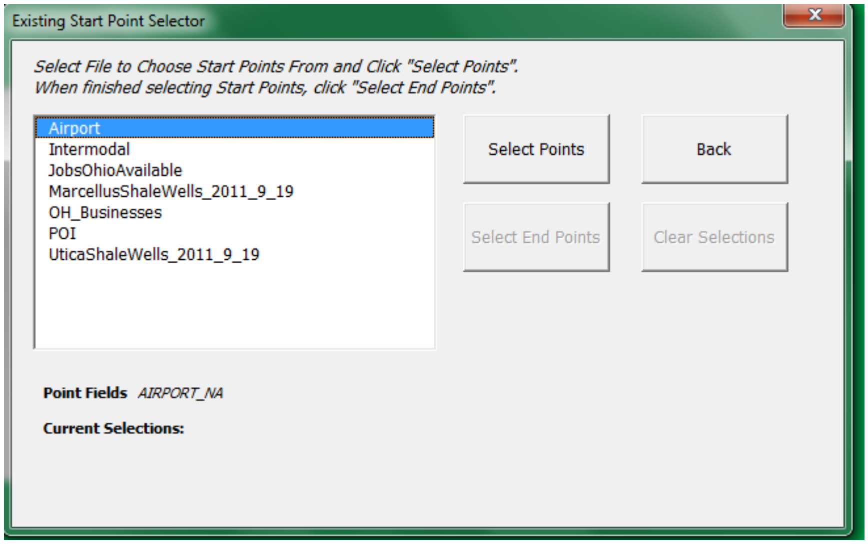

Figure 75. Existing start point file selector screen

Within the 'Start Point Selector' screen, when the user finds the point they want to add they select the point in the list and click the "Add" button. When the user is done adding points, they click the "Done" button to take them back to the 'Existing Point File Selector' screen where they can select another category of points. Select the "Back" button to select the "Manually Enter Latitude and Longitude Coordinates" button, or select the "Select End Points" button.

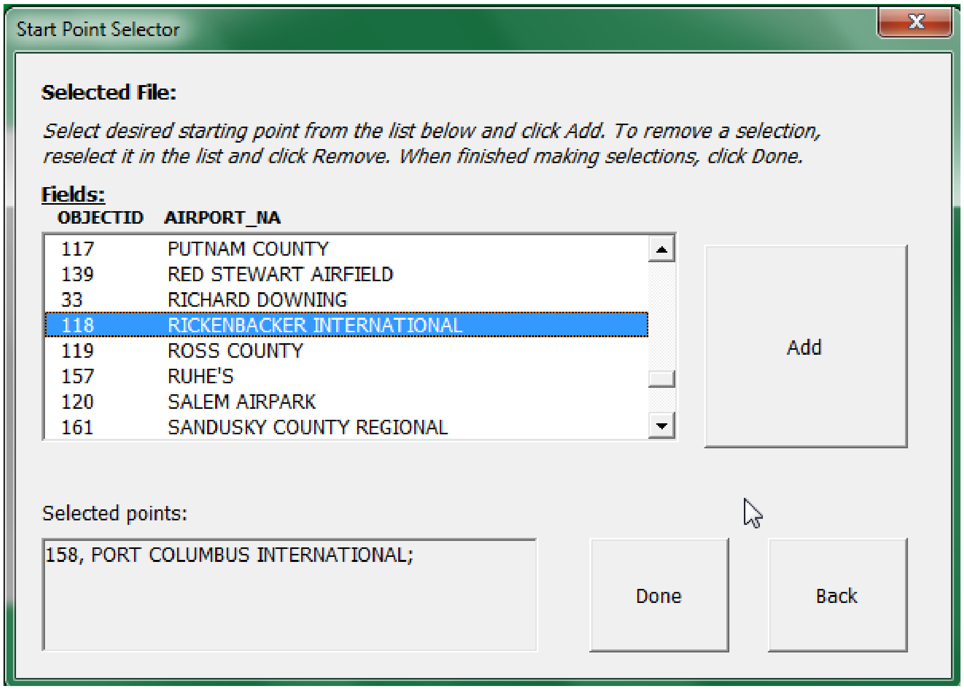

Figure 76. Start point selector screen

Manually Enter Point Latitude and Longitude Coordinates

Clicking the "Manually Enter Latitude and Longitude Coordinates" button initiates the 'Enter Site Latitude and Longitude' screen (Figure 77). Required inputs are a point description (using only alphanumeric characters and the underscore character where the first character must be alphabetical) and the latitude and longitude of the point in comma-separated decimal degree format. One method of getting the latitude and longitude of any point is to locate the point on Google Maps, right-click on the point, select the "What's here?" option, and copy and paste the resulting latitude and longitude from the search bar (Figure 78) into the OZ Program latitude and longitude input box.

Once the point description and the latitude and longitude have been entered, click the "Verify" button. If no errors are found, the user can choose whether or not to add another starting point. If yes (note not shown), then the user can do so using latitude and longitude again or by switching to the existing point list by selecting the appropriate button. If no, the user will click the "Select End Points" button.

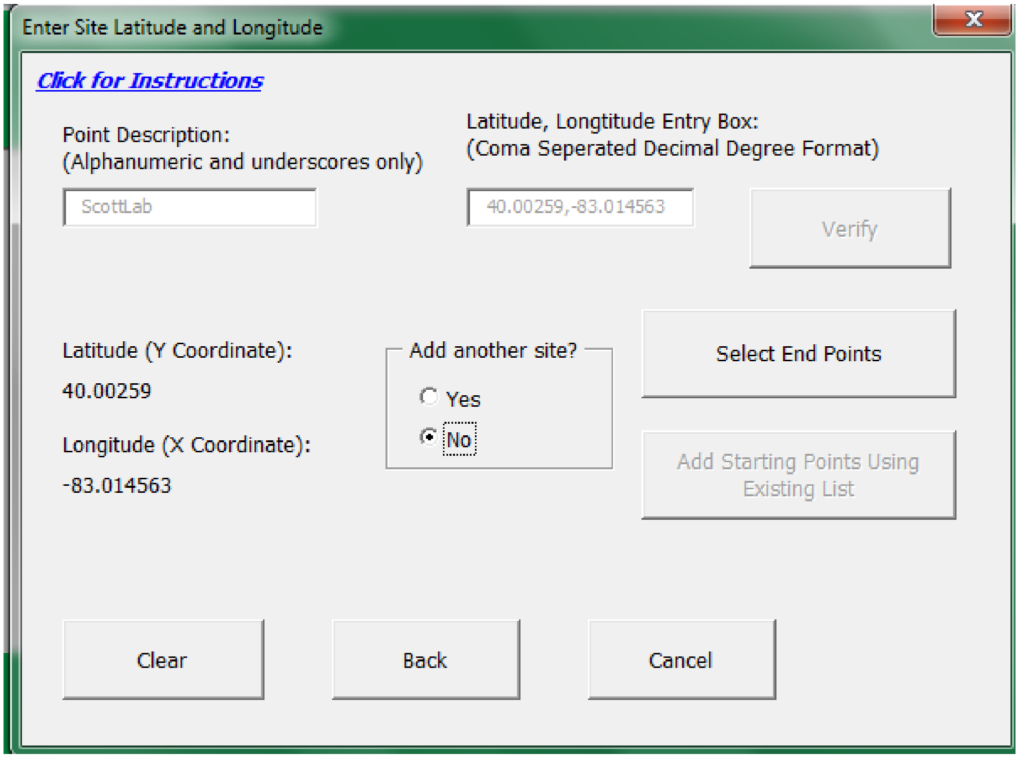

Figure 77. Enter site latitude and longitude screen

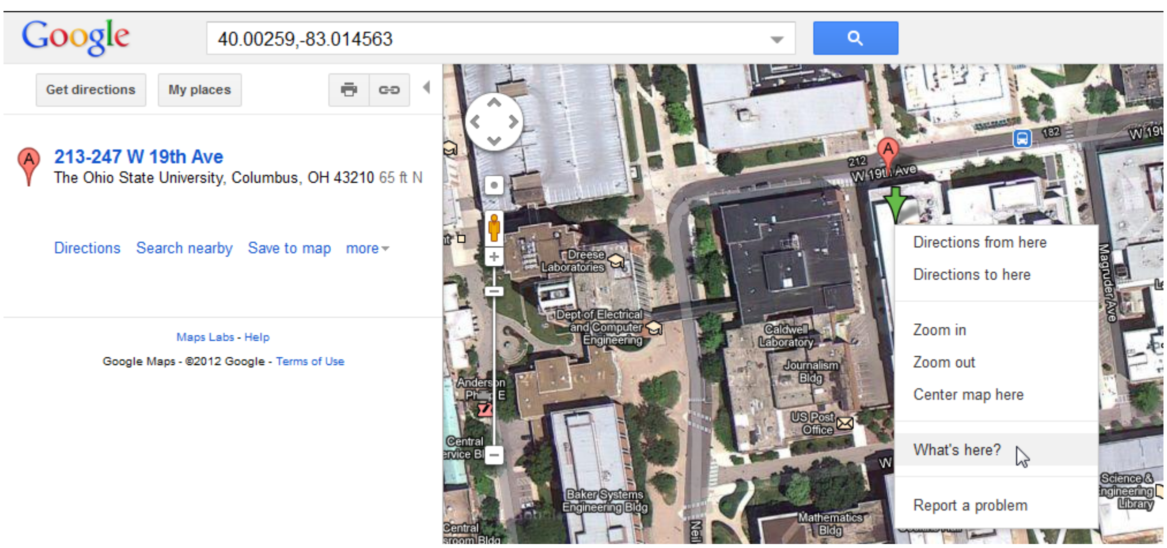

Figure 78. Finding latitude and longitude coordinates using Google Maps

The method for selecting ending points is the same as for selecting starting points and will not be shown in detail. The only exception is that when the user is done entering ending points, they will click the “Next” button instead of the “Select End Points” button.

Guiding Points

The purpose of the "Guiding Points" screen (Figure 79 and Figure 80) is twofold. The first is to allow the user to override the route that the program thinks is best. The second is to allow the user to solve a more advanced problem. The "Guiding Points" page allows the user to enter points that the route must travel through using latitude and longitudinal coordinates in comma-separated decimal degree format. These latitude longitude points can be found by right clicking on a point along a road which you want the program to follow using Google maps (or another mapping webpage) just as before. If there is more than one guiding point, the longitudinal coordinates for these points must be entered in the order in which the route should follow them. Note that this step is not necessary and can be skipped by clicking the "Next" button without entering any guiding points (Figure 79). Figure 80 illustrates what an entered guiding point looks like.

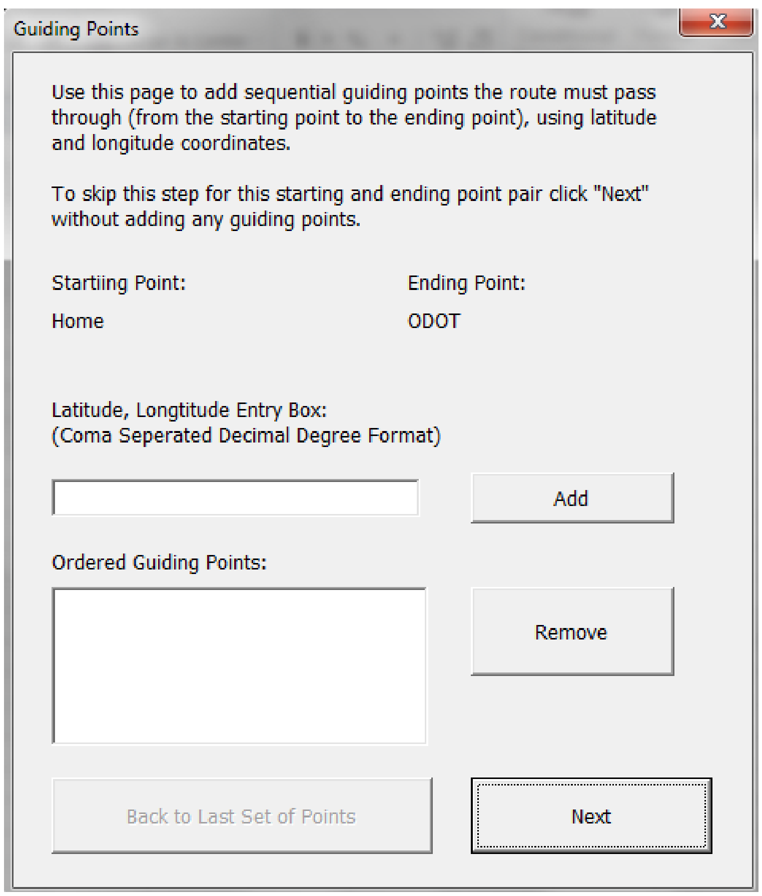

Figure 79. Guiding points screen sans guiding points

The route solver solves for what it decides is the best route between each start and end point using an algorithm that was developed based on assumptions derived from considering the whole state. User knowledge about a specific area may dictate altering the route in such a manner to make it more realistic. Another reason the solver may return an undesirable route is because of disconnects in the network caused by disconnects in the road inventory feature class files (Figure 81).

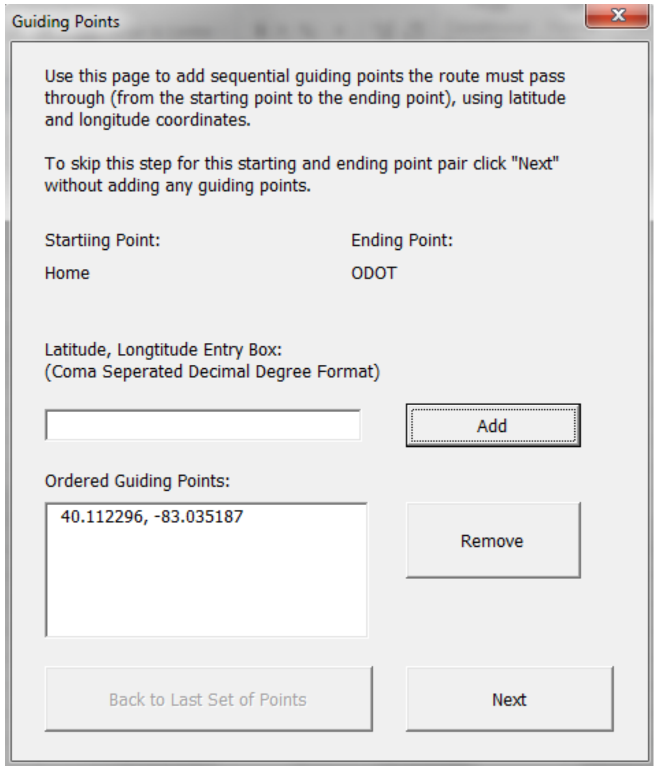

Figure 80. Guiding points screen with guiding point

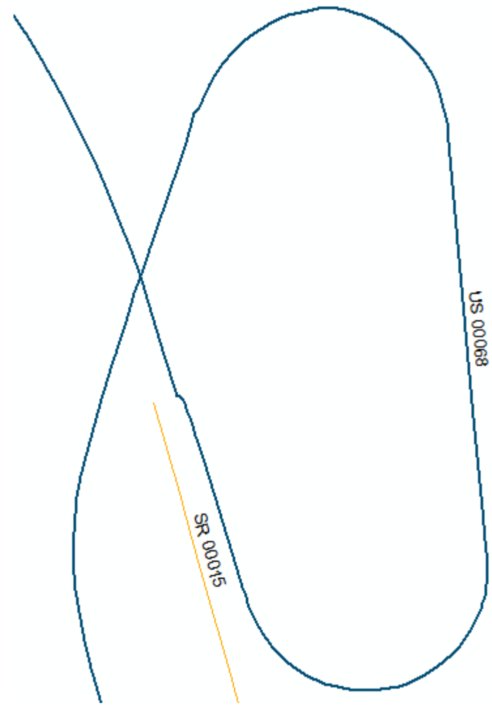

Figure 81. Example of a network disconnect

The guiding points screen also offers the chance for the user to model the 'supplier to company to customer' aspect of the supply chain, as opposed to just the supplier to the company or the company to the customer aspects. This would be achieved by having the starting points be the company's supplier(s), the ending points being the company's customer(s), and the guiding point being the company. This would force the program to route from the supplier(s) to the company's location and then from the company's location to the customer(s), thus capturing the whole transportation impact associated with the location of a company instead of one segment.

Route Flags and Optimization Preferences

The "Route Flags and Optimization Preferences" screen (Figure 82, Figure 83, and Figure 84) allows the user to specify the information that is contained in the output files. This screen has several items to consider, but is not overly complicated.

The first concept to understand is the flagging concept and how it differs from what the user might have already done by creating a custom network. In creating a custom network the user removed road segments from the network and thus from consideration of being used in creating a route. In flagging, you are merely adding a road segment or bridge to a list for future reference (the same way the user might flag an email as important). The flagging aspect is all post route analysis. Road segments or bridges that are flagged are those elements *along the route* that do not meet a desired property threshold value; this value is an acceptable value (or else it would have been removed from the network) or it is just not as good as the user would prefer. There are ten sets of radio buttons (split between Figure 82 and Figure 83) that attempt to capture road and bridge information that the user would be interested in flagging. In general, these are referred to the user's preferences for the route.

For example, the first set of radio buttons is the "Flag urban roads" set (Figure 82). Selecting "Yes" here would add to a list all road segments, along the solved for route, that are classified as urban using the Federal Functional Classification categorization. It is likely that the user would not want to remove urban road segments from the road network, but it simply might not be desirable for the route to use urban road segments due to the projected impact on, say, congestion.

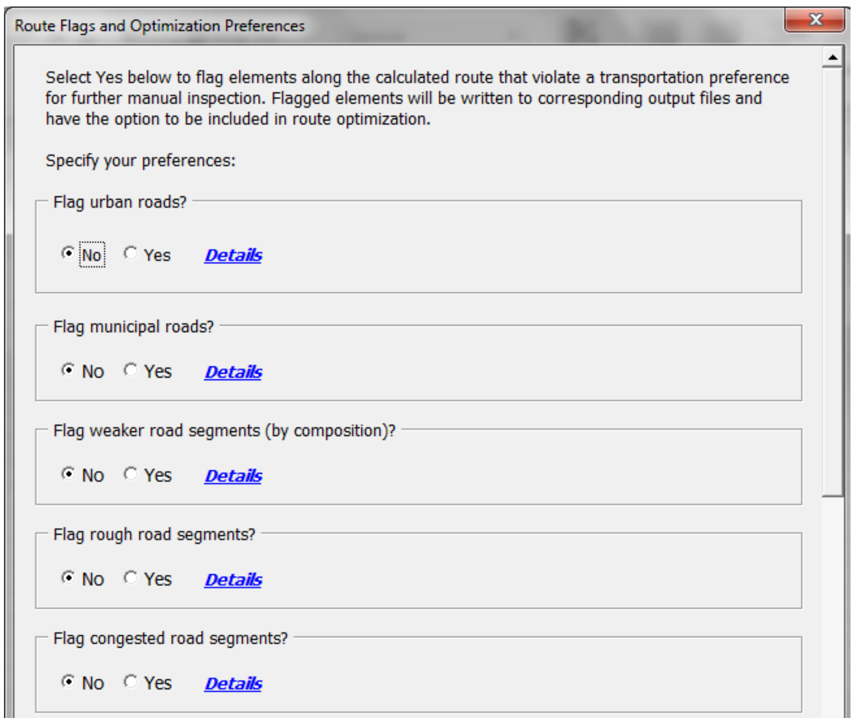

Figure 82. Route flags and optimization preferences screen (top half)

Road and bridge properties to flag are allowed to be unique for each study. If the user arrives at the "Route Flags and Optimization Preferences" screen while not on their final study, the user will click on the "Next Set of Points" button (Figure 83).

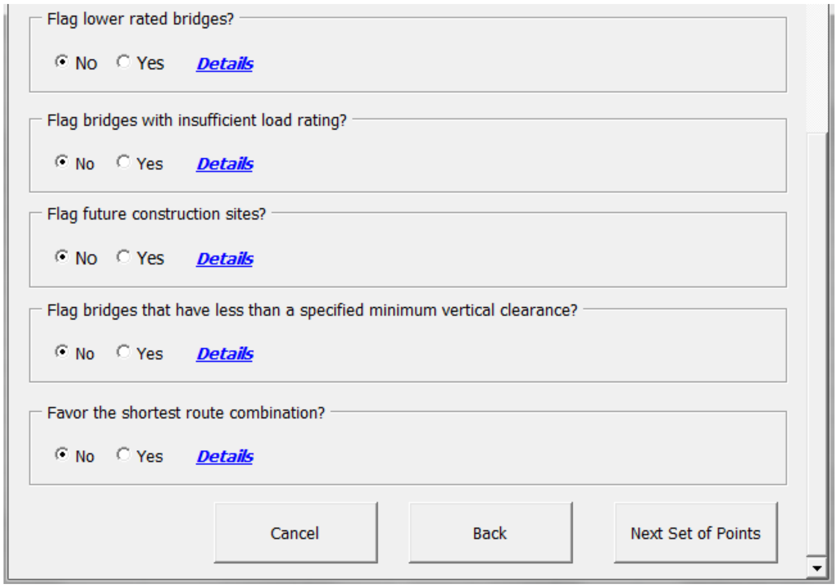

Figure 83. Route flags and optimization preferences screen (bottom half-select next set of points for next study)

When the user arrives at the “Route Flags and Optimization Preferences” screen for their final study, they are presented with three options before solving the routing problem (Figure 84):

- Show Route Only
- Show Route with Flagged Elements Only
- Show Route and Apply Start Point Optimization

The “Show Route Only” button will ignore any flags the user specified (same as selecting No on all radio button sets) and solve for the appropriate number of routes in accordance with the number of studies and start and end point pairs. The output files will include one ArcMap file and one directions file per study (with supporting layer and feature classes).

The “Show Route with Flagged Elements Only” button will, after solving for the appropriate number of routes, create additional layer (and feature class) files showing the road segments or bridges along the route that were flagged. For example, Figure 85 and Figure 86 show the route from the ODOT central office to Indianapolis (the Ohio portion) flagging all urban roads utilized. Figure 85 shows all elements, while Figure 86 shows the route with a focus on the flagged elements. Note in both figures that the flagged layers appear in the ArcMap Table of Contents tree on the left side of the screen as “ODOT_to_Indy_Route1_zzzinvs_FUNC_CLASS_lyr” and “ODOT_to_Indy_Route1_zzzinvm_FUNC_CLASS_lyr”. In Figure 86 the thick red lines along the thin grey line represent all urban roads (on the state system) that are utilized along the route from the ODOT central office to Indianapolis. There is also an excel file in the specified solutions folder that details each flagged segment. These extra layers and excel file do not influence the route; they are merely alerting the user to the location of the road segments that the user wanted flagged.

The "Show Route and Apply Start Point Optimization" button takes what was described in the previous paragraph and applies a cost to the flagged road segments in order to determine the preferred route. Note that this option is only useful if the user is comparing multiple candidate job sites. A cost is applied for each road segment or bridge in violation of a specified preference and summed over the route. The route with the lowest cost reveals the preferred candidate site based on the assumptions that went into assigning the costs. Obviously, this is only one metric and deterring the preferred site should not be made from this metric alone. Costs can be tailored by clicking the "Adjust Cost Values" button (Figure 84).

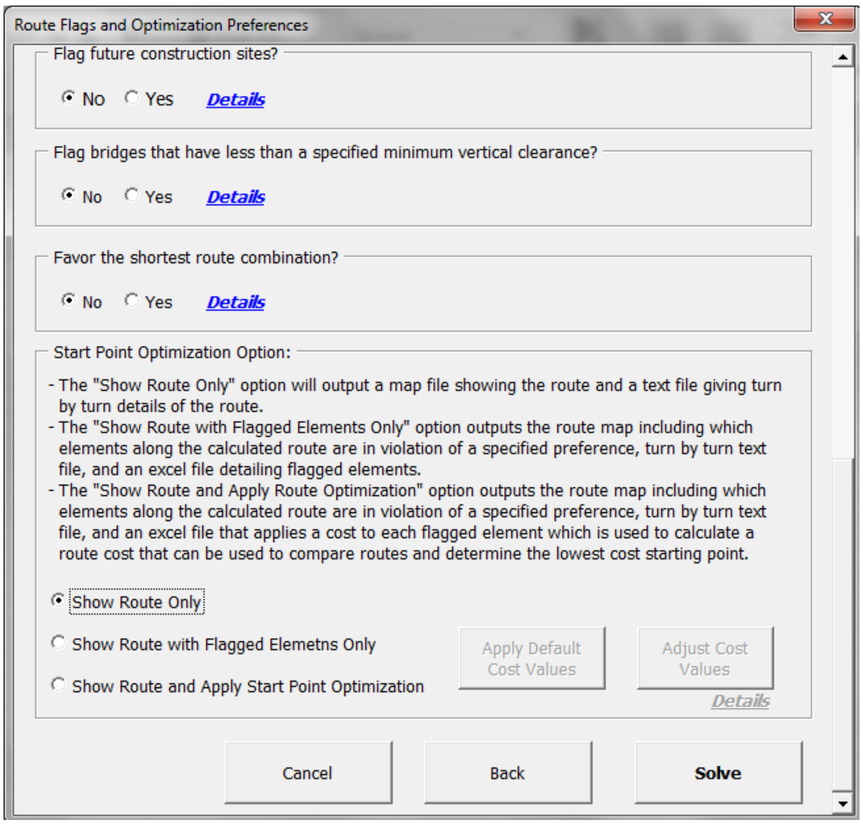

Figure 84. Route flags and optimization preferences screen (bottom half-ready to solve)

In general the purpose of this screen (Figure 84) is as follows:

When the user is doing a site location study between multiple candidate job sites, they can set appropriate transportation property thresholds along the projected route and the program will flag the undesired road segments; such as the threshold at which a bridge will be flagged for having too low of a rating. Then, a cost is applied to each of the flagged road segments which will numerically reveal the preferred ODOT route based on the transportation properties that were entered.

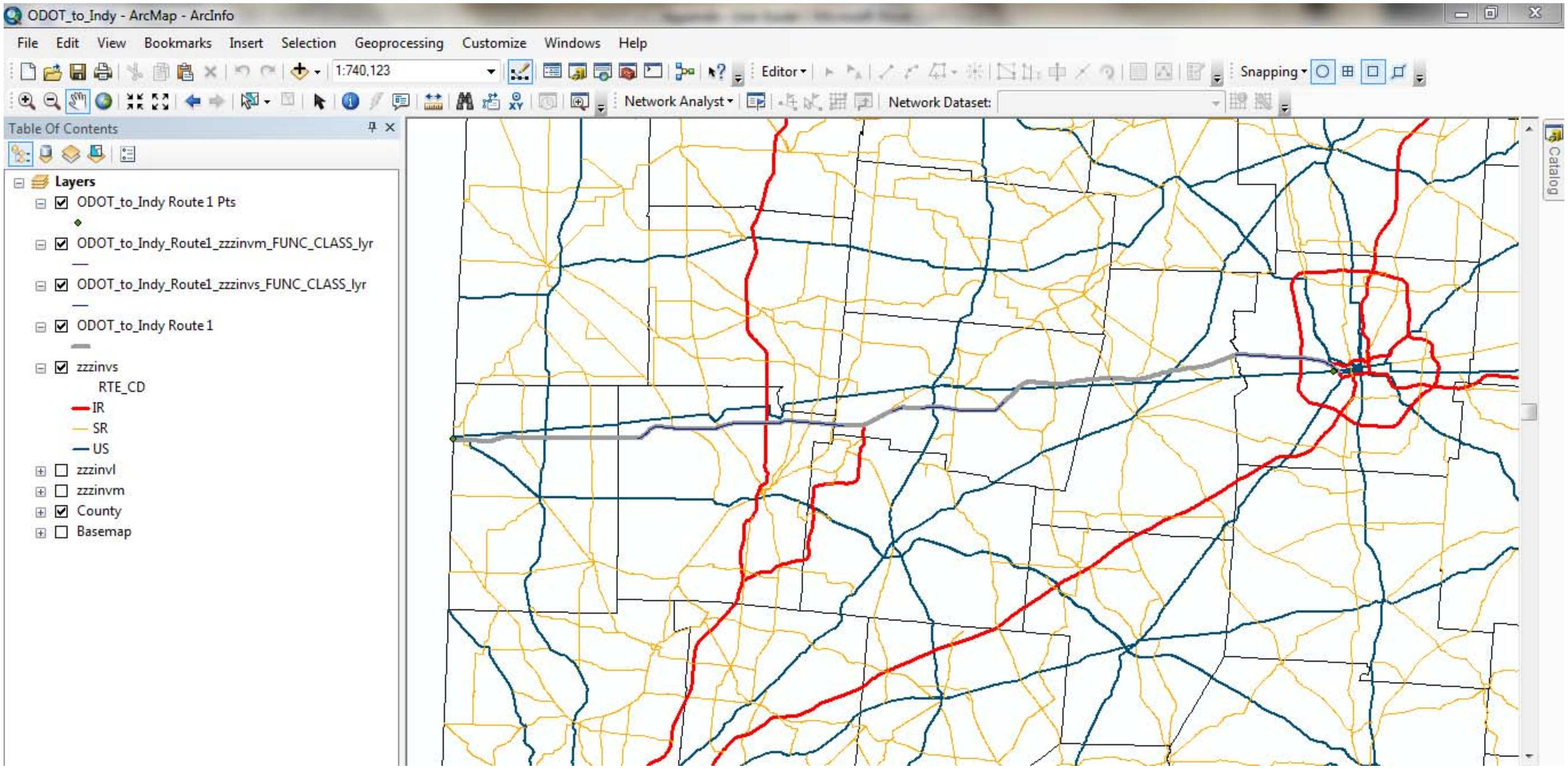

Figure 85. Example of route with flagged urban roads

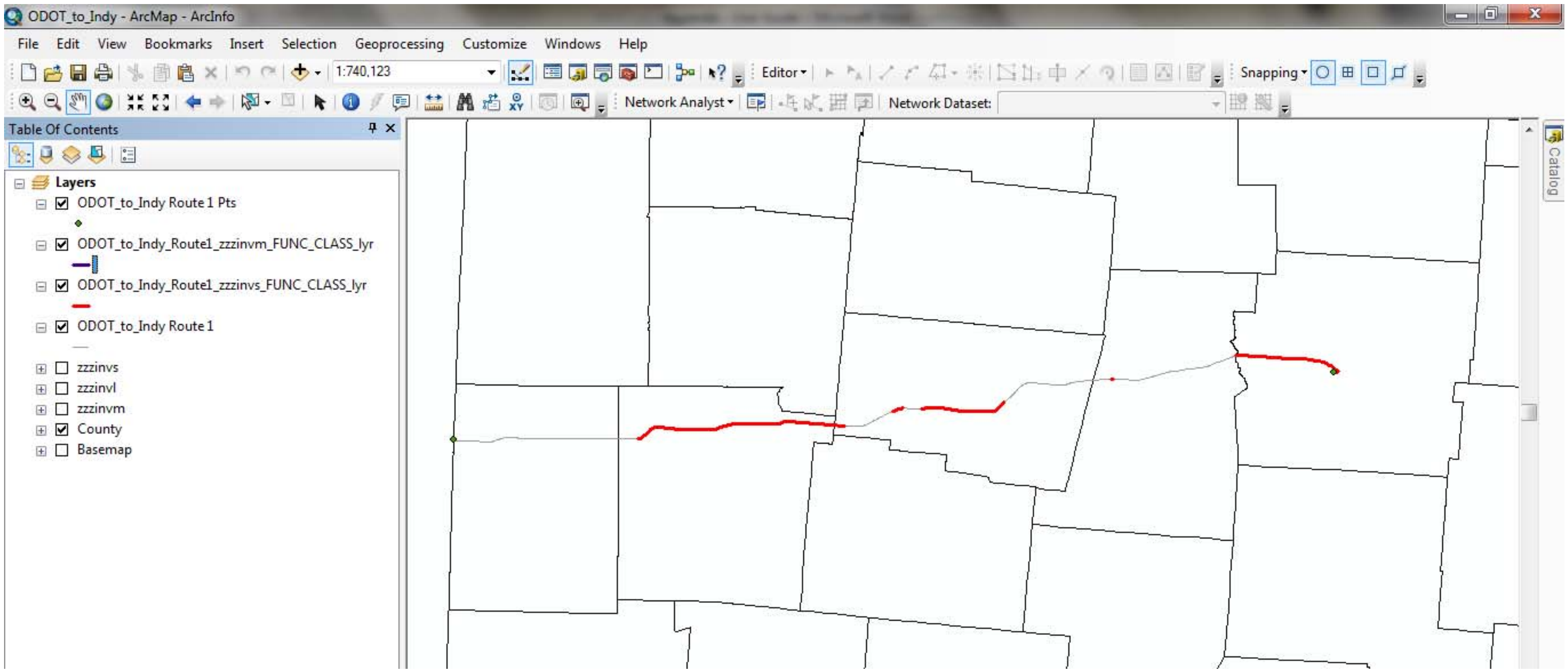

Figure 86. Example of route with flagged urban roads (focus on urban roads)

Predefined Route

The user can re-analyze an existing route (a route that has been created by a previous study) by clicking the "Select Predefined Route" button on the welcome screen (originally shown in Figure 59 and repeated below for convenience, Figure 87). Possible reasons the user would want to use this feature include recreating a deleted map document or creating a new report using new flag conditions. Note that this would re-analyze an existing route and would NOT create a new route. If a new route is desired, the user can manipulate which roads to include in the network using the "Set Road Network" button and associated functionality OR manually create a route using geoprocessing editing tools within ArcMap (for which the user would have to save a copy as a layer file).

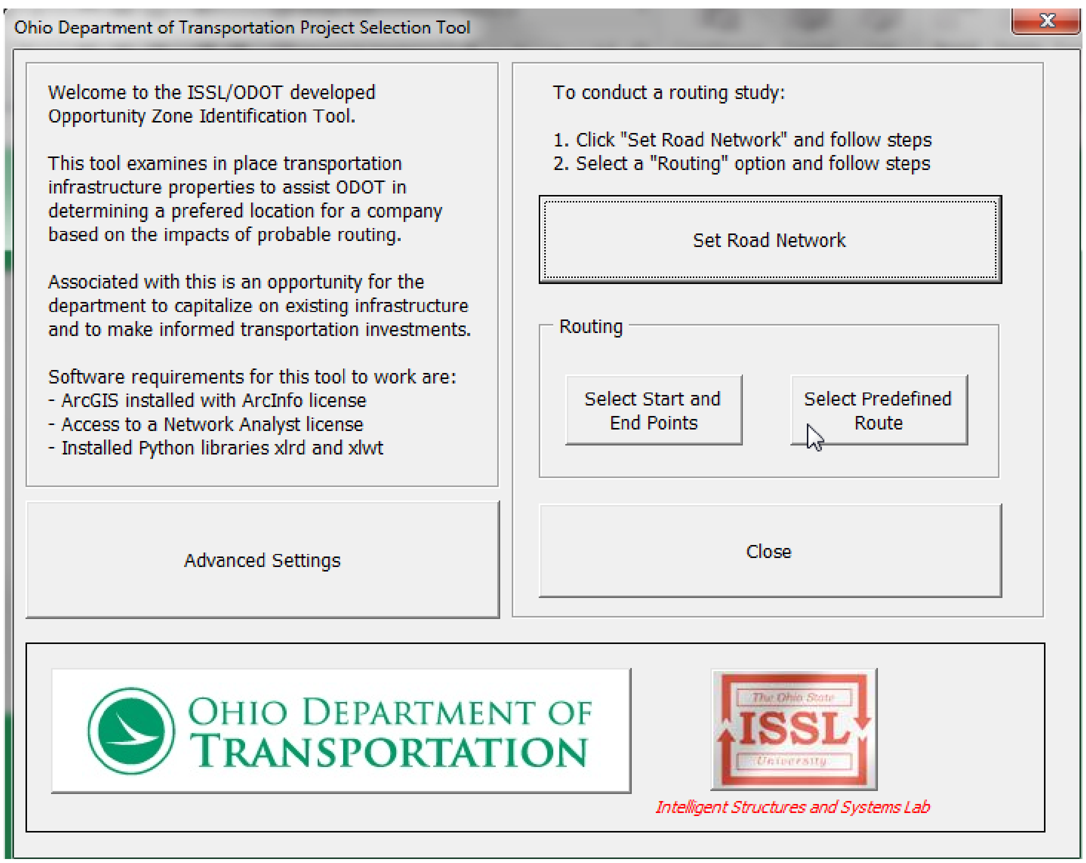

Figure 87. Welcome screen

After entering a valid description for output file naming (Figure 71) and specifying a location for the output files to be stored (Figure 72), the user is prompted to navigate to and select an existing route layer (.lyr) file as shown below in Figure 88.

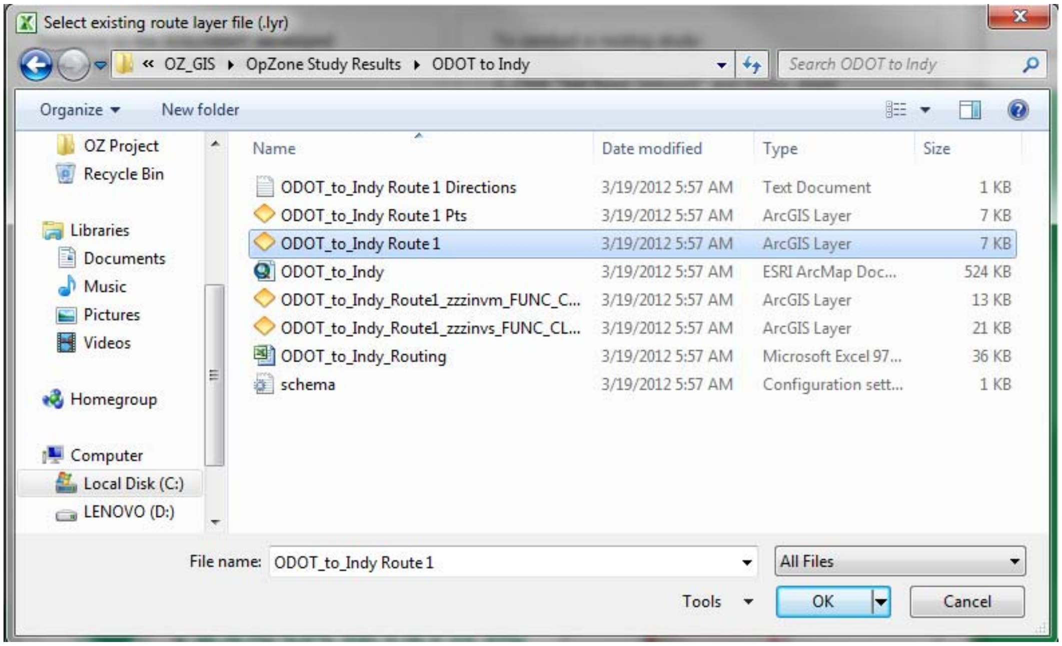

Figure 88. Select existing layer file for predefined route functionality

After selecting the existing route for re-processing, the user is prompted to specify the properties they want to flag (Figure 89). Note here that the option to “Show Route with Flagged Elements Only” is the only available option because of the characteristics associated with working with an existing route. When finished selecting the properties, click the “Solve” button.

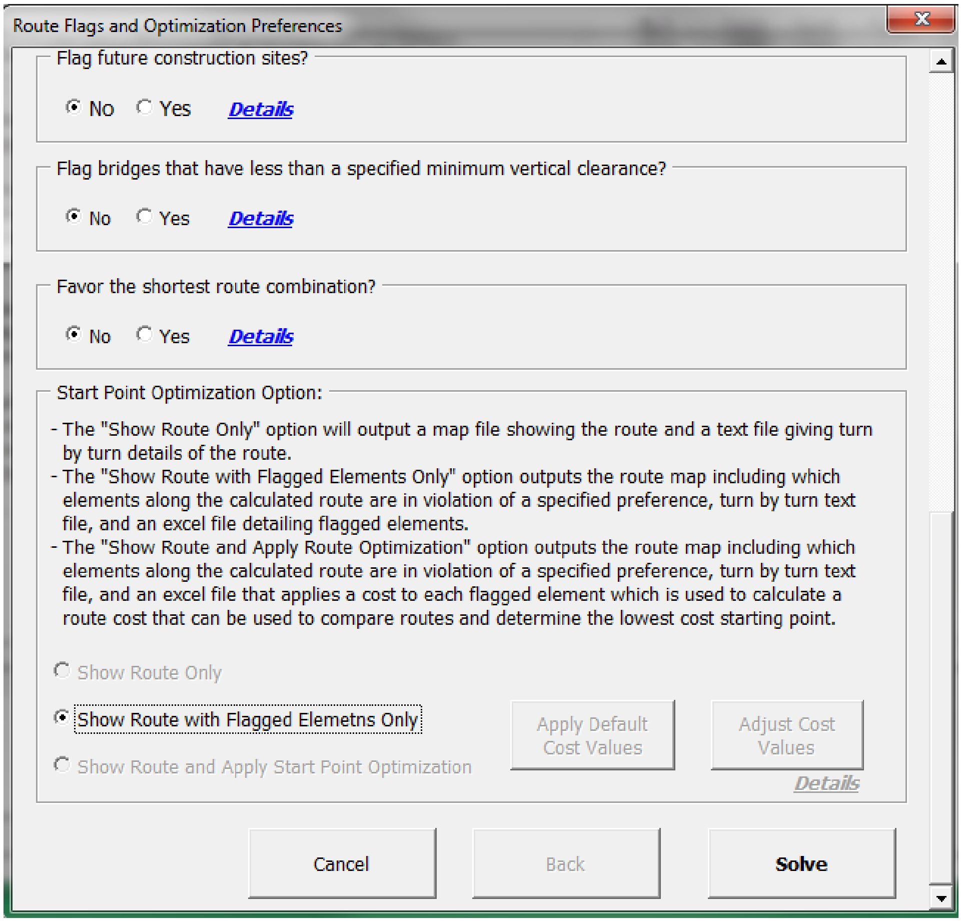

Figure 89. Predefined route flags and optimization preferences

Interpreting ArcMAP Results (Table of Contents)

When the OZ Program concludes the solving process (assuming a solution is found) an ArcMap screen, similar to the one shown in Figure 90, initializes. This section is dedicated to understanding the preloaded layers populating the table of contents.

First, the layers titled zzzinvs, zzzinvl, zzzinvm, County, and Basemap will appear every time; they are part of the template files titled OZProjectBaseMap stored in the C:\OZ_GIS\Coding folder. These simply are the road inventory files, the counties, and the OpenStreetMap (default toggled off).

The remaining files are all custom to the prompt. The user will notice there are, simply, four parts to the names of the remaining layers that can be generically written as 'j_k_l_m' where j is the name of the study, k is the study number (preceded by 'Route'), l is the feature class, and z is the name of the property of feature class l that was being queried and can be translated from Table 8 below.

For instance, from Figure 90, layer 'future_predef_test_Route1_Bridges10_GEN_APPRAI_lyr' is to be interpreted as follows. The points contained in this layer are all those bridges along route

1 in the study titled future_predef_test that has a rating that did not meet the user-defined criteria from the Route Flags and Optimization Preferences section on page 73.

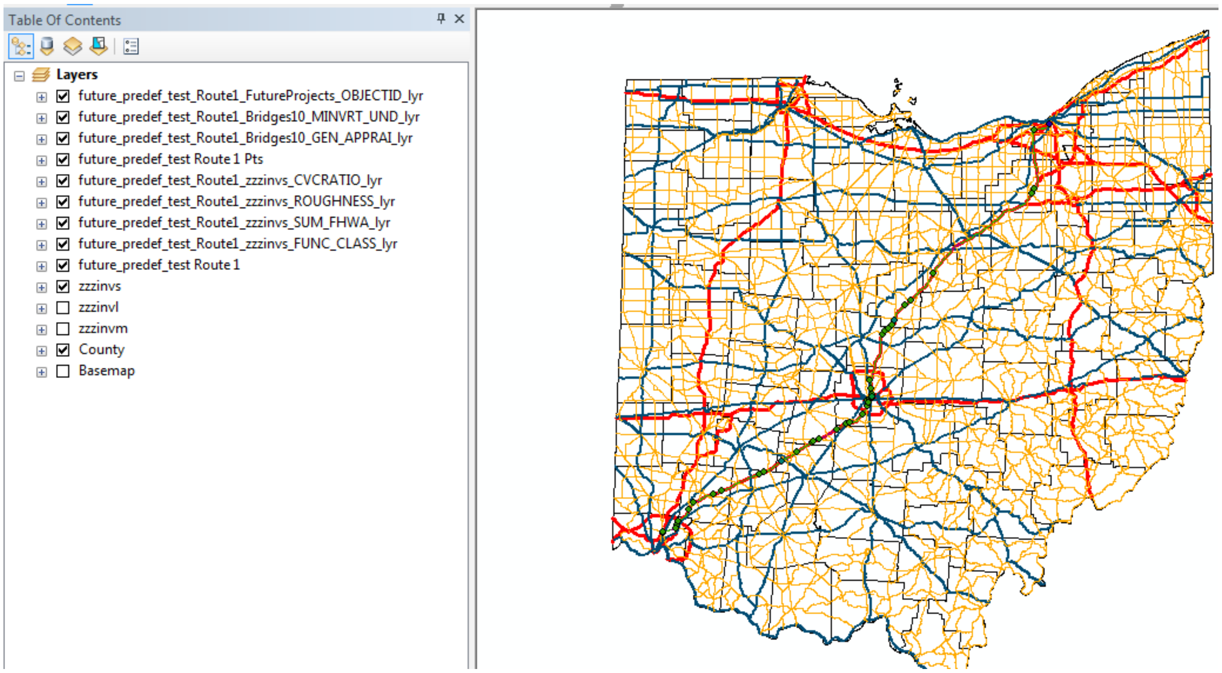

Figure 90. ArcMap results table of contents

Table of Contents Lingo	Translation (implied along the route)
Route#_FutureProjects_OBJECTID	Future projects
Route#_Bridges10_MINVRT_UNDR	Bridges that violate minimum vertical clearance
Route#_Bridges10_GEN_APPRAI	Bridges that violate the rating (GA) criteria
Route#_BRIDGES10_LOAD_RAT_P	Bridges that violate the load rating criteria
Route#_zzzinv*_FUNC_CLASS	Road segments that violate the urban road criteria
Route#_zzzinvs_SUM_FHWA	Road segments that violate the strength criteria
Route#_zzzinvl_SUM_SURF	Road segments that violate the strength criteria
Route#_zzzinv*_ROUGHNESS	Road segments that violate the roughness criteria
Route#_zzzinv*_CVCRATIO	Road segments that violate the congestion criteria
Route# Pts	The route's starting and ending points
Route#	The actual route

Table 8. Interpreting ArcMap table of contents
route number, * s/l/m

Interpreting Excel File Results

The Excel file that accompanies the geographic solution is, in essence, a summary of the geographic solution attribute table. An excerpt of the Excel file associated with the ODOT to Indianapolis route flagging all urban roads is shown below in Figure 91 and can be interpreted as follows:

- Row 2 shows which road inventory file the flagged segment is associated with
- Row 3 contains column headings of relevant attribute table columns where the column in bold is associated with the column that was flagged.
    - o All roads are classified using the Federal Functional Classification. Certain Federal Functional Classifications indicate that a road is urban. Therefore, in this case, the attribute column specifying whether a road is urban or not is the Federal Functional Classification column, which has the name of 'FUNC_CLASS'.
- Rows 4 and beyond show the values of all flagged points or, in this case, line segments.

	A	B	C	D
1	**ODOT_to_Indy:**			
2	**File**	zzzinvs	zzzinvs	zzzinvs
3	**FC Export Field**	OBJECTID	NLF_ID	**FUNC_CLASS**
4	**Values**	1	SFRAIR00070**C	**11**
5		2	SFRAIR00070**C	**11**
6		3	SFRAIR00070**C	**11**
7		4	SFRAIR00070**C	**11**
8		5	SFRAIR00070**C	**11**
9		6	SFRAIR00070**C	**11**
10		7	SFRAIR00070**C	**11**
11		8	SFRAIR00070**C	**11**
12		9	SFRAIR00070**C	**11**
13		10	SFRAIR00070**C	**11**
14		11	SFRAIR00070**C	**11**
15		12	SFRAIR00070**C	**11**
16		13	SFRAIR00070**C	**11**
17		14	SFRAIR00070**C	**11**
18		15	SFRAIR00270**C	**11**
19		16	SFRASR00315**C	**12**
20		17	SFRASR00315**C	**12**
21		18	SFRASR00315**C	**12**
22		19	SFRASR00315**C	**12**
23		20	SFRASR00315**C	**12**

Figure 91. Excel output for the ODOT to Indianapolis flagging urban roads example

Further, if the user were to select the "Show Route and Apply Start Point Optimization," the Excel output file would contain additional information as shown in Figure 92. Note here that the cost of the line segment or point (in the case of bridges or future projects) is contained on an element basis in columns following the bold columns (shown here to be columns E and I) and a "Total Cost" of a route is given in cell F1.

Each cost is the results of, in the case of line segments, multiplying the segment length by the cost per unit length assigned, as described in the Route Flags and Optimization Preferences section on page 73. In the case of a point, the cost per instance is applied. The total cost can be explained by the following objective function and is the method used to determine, based on user-defined criteria, which origin/destination pair should be pursued further.

$$\min\left(\sum_{j=1}^{m}\sum_{i=1}^{n} x_{ij}\right)$$

- m is the number of columns of costs
  - o number of properties selected from the 'Preferences' screen, Figure 82 and Figure 83, returning a non-zero query count
- n is the number of rows of costs
  - o number of elements returned in query m
- x_{ij} is the cost of the element in the i^{th} row and the j^{th} column
- Sum all elements in all rows over all columns
  - o Think of summing all the elements in a collection of column vectors, one column vector at a time, where each vector does not need to have the same number of rows as any other vector

	A	B	C	D	E	F	G	H	I
1	**A_Route2 Origin:**	**Ohio-Findlay (jcn US-224 & SR-12)**	**Destination:**	**ODOT**	**Total Cost**	**94.1333984**			
2	**File**	zzzinvs	zzzinvs	zzzinvs		zzzinvs	zzzinvs	zzzinvs	
3	**FC Export Field**	OBJECTID	NLF_ID	**FUNC_CLASS**		OBJECTID	NLF_ID	**SUM_FHWA**	
4	**Values**	1	SDELUS00023**C	**14**	1.392496595	1	SDELUS00023**C	**I**	0.329010715
5		2	SDELUS00023**C	**14**	0.009823464	2	SDELUS00023**C	**I**	0.161499541
6		3	SDELUS00023**C	**14**	0.009823532	3	SDELUS00023**C	**I**	0.375500352
7		4	SDELUS00023**C	**14**	2.36923548	4	SDELUS00023**C	**I**	0.537358989
8		5	SDELUS00023**C	**14**	0.348748543	5	SDELUS00023**C	**I**	0.131467332
9		6	SDELUS00023**C	**14**	0.340350522	6	SDELUS00023**C	**I**	0.424037183
10		7	SDELUS00023**C	**14**	1.100828447	7	SDELUS00023**C	**I**	0.346683819
11		8	SDELUS00023**C	**14**	0.100939005	8	SDELUS00023**C	**I**	0.104071031
12		9	SDELUS00023**C	**14**	0.020187828	9	SDELUS00023**C	**I**	0.483649992

Figure 92. "Show Route and Apply Start Point Optimization" Excel results

Appendix: Known Limitations and Issues

To maximize the effectiveness of the OZ Program, what follows is a short discussion of known limitations and issues, how to recognize if your solution is affected by a known issue, and why these issues exist.

Routing Limitations

As was touched on in the Aside on Connectivity section on page 46, the road inventory files were not built to be used in the manner that this analysis is using them; that is, they lack necessary details for the OZ Program to achieve maximum accuracy. Specifically, no field exists that can be used to determine or what is modeled as an intersection or whether the two 'intersecting' roads are on the same plane or not (the Connectivity tab of the Network Dataset Properties).

For example, when a driver approaches a 4-way stop, they can more often than not go straight or turn in either direction. On a highway when two roads appear to 'intersect,' it gets more complicated. There are 'intersections' that closely enough approximate a valid exit for the purposes of this program (since exit and entrance ramps are not modeled), and then there are what shall be called 'fake intersections' or bridges over the highway to which there is no immediate exit, such as what is shown in Figure 93. Readers familiar with the northern freeway portion of SR-315 (between SR-161 and the I-270 interchange) know that there is an overpass, Wilson Bridge Road, that drivers cannot exit onto. However, in the 2-d modeling world without a field communicating that these two roads are not in fact on the same plane, the OZ Program could arrive at a route where it exits SR-315 at Wilson Bridge Rd. If this were to happen, the user would have to reformulate the problem using guiding points to bypass this error.

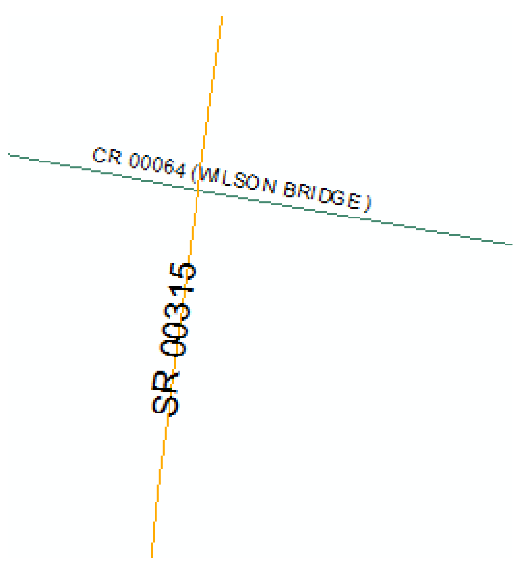

Figure 93. Illustration of un-captured bi-level intersection

Routing Issues

The only known routing issue at this time with the road inventory files is the presence of disconnects; roads that actually connect, but do not connect in the road models. The following are all the encountered (and reported) disconnects at the time of this document submission. It is possible that other disconnects exist and for this reason the user needs to be aware of this issue. Disconnects have been discovered by examining test routes and noticing 'abnormal route behavior'; the route would, for no obvious reason, turn off a highway onto a lower class road, travel for a distance, and then get back on the same highway it initially exited. In actuality, there would be a disconnect in the highway and therefore the route had to diverge.

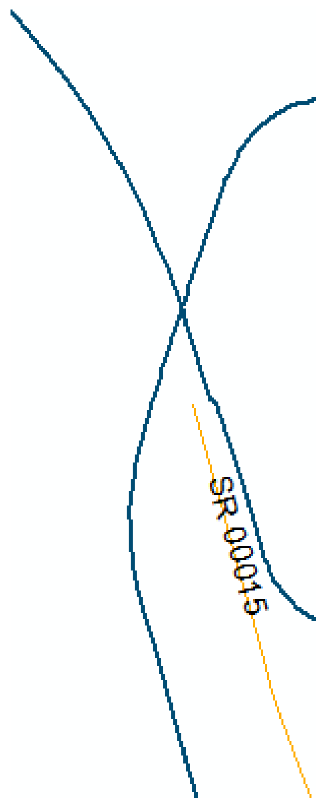

Figure 94. SR-15 disconnect in Hancock County

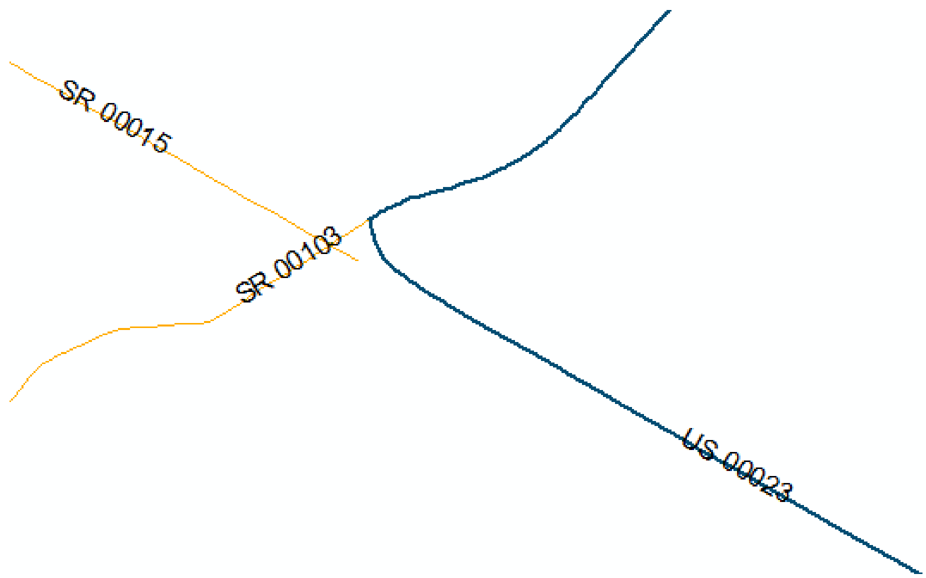

Figure 95. SR-15 & US-23 disconnect in Wyandot County

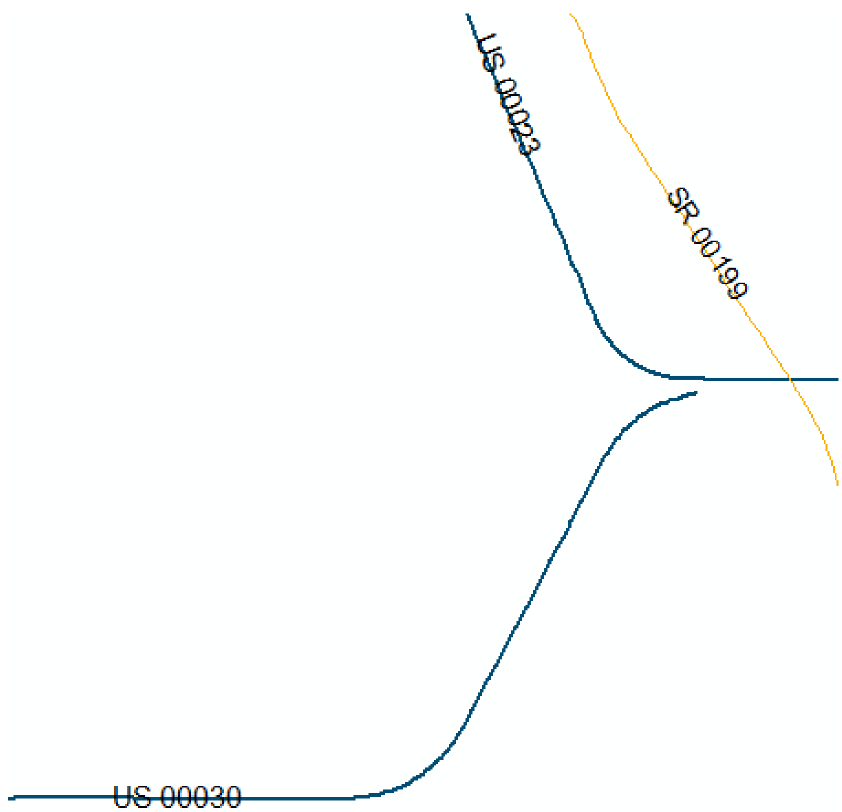

Figure 96. US-23 & US-30 disconnect in Wyandot County

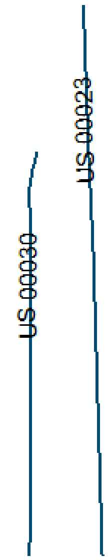

Figure 97. US-23 & US-30 disconnect in Wyandot County

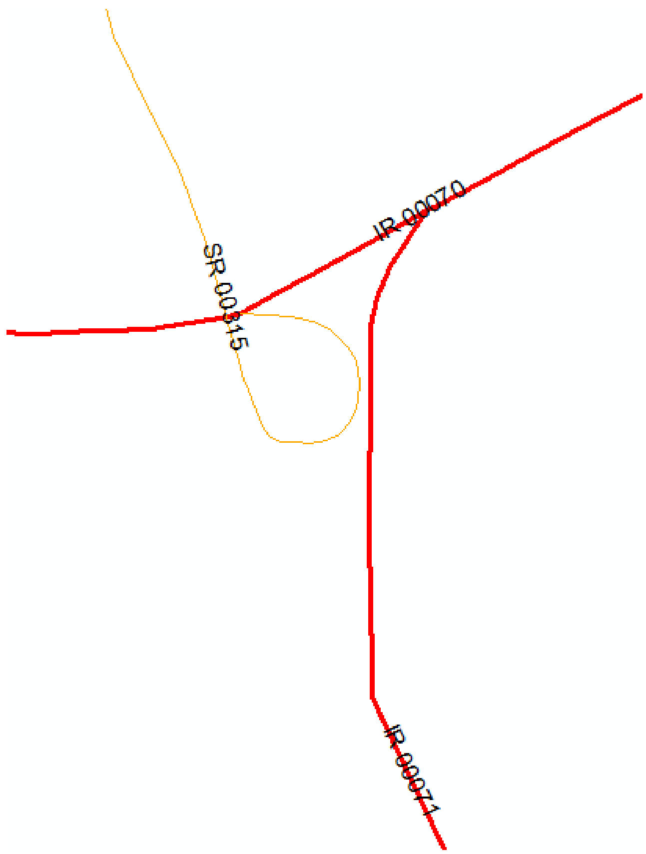

Figure 98. SR15 and IR71 disconnect in Franklin County

ArcMap Table of Contents Layer Issues

Every now and again, when ArcMap initializes at the completion of an analysis, the layers associated with the default template fail to display, as shown in Figure 99 by the red exclamation marks and the greyed out boxes. The work-around to this problem, which appears to be a form of a broken link, is to uncheck the check box, then check the check box. This will prompt the user to set the data source or repair the link, as shown in Figure 100. All the default template layers are located in the Display feature dataset in the OZProject geodatabase. Repairing one link seems to repair all broken links.

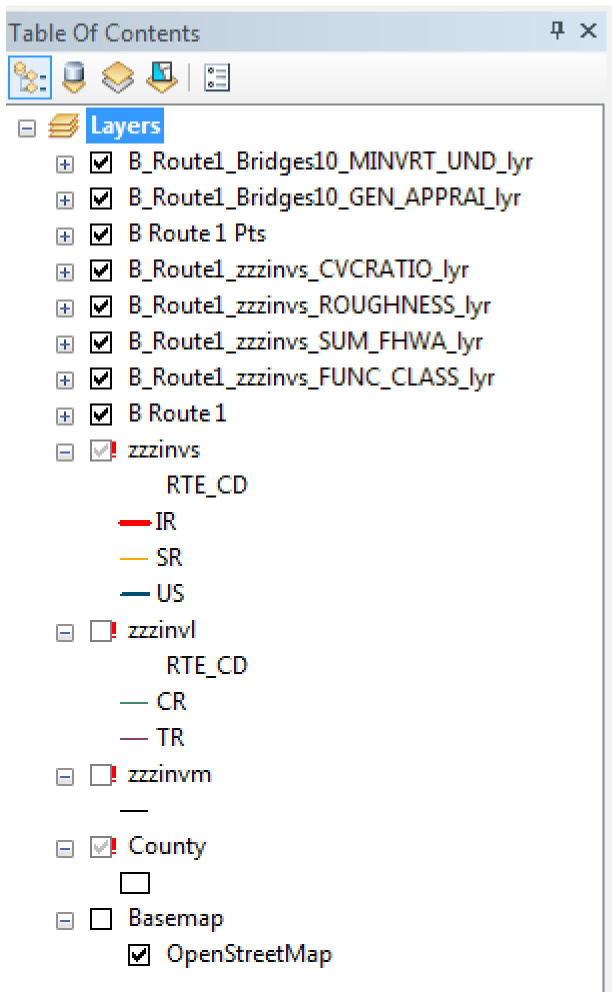

Figure 99. Template layers failing to load

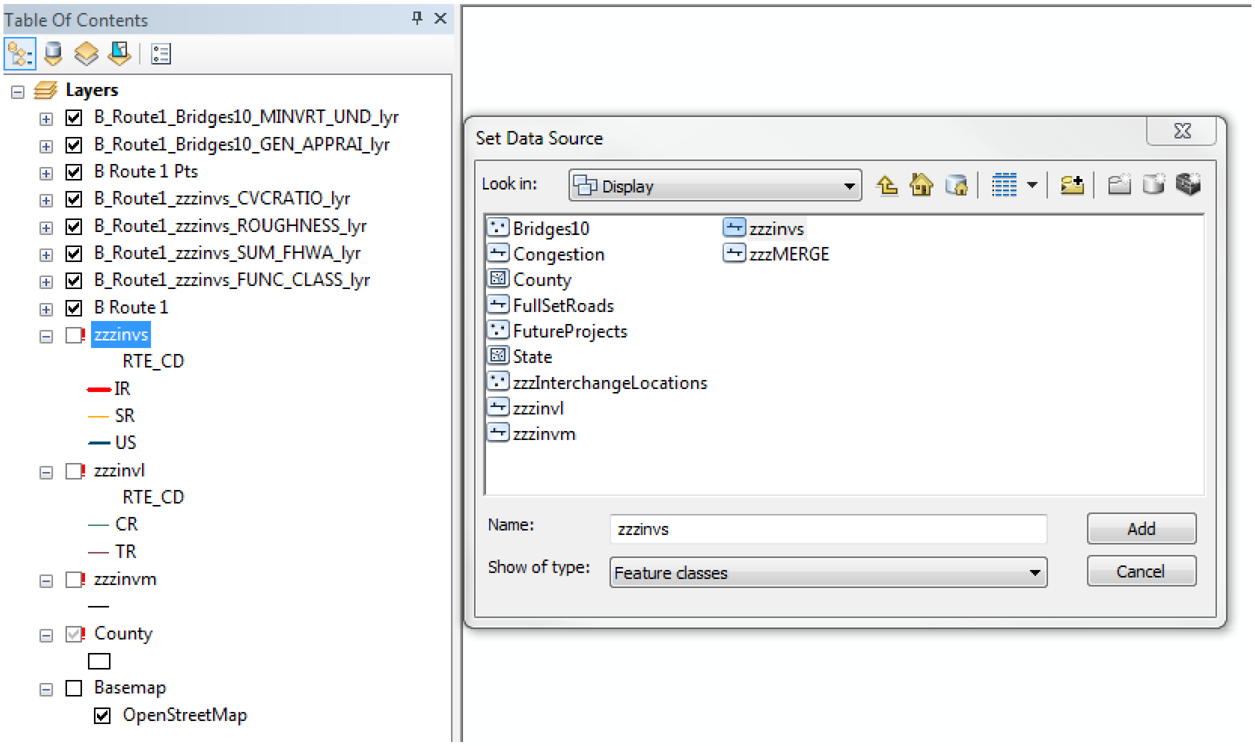

Figure 100. Set the layer data source