

Title: Network Geodatabase Design and Implementation

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I. Abstract

This technical presentation demonstrates design and implementation of a geodatabase for linear referencing, dynamic segmentation, and transportation network analysis. The object model offers an approach for implementing and maintaining a transportation database that supports dynamic segmentation, routing, and addressing. It covers the object model and design concepts using SDE, customization using ArcObjects in the .NET framework, and applications for ESRI's Network Analyst extension. The project demonstrates an application for modifying feature attributes, maintaining dynamic segmentation, and associating non-network features (e.g. parcels, address points, and bus stops) with a network. It also offers schema for constructing routes based on underlying feature segmentation.

II. Introduction

Adams County, Colorado is in the process of enhancing their geographic information system by implementing a transportation geodatabase. The data model was designed to provide an extendable repository of source data to support multiple user needs. In addition to management of transportation related assets, the database is conceptualized to meet several business objectives ranging from centralized address referencing, to voter information management, vehicle routing and emergency management. This paper presents a relatively simple but highly extensible data model for managing a linear referencing system as a source data repository. It provides a detailed look at the design concepts and components, the implementation framework and user interface, and the extensibility options for supporting linear referencing and network analysis.

The paper is organized into 3 parts:

- Part 1 provides a general discussion of the model design concepts, major components, and step required to build the database;
- Part 2 documents the Adams County Transportation Extension that contains utilities and tools developed to construct and administrate network databases.
- Part 3 expands on the data design by illustrating support for ESRI's linear referencing and network analyst components.

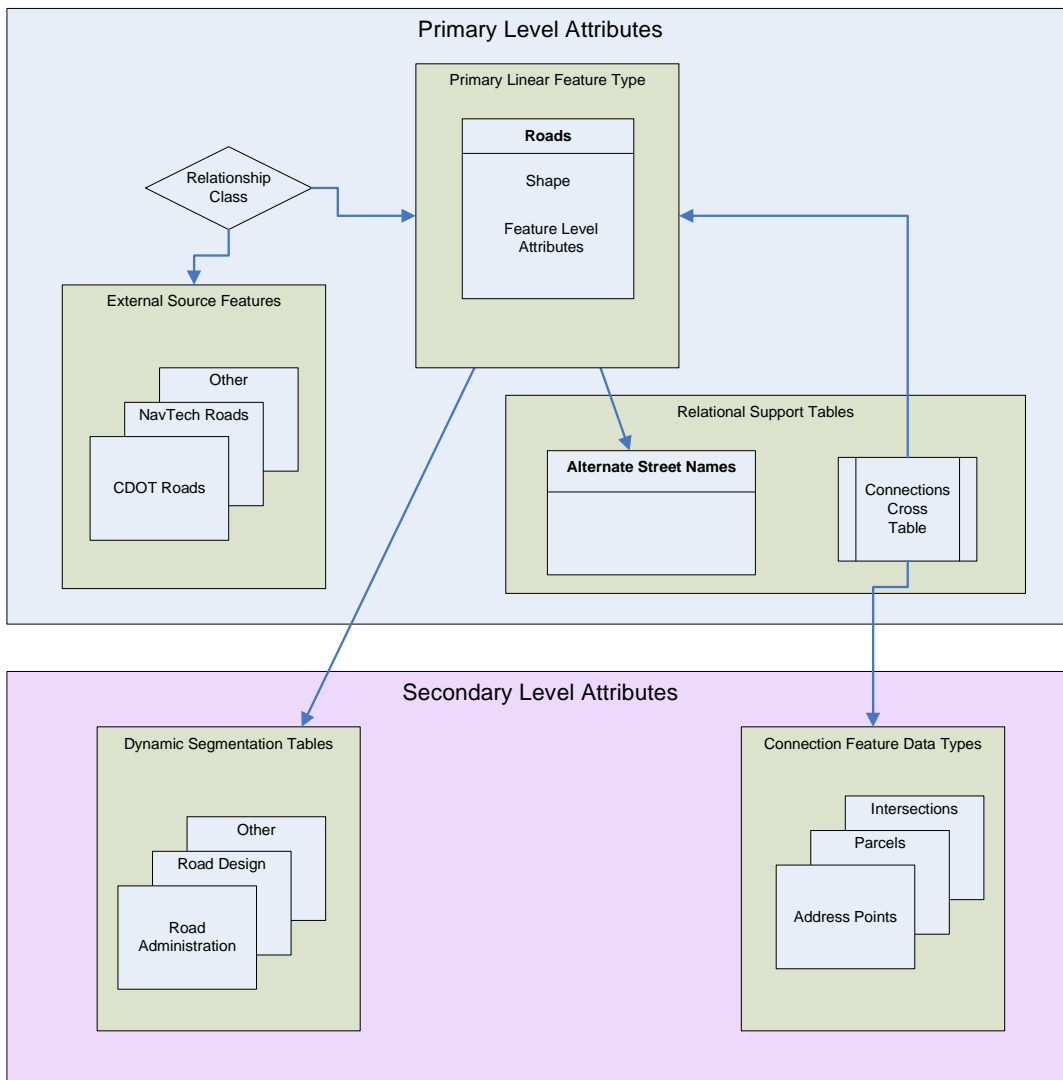
III. Part 1 – Object Model Design Concepts and Components

A. Design Objectives

The object model was developed based on the following design objectives:

1. The data will act as an extensible repository for transportation mapping, addressing, system integration, and validation.
2. Base level line work will be used to index, reference (name), and classify transportation features.
3. The network should support relationships to internal and external source datasets to assist with attribution and addressing.
4. The database should incorporate linear referencing and dynamic segmentation in order to enforce data normalization and topological integrity.

Exhibit 1 – Transportation Data Model Components



B. Primary Object Model Components

Exhibit 1 provides an overview of the data model components. One instance of these high level objects is used to define and attribute a single network feature type (e.g. roads). These model components are designed to create and manage attribution of linear network features. ESRI tools and utilities are used to capture the initial linear geometry of features.

Linear Attribution - Attribution of the primary linear feature type is achieved at two levels. *Primary level attributes* are used to describe line work at the feature level. Primary attributes are stored directly in the feature attribute table, as relational support tables, or external feature sources. Attributes at this level are used to describe the each feature in its entirety. *Secondary level attributes* are used to describe portions (segments) of a line, or specific locations (points) along a line. “Dynamic segmentation” tables and “Connection” tables are used to attribute “segments” and “points” along lines, respectively.

Primary Linear Feature Type - Polylines are used to represent the linear network feature type in the database. Each instance of the database relies on these polylines for indexing, referencing, and attributing at all levels. For this project, roads are the primary linear feature type represented. Additional transportation features such as trail or rail alignments would require new instances of the data model.

Linear reference system – At the primary attribute level, each linear (road) feature contains a start and end measurement based on a polylineM values in the shape field. These measurements are used to support linear referencing in the database.

External feature source data are feature datasets that reflect or extend attribution of the primary feature type. In this model, linear source data maintained by third party organizations is included for extending roadway attributes. Relationship tables allow external source data to be joined or cross referenced with primary features.

Dynamic segmentation tables reference portions (or segments) of the polyline features based on the established linear referencing system. These tables enable the database to manage attributes that do not coincide with the base feature topology. In other words, polylines do not need to be split to represent different attribution levels. ESRI’s linear referencing would describe these as “linear events” that occur along a portion of a polyline feature.

Connection feature tables are used to relate features and their attributes to specific locations along the (road) network without breaking underlying feature topology. ESRI’s linear referencing would describe these as “point event” tables.

C. Extended Object Model Components

ESRI has developed several objects and tools for linear referencing, dynamic segmentation, and network analysis. As part of the design criteria, this model supports several ESRI components. ¹ESRI defines a *route* as “a linear feature that stores a unique identifier and measurement system. This model provides a linear referencing system as the basis for creating routes with ArcMap.

¹ ArcGIS Desktop Help, ArcMap Release 9.1 Beta

Event tables are used to store route locations or references to locations along the network. This model uses connection features and dynamic segmentation tables to create point and line events, respectively. Network analysis is achieved by using ArcMaps topology rules to support network connectivity and primary and secondary level attribution to store network characteristics and related variables.

D. Database Model Implementation

Implementation of the data model requires programming at several levels in order to facilitate maintenance and visualization of relational tables and ensure integrity of the linear referencing system. Administrative code was developed to control user access and identify potential data errors. Maintenance code was developed to ensure the integrity of linear referencing data, unique record identification, and relationships between features and tables. For practical purposes, Adams County developed a roadway network as a central part of addressing and transportation infrastructure management. Tasks for development of the database are identified below.

Task 1 - Define the primary network feature type, topology rules, and attributes

Roadway features are the primary polyline feature type supported by this instance of the database. For purposes of this implementation, roads break only at their intersections with other roads, at bridges or tunnels, County boundaries, or when the primary road name changes. Required primary feature attributes (See exhibit 2) include a unique identifier (Road_ID), start measurement (StartM), end measurement (EndM), and Length. These required fields are needed to support linear referencing of each feature. Other primary level attributes such as the “StreetName”, DisplayClass, and “LineClass” can be added as needed for descriptive purposes. All other feature attributes that do not support the topology definition are considered secondary level attributes because they do not reflect the entire feature.

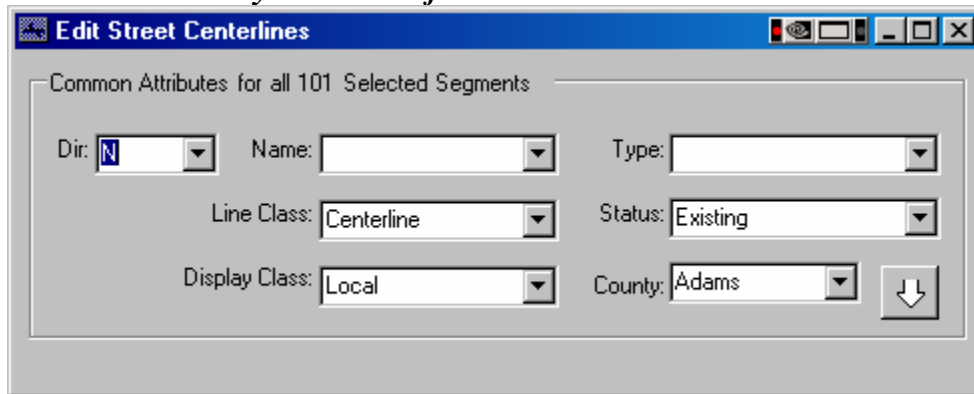
Exhibit 2 – Primary Feature Objects

ROAD	
	OBJECTID
I1	ROAD_ID LINECLASS LINECODE STREETDIR STREETNAME STREETTYPE COUNTY LIFECYCLESTATUS ROADSOURCE_ID STARTM ENDM LENGTH DISPLAYCLASS FULLSTREETNAME DIGITALANNOID USECLASS
U1	SHAPE

Task 2 - Identify primary feature attributes, sub-classes, and domains

Primary feature attributes used to identify, name and classify linear features are added to the database. In order to ensure data integrity several domains were incorporated to manage attribution. For example, standardized “line class” and “display class” domains were used to provide consistent object classification and mapping. Name domains for the street name, “Dir”, and “Type” were also used to enforce consistency. Domains and feature classifications are a convenient mechanism to simplify the data model, provide organizational consistency, and enforce data integrity.

Exhibit 3 – Primary Feature Objects



The screenshot shows a window titled "Edit Street Centerlines" with a standard Windows-style title bar. Below the title bar, there is a label "Common Attributes for all 101 Selected Segments". The main area of the window contains several dropdown menus for attribute selection:

- Dir: N
- Name: (empty)
- Type: (empty)
- Line Class: Centerline
- Status: Existing
- Display Class: Local
- County: Adams

There is also a button with a downward-pointing arrow on the right side of the attribute selection area.

Task 3 - Capture and attribute primary features

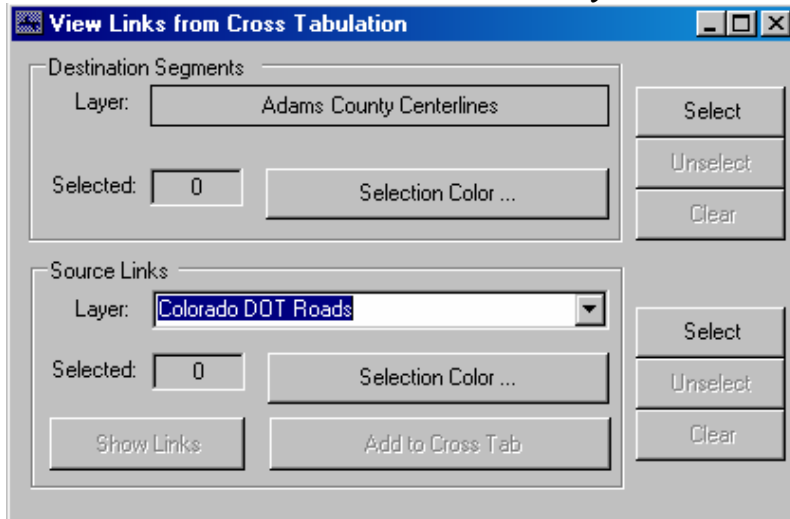
As the basis for linear referencing and secondary attribution tasks, primary features must be captured and appropriately attributed. An “Edit Street Centerlines” utility, depicted in Exhibit 3, was developed for this purpose. The utility allows a user to select one or many line features in order to assign names, display classes, and other important attributes. Behind the scenes, the utility makes sure that each of the required fields is appropriately populated to support linear referencing and secondary level attribution.

Task 4 - Identify external data resources and secondary level attributes

External data resources and secondary level attributes are used to extend the range of functionality of the network database. In this implementation, several utilities were developed to a) associate roads with external source features, b) “connect” source data features to locations along the road network, and c) segment or partition attributes along the path of a road.

a. External Source Feature support is provided via a “View Links from Cross Tabulation” (see Exhibit 4) utility, which relates road “destination” features and external “source” features. The utility allows a road to reference primary level attributes from another source feature dataset. In this model, Colorado Department of Transportation road and highway source data is linked to the road layer in order to cross reference State route names and other related attributes.

Exhibit 4 – External Data Source Link Utility



b. Connection features are used to associate point, line, or polygon feature layers, such as parcels or bus stops, to specific locations along the network. Any connected feature knows its location along the network and therefore can reference its relationship to other “connected” features. In the database parcels are connected to roads so that their address can be calibrated to with network address ranges. Bus stops might also be used to enable the roads to interact with bus routes at specific locations. The Maintain Street Connections utility (see Exhibit 5) was developed to facilitate maintenance of network connections.

Exhibit 5 – Maintain Street Connections Utility

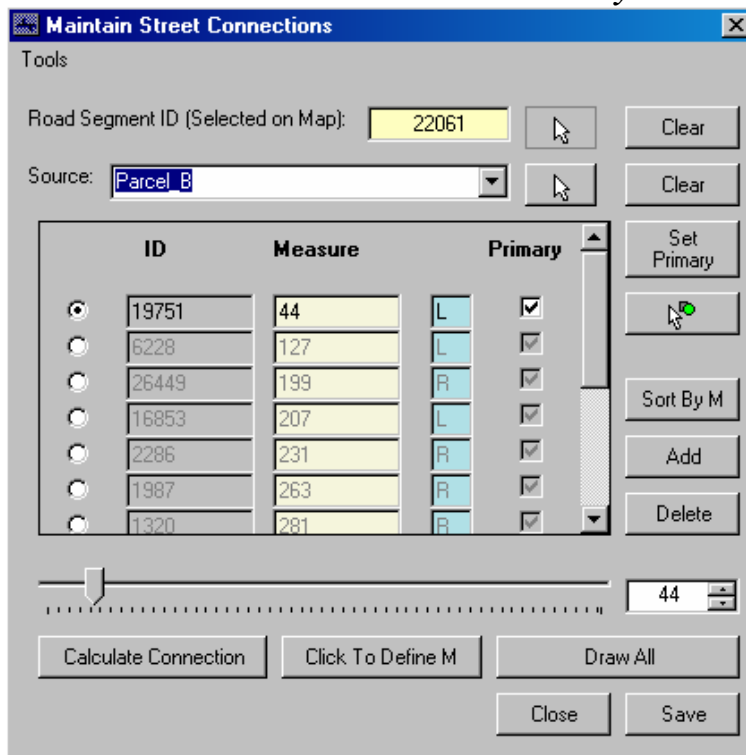
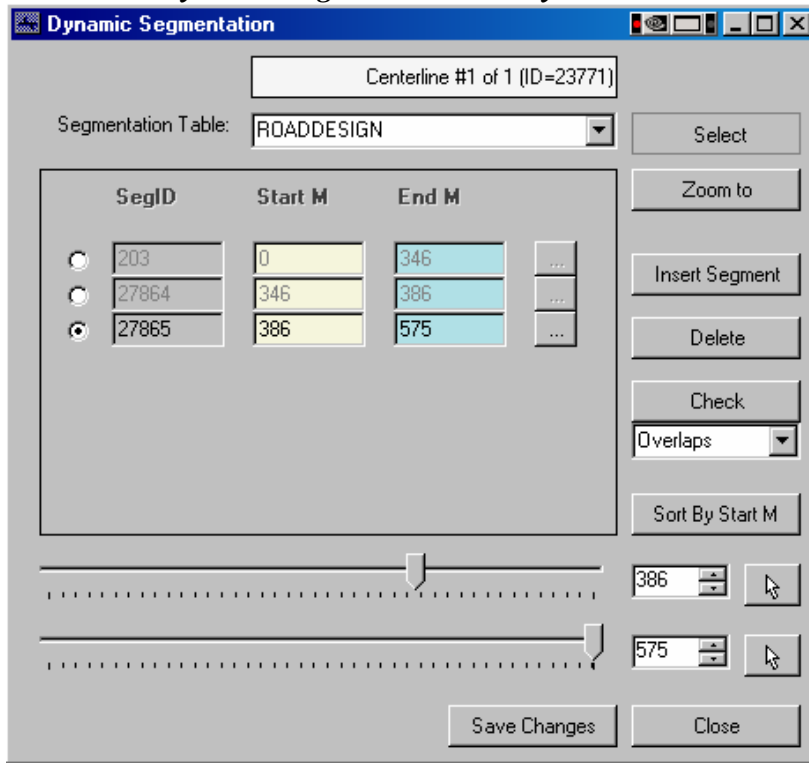


Exhibit 6 – Dynamic Segmentation Utility



c. Dynamic Segmentation tables, used to attribute linear portions of each road, are maintained using the Dynamic Segmentation Utility in Exhibit 6. This utility allows a user to visualize and attribute portions of a line. In this model, a Road Design (Exhibit 7) object holds attributes describing the functional design of each road feature. Road design attributes are dynamically assigned to roadway features without compromising feature topology.

Exhibit 7 - Road Design Database Object

ROADDESIGN	
	OBJECTID
FK1,1	ROAD_ID SURFACE_TYPE FUNCTIONAL_CLASS CDOT_ROUTE LANES STARTM ENDM

Tack 5 - Relate and extend data with secondary level attributes

Utilities described above are used to related and develop secondary level attributes. The key concept with using relational attribution is to simplify feature topology rules, normalize the database, and develop a network that can be adapted and expanded over time. In this data model,

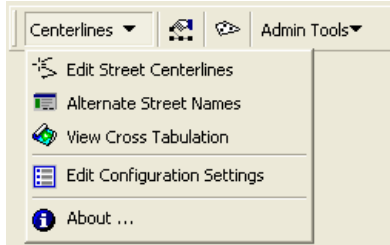
parcel “connections” was developed to assist with addressing and naming of roads. A Road Admin table was used to assign roads segments to specific jurisdictions. And a Road Design table was used to track functional characteristics of the road. The database maintenance utilities allow the model to manage an unlimited number of connection feature datasets and dynamic segmentation tables.

Task 6 – Network Database Implementation

Once the data model has been conceptualized and constructed to meet objectives, it is ready for linear referencing and network analysis functions. Assuming the data was developed using the Adams County Transportation Maintenance Utility, database objects are correctly related to support linear referencing and network analysis.

IV. Part 2 – Adam County Transportation Application

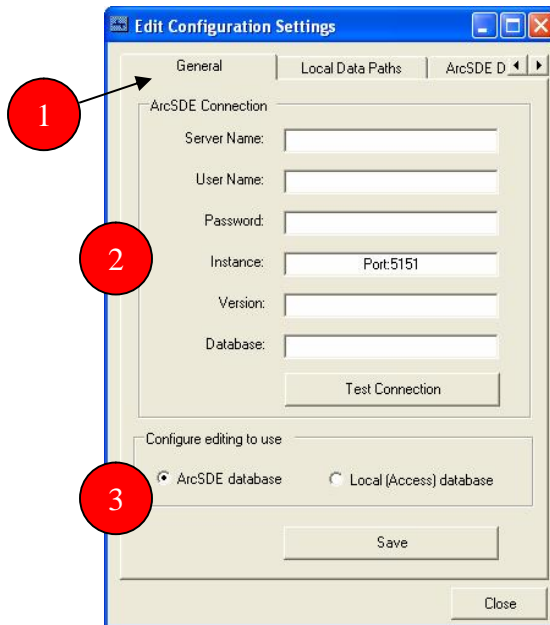
The Adams county Transportation Application was constructed with ArcObjects using Visual Studio .NET. Currently, it is designed to attribute road network databases. It was designed to work with SDE for Oracle or a personal geo-database. Once the application has been installed on a computer that is running ArcGIS 9.x, the extension will be available. The application is added to ArcMap as an extension. It provides a new toolbar item in the workspace. Several components contained in the application are described below.



Edit Configuration Settings

The first option that must be completed to use this tool is the configuration of the data that will be used. To set the option, select the Edit Configuration Settings menu item from the Centerlines main menu.

General Tab:



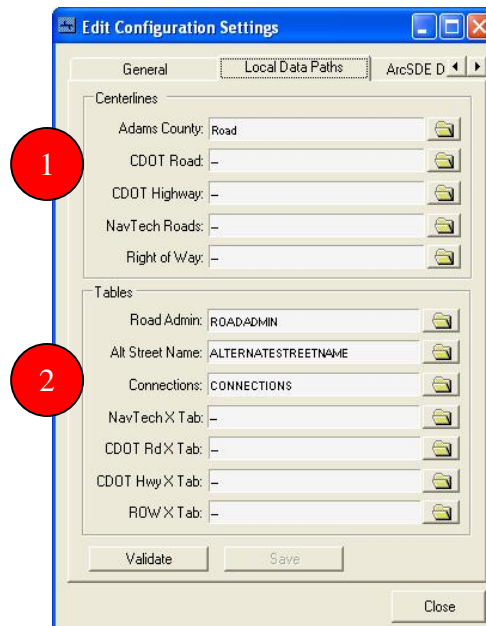
1. The Configuration tabbed pages: Using this tabbed approach, you may get to each of the pages of configuration: General, Local Data Paths, ArcSDE Data Paths, Dynamic

Segmentation, Connection Datasets and Admin. Clicking on the left and right arrows scrolls the tabbed dialog box.

2. ArcSDE Connection: This section contains information needed to make a connection to ArcSDE. The parameters needed are: Server Name, User Name, Password, Instance (generally Port:5151), Version (version of the database you will edit from) and Database. After entering all of the proper data, clicking on the Test Connection button will connect to the ArcSDE database and confirm proper database settings.
3. Configure Editing to Use: When using this application, you can use either a Personal Geodatabase (Local Access database) or a global ArcSDE database. This section will set what option you want to use for database configuration.

If any options change on this dialog box, the Save button will be available for you to save the options to a local configuration database, which is configured for all users of that machine.

Local Data Paths:



1. Centerlines: This section contains the data and paths to feature data sets that are used in this application. The centerlines used are: Adams County (the road line work for the county), CDOT Road (the road line work for Colorado Department of Transportation), CDOT Highway (the road line work for Colorado Department of Transportation), NavTech Roads and Right of Way. Requirements for the Adams County centerline feature data set include Road_ID, StartM and EndM. The Road_ID field is a numeric data type that is initially set to -1 and will be initialized to a unique value when a common attribute of the line is edited.
2. Tables: This section contains the data and paths that are needed for supplemental tools and attributes. The Road Admin table is the primary dynamic segmentation table used for the Adams County road feature class. Alt Street Name is the table that contains alternate names for a given Adams County road and is linked by the Road_ID field. The Connections Table is defined as a table that links roads with other feature classes. This

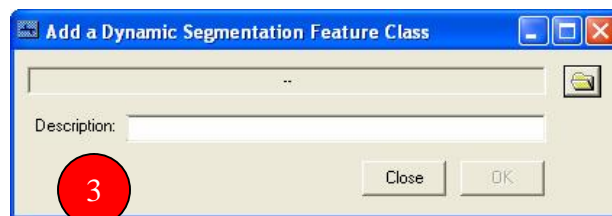
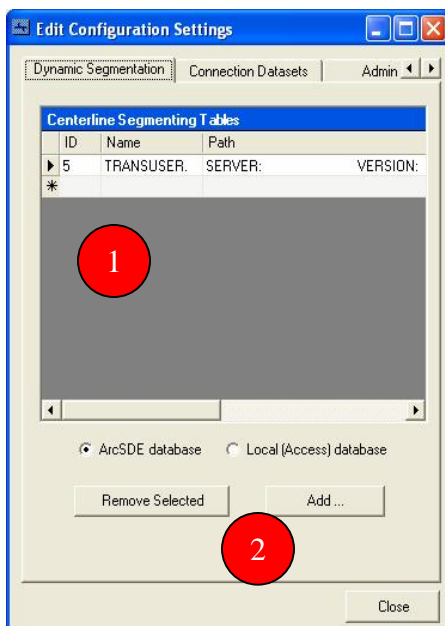
table contains a DatasetID field that defines what the source feature class that will be connected comes from. A ConnectID field contains the object that is being connected unique ID. A Measure field that contains the point along the line where the object is being connected to, from the start of the line. A Side field that has a domain and represents the side of the line the object is connected to. An IsPrimary field is available for objects that are connected to multiple lines. This field determines which of the many connections an object may have is the primary connection for that object. Also, the Road_ID field is included as the ID of the road this object is connecting to. Each of the four X Tab data fields, stands for cross tab, are the corresponding Relationship Classes to the above linear Feature Classes.

The Validate button checks to make sure all of the entered data fields come from the same Personal Geodatabase. If any of the above parameters changes from the initial form open, the Save button will be enabled to save the data to the local configuration database.

ArcSDE Datapaths

This tabbed dialog box is just like the Local Data Paths form except that the data should be connecting to an ArcSDE geodatabase.

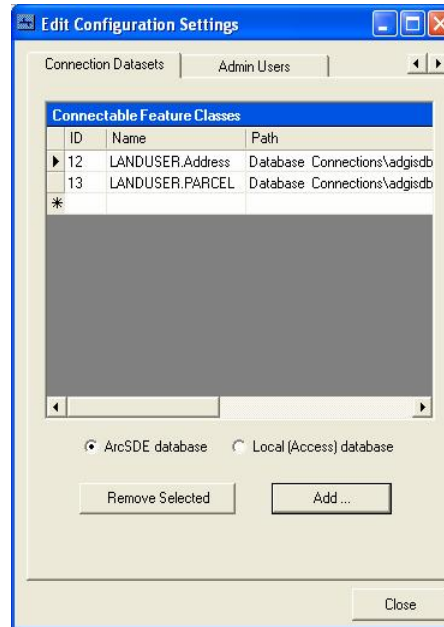
Dynamic Segmentation:



1. This configuration tab is for defining the Dynamic Segmentation tables for the main road centerline feature dataset. The implementation of the application requires there to be a RoadAdmin table. Any number of dynamic segmentation tables can be added from this dialog box.
2. This is the location where you can select from what data source the above data is coming from, ArcSDE or personal geodatabase. You can also remove a dynamic segmentation table from the list of available tables and add a new table.

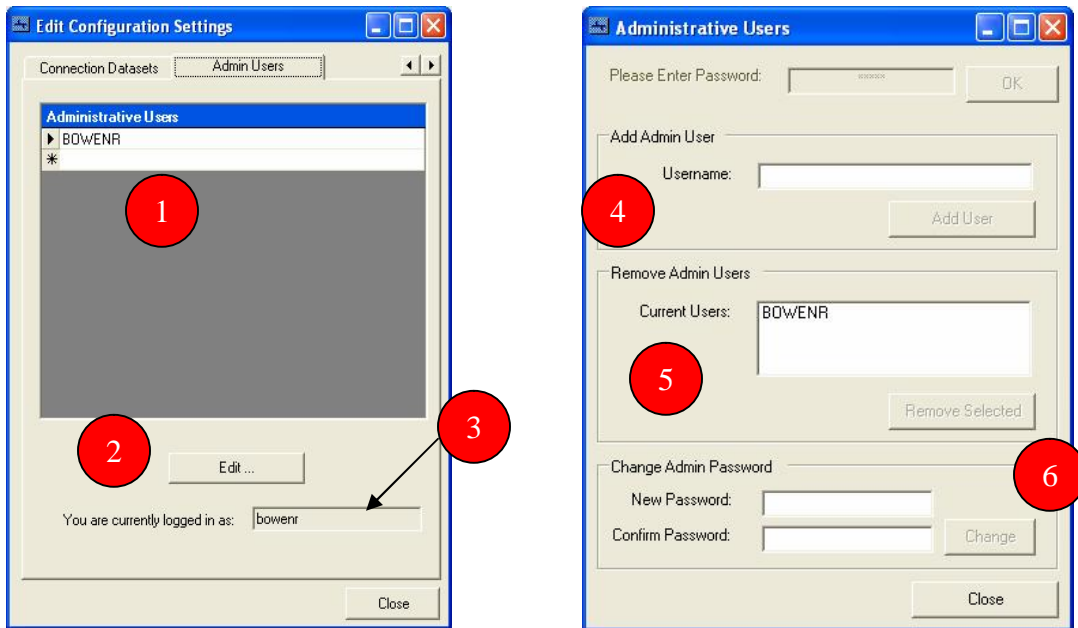
3. The Add a Dynamic Segmentation Feature Class allows you to select a table that will act as a dynamic segmentation table. Select the table you want to use by clicking on the folder button and enter a description for the data. Each added table must have a Road_ID field, a StartM field and an EndM field.

Connection Datasets:



Like the Dynamic Segmentation dialog box, the connection Datasets dialog box configures data that will be used by the application. Connection datasets are point, line or polygon feature data sets that may be “connected” to a line feature type, i.e. the Road feature class. Data source is configured by selecting the ArcSDE or Local database option. Connection data sets may be deleted by clicking on the Remove Selected button. Click on the Add button to add new data sets to the application. One requirement for all data sets that are to be used for connections is to have a field named ConnectID that contain unique values for each record.

Admin Users:



1. The Admin Users dialog box lists the users that have been entered into the system that are allowed to use the administrative tools of the system. This list shows who has been entered has Administrative Users.
2. The Edit button will require a password to bring up the Administrative Users dialog box, explained below. If the password is not entered or incorrect, the dialog box will not appear.
3. This area shows who is currently logged into the Windows operating system and who is using this application. This is informational so that it is easier to determine if this person needs to be added to Administrative users.
4. This is where you can add Admin Users to the system. Just enter the username, usually the NT username used by the operating system, and click on the Add User button. This will add the name to the list below.
5. This shows a list of current administrative users for the system. If someone needs to be removed, select them in the list box and click the Remove Selected box.
6. This is where the Admin Password can be changed. Enter the new password twice and click the Change button to save that new password into the system.

Edit Street Centerlines

This tool is used to edit the common attributes of a linear feature class, in this case, the Roads data layer. This form is currently statically linked to the attribute fields that are contained in the Roads feature class.

The screenshot shows the 'Edit Street Centerlines' dialog box with the title bar 'Edit Street Centerlines'. The main area is titled 'Common Attributes for all 0 Selected Segments'. It contains several dropdown menus: 'Dir:' (empty), 'Name:' (empty), 'Type:' (empty), 'Line Class:' (empty), 'Status:' (empty), 'Display Class:' (empty), and 'County:' (empty). A red circle with the number '1' points to the title bar area. A red circle with the number '2' points to the 'Line Class' dropdown. A red circle with the number '3' points to a small icon in the bottom right corner of the dialog box.

1. This area displays how many segments you have selected from the Roads feature class. Changing any of the attributes will affect all of the selected features. If all of the attributes are the same for all of the selected segments, their values will be displayed in each of the drop down boxes. If a value is not the same for all of the selected segments or the value is null, no data will be displayed in the drop down box.
2. This area displays the common attributes available for editing. These attributes are all domained values and data can not be entered that is not within the domain. The Dir, Name and Type fields define the direction, street name and street type of the Road feature class. The Line Class field defines what type of road the line represents, i.e. centerline or ramp. The Status field represents the life cycle status of the road, i.e. existing, proposed or abandoned. Display Class defines how the road will be displayed for mapping purposes. The County fields displays what county the road segments lie within.
3. This box is used as a save data event and to open additional attributes for the selected segments. If any of the attributes have changed, a message box will be displayed to ask to save the changes. If you select no, the data reverts to the original values and the additional attributes will be displayed.

The screenshot shows the 'Edit Street Centerlines' dialog box with the title bar 'Edit Street Centerlines'. The main area is titled 'Common Attributes for all 1 Selected Segments'. It contains several dropdown menus: 'Dir:' (None), 'Name:' (Imboden Mi), 'Type:' (Road), 'Line Class:' (Centerline), 'Status:' (Existing), 'Display Class:' (Major), and 'County:' (Adams). A red circle with the number '4' points to the 'City' dropdown menu. Below the main area, there are two columns: 'Left' and 'Right'. The 'Left' column has 'City:' (Adams County) and 'ZIP:' (80642). The 'Right' column has a checked checkbox 'Same as Left' and 'City:' (Adams County) and 'ZIP:' (80642). At the bottom, there are two buttons: 'Update All' and 'Cancel'.

- The lower part of the Edit Street Centerlines dialog box allows editing of the RoadAdmin dynamic segmentation table. The City and Zip fields, based on left and right values, comprise this table. If the left side values are the same as the right, checking the Same as Left box allows you to only have to enter values on the Left side and the get copied to the right. The Update All button will save attributes to the Road table and values to the RoadAdmin dynamic segmentation table.

Alternate Street Names

This tool is used to assign alternate street names to road feature classes and to also display alternate street names for those roads.

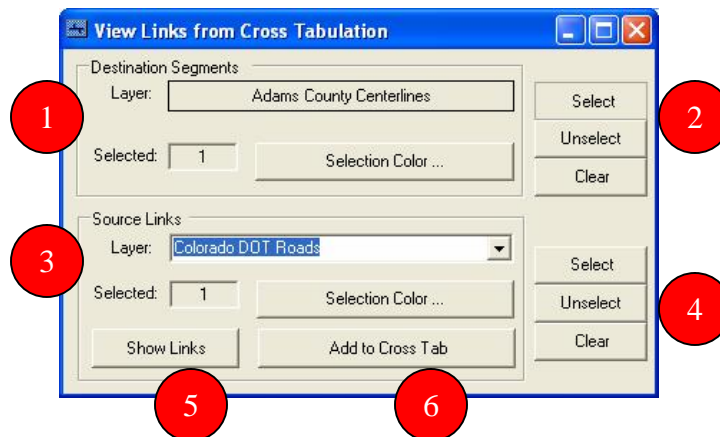


- The Primary Street Name field acts in 2 different facets: one, it will display the primary names of all selected streets or two, displays all primary streets of the Road feature class if no road features are selected. In either case, the available alternate street names for the selected road are displayed below.
- This displays the alternate street names for the selected street in the above drop down box. If the list is comprised of all of the street names, the alternate street name listing is a read only box and edits can not be made. Otherwise, selecting a row in this list will allow editing of the record in the fields below.
- This list of boxes allows for the editing or addition of alternate street names for the given selected road feature. Each box corresponds to the above list values: Dir (direction), Name, Type, Count and No Label. Each box can derive its' value from the associated domain or a value can be typed it. This allows for common misspellings of streets to be associated with the actual street name. The Count field is used as a placeholder for the order of alternate names. A value of one indicates that the record is the primary alternate street name and subsequent numbers indicate their placement. A check in the No Label field indicates that this record should never be used in labeling of the feature.
- This area contains the actions available on this from. If editing alternate street names, all of these options are available. If you are only viewing alternate street names, only the Close button is available. The Make Primary button will exchange the currently selected name in the alternate street name listing with the primary name in the Road feature class. This will only be allowed if the street name is present in the domain list for street names.

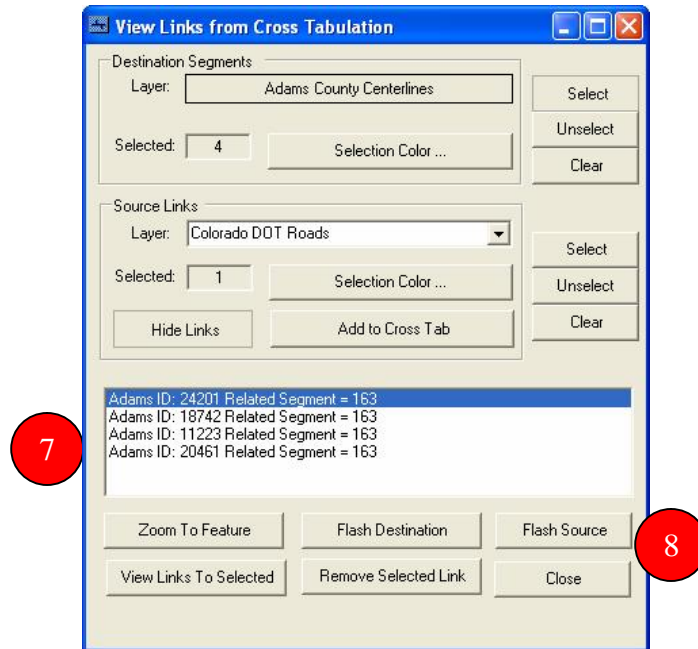
This prevents adding bad street names to the Road feature class. The primary name that was in the Road feature class will be subsequently copied to an alternate street name record. The Delete button will remove the currently selected alternate street name for the list. The Add button will add the record that is being edited to the list of alternate street names. The Save button will save all records to the Alternate Street Name table.

View Cross Tabulation

This tool is used to make relationship links between the Road feature data set and other external data sets.



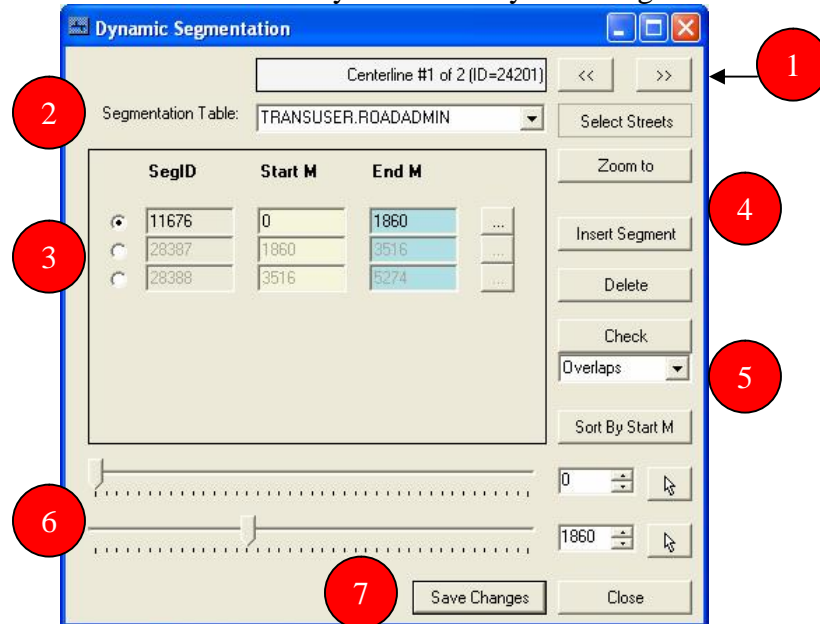
1. The Destination Segments section only refers to the Road feature data set. It displays how many features are selected. It also allows you to select a color for the display when the feature or features are selected.
2. This group of buttons allows you to either select road features, adding them to the current selected set, unselect from the current selected set or to clear all of the selected road features.
3. The Source Links section allows you to select which feature data set you want to link road features to. It displays how many features are selected from the source layer. It also allows you to select a color for the display when the feature or features are selected.
4. This group of buttons allows you to either select features from the source feature layer, adding them to the current selected set, unselect from the current selected set or to clear all of the selected features.
5. This button will expand the dialog box to show the links between the two data features and additional linking tools.
6. This button will create connections to the table between the selected features of the two layers.



7. This list box displays the links between the selected features. This can be a many to many type of relationship, as defined by the relationship class.
8. This set of buttons contains tools to help manage and display the associated links. They become enabled once a segment above is selected. The *Zoom To Features* will zoom to the selected link. The *Flash Destination* button flashes the selected Road feature on the map. The *Flash Source* button flashes the selected Source Link from above on the map. The *View Links to Selected* button displays the entire Road segment IDs that the currently selected Source feature is connected to. The *Remove Selected Link* button removes the selected link from the cross tabulation table. The *Close* button closes the dialog box.

Dynamic Segmentation

This form is the main way to edit the dynamic segmentation tables.



1. This area is used to navigate through the selected road features. It will display the number of features selected and you can navigate through them using the << and >> buttons. Each selected segment will highlight on the map.
2. This drop down box allows you to pick which dynamic segmentation table you want to use for this form.
3. This area lists the dynamic segments for the selected line feature from above. It lists the unique Segment ID and the Start Measure and End Measure of each segment. The ... button to the right of each segment will allow you to edit each of the segments individual attributes. Each segment will have its' own individual attributes.
4. These sets of buttons add tools to interact with the form. The Select Streets button will let you add features to the selected set. If you click on it, you can remove or unselect road features from the selected set. The Zoom to button will zoom the map to the selected Road features. The Insert Segment button will add a new dynamic segment below the currently selected segment on the left. A negative SegID will indicate that the record has not been saved to the database. The Delete button will delete the currently selected dynamic segment.
5. The Check button is a system integrity check. It works in conjunction with the drop down box below it. It will check for Overlaps or Gaps in the segmentation table for the selected Road. The Sort By Start M button will sort the segments is ascending order by their Start measure.
6. This is a graphical representation of the selected Road feature and its' segmentations. The top bar represents the Start M value while the bottom bar represents the End M value of the currently selected dynamic segment. You can slide either bar to change either value. This will affect the adjacent line segments to adjust themselves with the change in the measurement value. The number boxes to the right of each slider is the numerical

representation along the selected Road feature of the start and end measures. You can type a new value within each or use the up or down arrows to change their values. The points to the right of each slider allow you to click on the map to place either the start or end measure of the dynamic segment.

7. The Save Changes button will save all of the edits made on this form to the selected dynamic segmentation table. The Close button will close the form.

The Edit Segment Attributes, described in number three above, allows you to edit the dynamic segment attributes for the selected segmentation table. Some fields can and may have a domain.

Street Connections

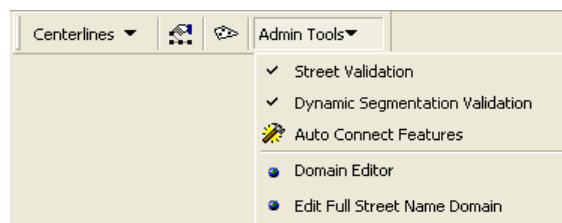
This tool maintains connections from any feature data type, i.e. point, line or polygon, to a selected Road segment.

ID	Measure	Primary
71594	79	L
17666	92	R
43814	173	L
46411	178	R
35729	253	L
34287	254	R
31851	332	R

1. From this area, you can select the Road segment that you want to attach other feature items to. You can select a road by clicking on the pointer to the right of the segment ID box. To clear the selected Road, click the Clear button. The Source drop down box displays a listing of Feature classes that you can connect to the Road. After selecting the Source, you can select the features of the source by clicking the pointer box to the right of the Source field. To clear the selected features from that source, click the Clear button.
2. This area displays the features that are connected to the selected Road and where they connect. Also, the side of the connection, either Left, Right or Both, and whether the connection is the Primary connection for the feature or not.
3. The tools for the dialog box are on the right side. The Set Primary button will make the currently selected connection the Primary connection for that feature. If that feature has other connections, their Primary flag will be set to false. The next button will allow you to select a feature from the Source and show all of the connection for that single feature. The Sort By M button will sort all of the connections listed by their Measure value in ascending order. The Add button will let you add the currently selected feature or features to the selected Road. The Delete button will allow you to delete the currently selected connection.
4. The scale bar below the connections list will allow you to change the connection point for the active connection feature. You can either move the slider bar, type in the value in to the right of the scale bar or use the up and down arrows of the numeric value connections. The Calculate Connection button will perform the automatic calculation of the connection point or points of the selected Source features to the selected Road feature. The Click to Define M button will allow you to click on the map and choose the connection point for the currently selected connection. The Draw All button will display all of the connections and the connection points to the currently selected Road feature.
5. This picture shows a selected Road feature with its' selected Address Points. It also displays the connection point for one of the connections.

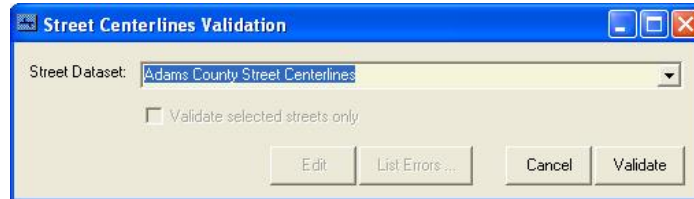
Admin Tools

This is a set of tools that are only allows for users that are set up with Administrative rights to the applications. These toolbar items will not be available to any user that does not have these rights.



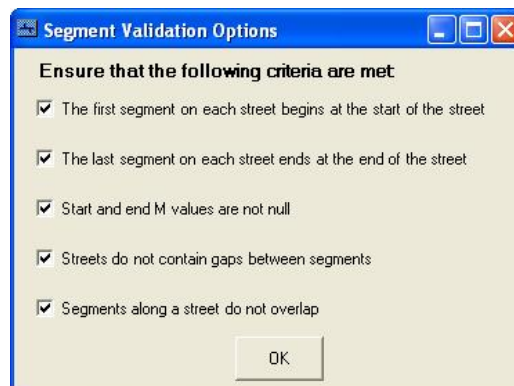
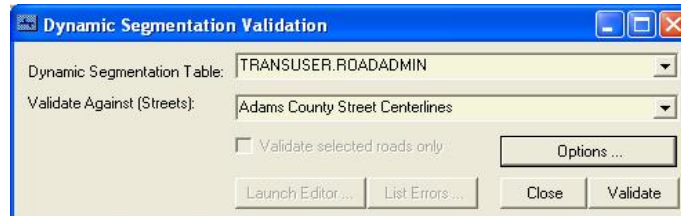
Street Validation

This tool allows you to do some data integrity checks with the Road Feature Class. Some of the tests include checking of the Start M and End M values to make sure they correspond with the actual length of the feature. It also checks to make sure the full street name is in synchronization with the parts that comprise the full street name.



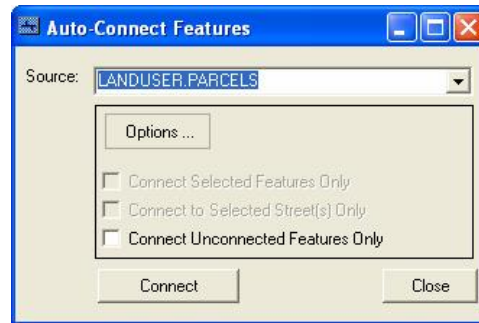
Dynamic Segmentation Validation

This tool performs multiple data integrity checks with particular Dynamic Segmentation tables.



Auto-Connect Features

This tool allows the administrator to automatically create connections from one Source Feature Class to the Roads data feature class. There are multiple options available.



Edit Domain

This tool allows you to edit the Domains and their values from the currently selected database.



Edit Full Street Name

This tool is designed to edit the list of full street names. It will allow you to join the Direction, Name and Type into one record that comprises the full street name.

The screenshot shows a software window titled "Full Streetname Domain Editor". At the top, there are three dropdown menus labeled "Dir:", "Name:", and "Type:". Below each dropdown is an "Edit" button. In the center, there is a button labeled "Add Full Streetname to Location Below". The main area of the window is a list box containing the following text:

- 104th to I-25
- 104th to E-470
- 105th Way
- 106th Way
- 120th to E-470
- 120th to I-25
- 136th to I-76
- 144th to I-76
- 152nd to I-76
- 1st Ave
- 1st St
- 224
- 225
- 25
- 270
- 2nd Ave
- 2nd St

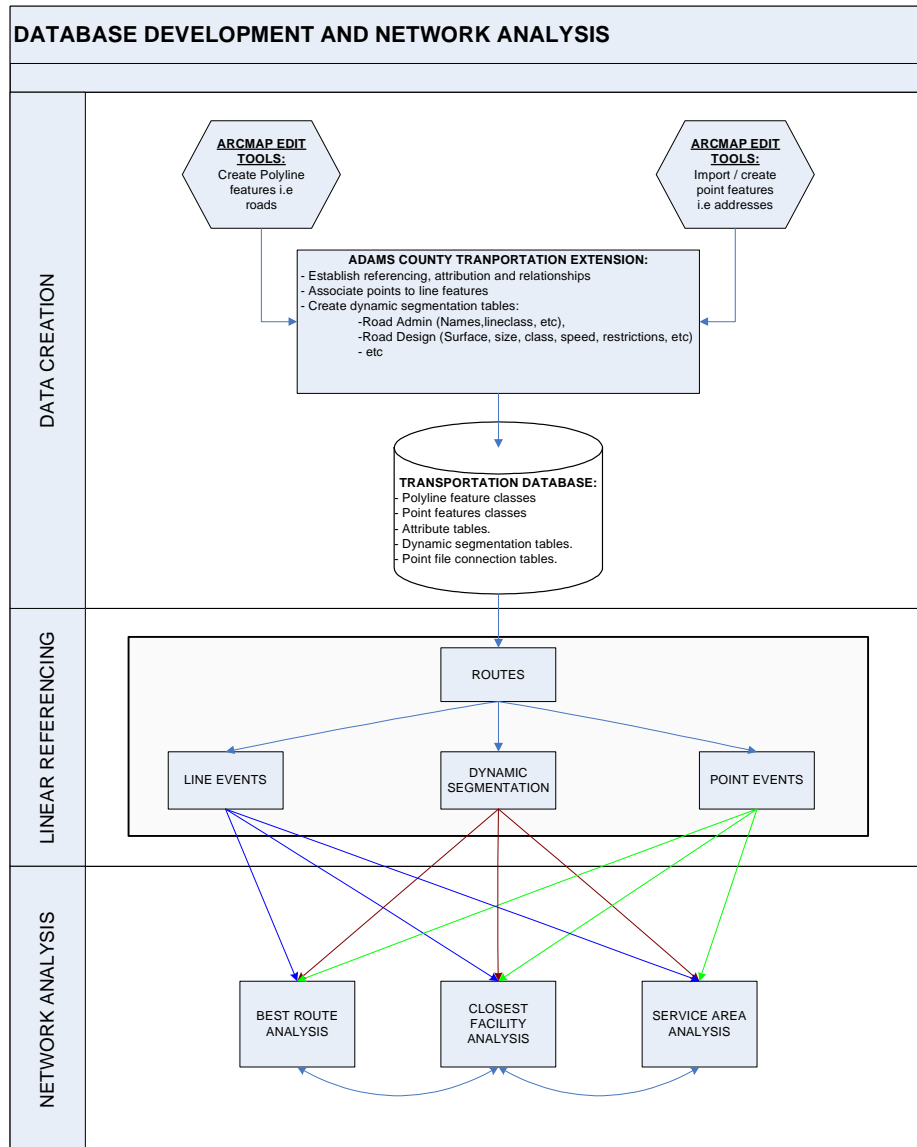
To the right of the list box are four navigation buttons: a "Delete" button at the top, followed by three arrow buttons (up, up, down, down). At the bottom of the window, there are three buttons: "Sort", "Save", and "Cancel".

V. Part 4 - Database Development and Network Analysis

A. Database Development and Analysis

Three steps broadly cover the implementation and use of the Adams County Transportation Database; Data creation, Linear Referencing and Network Analysis. The implementation utilizes the ArcInfo level of ArcGIS software and ArcSDE for the Geodatabase implementation. Lower levels of software or database implementations are possible but are not recommended. Data creation and analysis will focus on point and line data since they are the basis for most transportation networks. Polygon data will be used to generate point data and for location reference where necessary. A lot of references for this process are from ESRI's ArcGIS 9 Building a Geodatabase, Linear Referencing in ArcGIS and ArcGIS Network Analyst Tutorial. Exhibit 8 provides a visual guide to the following text

Exhibit 8



B. Data Creation

The Line feature dataset created from digitizing and import support the ability to hold measures or “M-values”. This option available only during the initial creation cannot be subsequently added to the feature class. M-values allow the feature class to store route measures by providing fields that store lengths of segments between vertices. Routes and measures serve as the basis for any linear referencing or network analysis and thus is a requirement for any “Transportation” dataset or Geodatabase.

Point data included in this dataset had no special requirements but was built with the same Spatial Reference as the line data for use in the same network. Attribution of these features was kept to a minimum providing only those attributes that support identification and display. Any more complexity nullifies the core idea of leaving geometry as generalized a possible while leaving complex attribution to the segmentation tables generated by the Adams County Database Extension.

Topology is established defining how the different line segments relate to each other. Rule such as “Must Not Self Intersect” enforce the integrity of the transportation database.

Once the feature classes have been completed the Adams County Database Extension is used to:

- Create Dynamic Segmentation Tables that hold the attribute data for more specific “segmenting” of the data. For example a “Road Admin” table was created that holds data like city, zip code, address range, etc for use in addressing and jurisdictional referencing of the road network. A “Road Design” table used for transportation modeling and surface administration using attributes like surface type, lanes, functional class, etc.
- Establish relationships between the segmentation tables and the underlying feature classes. Road features are linked to the Road Admin tables by ID for attributing, linear referencing and updates.
- Create and update attributes in the dynamic segmentation tables using relationships established between the tables and the feature class. Updates can be made to the Road Admin table specifying zip code and cities for each road segment.
- Connect point features to line features. In this example points generated from the centroid of parcels are connected to the line segments to which they are associated with either by a common name (street name) or proximity. This can then be used to provide a “true” street number range using the actual property address numbers. Several modeling possibilities exist for this connect feature.

The result of this Data Creation section is a comprehensive Geodatabase containing features, topology, relationships and several attribute tables specifying dynamic segmentation of the underlying data. The data model resulting is structured such that it can be extended easily to support ESRI’s extensive library of Linear Referencing and Network Analysis functions.

C. Linear Referencing

Linear referencing as described by ESRI is the ability to associate multiple sets of attributes to portions of linear features. The advantage of this is the ability to display or utilize your data in many different environments without the need to modify the underlying geometry. The Adams County Transportation Database supports the ESRI linear referencing model by providing the

ability to create Routes. ²A Route is any linear feature, such as a city street, highway, river, or pipe that has a unique identifier and a measurement system. Discrete locations along the route are defined as either Line Events using measure along the route or point events as locations along the route. The Adams County Transportation Database supports the point and line events using segmentation tables in the database created by using the Adams County Transportation Extension.

During the new route creation process using ESRI's tool the Route Identifier Field, Measure Source Field, From-Measure Field and To-Measure Field are options needed to build a new route. In fact, ArcInfo's linear referencing capabilities are necessary to visualize data contained in dynamic segmentation tables. The Road_ID, STARTM and ENDM fields in the Adams County Transportation model were created to support this function. The Edit Street Centerline utility described in Part 2 is used to construct the linear referencing system used to support ArcMap functionality.

D. Network Analysis

Network analysis in the ESRI model is broadly described as modeling one of three functions, best route analysis, closest facility analysis and service area analysis. Stops, Barriers, Network Attributes and the inherent connectivity of the network control how the network is traversed.

³Stops are locations between which a route is calculated in a route analysis. Barriers are locations where the analysis should not traverse. Network attributes are properties of the network elements that control traversability over the network.⁴Network connectivity defines how features that participate in a network connect to each other. Connectivity in an ESRI network dataset is based on geometric coincidences of line endpoints, line vertices, and points and applying connectivity rules that you set as properties of the network dataset.

Stops in the Adams County Transportation Database are represented by point events created with the "Connections" utility. Network Attributes, Restrictions and Barriers are represented as line events supported as part of the model and created with the "Dynamic Segmentation" utility. Network dataset building from the Adams County model involves using the primary linear feature type as source data to create the network. Primary and secondary level attributes are used to store and construct analysis variables for the network.

² ESRI Press – ArcGIS 9 Linear Referencing in ArcGIS

³ ArcGIS 9.1 Desktop Help

⁴ ESRI Press – ArcGIS 9.1 Network Analyst Tutorial

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