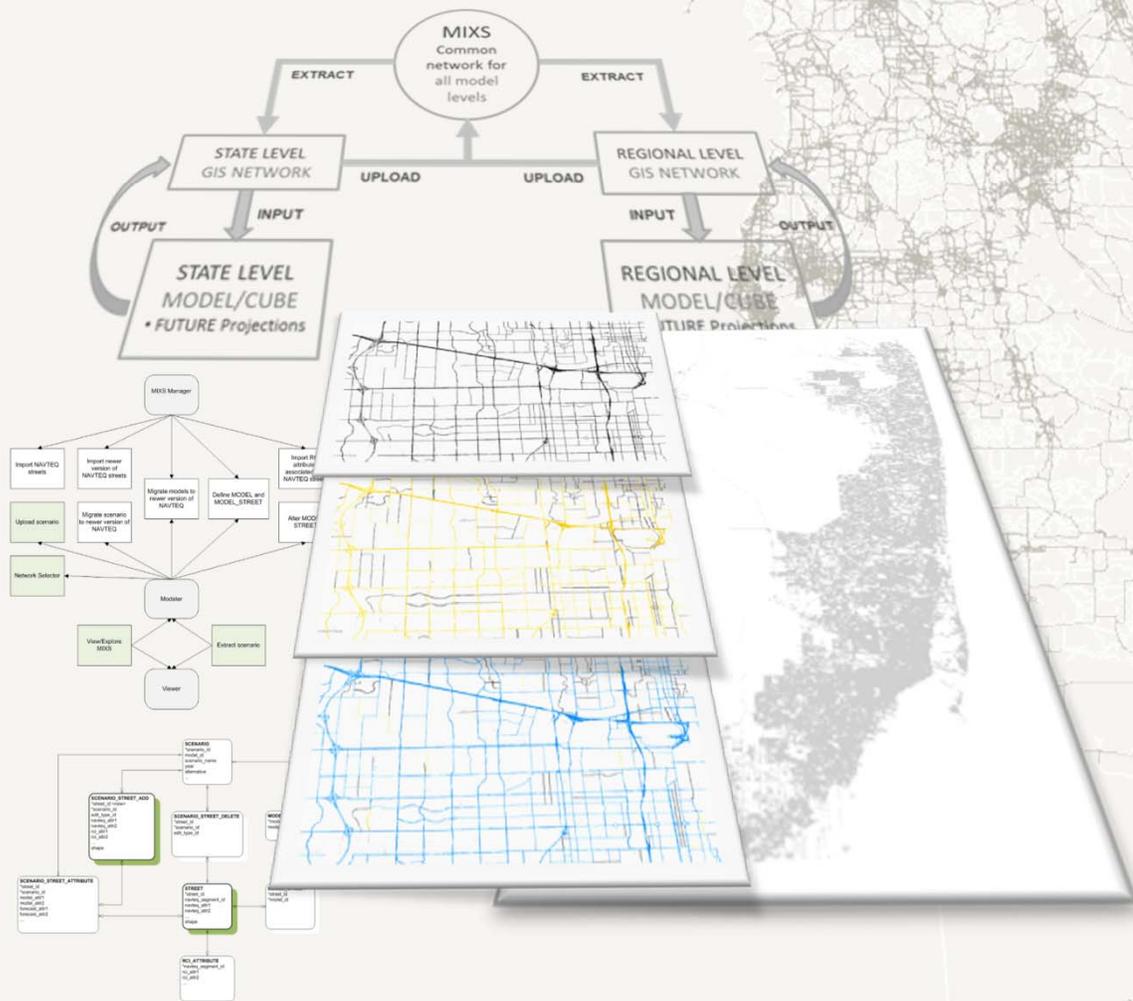




Model Information eXchange System (MIXS)



August 2013

Florida Department of Transportation
FDOT Contract BDK75 977-55

Model Information eXchange System (MIXS)

FINAL REPORT

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August 2013

DISCLAIMER

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the State of Florida Department of Transportation.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Model Information Exchange System (MIXS)		5. Report Date August 2013	
		6. Performing Organization Code	
7. Author(s) Ilir Bejleri, Yiqiang Ouyang, Zhong-Ren Peng		8. Performing Organization Report No.	
9. Performing Organization Name and Address University of Florida 418 Architecture Building Gainesville, FL 32611		10. Work Unit No. (TRAIS)	
		11. Contract or Grant No. BDK75 977-55	
12. Sponsoring Agency Name and Address Florida Department of Transportation 605 Suwannee Street, MS 30 Tallahassee, FL 32399		13. Type of Report and Period Covered Final Report May 2011 – Sept 2013	
		14. Sponsoring Agency Code	
15. Supplementary Notes			
16. Abstract <p>Many travel demand forecast models operate at state, regional, and local levels. While they share the same physical network in overlapping geographic areas, they use different and uncoordinated modeling networks. This creates difficulties for models to exchange common information and can result in data collection redundancies and difficulties in finding data errors or comparing future projections. This research investigated the issue of network information exchange among models and proposed a framework to accomplish the information exchange using a unified statewide Geographic Information Systems network approach. Named 'Model Information eXchange System' (MIXS), the proposed solution includes a geospatial relational data model that can support all participating models with their input variables and forecast scenarios; protocols to guide the exchange process; Web-based tools to visualize, compare, extract and upload models; and a process to handle network updates. Two tests, one with a small database and another with a full statewide model, confirmed the feasibility of the MIXS database and processes. Although participation in MIXS is not without challenges, most technical problems considered can be solved. Successful implementation of MIXS will require Department of Transportation leadership and support, participation and commitment of various regional and local modeling agencies, and a one-time conversion to the unified network for any model to participate in MIXS. MIXS will create an environment that promotes convergence, standardization and unification of data and potentially model assumptions, reduction of duplicate data collection efforts, reduction of errors, and ultimately will result in better and more consistent models throughout the state. A potential linkage of MIXS with a cloud-based modeling engine is recommended as one of the future items to explore during its practical implementation.</p>			
17. Key Word demand modeling, GIS, unified network, NAVTEQ, conflation, CUBE, information exchange, database framework, basemap, statewide		18. Distribution Statement No restrictions	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 118	22. Price

ACKNOWLEDGEMENTS

The authors would like to thank Vidya Mysore and Frank Tabatabaee of the Florida Department of Transportation (FDOT) Systems Planning Office for their leadership, guidance, and support for this research.

Thanks to many contributors to this research, including Mark Knoblauch, Eric Songer and other URS staff members, as well as Abishek Komma and other staff members of Citilabs.

Special thanks to Nellie Fernandez of Palm Beach County Metropolitan Planning Organization for her input, support, and enthusiasm and to Sung-Ryong Han of BBC Engineering for sharing information and being supportive of this research.

This research has benefited from the Florida Modeling Task Force members' engagement and approval during presentations of the research and especially from the Geographic Information Systems Committee for their constructive feedback, and support for this work.

The authors are grateful to the FDOT research office for providing the funding support to make this research possible.

EXECUTIVE SUMMARY

Transportation planning makes extensive use of travel demand forecast modeling to guide future planning of transportation needs. To this aim, Florida has many transportation models that operate at state, regional, and local levels. Many of these models cover overlapping geographic areas, and while these models “share the road” in these areas, they use different representations of that same physical roadway network. This is a problem because it creates difficulties in sharing common network attributes, such as speed, number of lanes, traffic volume, etc., makes it difficult to compare future projections across different models, creates major redundancies and duplications in data collection and processing and, most importantly, prevents successful coordination of agencies that rely on the same physical network, such as Metropolitan Planning Organizations, Department of Transportation, transit agencies, and toll operators.

This research investigated the issue of facilitating network information exchange among models and more specifically concentrated on two primary objectives: (a) identify solutions to the model information exchange problem, focusing on the network, and (b) assess the feasibility of the implementation of the proposed solution and provide recommendation for its practical implementation.

To address this issue, two options were explored: (a) keeping independent networks in place but developing associations among them in order to facilitate information exchange and (b) using one unified common network for all models. It was concluded that the second method is superior and more sustainable in the long run. One typical challenge for the second solution has traditionally been the lack of a single statewide GIS network, but Florida already has a unified GIS street network (NAVTEQ streets) for all roads which can support this solution. However, the availability of a unified network per se is not sufficient to enable information sharing (in fact this unified network has been available in Florida for a few years now, but all the models continue to use their own independent networks). To establish a successful information

exchange process, the research team developed a framework for a Model Information eXchange System, or MIXS.

MIXS's proposed framework includes a database model, an organizational structure, and tools to support the information exchange operations. The statewide unified network is stored in a geospatial relational database that includes all participating models and their input variables and forecast scenarios. The MIXS database will be centrally managed but in close coordination with each model owner that will have to contribute to model maintenance and updates. Web-based tools will be developed to assist users to visualize and compare models, extract out of the MIXS models/scenarios of interest to conduct modeling as usual, and upload forecasts back into MIXS.

The MIXS database model was validated by a small-scale manual test of expected operations that included population of the database, extraction of a model network out of MIXS, modifications of the network to simulate forecasted volume scenarios, and uploading of the forecasts back to MIXS. The testing concluded that the data model can support the proposed model information exchange system. A second test, which used a full-scale statewide model converted to the unified network, concluded that models that use the unified network can be successfully processed by a modeling package and the future forecasts can be returned back successfully on the same unified network. These tests demonstrated that the proposed MIXS database and processes are feasible.

However, successful implementation of MIXS will depend on several factors. They include commitment of Florida DOT to lead, develop internal collaboration among relevant departments, and provide the necessary resources to support MIXS. Additionally, it is important to gain modeling community buy-in and participation and commitments of model owners to follow the requirements and perform the tasks defined in the MIXS framework. From the technical point of view, a one-time conversion/conflation to the unified network will be required for any model to participate in MIXS. Although migration to MIXS is not without challenges, most technical problems considered can be solved.

If implemented, MIXS will create an environment that promotes convergence, standardization, and unification of data and potentially model assumptions, reduction of duplicate data collection efforts, reduction of errors and ultimately result in better and more consistent models throughout the state. By storing a unified network centrally, the MIXS framework also creates a natural opportunity to link to a cloud modeling engine which will release modelers/planners from many database management and software update tasks and redirect the gains to a greater emphasis on modeling improvements. Additionally, MIXS can also have broader implications for transportation planning and DOT information systems. MIXS can serve as a catalyst for a greater use of the unified network as a platform for Florida DOT data visualization under one reference system (unified network). At a minimum, this may include visualization of forecasted travel volume for future years for Strategic Intermodal System (SIS), National Highway System (NHS), State Highway System (SHS), and Florida Intrastate Highway System (FIHS) networks as well as the Florida DOT Work Program planned projects.

This research explored and confirmed the feasibility of MIXS. It provided a framework and a proof of concept. To implement MIXS in practice, several steps should be considered: (a) populate the MIXS database initially with two statewide models and one regional model; (b) populate the MIXS database with the future work program information relevant to forecast modeling starting with the 5-year adopted projects; (c) develop MIXS web-based tools – MIXS Explorer/Viewer, Extract, Upload and Versioning; (d) develop a user guide for beta testing; and (e) explore the feasibility of linking MIXS with a cloud computing engine such as Cube Cloud for model computation.

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List of Acronyms

AADT	Annual Average Daily Traffic
ArcGIS	ESRI Desktop GIS Software
DLGF	Digital Line Graph Format
D/T	Dynamap Transportation
DOT	Department of Transportation
ECS	ESEA's conflation system
ESRI	Environmental Systems Research Institute, Inc
FDOT	Florida Department of Transportation
FGDL	Florida Geographic Data Library
FIHS	Florida Intrastate Highway System
FSUTMS	Florida Standard Urban Transportation Model Structure
GIS	Geographic Information System
LRS	Linear Referencing System
MPO	Metropolitan Planning Organization
NERPM	Northeast Regional Planning Model
NHS	National Highway System
RCI	Roadway Characteristics Inventory
SERPM	Southeast Florida Regional Planning Model
SHS	State Highway System
SIS	Strategic Intermodal System
SWM	Statewide Model
TP+	TRANPLAN
TSM	Turnpike State Model
WPA	Work Program

Chapter 1: INTRODUCTION

Travel demand forecast modeling is conducted at different geographic scales – statewide, regional or multi county scale, and local scale, which typically covers a single county extent. Florida uses two statewide models, Turnpike State Model (TSM) and Statewide Model (SWM), several regional models such as Southeast Florida Regional Planning Model (SERPM), Northeast Florida Regional Planning Model (NERPM) and a few local models that operate at a county extent. Many of these models cover, partly or entirely, the same geographic area. The models that cover overlapping geographic areas “share the road” i.e. use the same roadways. For example, in the South Florida area, the TSM model (state level) overlaps greatly with the SERPM (regional level). This reality creates opportunities to share and/or exchange roadway characteristics, variables or attributes of common interest on the shared network links such as capacity, traffic volume, speed, facility type, area type, number of lanes, and road direction to mention a few. These opportunities for exchange by sharing the road network can provide many benefits, such as reduced need for data processing by eliminating duplicate efforts, ability to easily compare travel demand generated by different models on the same GIS planning network, and ability to much more easily find potential errors and discrepancies on the shared links. Most importantly the use of shared information and exchange can facilitate coordination of agencies that rely on the same network – MPO, FDOT, transit agencies, and toll operators. More broadly, a shared information exchange can bring together additional information on shared links, such as the Work Program (WPA) planned projects, which should be taken into account in future projections.

1.1 Problem Statement

However, the reality of travel demand forecast modeling in Florida is different. While many models “share the road”, they don’t share the representation of the road, i.e. the modeling network. Different models use different networks to represent the same physical network. Most models still use the “stick” network which typically connects nodes by straight lines that ignore the detailed geography of the links. Even for those few models that have made the jump to use a geographically accurate network using GIS streets, no benefits toward sharing and exchange are seen because the networks remain different and uncoordinated. This issue is also problematic when considering a great deal of effort that the Florida Modeling Task Force (MTF) has put into developing a variety of standards aimed at consistency for travel demand forecast modeling. While MTF has successfully developed modeling standards (Gan, Liu et al. 2010), we still lack a standard or a solution on how to enable information exchange.

1.2 Objectives

Given the benefits of sharing and exchange for transportation modeling, the research question arises: How to facilitate network information exchange among models? Most specifically this research identified two specific objectives:

- Identify solutions to the model information exchange problem focusing on the network
- Assess the feasibility of implementation of the proposed solution

1.3 Research Approach

To accomplish these objectives this study looked at the following approach/tasks:

- Identify methods to facilitate associations among models
- Identify challenges and limitations
- Develop and demonstrate a proposed solution
- Develop a framework necessary to implement information exchange
- Make recommendations for implementation based on findings

1.4 Report Organization

The next chapter presents a summary of the review of literature of existing work or other previous relevant efforts on the topic. Chapter three describes the methodology followed and chapter four that presents the results followed by discussion in chapter five. Chapter six provides a summary of the research, conclusions and recommendations for implementation. Appendices include detailed technical information that relates to the method and the testing.

Chapter 2: LITERATURE REVIEW

The need to use a unified street network to support transportation information systems is quite common and many organizations have made numerous efforts to find solutions to this problem. In reviewing these efforts we have identified three main categories of existing work that revolve around the broad idea of creating unified networks: network conflation, unified statewide networks and statewide enterprise GIS.

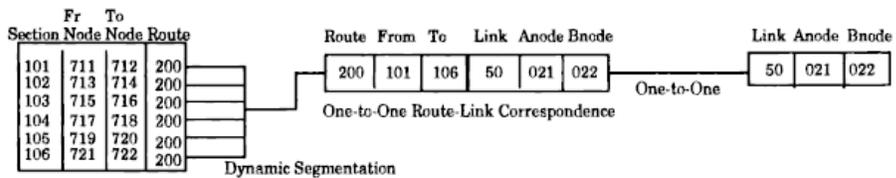
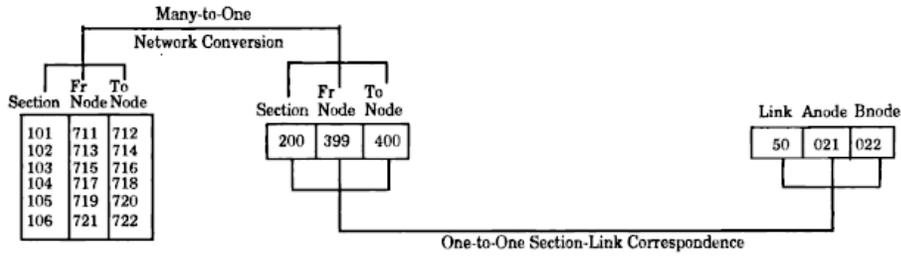
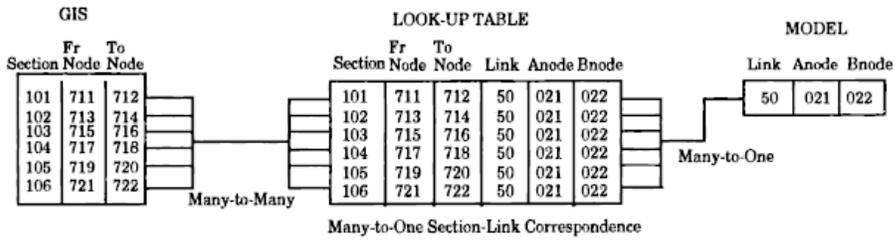
2.1 Network Conflation

Network conflation is a concept that is widely used in transportation modeling to support data unification and information exchange. Conflation is the process of combining the information from two or more geospatial data sets to make a master data set that is a superior source data set in either spatial or attribute aspects (Yuan and Tao 1999). The two main steps for the network conflation are spatial matching and attribute transfer.

There are several studies published or presented since 1990 that have looked into approaches to network conflation. Sutton (Sutton 1996; Sutton 1998) states that there are three broad approaches to network conflation: hard coding, warm linkage and hot linkage ((top, cold linkage; middle, warm linkage; bottom, hot linkage (Sutton 1998))

Figure 2-1).

- In the *hard coding* approach, a correspondence table that relates the many sections in the GIS to the lower number of model network links is created.
- The so-called *warm linkage* methodology attempts to simplify the network conflation issue by defining the model networks entirely within GIS. This approach extracts the model network from the single source network file. Thus, the model network is a subset of the street network and the correspondence is more easily established and maintained.
- The *hot linkage* approach uses the route-system and dynamic segmentation capabilities of GIS to cross-reference the model network link in the GIS network. Each model link is a route that contains several sections (GIS links) that are linearly referenced.



(top, cold linkage; middle, warm linkage; bottom, hot linkage (Sutton 1998))

Figure 2-1 Network conflation models

Yuan and Tao (1999) identified three general conflation methods: geometric, topological and attribute. In the geometric methods, the geometric objects from the two networks are scanned and compared using geometric criteria. The topological methods use topological information to correlate objects. Topological information includes topological relationship such as connectivity between lines, adjacency between polygon and composition relationship such as outlets of a node, arcs that form a polygon, and so on. These methods can be used only when topological information is available. The attribute method is efficient if both data sets contain common attribute fields and the semantic information of both data sets is known (Yuan and Tao 1999).

Pendyala (2002) conducted an FDOT funded project in which a GIS-based conflation algorithm and tools are developed. The objectives of this research were network matching and attributes transfer between the FDOT databases (RCI, WPA, TRIS, etc...) and the FSUTMS model. The research focused on the investigation of an algorithm that consists of three types of matching: node matching, segment matching, and edge matching. A lookup table is used in the conflation tool for addressing the issue of many-to-many relationship between the local models and the

state models. The conflation algorithm uses a two stage computational strategy: bottom-up and top-down. In the bottom-up stage, the algorithm starts with node matching, then proceeds to segment matching, and finally concludes with edge matching. The top-down procedure operates in the reverse. The algorithm has some shortcomings. First, the segment matching algorithm which is based on the distance and angle differences is not reliable when the network edges are distorted significantly. Second, the matching strategy of the algorithm is focused on local matches and it needs improvement for matching at the cluster or sub-network level.

The conflation process is challenging especially when converting from stick network to real shape GIS network. The stick network is composed of links which are connected from node to node with a straight line. The stick network usually doesn't represent the transportation network in a visually pleasing way and are commonly modified to allow some roadway curvature by breaking their network links into smaller pieces (Davis and Lu 2009). Davis and Lu (2009) summarized the challenges of the conflation:

- 1) Consolidate the stick network from small link pieces;
- 2) Match every vertex to the true shape curve in GIS network. Since the stick network data lack accurate geographic reference and do not match either local or state GIS data, such discrepancies increase the difficulty.

Currently, there is no fully automated method for the conflation. Rousseau and Zhang (2004) developed an efficient approach of integrating the Digital Line Graph Format (DLGF) centerline network with the TRANPLAN (TP+) model network. First, a method and a custom GIS tool were developed to match the TP+ model network nodes to their corresponding nodes of the DLGF centerline network; then an additional custom GIS program was developed to automatically find the shortest path on the DLGF network that corresponds to each TP+ model network link between its A-node and B-node. Unlike the time-consuming manual matching method used in conventional network conflation methods, the research instead created two relationship tables to record the matched nodes and the matched links between the DLGF centerline network and the TP+ model network. This innovative approach proved to be very effective and efficient in accomplishing the task objectives and resulted in a high percentage of records matched.

The industry has also made efforts to develop conflation methods which have resulted in many commercial or free software tools shown in Table 2-1.

Table 2-1 Network conflation tools

Name	Vendor	Commercial/free
Conflex 3	Citygate GIS	Commercial
Mapmerger 9	ESEA	Commercial
JCS Conflation Suite	Vivid Solutions Inc	Free API
RoadMatcher 1.4	Vivid Solutions Inc	Free API
adjust.IT	we-do-IT consultants	Commercial
GIS/T-CONFLATE	GIS/Trans, Ltd	Commercial
CUBE Conflation Tool	Cube	Commercial
TransCAD conflation tool	Caliper	Commercial

ESEA's conflation system (ECS) was successfully used to conflate Florida state highway data to larger scale county data for the Florida Department of Transportation (Dallal 1999). The conflation process was carried out in three steps: node matching, line matching, and feature merging.

2.2 Unified Statewide Networks

Due to the development of GIS technology and its rapidly increasing demand, many states have made efforts to create their own unified statewide networks. These networks are built for different purposes such as creating a digital infrastructure to support E911 and other emergency response systems, addressing geocoding, routing and modeling transportation routes. Because of the difference of purposes, the data and methods that were used to create these networks are different. Table 2-2 shows a summary of these efforts in various states.

Table 2-2 Unified statewide network efforts

State	Type of Unified Network	Primary Purpose	Geometry Source	Method
Illinois ¹	Statewide comprehensive digital road network database	To serve as a key component to integrating information within one database, serving as a foundation for a statewide enterprise system	NAVTEQ	
Virginia ²	Statewide road centerline for state enterprise geospatial repository	To support the base mapping needs of state and local government, while achieving a singular, consistent and maintainable base map dataset usable by all entities.	NAVTEQ	
North Dakota ³	Statewide road centerline	For various applications including but not limited to E911, emergency management, routing services, geocoding services, tax assessing with each area of specialty requiring specific attributes and maintenance methodology	Local networks maintained by counties	Local networks combined into the statewide network

¹ <http://www.govtech.com/e-government/Illinois-Department-of-Transportation-Building-GIS.html>

² <http://www.vita.virginia.gov/isp/default.aspx?id=8422>

³ <http://www.nd.gov/gis/resources/standards/docs/ndRoadCenterlineDataStandardsDraft.pdf>

Table 2-2 Unified statewide network efforts (continued)

State	Type of Unified Network	Primary Purpose	Geometry Source	Method
South Carolina ⁴	Statewide seamless E911 road centerline	For a seamless E911 and geocoding data from a multitude of sources	Topologically Integrated Geographic Encoding and Referencing (TIGER)	Local networks combined into the statewide network
Nebraska ⁵	Statewide road centerlines and addresses	E-911 address mapping or geocoding applications	Network maintained by Nebraska Public Service Commission (NPSC); network maintained by counties;	
New Jersey ⁶	Statewide road network of all public roads	For various statewide applications	Department of Transportation (DOT), Topologically Integrated Geographic Encoding and Referencing (TIGER), and county data sources	

From the table we can derive the following characteristics of the statewide network unification efforts:

⁴ <http://downloads2.esri.com/campus/uploads/library/pdfs/60928.pdf>

⁵ <http://www.nitc.ne.gov/gisc/workgroups/StrAdd/Draft%20Centerline-Address%20Database%20Characteristics%2012-08.pdf>

⁶ https://njgin.state.nj.us/oit/gis/NJ_NJGINExplorer/docs/NJRoadsCenterlines.pdf

1. In most cases the main purpose for creating a statewide unified network is to serve the demands of E911 services or to create a broad enterprise GIS. We found no specific efforts to support the needs of transportation modeling and information exchange.
2. For most states, the geometry representation of the unified network is the most important aspect, and the street centerline usually is selected for the network geometry.
3. The network source used to create the unified network varies from state to state. Some states like Illinois and Virginia are using the NAVTEQ network, while other states combine the state, locally maintained networks into a single unified network.

Some states including New York, Illinois, Massachusetts and Connecticut, have developed (or are in the process of developing) a centerline data set by partnering with a commercial vendor (e.g., TeleAtlas or NAVTEQ).

Several states like Vermont, Maine, Kentucky and Wisconsin and New Jersey have two centerline data sets. One is developed by the state DOT, it contains a linear referencing system and often focuses primarily on state and county roads. The other contains local roads with address ranges and it is used for address matching and mapping.

2.3 Statewide Enterprise GIS

Many state DOTs have made various efforts to develop database structures for facilitating data integration and management (Vandervalk-Ostrander, Guerre et al. 2003).

Virginia DOT's inventory and condition assessment system is a comprehensive asset management system that stores all assets (pavements, bridges, drainage, roadside, and traffic amenities and enhancements) and conditions for providing data for business decisions (Larson and Skrypczuk 2004).

Ohio DOT's Base Transportation Reference System is a point reference system that splits road inventory into a 0.01 mile point table (Blackstone and Aquila 2003). The table, which includes key highway location data, incorporates eleven critical enterprise systems (Automatic Traffic Recording, Bridge Management Systems, Construction, Management Systems, Culvert Inventory, Overweight Permitting, A Highway Safety Program, Pavement Management Systems, Project Development Management Systems, Roadway Inventory, Transportation Management Systems, and Weigh-In-Motion).

Minnesota DOT's Roadway Network Database project develops a location reference system that provides transportation data integration and analysis functionality utilizing ESRI's Geodatabase and Oracle (Vandervalk-Ostrander, Guerre et al. 2003).

Oregon DOT's Transportation Management System is a web-based data storage and management system that incorporates transportation datasets such as pavement, bridge, congestion, safety, an Integration Transportation Information System, freight/intermodal, and traffic monitoring.

As summarized by Bejleri et al., (2006), many state DOTs efforts can be classified into three general categories. First, most DOT efforts have been focused on developing unified reference systems of their roadway networks using either point or linear systems. Second, these efforts are primarily dealing with data sharing among state agencies. The information exchange between local MPOs and state DOTs is not considered. This is crucial because transportation planning starts at the MPO level. Finally, most of DOTs efforts focus on integrating roadway and asset management systems. Since major datasets that DOTs use are roadway datasets and asset management datasets, most of the DOTs are primarily concerned with managing such datasets.

2.4 Summary

Literature points to various efforts geared toward network unification and standardization. Conflation, a very common method used to unify networks, has been generally applied for a long time and various tools have been developed. However, due to the complexity of street networks, fully automatic conflation cannot be completed yet and some manual work is still required. Efforts to create unified comprehensive networks (for all roads) are primarily driven by the needs of services like E911 and many times are not coordinated with the needs of transportation planning. Departments of Transportation around the country have made their own efforts to create unified networks either by using commercial products like NAVTEQ or by combining locally maintained networks. While these efforts are most of the time driven by the need to create enterprise GIS systems to support broadly the needs of DOTs, no specific documented efforts have been geared toward replacing transportation modeling stick networks with a unified, geographically accurate network to support the needs of exchanging information among various models.

Chapter 3: METHODOLOGY

To achieve the research goals, the methodology followed four steps: (1) review of the standardized FSUTMS framework, (2) review of the networks of the current travel forecast demand models, (3) analysis of model information exchange methods – network associations and unified network - and (4) the development of the unified network.

3.1 Review of FSUTMS framework

Florida has developed some standards to guide the travel demand forecasting modeling efforts of transportation planners and the modeling community in the state. These standards are crystalized in what's called the Florida Standard Urban Transportation Model Structure, or FSUTMS, which is a collection of standards designed to create consistent transportation modeling practices across various state, regional, and local models in the state. An extensive website – FSUTMS Online⁷ – provides a wealth of information about the FSUTMS efforts. More specifically, from a data structure point of view, a data framework was developed by a research project titled “Development of a Data Framework for the Florida Standard Urban Transportation Model Structure” conducted by a team of researchers at Florida Atlantic University (Gan et al., 2010). The framework developed in this work establishes standards for handling of file and table structures and naming conventions, and recommends development of standard metadata. The research has produced a personal geodatabase (MS Access format) template that now includes all former flat files into a database format designed to be used by any model as a way to enforce the proposed standards. The proposed template is designed to accommodate the diversity of the various local models in Florida.

One important aspect of the FSUTMS data framework is the standardized attribute names and data types for the network component. This standard attribute structure will be very useful in the information exchange of network attribute information among various models.

3.2 Review of Model Networks

Florida has several travel demand forecast models at different geographic extents: two statewide models; several regional models (multi county extent) that generally follow FDOT districts; and a few local models, typically at a single county extent - see FSUTMS Online for

⁷ FSUTMS Online <http://www.fsutmsonline.net/index.php>

more information⁸. Although standardization efforts have led to useful data framework standards to improve consistency across Florida models, one deficiency of current models is the network layers that the models use. All Florida models use their own network layer, independent and uncoordinated, typically in the form of a “stick” network which is not geographically accurate. Especially in overlapping geographic areas the different representations of the same physical network are very apparent. Figure 3-1 below illustrates the difference for a small area of Florida where three models – a state model, a regional model and a local model – don’t share the same network. This creates difficulties in sharing common input data elements that all these models need such as speed, number of lanes, traffic volume, link direction etc. Likewise it is difficult to view and compare future forecast results. There is quite a bit of duplication or multiplication of effort that goes into developing the input data for each of these models independently. Input variables are collected separately by each model for each link, where these should be the same for all the models that share that link.

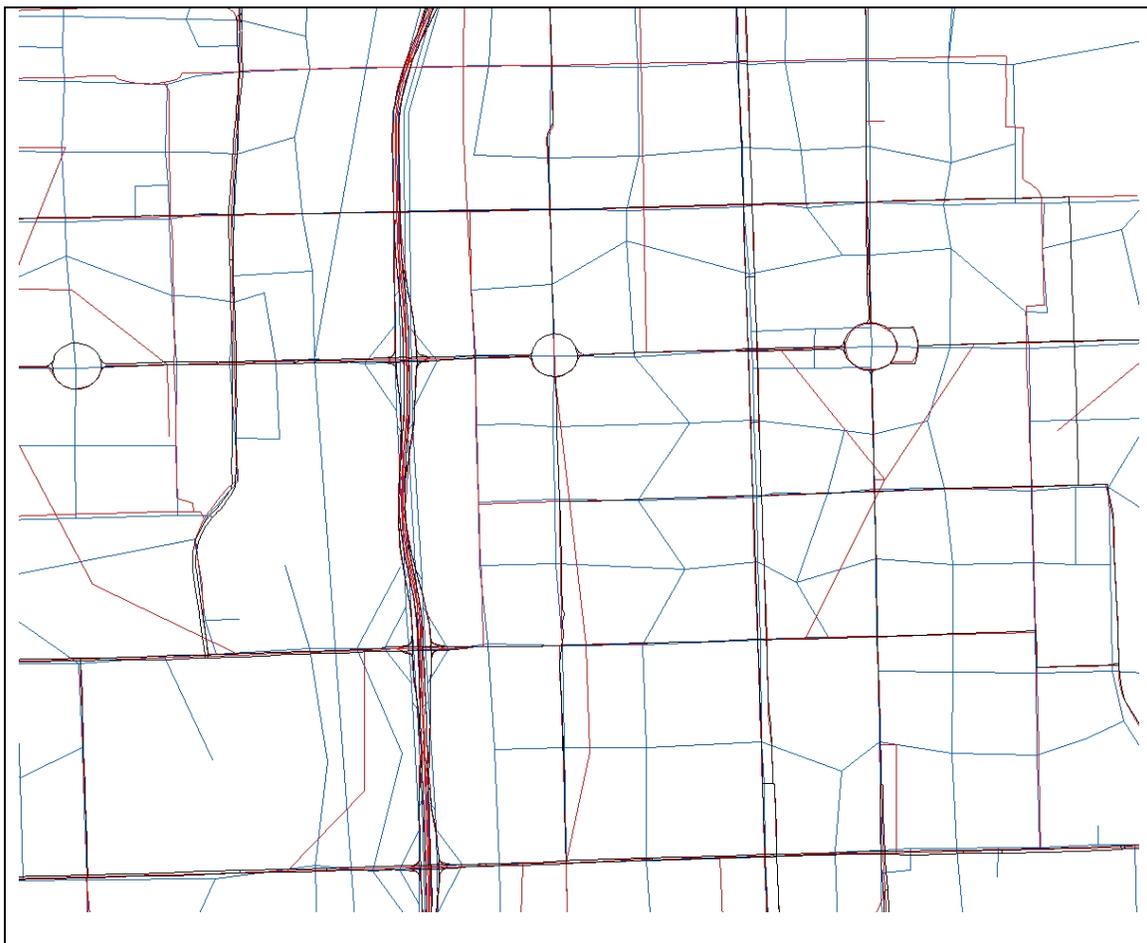


Figure 3-1 Three models using three different networks
(blue – local, red – regional, black – state)

⁸ http://www.fsutmsonline.net/index.php?/model_pages/model_pages/

3.3 Information Exchange Methods

To address the issue of the network discrepancies for the purpose of supporting information exchange we looked at two methods: (a) leave the individual networks intact but establish and maintain associations among them and (b) use the same unified network for different models. The sections below describe each method and discuss the benefits and shortcomings of each method.

3.3.1 Network Associations

This method keeps the original networks and establishes associations among them at the link level (Bejleri et al., 2006). If a one-to-one correspondence is possible the associations can be established simply by connecting link identifiers of the participating models into an association table. However a one-to-one correspondence is very unlikely. The most common situation is a many-to-many association among the links of the participating models. Figure 3-2 shows an example of three participating networks where all three of them have different number of links for the same physical street network. The table below the figure shows the association of the three networks. RCI represents a state network that contains a linear referencing system, D/T represent the most detailed network available (most links) and Local represents a third network in between RCI and D/T. As shown the associations are complex and a linear referencing system will need to be included to handle segmentation by using the common denominator of all which is the network with the finest granularity of links.

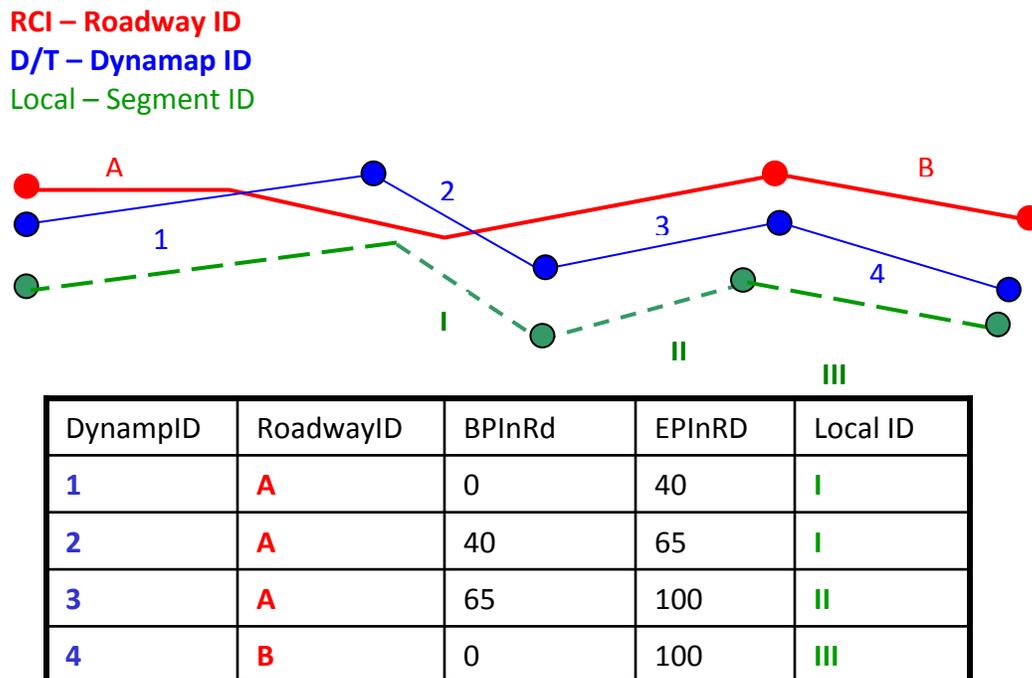


Figure 3-2 Many-to-many network association (Bejleri et al., 2006)

The advantage of this model is that there is no need to conflate/transform the model network to another network. The models maintain the same geometry and attributes and the information exchange with other models can be done using the association table.

On the other hand this method presents a number of disadvantages. The associations between the independent networks can be complex and challenging to establish and especially to maintain. Each participating network must be mapped to the finest segment network which can serve as the common denominator to create associations among the rest of the models.

Figure 3-3 shows the relational data model required to establish and maintain the associations. Due to such complexity these associations are challenging to maintain in the long term. Sophisticated tools will be required to be built to maintain the associations in order for the models to benefit from exchange of information. Due to these complexities and challenges the association method is not realistic and not sustainable in the long term.

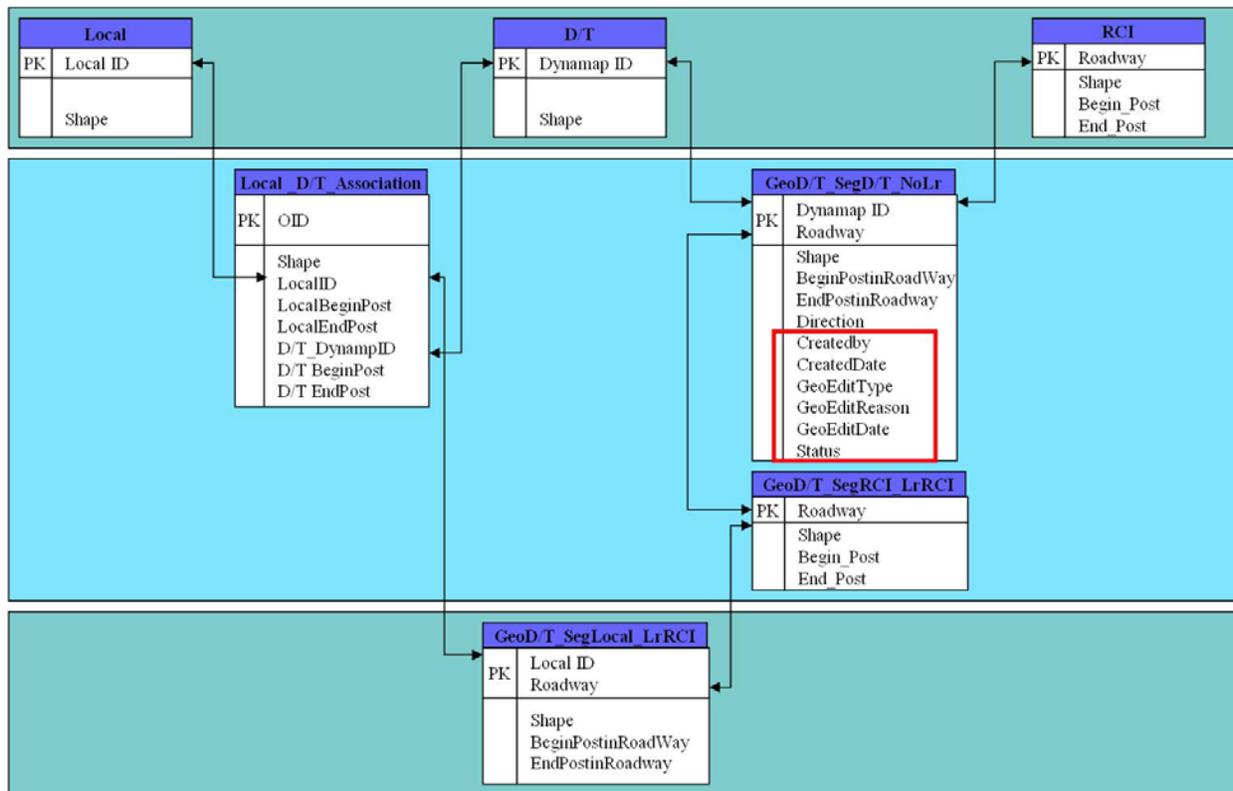
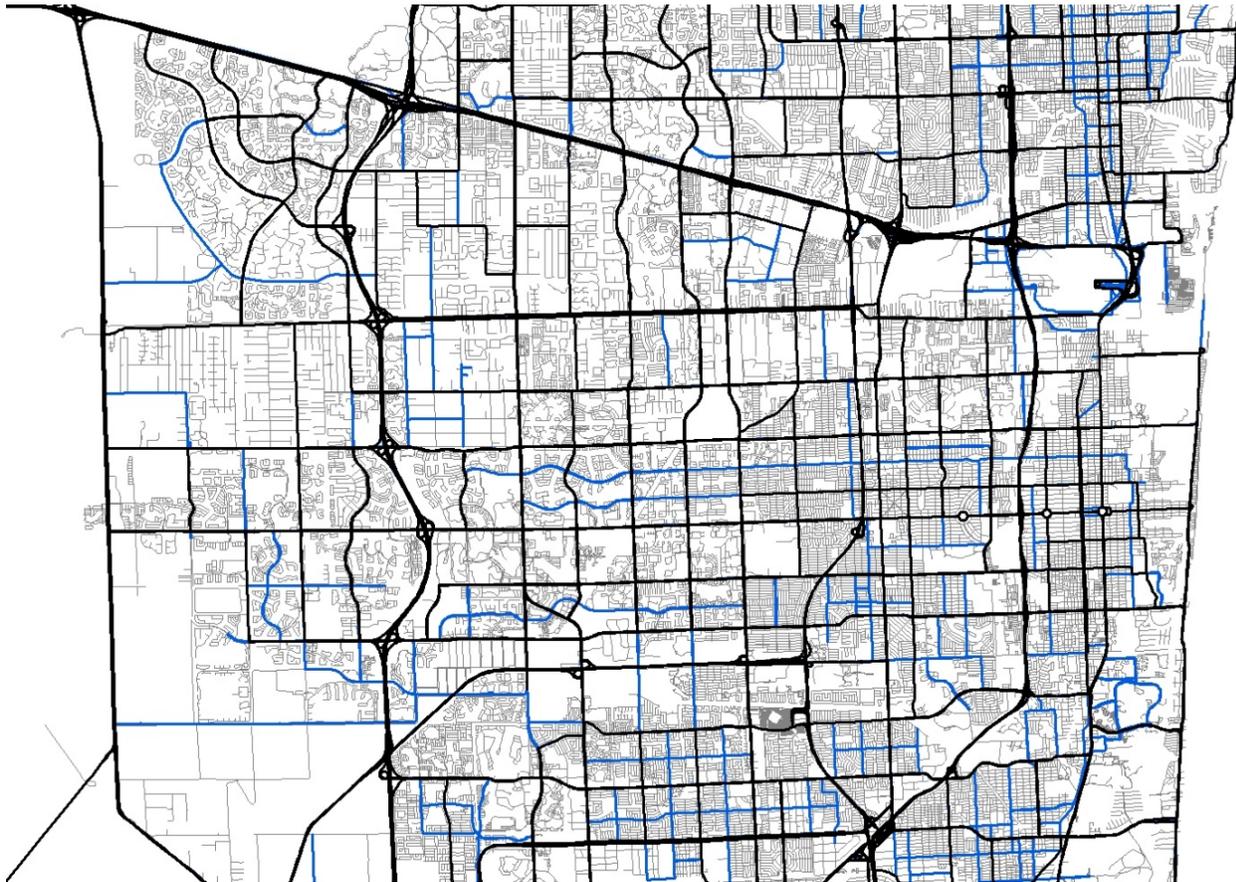


Figure 3-3 Data model to support many-to-many network association (Bejleri et al., 2006)

3.3.2 Unified Network

The unified network method uses the same network for different models. The links of the shared/common network are tagged with identifiers of the models that participate in the

information exchange. The common network serves as the platform for information exchange. The attributes of each model can be stored in a shared table with links to the common network based on link identifiers. This enables easy visualization and comparisons of the networks of the various models that participate in the exchange. Figure 3-4 illustrates visualization of the common network and two models that share it.



(black – state model, black + blue – regional model, grey – rest of the unified network links)

Figure 3-4 Unified network supports multiple models

The unified network solution has many advantages. First, it eliminates data redundancies because the input variables for speed, volume, number of lanes etc. are developed only once. Long term maintenance is no more complex than the typical network maintenance required to keep up with the network updates. Shared network links can be easily established once models have been migrated to the unified network. The unified network can serve as a platform to link even more information such as RCI, WPA and new roadway data collected from GPS, Bluetooth, wireless networks or other technologies. Another significant advantage that would support this method applies to cases when the unified network is available and is used for other purposes. This allows the modeling community to leverage resources already available.

The disadvantage of using the unified network is that it requires a one-time conversion/conflation of models to the unified network. Depending on how this is done it could be time consuming to accomplish. This process of conflation is very common in transportation network development and maintenance.

Due to numerous advantages of the unified network method versus the association method, this research proceeded to assess the feasibility of using the unified network as a platform for the model information exchange and determined the supporting exchange framework. The detailed results are presented in the Results chapter.

From a methodology point of view, one of the challenges of adopting a unified network for all the models is the development of the unified network itself. The section below presents the major methodological steps to accomplish this goal.

3.4 Development of the Unified Network

One key ingredient in implementing the concept of one unified network for multiple models is the availability of a unified GIS street basemap or network. Florida has resolved this challenge by selecting a commercial product – NAVTEQ streets. The availability of the NAVTEQ streets statewide supports the implementation of the unified network method for model information exchange. However, just the availability of the unified basemap doesn't equate to an operational unified network for model information exchange. Several additional operations are required to convert the basemap to a network suitable for travel demand forecasting. This research identified and performed several steps to construct a unified network for model information exchange: (a) Associating the FDOT basemap with the NAVTEQ basemap in order to carry RCI attributes to NAVTEQ; (b) Conflation of the model network to NAVTEQ; and (c) Testing the use of the unified network for inputs and outputs in a modeling package such as CUBE or TRANPLAN.

A description of the unified streets basemap and the methodological steps performed to develop the unified network are presented below.

3.4.1 Unified Streets Basemap

The NAVTEQ-based unified basemap is a street layer in GIS format. It contains all roads in the state with about 1.5 million links and 600,000 intersections. The link geometry is organized using a dual centerline for major roads a single centerline for minor roads. Limited access highways are represented by their own centerline for each direction and the ramp connections are very detailed. Figure 3-5 shows and illustration of the network.

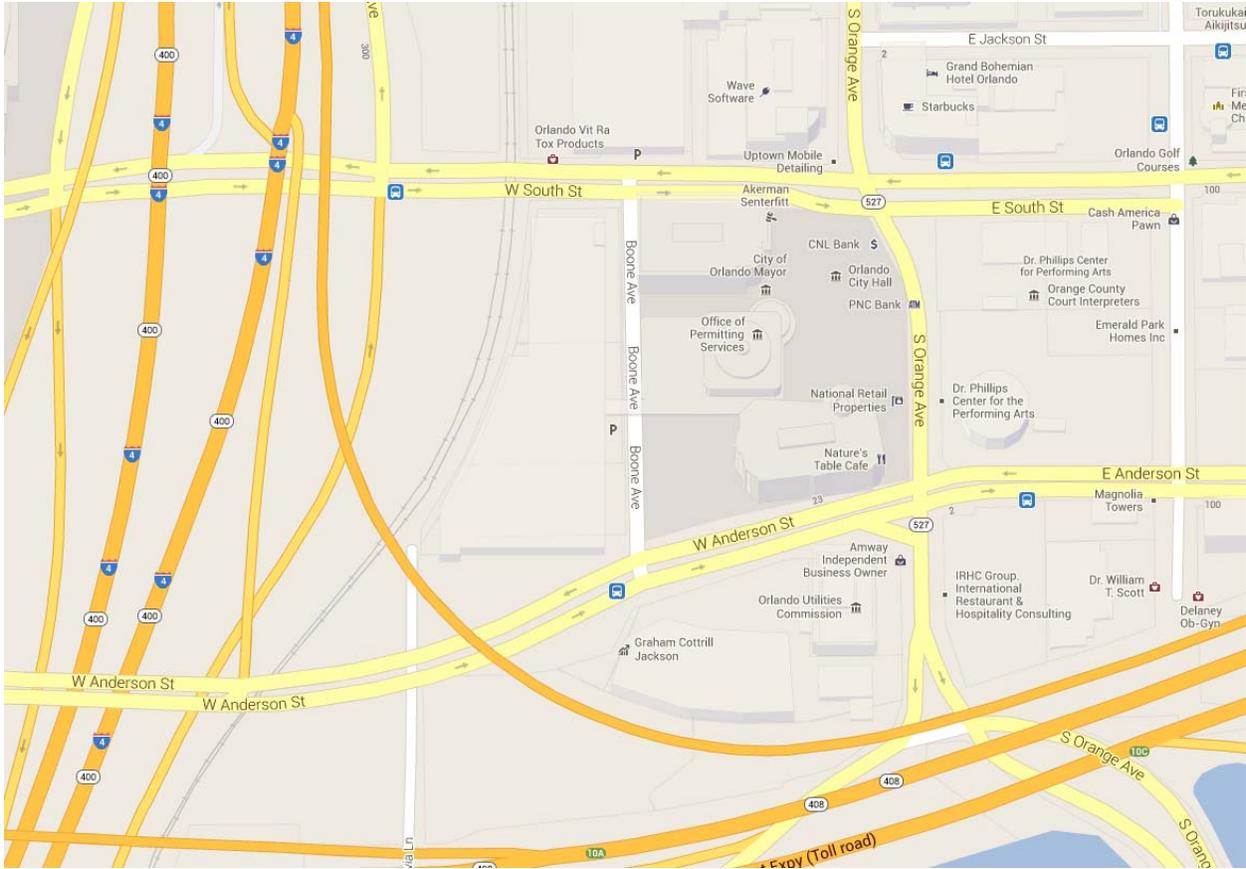


Figure 3-5 Centerline geometry of the unified basemap

Most Florida models currently use a single centerline model for most roads. The use of dual-centerline – two single directional lines instead of a single dual-direction centerline - is a consideration that should be reflected in the model structure. Also the representation of intersections is different. There are four nodes at an intersection where two dual-centerlines intersect instead of a single node in the single centerline traditional models. There are three nodes in intersection where a dual-centerline and a single centerline intersect.

A related node layer contains Z values that are useful to correctly depict the network for overpasses and underpasses. The NAVTEQ-based unified basemap contains numerous attributes. Some attributes that are useful for modeling include speed, direction, number of lanes etc.

The unified basemap is updated quarterly.

3.4.2 RCI and the Unified Basemap

Florida DOT has a large inventory of roadway characteristics that are relevant for use in travel forecast modeling such as speed, number of lanes, traffic volume, facility type, area type etc.

These characteristics are maintained in a non-NAVTEQ basemap that relate this information to associated straight-line original diagrams. In recent years the FDOT Safety Office has put significant effort into associating the RCI basemap with the NAVTEQ basemap in order to carry over the various RCI attributes to NAVTEQ. This is an additional major advantage in support of using the unified basemap for travel forecast modeling. The combination of NAVTEQ-based attributes and RCI-based attributes provides a wealth of information already available on the unified basemap that can be used to support the travel forecast models.

Figure 3-6 illustrates graphically the process of associating RCI basemap identifiers to the unified basemap segments. Each NAVTEQ segment in the FDOT network has been tagged with an FDOT route identifier, begin and end milepost, and roadside. Once this association has been established the RCI attributes can be carried over to the unified basemap segments. Figure 3-7 shows key FDOT RCI fields associated with NAVTEQ segments in an association table.

The highlighted column is the field that contains the unique Navteq identifier. This table shows that each Navteq segment in this table has been tagged with RCI data such as AADT, functional class, posted speed, and number of lanes. There are approximately 1.5 million segments in the Navteq Street Network for Florida. Over 300,000 Navteq segments have FDOT LRS information and can be tagged with any additional corresponding RCI data.

A more detailed process for associating the FDOT LRS with a unified streets basemap is provided in Appendix A.

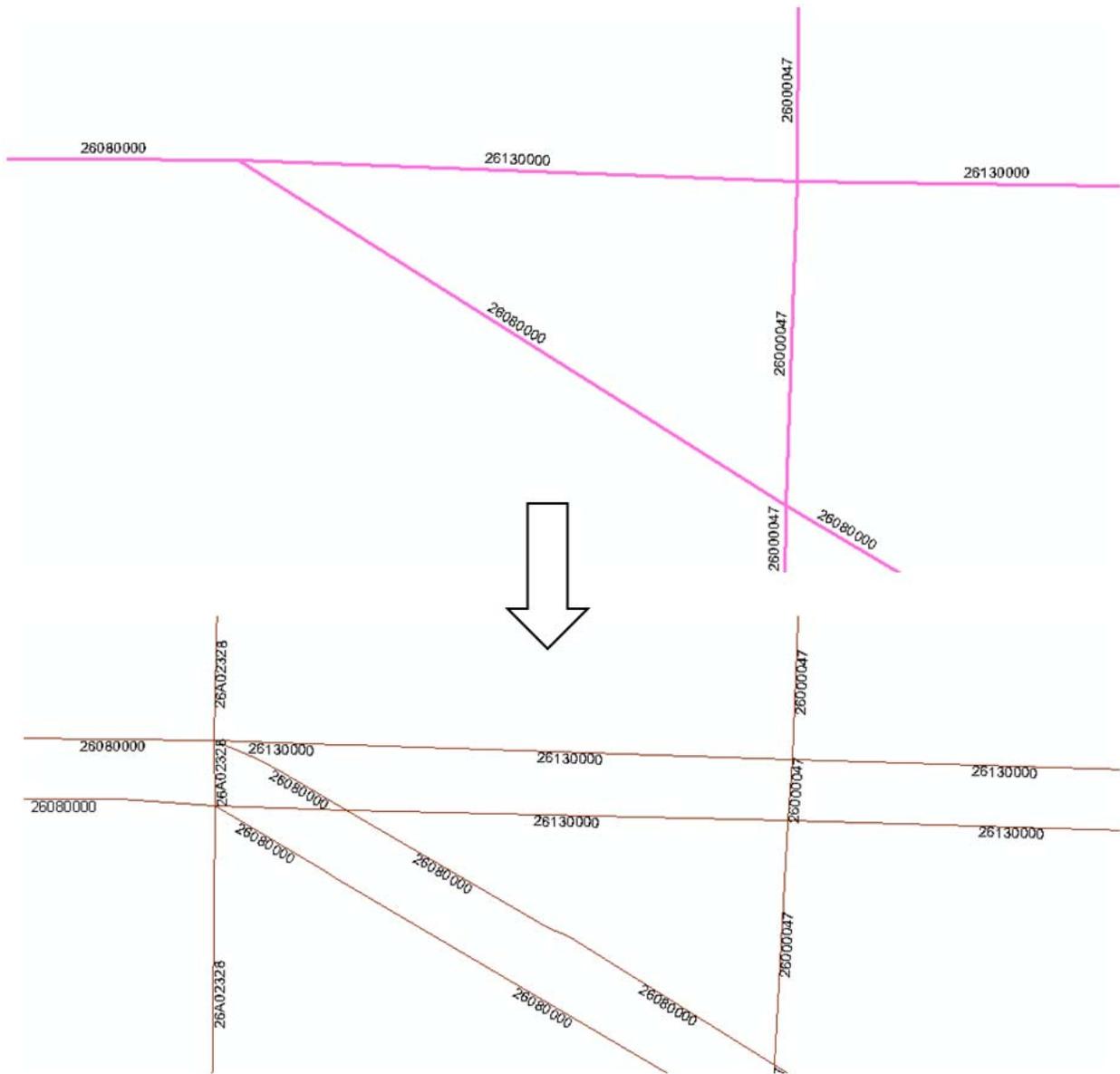


Figure 3-6 Linking of FDOT roadway IDs to unified basemap.
 (pink – FDOT centerline; brown – Unified basemap centerlines)

Col	LINK_ID	ROADW	BMPADJ	EMPADJ	ROADSIDE	aadt	aadt2	funcclass	localnam	maxSpeed	lane	lane2	interstate	usHwy	stateRd	Col
volu	37907950	79002000	29.328	29.4124	L	70500	35250	11	I-95		65	6	3	95		9
volu	776423813	79002000	29.373	29.5178	R	70500	35250	11	I-95		65	6	3	95		9
volu	734463163	79002000	29.4124	31.4512	L	70500	35250	11	I-95		65	6	3	95		9
volu	776423814	79002000	29.5178	31.0297	R	70500	35250	11	I-95		65	6	3	95		9
volu	821684235	79002000	34.9846	35.0263	R	68000	34000	11	I-95		65	6	3	95		9
volu	134910505	79002000	29.1013	29.328	L	70500	35250	11	I-95		65	6	3	95		9
volu	119025456	79002000	41.1895	43.3911	L	67000	33500	11	I-95		70	6	3	95		9
volu	807464958	79002000	34.9347	35.037	L	68000	34000	11	I-95		65	6	3	95		9
volu	37907881	79002000	40.958	40.9694	L	67000	33500	11	I-95		70	6	3	95		9
volu	37907879	79002000	40.958	40.9714	R	67000	33500	11	I-95		70	6	3	95		9
volu	37880285	79002000	40.9694	41.093	L	67000	33500	11	I-95		70	6	3	95		9

Figure 3-7 NAVTEQ segments associated with FDOT RCI attributes.

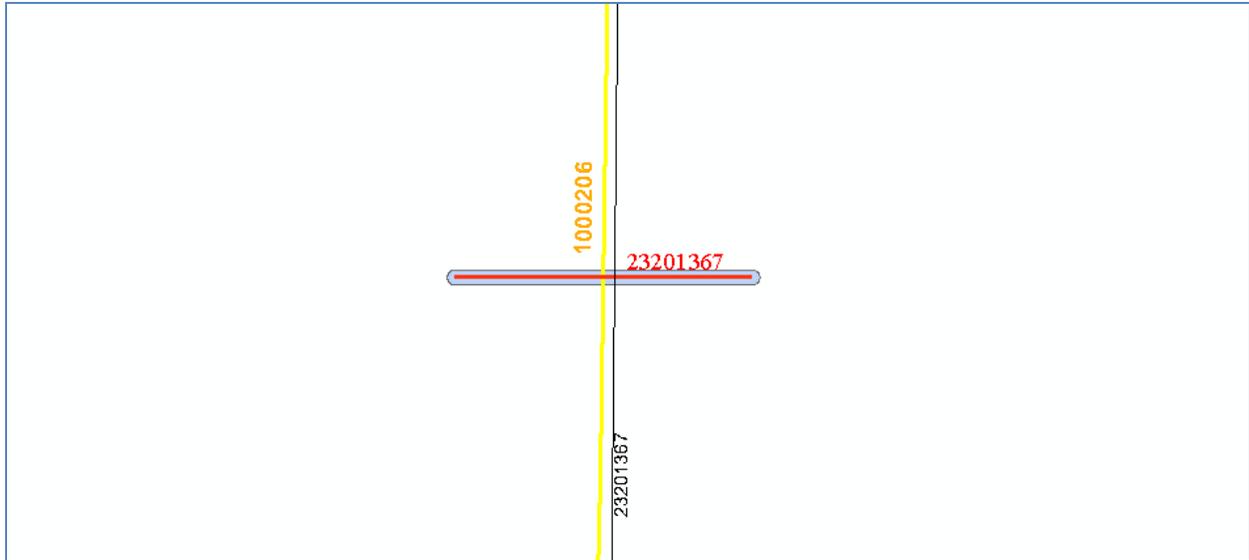
3.4.3 Conversion of TSM to the Unified Basemap

The availability of a unified basemap with useful input attributes for travel forecast modeling is a critical ingredient for the model information exchange. However, each model that participates in the exchange is required to use the unified basemap for its network layer. At present, most Florida models use their own networks, which are either stick networks or non-NAVTEQ GIS networks. Two methods can be considered to enable the models to use the unified basemap network: (a) Conflate the existing model network to the unified basemap or (b) start with the unified basemap as the model network by selecting the links of interest and using the attributes that are available in the unified network. The conflation method that carries over the existing model network from one network was used to convert the TSM model to NAVTEQ network as a proof of concept for this research. The major methodological steps of the conflation are presented below and illustrated in Figure 3-8. The detailed technical steps are provided in Appendix B.

Conflation of TSM network with the NAVTEQ network:

- Establish the *target* and the *source* network. In this case, the target network is the NAVTEQ network, and the source network is the existing non-NAVTEQ network. The goal is to transfer the attributes of the source network to the target network.
- For each segment in the target network, create a perpendicular line called a “seeker”. This size of seeker could be variable and depends on how spatially close the two networks are. Five-meter and ten-meter distance were used in this case, depending on the geographic area.
- Create a small buffer polygon around each seeker.
- Intersect the buffer with the source network. If only one source network segment is found, associate the segment identifier of the source with the segment identifier of the target. This association is recorded in a table illustrated in Table 3-1 below.
- When zero or more than one source segment intersects the buffer, tag the source segment for review by editors.
- Once the above process is applied to all the links, the attributes from the source network are passed to the target network through relational table joining operations.

Exceptions to this general method are handled by editors or with further special programming. A detailed description of the method used to correct the conflation errors is presented in Appendix C.



(Black: target network; Red: Seeker; Yellow: source network)
Figure 3-8 Method used for conflation of two networks

Table 3-1 Association between target and source networks

Segment Id in Target Network	Id of segment in Seeker layer	Id of buffered segment in Seeker layer	Buffered Seeker Id and Source Segment Id retrieved from intersection file	Segment Id in Source Network
23201367	23201367	23201367	23201367/1000206	1000206

3.5 Managing Unified Network Updates

As with any geospatial information system the unified network is expected to change periodically. More specifically, the unified NAVTEQ-based GIS streets map is expected to be updated two to four times per year. The related RCI attributes will have to be updated accordingly. The FDOT Safety Office has already developed a process and tools to determine the NAVTEQ changes and update the RCI information on the unified network. While this process was developed to support safety needs, the updated NAVTEQ/RCI network is no different than the one needed for modeling. In fact this is an opportunity to leverage the FDOT investment for the procurement and maintenance of the NAVTEQ network for applications beyond safety and into other areas of FDOT activity such as transportation modeling.

We reviewed the safety’s office NAVTEQ/RCI update method to ensure that it can be used or adopted to handle the NAVTEQ/RCI updates for modeling needs. At the heart of this method is

the 'crosswalk' table which is constructed to document the differences between the current and the new version of NAVTEQ. Most changes are determined programmatically and a small percentage is determined manually. RCI attributes are also updated to reflect the changes. A statewide table that associates the updated NAVTEQ links and the corresponding RCI attribute is developed annually by the safety office. As shown in the (Association established through LINKID-ROADWAY)

Figure 3-9 below this table contains the association between NAVTEQ segment identifier LINK_ID and RCI identifier ROADWAY and contains information about AADT, functional class, speed, number of lanes etc.

County	LINK_ID	ROADWAY	BMPADJ	EMPADJ	ROADSIDE	aadt	aadt2	funcclass	localnam	maxSpeed	lane	lane2
dade	122655513	87200000	12.695	12.9679	R	124500	62250	11	DOLPHIN EXPR	55	4	2
dade	122655514	87200000	12.6952	12.9639	L	124500	62250	11	DOLPHIN EXPR	55	4	2
dade	723137806	87200000	12.9639	13.048	L	124500	62250	11	DOLPHIN EXPR	55	4	2
dade	122658832	87200000	12.9679	13.048	R	124500	62250	11	DOLPHIN EXPR	55	4	2
duva	122665572	72020000	0.0316	0.189	L	121000	60500	11	I-95	55	6	3
duva	23242043	72020000	0.189	0.3837	L	121000	60500	11	I-95	55	6	3
duva	17002947	72020000	0.3837	0.4699	L	121000	60500	11	I-95	55	5	2
duva	821676116	72020000	0.4699	0.5804	L	121000	60500	11	I-95	55	6	3
duva	821676117	72020000	0.5804	0.6912	L	121000	60500	11	I-95	55	6	3
duva	122666426	72020000	0.6912	0.753	L	121000	60500	11	I-95	55	6	3
duva	122666429	72020000	0.6916	0.753	R	121000	60500	11	I-95	55	6	3
duva	779285333	72020000	2.4424	2.9021	L	94500	47250	11	I-95	55	5	2
duva	802546528	72020000	2.4582	2.7135	R	55000	27500	11	I-95	55	6	3
duva	802546529	72020000	2.7135	2.9118	R	94500	47250	11	I-95	55	5	2
duva	779284791	72020000	2.9021	3.1489	L	94500	47250	11	I-95	55	5	2

(Association established through LINKID-ROADWAY)
Figure 3-9 NAVTEQ/RCI annual table.

This table can be linked to the unified network in MIXS through the NAVTEQ link identifier. A more detailed description of this process is provided in Appendix D.

3.6 Summary

The main methodological steps for this research focused on an analysis of the FSUTMS standards, a review of the network of existing models, a comparison of two information exchange methods – network associations and unified network, association of RCI attributes with the unified basemap and development of the TSM network by conflating it to the unified basemap as a proof of concept for using a unified network. In addition to TSM, a draft of the SERPM model network conflated to the unified network was also used to inform the development of the model information exchange framework presented in the results chapter.

Chapter 4: RESULTS

The use of a unified network is a key prerequisite to accomplish effective model information exchange. However, the unified network alone is not sufficient to perform the information exchange among the various models. In this section we present the solution to the information exchange problem: MIXS – **M**odel **eX**change **I**nformation **S**ystem, a complete framework that includes proper data structuring and the necessary protocols and tools required to accomplish this goal.

4.1 MIXS Framework

The concept of MIXS revolves around a unified common network that is centrally stored for all the models that participate in the model information exchange. The central database stores the attributes of all the models which are linked to the network links. The network links are only stored once (not duplicated for each model). This setup allows sharing of the network attributes about the participating models and enables the ability for models to exchange attributes including both inputs and forecast results. Figure 4-1 below illustrates the overall MIXS concept.

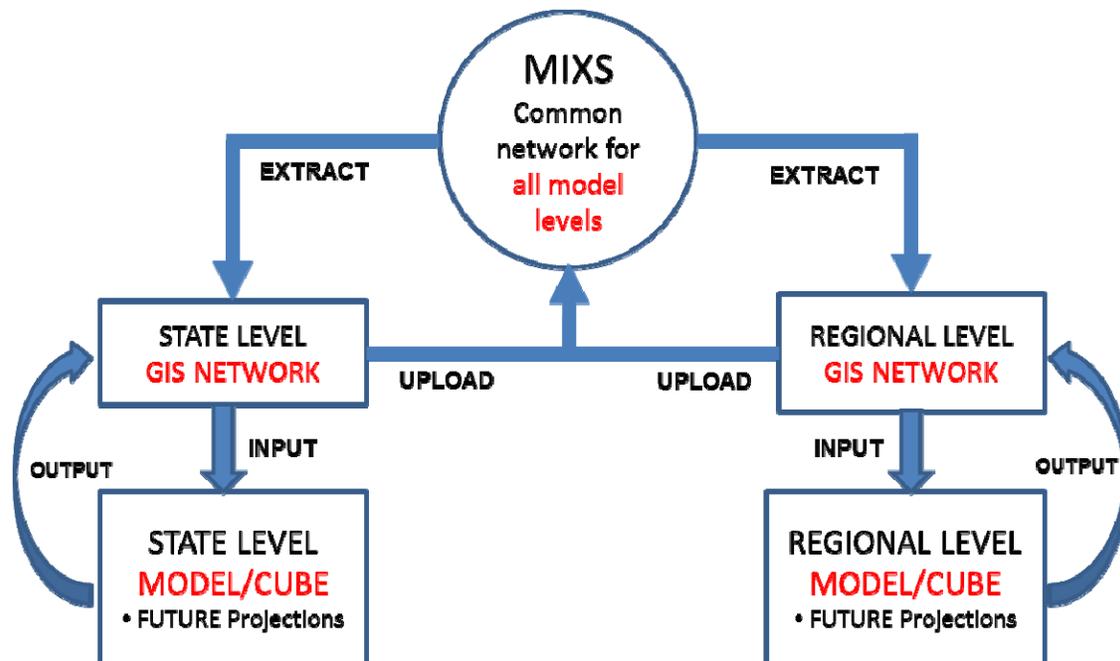


Figure 4-1 MIXS concept

Modelers will be able to extract the network of their models from MIXS in GIS format, whether it is a state, regional or local model. The extracted network can then be used as input in a transportation modeling package like CUBE, TRANPLAN or other packages. It is expected that the forecast projections from modeling (the output) will be returned on the same network layer which then can be uploaded back to MIXS. The modelers can choose which results to post back (upload) into MIXS, for example they can load the final results of modeling for various future scenarios. The MIXS database is structured to accommodate multiple scenarios of multiple models on existing and future roads. The data model for MIXS is presented below.

4.2 Data Model

Figure 4-2 below shows a more detailed MIXS framework. Two databases are involved in MIXS: the central MIXS database shown in green and the data of individual models shown in light blue at the bottom.

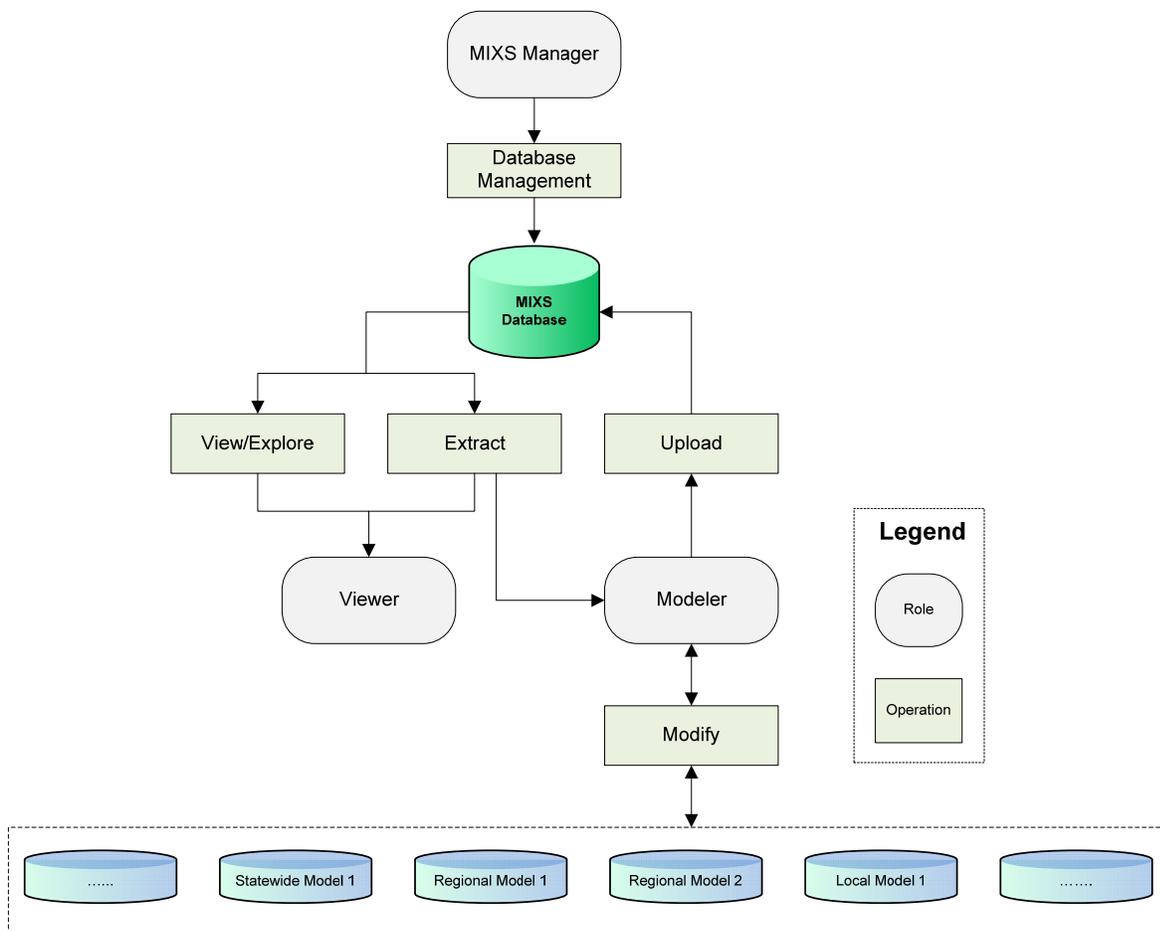


Figure 4-2 Data components in the context of MIXS framework

The exchange between the two will be accomplished through a protocol and with the assistance of several proposed tools. The two sections below explain in more detail the data model for the central (MIXS) and local networks.

4.2.1 MIXS Database

Figure 4-3 shows the data model for the MIXS database. At this time the data model includes only the handling of the shared network. Zones and centroid connectors are not included at this time. More information about the zones and connectors is presented in the Discussion chapter.

At the core of the database is the STREET table which represents the unified common network. This is a spatial table that contains the NAVTEQ GIS streets with all the related attributes. The NAVTEQ streets are provided by FDOT. The STREET is linked to the RCI_ATTRIBUTE table which contains the RCI attributes of interest for forecast modeling, such as the number of lanes, AADT, etc. The RCI_ATTRIBUTE table is available from the FDOT Safety Office. The MODEL table contains the names of the models that participate in the exchange. It may include state, regional or local models. MODEL_STREET is an association table that links models to streets. This table contains the link identifiers that are used by each model. The same link may be used by one or more models.

SCENARIO is the fundamental organizational unit designed to handle the various model scenarios. Each model has at least one default scenario that may simply include the base year information. The attributes for each link included in each scenario are stored in the table named SCENARIO_STREET_ATTRIBUTE. This table contains both the model input variable and the forecast attribute.

The future line work not present in the STREET is stored in the SCENARIO_STREET_ADD spatial table. This table can also contain any local roads not available in the STREET table such as any missing roads in the NAVTEQ GIS streets. It also can contain approved and planned to be built in the future such as those in the FDOT Work Program. The core attributes of these streets can be stored in the spatial table itself and the related SCENARIO_STREET_ATTRIBUTE table. The field called 'edit_type_id' is used to attribute the various links e.g. to describe if the link is a missing road, planned, adopted.

The table SCENARIO_STREET_DELETE is used to handle exclusions of certain links from various scenarios as modelers explore various alternatives.

The types of relationships among the tables in the database are explained in the legend.

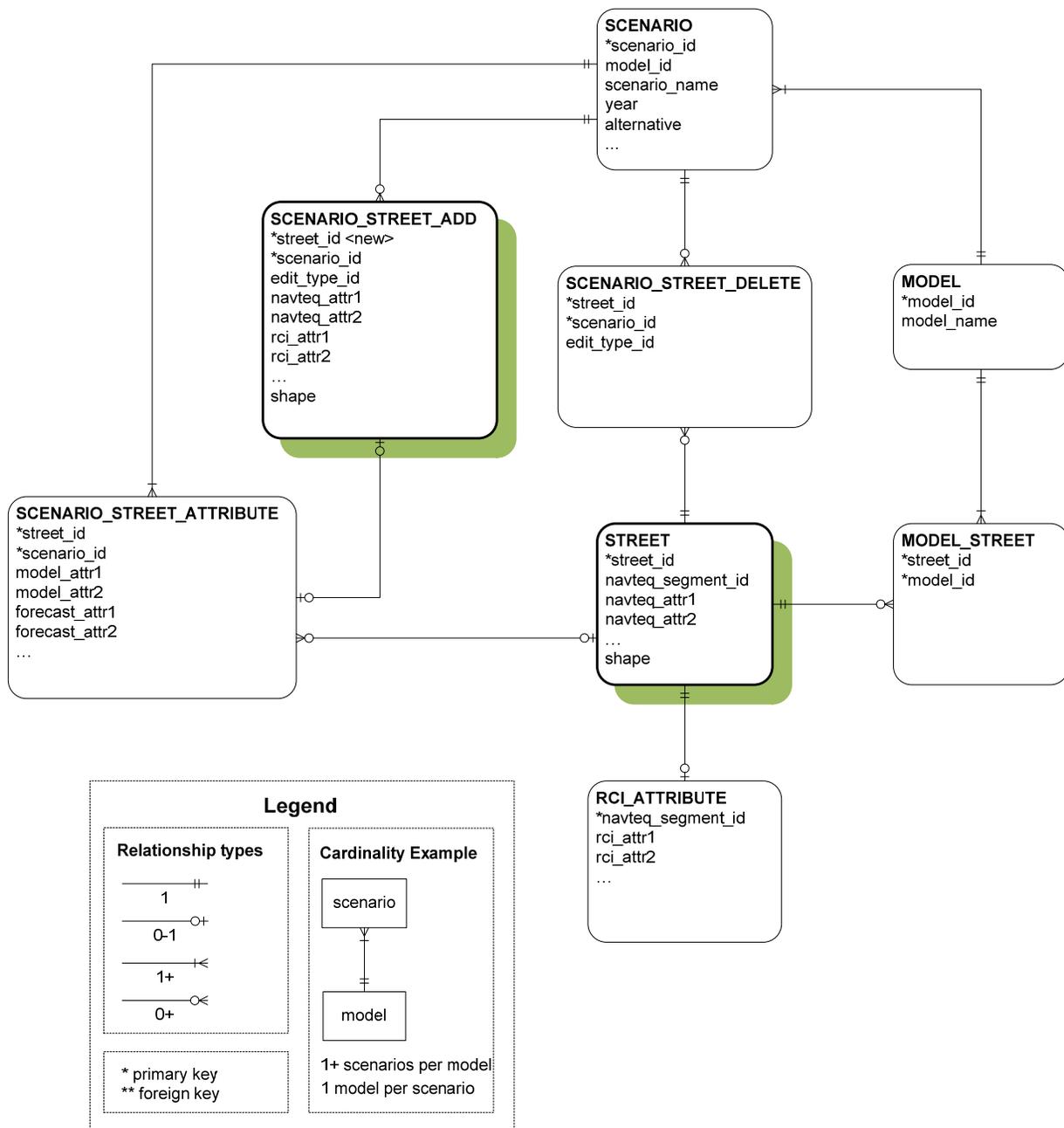


Figure 4-3 MIXS data model

Note that the actual attribute names in SCENARIO_STREET_ATTRIBUTE, STREET, SCENARIO_STREET_ADD and RCI_ATTRIBUTE are now shown in this model. They will be named using the FSUTMS standard framework when MIXS is implemented. The data model presented above is aimed to show the types of information and its fundamental organization to support the concept of MIXS.

4.2.2 Model Network

The MIXS data model described above is organized in a normalized relational structure because it is designed to handle multiple models and scenarios. The modelers will not interact directly with the MIXS database. Rather the structure of the network data that will be extracted and uploaded into MIXS will be much simpler. As shown in Figure 4-4 below the model network will be provided in a single spatial table, one per scenario. In this diagram the model network is called SCENARIO-STREET. The SCENARIO-STREET will contain all the links used for the scenario extracted from the STREET and SCENARIO_STREET_ADD spatial tables. It will contain all the necessary input attributes for modeling and also it will contain the forecast attributes either from a previous scenario or with empty values from the default base scenario.

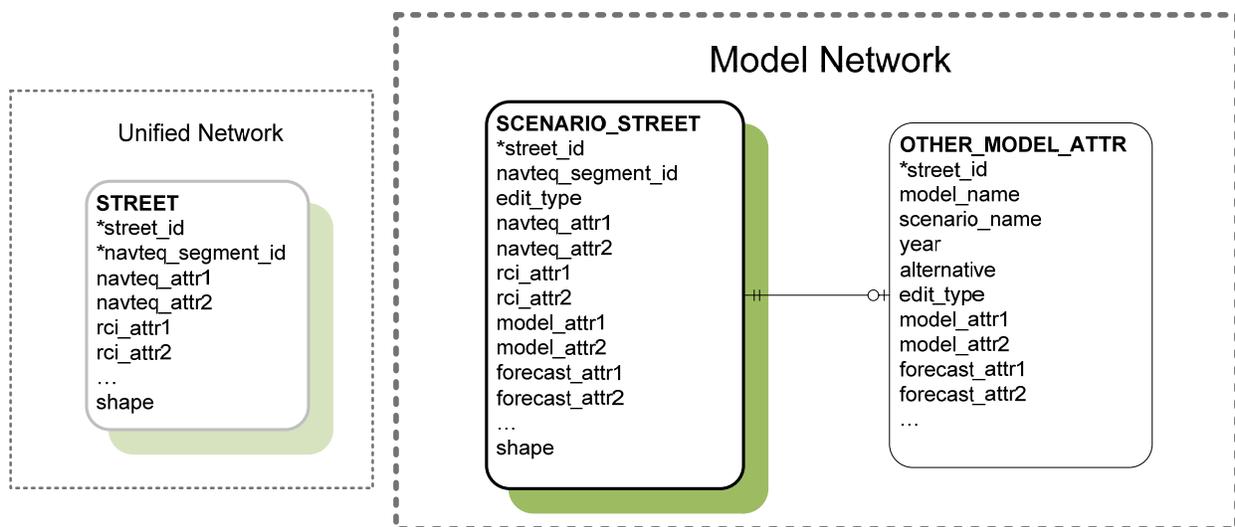


Figure 4-4 Model network

Optionally the attributes of the other models that share the same link with the extracted scenario can be retrieved. These attributes will be available in a related table which in the figure 4-4 above is labeled OTHER_MODEL_ATTR. Modelers can use this table during modeling as a reference to compare the inputs and forecasts and/or modify their model variables to match the ones from other models, especially the input variable such as AADT, speed, number of lanes, link direction, functional class etc. This is one of the direct benefits of the MIXS – it allows modelers to reduce data collection efforts and compare the model outputs with the results of other models that share the same geographic area.

Optionally the entire unified network layer can also be extracted from MIXS. This layer is called STREET in the Figure 4-4 above. Modelers can use this layer as a reference to modify their model by adding more links or using the updated attributes of existing links.

4.3 Tools

Another important component of MIXS framework is a set of tools aimed at facilitating various operations necessary to apply MIXS. The following sections describe each tool, detailing their purpose and their functional characteristics.

4.3.1 Viewer/Explorer

All MIXS users will need to view or explore the MIXS geospatial database. To support this need we recommend development of MIXS Viewer/Explorer tool. This tool will be web-based, interactive and map-centric. It will have the following initial functionality:

- Ability to show the MIXS network either in its entirety or by model/scenario combination
- Ability to show a reference map such as aerial photography or cartographic map
- Ability to navigate the map with ease
- Ability to show a tabular view of the attributes of each link for each model/scenario combination
- Ability to compare links and show differences and similarities in the attributes of the overlapping networks
- Ability to show specific FDOT networks such as SIS, FIHS, NHS or any other network of interest
- Ability to show the FDOT work program links and the related attributes by various planning phases
- Ability to show zones and network connectors and their attributes for participating models
- Ability to show the transit network for applicable models
- Ability to create simple queries

Additional features can be added over time based on users' needs. It is envisioned that the MIXS Viewer/Explorer map-based interface will serve as the "window" into the MIXS and serve as platform to attach the rest of the MIXS tools.

4.3.2 Extract

The purpose of Extract tool is to support users' needs to download the network and related data for any of the models of interest. Figure 4-5 below shows the data model of the extracted network. The Model Network shows the layers that can be extracted. At a minimum the extract

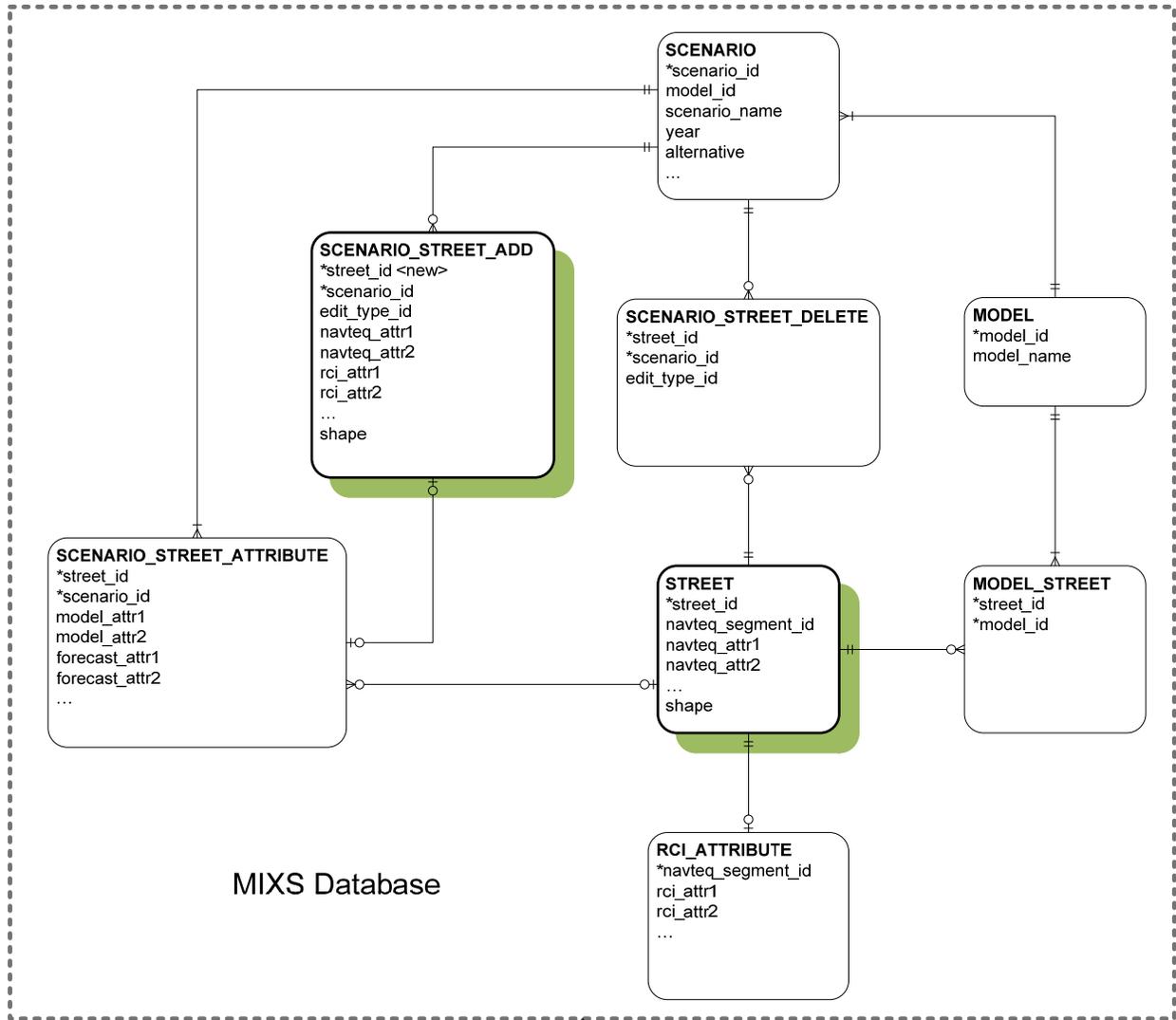
tool will allow users to extract the network layer for a model/scenario combination. The network layer is a GIS layer (Scenario_Street) that contains all the input and output attributes. Optionally, users can choose to download a related table with all the attributes of the shared links, from other participating models (Other_Model_Attr). This table can be used by modelers to compare inputs and outputs and potentially use the information as needed. A third optional layer that can be included in the download is the entire unified street network for the geographic area of interest (Street) that can potentially be used by modelers to add additional links to their network or simply as a reference layer.

It should be pointed out that the extracted Scenario_Street layer will contain any line work that is not part of the unified network but that has been added during the model upload. This line work may include missing links on the unified basemap, FDOT work program links and future projected links. All this information stored in the table Scenario_Street_Add of the MIXS database will be merged with the unified network and properly annotated before the download process.

Figure 4-6 shows a simple mockup to illustrate the extract tool user interface. The users may choose to download a specific scenario for any model. Other options (not shown in the interface) are the ability to download all of the scenarios for a given model and optionally download the table with the attributes of other models on the shared links as well as the entire unified network.

4.3.3 Upload

The purpose of the Upload tool is to allow modelers to upload the modeling results back into the MIXS database. It is expected that the modeling results will be stored in the same GIS format used when data is downloaded using the Extract tool. The users will be able to specify the network layer to upload for any given model/scenario combination. It is recommended that a log file, ideally in tabular form, should also be provided to indicate the changes applied to the network during the modeling process. The CUBE software does have the ability to provide a log of network changes. The tool will have the ability to take the network layer and the log file and load the information in the MIXS database by updating all the related tables accordingly. Due to the complexity involved, the automated upload process may fail for a small percentage of the changes. Therefore, it is expected the complete successful upload may involve some manual effort. The upload process will require close coordination of the MIXS manager with the modelers that are uploading models in the MIXS. A simple illustration mockup of the Upload tool user interface is shown in Figure 4-7.



UPLOAD ↔ EXTRACT

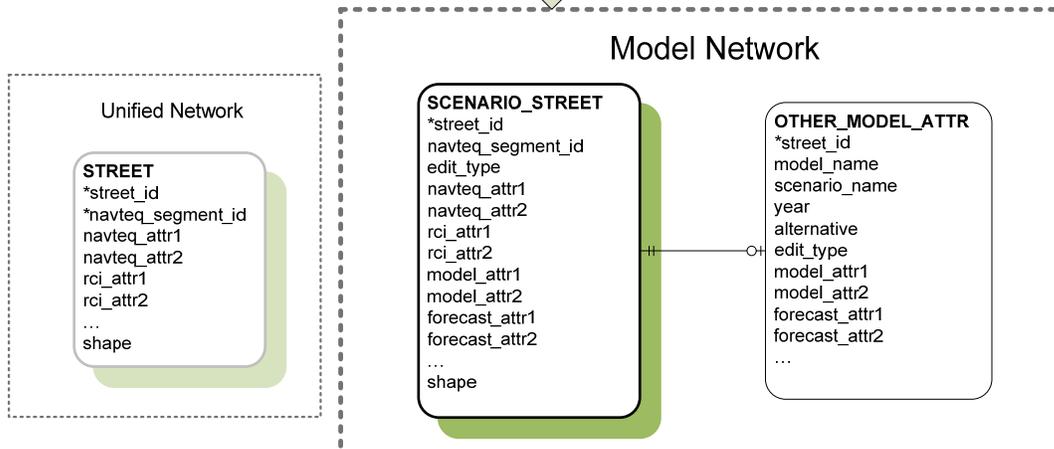


Figure 4-5 UPLOAD/EXTRACT operations

Extract scenario

This step exports all scenario-specific customizations to your model streets. This includes linework, scenario attributes, and forecast attributes.

Model name

Scenario year Alternative

Target shapefile

Figure 4-6 Extract tool user interface mockup

Import scenario

This step imports all scenario-specific customizations to your model streets. This includes linework, scenario attributes, and forecast attributes.

Model name

Scenario year Alternative

Model streets shapefile

Street ID field

Navteq segment ID field

Edit type field

Allowed values: BASE, EXTERNAL, LOCAL, PLANNED, FUTURE

Model attribute 1 Forecast attribute 1

Model attribute N Forecast attribute N

Figure 4-7 Upload tool user interface mockup

4.3.4 Network Selector

The Extract tool discussed above allows users to download the network of their models and optionally attributes of other models on the shared links. However, when exploring the MIXS, modelers may realize that they may be interested in expanding their network with additional links of the unified streets basemap before downloading it for modeling. The Network Selector tool will accomplish this need. It will allow the user to select links of interest along with input attributes stored in the MIXS database and include them in the download. For links that have attributes from more than one model the tool will provide the option to choose the attribute source or optionally include all of them. The Network Selector may eventually be included in the Extract Tool.

4.3.5 Versioning/Update

Handling updates is an unavoidable process that needs to be applied at a certain frequency to keep the MIXS database current. There are two layers of update that will be required: the update of the NAVTEQ/RCI statewide table as explained in the Methodology chapter, section 3.5 *Managing Unified Network Updates* and the update of the rest of the tables in the MIXS database. Handling updates is complex and probably it is going to be the most challenging item in the MIXS implementation and long term maintenance. To reduce the complexity and simplify the update process we propose that for each update, most likely once a year, start with the new copy of NAVTEQ/RCI. Link the new copy to the old copy – the one that is current in the MIXS database – and migrate over to the new copy all the related information. It is highly unlikely that this process can be fully automated, therefore a combined automatic and manual method will need to be applied. The purpose of the Versioning/Update tool is to automate the migration of the MIXS database to the new version of NAVTEQ/RCI. Development of more detailed technical specifications will be needed for the development of this tool once the MIXS database has been populated with at least two models and a new version of NAVTEQ/RCI is available.

4.4 Organizational Structure and Operations

The operationalization of MIXS will require coordination of several components: roles, operations and tools. Figure 4-8 below show the organizational structure of MIXS in which roles, operations and tools are integrated and coordinated to enable successful implementation of model information exchange. The tools are already explained in the section above. This section is focused on the roles and operations.

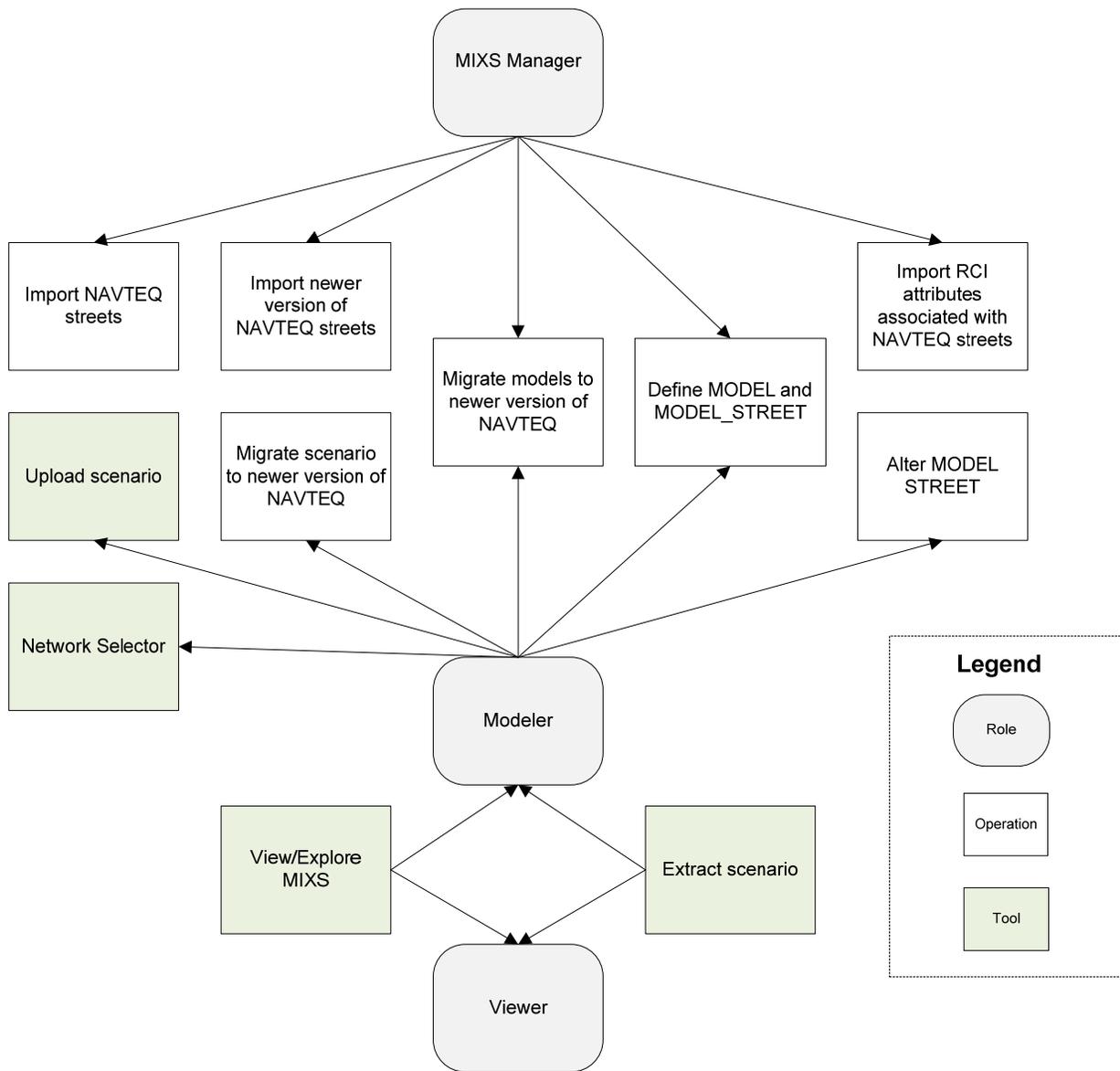


Figure 4-8 Organizational Structure and operations

MIXS Manager will be responsible for management of the MIXS database. Responsibilities of MIXS manager will include:

- Loading/Importing of NAVTEQ streets in the database to create and maintain the STREET layer.
- Loading/Importing of RCI attributes associated with the NAVTEQ streets. The MIXS manager will coordinate tasks with the FDOT Safety Office which develops the RCI table mapped to the NAVTEQ links.

- Developing MODEL and MODEL_STREET tables for each model that gets loaded in the MIXS. This task will be shared and coordinated with each model owner.
- Importing newer versions of NAVTEQ streets and coordinating updates of the NAVTEQ streets to the newer version. Management of update is a major responsibility of the MIXS manager
- Migrating models to newer versions of NAVTEQ/RCI. This task will be closely coordinated with each model owner.

Modeler is a role defined here for the model owners, the one responsible for model development and maintenance. Each model owner is expected to carry out the following responsibilities:

- Populate the MODEL_STREET table with the network links that apply to their model. Some coordination with the MIXS manager may be involved in this task.
- Alter MODEL_STREET table as it may become necessary especially after model updates.
- Migrate models to the newer version of NAVTEQ. This will be accomplished in close coordination with the MIXS Manager.
- Migrate scenarios to the new versions of NAVTEQ. Some coordination with the MIXS Manager may be required.
- Upload of forecast scenarios in the MIXS database when models or scenarios are updated. This will be accomplished using the Upload tool.
- Use the Network Selector tool to choose additional links from the unified network to be considered for inclusion in the future scenarios.

Viewer is a role for the rest of the users interested in accessing the MIXS database to review the models and their future travel forecasts. Viewers have read-only access to the information but can't modify it. Viewers are expected to have the following privileges:

- View/Explore the models loaded in the MIXS database. Viewers will be able to visualize the future travel forecast projections on the map of the unified network. They will be able to view the attributes of each model as well as compare various models to see differences and similarities of input variables and future projections. They will also be able to compare various scenarios for any given model. The view/explore operations will be accomplished through the MIXS Explorer tool.
- Extract scenarios of interest and download them to their computer. This may be useful for transportation planners that are interested in running the models in a modeling package. The extract will be available through the Extract tool.

Note that both MIXS Manager and Modeler can also be viewers i.e. they will have viewer privileges in addition to their other responsibilities:

4.5 Summary

MIXS is a collection of databases, tools and organizational protocols and operations designed to perform the model information exchange by using a unified network approach. The unified network is stored in a relational database that includes all participating models and their input variables and forecast scenarios. The MIXS central database will be managed by a MIXS Manager who will work in close coordination with each model owner to populate and update the MIXS database when models or NAVTEQ are updated. Most users will be able to access information in the MIXS database to visualize and compare models but not modify the information. Model owners will be able to upload and manage scenarios in the MIXS database. Tools will be developed to assist users to perform the expected operations such as a Viewer/Explorer to view information, an Extract tool to download models/scenarios of interest, an Upload tool to upload travel forecast scenarios developed through modeling.

Chapter 5: DISCUSSION

This chapter discusses MIXS feasibility, the factors and challenges that may affect its results, and broader implications of MIXS for transportation planning and FDOT information systems.

5.1 Feasibility of MIXS

Several tests were conducted to assess the feasibility of the proposed MIXS: a small scale proof of concept testing that focused on performing the various expected processes to validate the data model, a proof of concept testing in Cube of the NAVTEQ-based TSM and return of the forecast projection in MIXS expected format, and a review of the NAVTEQ update methods used by the FDOT Safety Office and its applicability to MIXS.

5.1.1 Data model validation

The purpose of the data model validation was to ensure that the proposed MIXS geospatial relational database and the model network data structure were able to store the information as expected during the initial database setup and during the extract and upload processes. A second purpose of the testing was to validate and refine the required functional specifications of the Extract and Upload tools. Testing followed four steps: (1) Development of the MIXS database; (2) Extraction and modification of the model network outside MIXS to simulate future forecasts; and (3) Uploading of the modified model network back into MIXS.

1) Development of the MIXS database (Figure 5-1, a through d): Initially all the tables proposed in the MIXS data model were created in both Oracle and in a standalone file geodatabase. This was done to ensure that MIXS data model can work at both an enterprise level and at an individual level. Next, the Street table was populated with a small fragment of the unified network (Figure 5-1, a). The rest of the tables were populated with the necessary information to simulate two different models that partly share the same links – a regional model (Figure 5-1, b) and a state model (Figure 5-1, c). Additionally some information was added to simulate future links planned by the Work Program (Figure 5-1, d) that don't yet exist in the unified network. Modelers make use of this information for future projections especially those planned future projects that are in the 5-year adopted work program.

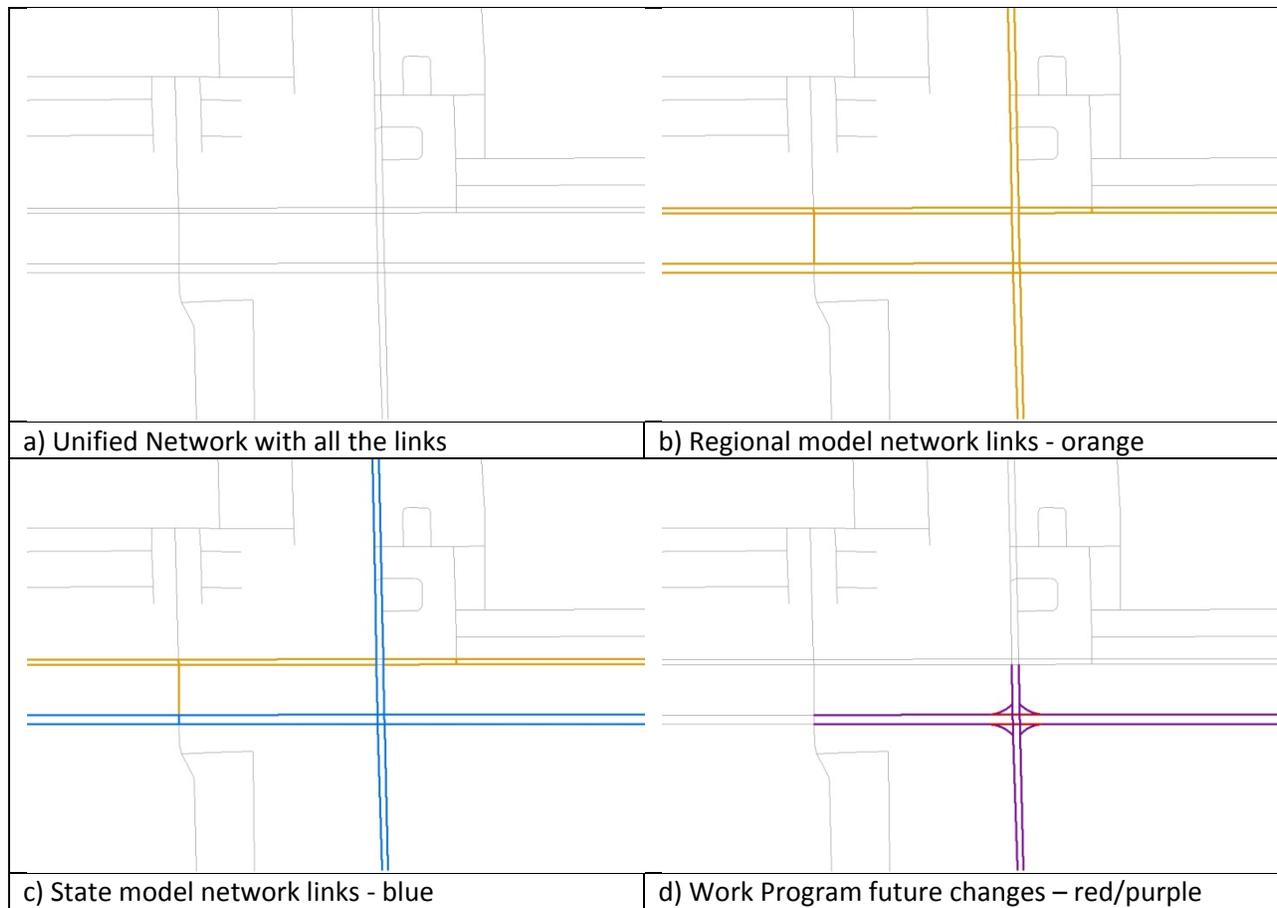


Figure 5-1 MIXS initial database

2) Extraction and modification: After the initial MIXS database was setup, the network of one of the models that was included in the MIXS was manually extracted and modified. The extraction pulled out all the links of the models into a GIS layer that matched the proposed model network data structure (Figure 5-2, a). Work Program links and related attributes were also extracted into another layer (Figure 5-2, b). Next, both layers were modified manually to simulate network changes during the modeling process. Two future scenarios were created – Scenario A (Figure 5-2, c) made use of the Work Program layer and added two new links as a proposed new street and Scenario B (Figure 5-2, d) projected some other future links. The goal of this step was to simulate potential changes of the network to test whether they can be uploaded back into MIXS.

(3) Uploading back into MIXS: The network of both future scenarios was loaded back into MIXS (Figure 5-3). This was accomplished by identifying all changes to the original network. They include attribute changes such as new forecasts on existing roads and all geometry changes to accommodate new proposed roads or changes to the roadway geometry. Such changes may be new lines added, lines that were removed and lines that were modified e.g. if a node was

moved to a new location. All the changes simulated in Scenarios A and B were successfully loaded into the proper database tables. The changes were applied to only one of the models but in two different scenarios. The application of changes to a second model will be no different. It should be noted that this step is one of the most challenging in the MIXS framework because changes need to be detected and loaded cleanly in the database. This step validated successfully that the proposed data model supports the changes while preserving the original database information.

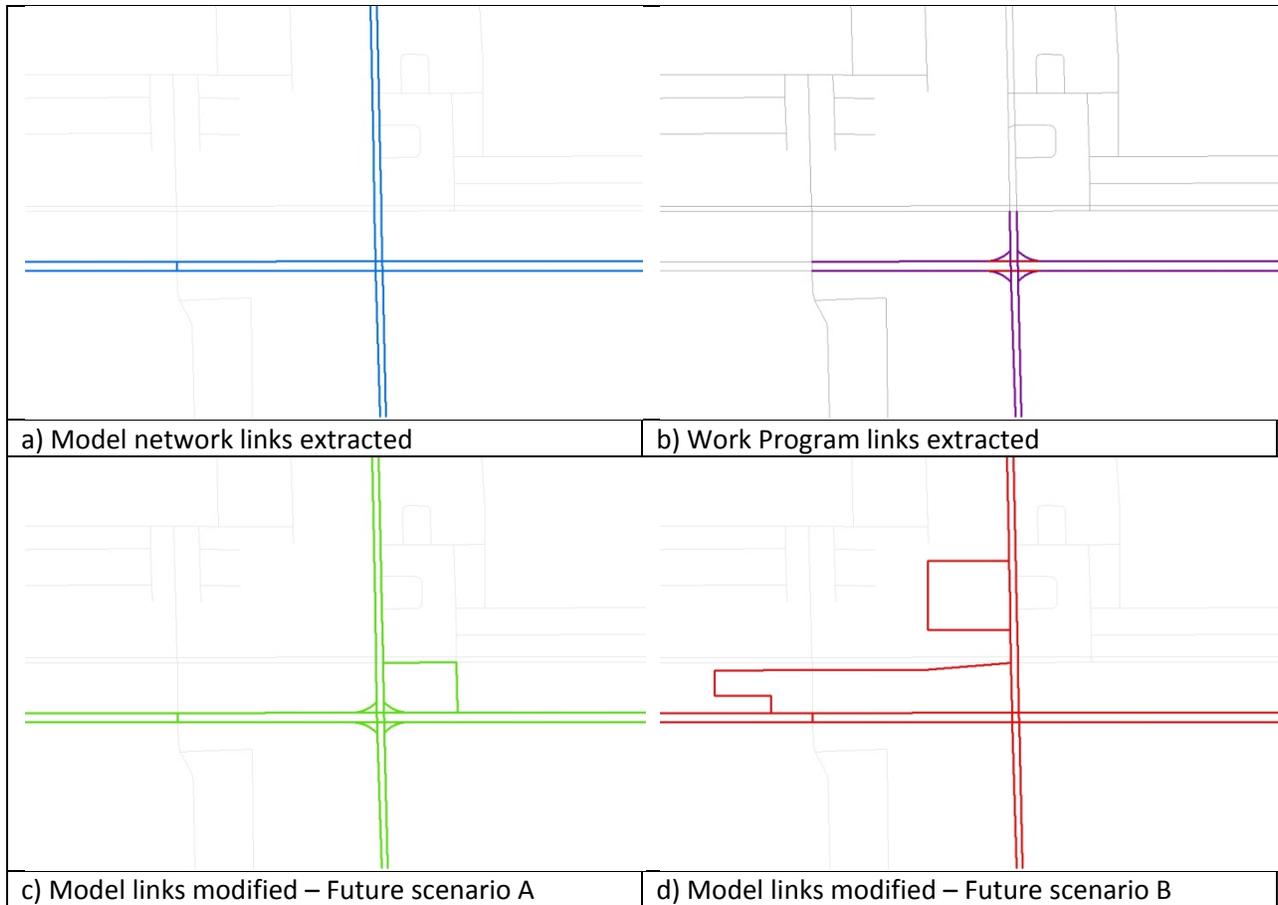


Figure 5-2 Extraction and modification

5.1.2 TSM Cube testing

The second test to assess the feasibility of MIXS focused on using the full network of a model. The purpose of this test was to ensure that a model using the unified network could be read by a modeling package and the future forecasts could be returned back in the expected MIXS format. For this we chose to use the Turnpike State Model. This is one of the two statewide models that was originally using a GIS-based network but different from the unified network.



Figure 5-3 Future scenarios loaded in MIXS

The testing involved three steps: (1) preparing the TSM model for CUBE modeling (2) loading of the model into CUBE and development of a simple proof of concept assignment and (3) exporting the forecast results from CUBE out to a format compatible with the MIXS. A more detailed description of these steps is provided below:

(1) Preparing the TSM network for modeling: The TSM network was initially converted to a NAVTEQ-based network (The details of this conversation are explained in Chapter Three – Methodology under section 2.5.3 *Conflation of TSM to the Unified Basemap*). The converted TSM network was imported into the TSM modeling software, and the modeling software checked for gaps or errors in the network. After the network passed this test, zones were built by merging the TSM network with county boundaries and water features. Polygons were created from the line work of these three datasets, and each polygon/zone was assigned an id by transferring the zone ids from the TSM centroid connectors to the zone polygons. The TSM modeling software checked the validity of the zones and centroid connectors. These three datasets, the TSM network, zones and centroid connectors, were the inputs for CUBE modeling along with assignment and trips tables which were generated by the TSM modeling software.

(2) Loading and testing the model in CUBE: A Cube Voyager script based application was created to streamline and automate the process of converting a network extracted from the MIXS database into a network dataset that could be used in travel demand modeling. This step also includes adding the required centroids and centroid-connectors to the network. Next, a simple traffic assignment was performed on the network created to produce various performance measures such as loaded volumes, congested speed, volume-to-capacity ratio, vehicle-miles traveled (VMT), vehicle-hours-traveled (VHT). Finally, this network is exported out as a shapefile retaining all the original attributes in addition to the attributes created during the assignment process.

(3) Exporting of the forecast results in MIXS format: The forecast results were exported out of CUBE in the same GIS network layer that was passed to CUBE as input. Figure 5-4 shows a fragment of the network before and after CUBE forecasting. As shown the underlying network is the same. Forecast fields were populated with values based on the test assignment performed in CUBE. The goal was to ensure that the unified GIS network can be processed by CUBE and the results can be returned on the same unified network. No calibration or validation of the model itself was conducted because the test was meant as a proof of concept to validate CUBE capacity to use and export the unified GIS network.

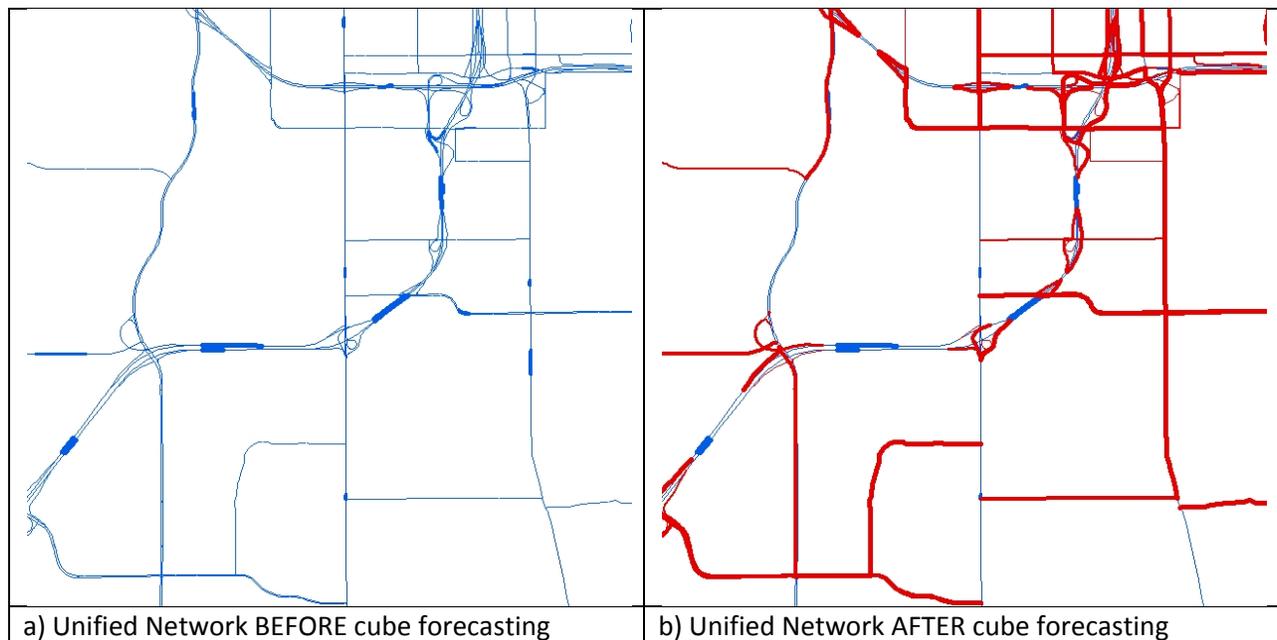


Figure 5-4 Illustration from TSM Cube testing

(TSM traffic volume shown on the unified GIS network before and after Cube forecasting)

5.1.3 NAVTEQ Updates

As with any database the unified network is expected to change. These changes have to be reflected in the MIXS unified network and the participating models. The NAVTEQ and RCI update process developed by the FDOT Safety Office that was reviewed in section 3.5 *Managing Unified Network Updates* of the Methodology chapter can be applied to handle the NAVTEQ/RCI updates for the MIXS database. The annual updates include many attributes that are part of the MIXS data model such as AADT, functional class, speed, number of lanes and direction. Therefore there is no need to duplicate or reinvent the NAVTEQ/RCI update process but rather obtain the updated unified network from the Safety Office to use it for MIXS purposes.

It should be noted that the NAVTEQ/RCI updates in the MIXS will have to be propagated to the participating models in MIXS, a process that will be conducted by the MIXS manager in coordination with each model owner and through the assistance of the proposed Versioning tool described in the Results chapter.

5.2 Factors Affecting the Results

Successful implementation of MIXS is dependent on some factors that can be grouped under two categories: organizational and technical. This section discusses these factors and outlines some expected requirements for implementation of MIXS.

5.2.1 Organizational Factors

The following organizational factors should be considered for the successful implementation of MIXS:

1) *FDOT commitment to lead the effort and provide the necessary resources.* At the heart of MIXS are the central database and the tools that facilitate the use of MIXS. FDOT should commit to support the MIXS database development and maintenance. Many processes, such as updates of NAVTEQ/RCI and corresponding updates to the participating models, will require the MIXS Manager and potentially some assistance by editors to handle the periodic updates. Support for the maintenance of tools will also be needed.

2) *FDOT internal coordination / collaboration among departments.* While MIXS is a system designed to support the needs of Systems Planning and the modeling community, its successful implementation will require collaboration with some other departments. First, it is expected that at a minimum the Safety Office will continue to provide the annual NAVTEQ/RCI updates. Leveraging the NAVTEQ/RCI updates is critical to keeping the cost down and avoiding any duplication. Second, collaboration with the Work Program staff is also critical to fulfill the MIXS design intent and to include Work Program adopted and planned projects into the database. The Work Program projects will need to be projected into the NAVTEQ unified basemap and included in the MIXS. The Systems Planning office currently maintains an inventory of the Work Program. This effort should continue and should be integrated in the MIXS database. The NAVTEQ Work Program project will be one of the major benefits of MIXS because it will provide one place for all the modelers to obtain consistent information on adopted and planned projects, thereby eliminating duplicative and potentially inconsistent re-creation of the same data. Another department that may need to collaborate is Transportation Statistics, which maintains the RCI database.

3) *Modeling community buy-in and participation.* At a minimum, MIXS will be a useful resource to support the Systems Planning office with its statewide planning activities. Systems Planning will benefit by including in the MIXS the Florida Statewide Model and the Turnpike State Model. However, MIXS is designed to be a resource for all transportation planners in the State of Florida. Most models in Florida are regional and local and are developed and used by non-FDOT transportation agencies such as MPOs. MIXS benefits will be maximized once regional and local models participate in it. The benefits of MIXS should be presented to the modeling community through various venues such as the Modeling Task Force and other dissemination/outreach activities. The buy-in and participation will eventually be achieved by getting the broad consensus of the modeling community and by showcasing concrete implementation of MIXS in practice.

4) *Model owners' willingness to participate in the MIXS.* Once the regional and local agencies agree to participate, ultimately it will come down to the model owners to embrace and commit to participate in the MIXS. It is important to point out that this commitment involves concrete requirements and tasks to be implemented. As explained in the Results chapter under section 3.5 Organization Structure and Operations, the model owners will be obliged to commit to certain tasks once their models are included in the MIXS as well as to follow the established standards necessary to operate within the MIXS network.

5.2.2 Technical Factors

The following are important technical considerations for the successful implementation of MIXS:

1) *One-time conversion of any model to the unified network is required.* Using the unified network is a prerequisite for any model to participate in the MIXS. No model can participate in the MIXS unless they are converted from their current network (stick or GIS-based) to the unified network. This applies mostly to regional and local level models since the statewide models already have a version that's based on the unified network. Regional or local models have two options for this conversion:

(a) One option is to conduct a *typical conflation* as explained under the Methodology chapter. This may be the most time consuming option but it has the main advantage that the attribute values are ensured to come from their old model. This may be an option for organizations that have the confidence that their old model is accurate and they want to maintain the values that they have. This option will only change the network geometry while maintaining the original attribute values.

(b) A second option is to construct the network from the *existing networks of state models*. Typically regional or local models have more links than the state models and it is likely that all links used in a state model will be part of a more detailed model i.e. for any given geographic area the links of the state model generally are a subset of the links of the regional model for that area. A regional model can develop the network by starting with all the links of the state model for their geographic area and use *conflation* to append the rest of the links along with their attribute values. In this case organizations should feel comfortable that the attribute values of the links from the state models generally match theirs.

It should be noted that a typical conflation (first case) may require more effort than using the network of the state models. Each organization should carefully review their options and consider conducting a small scale pilot assessment before moving forward with full scale conversion.

2) *Concerns regarding moving to NAVTEQ network for modeling*. So far, there have been at least three efforts to migrate models from a stick or GIS network to the NAVTEQ network. These efforts include the conversion of the TSM model (explained in the Methodology chapter under section 2.5.3 *Conflation of the TSM to the Unified Basemap*), the conversion of the Florida Statewide Model and the conversion of SERPM model. These efforts have not been without challenges. Issues with the NAVTEQ network identified from these efforts include:

- Occasional missing links
- Occasional miscoding of links e.g. one-way vs. two-way
- Centroid connectors to divided links (dual centerline) should be established properly
- NAVTEQ lack information on turn penalties. These will have to be coded.

Concerns have been brought up about expected increased effort for coding of link attributes. The use of dual-links for major roads may increase the complexity of intersections and centroid connection to the network which may translate in more effort for data preparation. Similarly, overlaying of bus routes on this network may also create additional data preparation overhead.

Another concern is the longer computing time when using the NAVTEQ network due to larger number of links. To further assess this issue some CUBE preliminary testing was conducted to explore methods for aggregating or consolidating links to reduce computation time using the SERPM model. Below are some rough preliminary results based on different methods used:

- NAVTEQ on the fly consolidation - 91 seconds
- NAVTEQ pre-consolidated (add zones and consolidate) - 53 seconds
- NAVTEQ pre-consolidated (consolidate and add zones) - 48 seconds

- Existing Cube network - 36 seconds

More experimentation will be needed with a completed NAVTEQ network for more definite results.

It is also important to point out that network chaining may require shifting the point of connection of zone centroids to the network. Therefore chaining should be applied using the exact same variables – e.g. area type, facility type, speed, number of lanes - regardless of the modeling package so that the resulting chained segments are identical and therefore can be used in data exchange. Otherwise, chaining can result in creating different uncoordinated outcomes, which will hinder the exchange process.

The preliminary TSM model testing in CUBE showed that the NAVTEQ network can be used for modeling by the CUBE modeling software. However, the concerns highlighted above are valid and should be addressed in order to ensure the accuracy and validity of modeling results. Although addressing these issues will require some effort, use of the same unified network for models that share the same geographic area should offset that effort by eliminating duplication in data preparation and maintenance.

3) Handling of NAVTEQ updates. After organizations have developed and finalized a working model using the NAVTEQ network once, the handling of updates is one of the ongoing tasks that will have to be addressed periodically. While the frequency of the updates may depend on many factors, a yearly update is the minimum expectation for the NAVTEQ network. The NAVTEQ updates will need to be propagated to all relevant files in each of the participating models.

At present the updates of the NAVTEQ network are accomplished partly programmatically and partly manually by DOT editors. FDOT has developed a method to determine what has changed in each new version of NAVTEQ before the updates can be applied (See section *3.5 Managing Unified Network Updates* in the Methodology chapter). However these updates can be done faster and more efficiently if the NAVTEQ vendor provides a list of changes along with the new versions of the network. These changes are delivered in what is called delta tables or change tables. It is expected the new contract with the vendor will include a requirement for the vendor to provide these tables and it is very likely that when MIXS is implemented these tables will be available.

4) Handling of network modifications. Changes are applied to the network during travel forecast modeling in Cube or any other modeling package. The MIXS data model has provisions to store these changes using the concept of scenarios. The updates may include attribute changes for existing links and/or proposed new links for future roads. Cube can track any changes to the network during modeling and make them available through log tables. These

tables are in text format and metadata are provided to help understand how the changes are recorded. The proposed Upload tool (see 4.3.3 *Upload* in the Results chapter) will utilize these log files to identify the changes and update the MIXS database accordingly.

5) *Handling of analysis zone and centroid connectors.* This research focused on the network portion of the models and looked into developing an information exchange system that can facilitate the information exchange process through a unified network solution among models that share the same geographic area. Obviously full functional models should include analysis zones and centroid connectors. Exploration of an information exchange system for analysis zones was not in the scope of this study. At present all the models have their own zones which are not structured in any particular way that can enable sharing. We believe that a unified zone generation method and a hierarchal structuring of zones in a parent-child relationship would be suitable to accomplish zone information exchange however more research is required to explore this issue in depth. For now, zones and connections can be stored and retrieved in MIXS as flat files for each model. The data model can be expanded to accommodate zones and connectors during the pilot implementation phase.

6) *Network Nodes.* Nodes are not included explicitly in the data model at this time. The z-level attribute of the NAVEQ node layer should be used to code NAVTEQ links to properly determine network connectivity such as to detect overpasses or underpasses. The node layer is available in NAVTEQ and can be included as a layer in MIXS for reference. For modeling purposes nodes can be generated by CUBE for the needs of the model. In this research it was assumed that nodes will be managed by CUBE. No specific needs were identified that warranted storing and managing nodes specifically other than including them as they are in the MIXS database.

7) *Transit.* At present the MIXS data model doesn't address the handling of transit which is used in some regional models. However, the current structure can easily accommodate transit by organizing the information in three tables: (a) The first table will contain an association between a bus route identifier and corresponding NAVTEQ segment identifier (LINK_ID), a one-to-many relationship; (b) the second spatial table will have the locations of stations and their attributes and (c) the third table will contain the association of station identifier to route identifiers, a many-to-many relationship. These tables can be constructed and implemented during the pilot implementation phase.

5.3 Implications of MIXS

We expect that if implemented MIXS will have a broader impact for both travel demand forecast modeling and more broadly for transportation planning and DOT information systems.

First, the implementation of MIXS will lead to overall improvements in quality and consistency of the information used for travel forecast modeling. The ability to present the input variables and forecast projections from various models on the same reference system – the unified network – will help highlight the differences and commonalities and hopefully bring modelers together to start a dialog about opportunities for convergence, standardization and unification of data and assumptions (when applicable) that will result in better and more consistent models. The use of MIXS can lead to the improvement of the NAVTEQ unified network as well. The MIXS data model accommodates additions of local roads that may be missing or incorrectly represented in NAVTEQ. This information can be shared with the commercial vendors to make corrections and improve the quality of the unified network.

Second, there is an opportunity to link MIXS with Cube Cloud. Cloud computing in general has gained wide acceptance and is rapidly expanding in many application areas including transportation. Commercial products for travel forecast modeling such as CUBE and TransCAD are offering opportunities to conduct modeling in cloud-based computers. Similar trends are happening in the GIS industry with consumer products like Google Maps or professional GIS systems like ESRI's ArcGIS. MIXS's concept of using a unified basemap and centralizing the storage of multiple models driven by the need to share data and share knowledge in order to reduce duplication and improve the results is compatible with cloud computing which centralizes computing resources in order to increase speed, consistency and collaboration opportunities. Linking MIXS with Cube Cloud will release modelers/planners from many database management and software update tasks and redirect the gains to a greater emphasis on modeling itself. It will also help develop a broader consistency and standardization among the model's data and results and foster better collaboration. One can envision, for example, a modeler using Cube Cloud would load the model network to Cube Cloud from MIXS rather than from the individual computer. This will free individual computers from storing data and dealing with frequent software installation and updates. It should be noted that while modelers will be able to use MIXS for data and Cube desktop for computation or use Cube Cloud without MIXS, an integration of MIXS and Cube Cloud will create a unique synergy that will leverage data and the computation engines to produce greater value to the modeling community.

Third, MIXS can serve as a catalyst for greater use of the unified basemap as a platform for FDOT data visualization. The association of the RCI with the NAVTEQ streets creates opportunities to visualize various DOT networks such as SIS, SHS, NHS and FIHS networks with forecasted travel volume for future years on the MIXS unified network. Additionally the Work Program planned projects can be visualized on the same network. Moreover, Safety's Office traffic crashes are already mapped and displayed on the same network. The integration of all this information under one reference system (NAVTEQ network) becomes a useful resource for transportation planners and modelers. It is our hope that this tangible benefits will serve as

incentive for FDOT to start laying out a transportation planning information system that integrates a geographically accurate network as a basis not just for modeling but more broadly as a truly unified reference system for other planning, design and construction activities.

5.4 Summary

The MIXS' data model was validated by a small scale manual testing of expected operations that included population of the database, extraction of a model network out of MIXS, modifications of the network to simulate forecasted volumes scenarios and uploading of the forecasts back to MIXS. The testing concluded successfully that the proposed MIXS data model supports the proposed model information exchange framework. A second test used TSM – a full scale NAVTEQ-based model - to ensure that models that use the unified network could be processed by a modeling package and the future forecasts could be returned back on the input network which is supported by MIXS. This test concluded successfully as well.

Successful implementation of MIXS will depend on several organizational and technical factors. Organizational factors include FDOT commitment to lead the effort and provide the necessary resources, FDOT internal coordination / collaboration among departments, modeling community buy-in and participation and commitments of model owners to follow the requirements and perform certain tasks defined in the MIXS framework. From the technical point of view successful implementation of MIXS will be dependent upon several factors. Each model that participates in MIXS will require one-time conversion to the unified network. Annual updates of NAVTEQ and its associated RCI and model information will be required. The use of NAVTEQ streets as the network layer for modeling presents some solvable technical challenges that will require some effort. However, the benefits of using a unified network for transportation modeling may offset such effort in the long term. Analysis zones and centroid connectors can be stored as flat files in the MIXS until more research can determine a unified solution for development and maintenance of shared analysis zones. Support for transit information can be easily added to MIXS database during the pilot implementation phase.

It's expected that if implemented MIXS will have several positive implications for travel demand forecast modeling. Implementation of MIXS will lead to overall improvements in quality and consistency of the information used for travel forecast modeling. The use of the unified network will create an environment that can promote convergence, standardization and unification of data and potentially modeling assumptions and result in better and more consistent models. The use of MIXS can also lead to an improvement of the unified network itself by providing a mechanism for locals to log problems found in the network and supply them to the commercial vendor for corrections. Moreover, MIXS may have implications related

to cloud storage and computing. Linking MIXS with Cube Cloud will release modelers/planners from many database management and software update tasks and redirect the gains to a greater emphasis on modeling improvements. The MIXS & Cube Cloud synergy will also help develop a broader consistency and standardization among the model's data and results and foster better collaboration.

MIXS can also have broader implications for transportation planning and DOT information systems. MIXS can serve as a catalyst for a greater use of the unified basemap as a platform for FDOT data visualization under one reference system (NAVTEQ network). At a minimum this may include visualization of forecasted travel volume and related variables for future years for SIS, SHS, NHS and FIHS networks as well as the FDOT Work Program planned projects.

Chapter 6: CONCLUSIONS & RECOMMENDATIONS

A summary and the conclusions of the research are presented below followed by some recommendations for future implementation of MIXS.

6.1 Summary & Conclusions

The purpose of this study was to address the problem of the discrepancy among the networks used by different models at state, regional, and local level. The use of independent networks by the models that operate on shared roadways creates data processing redundancies and difficulties in sharing inputs, detecting errors, and comparing forecast projections. To address this issue, two options were explored: (a) keeping independent networks in place but developing associations among them in order to facilitate information exchange and (b) using one unified common network for all models. It was concluded that the second method is superior and more sustainable in the long run. Florida already has a unified street network for all roads, which can support the second solution. However, the availability of a unified network per se is not sufficient to enable information sharing. To establish a successful information exchange process, the research team developed a framework for a Model Information eXchange System or MIXS.

MIXS's proposed framework includes a database model, an organizational structure, and tools to support the information exchange operations. The unified network is stored in a geospatial relational database that includes all participating models and their input variables and forecast scenarios. The MIXS database will be centrally managed but in close coordination with each model owner that will have to contribute to model maintenance and updates. Web-based tools will be developed to assist users to visualize and compare models, extract models/scenarios of interest, and upload future projections.

The MIXS' data model was validated by a small-scale manual test of expected operations that included population of the database, extraction of a model network out of MIXS, modifications of the network to simulate forecasted volumes scenarios and uploading of the forecasts back to MIXS. The testing demonstrated that the data model can support the proposed model information exchange system. A second test used a full-scale NAVTEQ-based model and demonstrated that models that use the unified network can be processed by a modeling package and the future forecasts can be returned successfully on the same unified network.

Successful implementation of MIXS will depend on several factors. They include commitment of FDOT to lead, develop internal collaboration among relevant departments and provide the

necessary resources to support MIXS. Additionally it is important to gain modeling community buy-in and participation and commitments of model owners to follow the requirements and perform the tasks defined in the MIXS framework. From the technical point of view a one-time conversion to the unified network will be required for any model to participate in the MIXS. Although migration to MIXS is not without challenges, most technical problems considered can be resolved.

If implemented, MIXS will create an environment that promotes convergence, standardization and unification of data and potentially the model assumptions and ultimately result in better and more consistent models throughout the state. By storing a unified network centrally the MIXS framework also creates a natural opportunity to link to a cloud modeling engine which will release modelers/planners from many database management and software update tasks and redirect the gains to a greater emphasis on modeling improvements.

Lastly, MIXS can have broader implications for transportation planning and DOT information systems. MIXS can serve as a catalyst for a greater use of the unified basemap as a platform for FDOT data visualization under one reference system (NAVTEQ network). At a minimum, this may include visualization of forecasted travel volume for future years for SIS, SHS, NHS and FIHS networks as well as the FDOT Work Program planned projects.

6.2 Recommendations

This research explored and confirmed the feasibility of MIXS. It provided a framework and a proof of concept. To implement MIXS in practice a follow up pilot project is recommended. Below are some recommended tasks for the MIXS implementation pilot:

- Populate the MIXS database initially with three models: TSM, SWM and SERPM.
- Populate the MIXS database with the future Work Program information relevant to forecast modeling starting with the 5-year adopted projects.
- Develop MIXS web-based tools – MIXS Explorer/Viewer, Extract, Upload and Versioning
- Develop a user guide for beta testing
- Explore the feasibility and implementation of linking MIXS and Cube Cloud

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Appendices

Appendix A. Associating FDOT LRS with the Unified Streets Basemap

Appendix B. Conflation of TSM to the Unified Streets Basemap

Appendix C. Correcting Conflation Errors

Appendix D. Managing the Unified Street Basemap Updates

Appendix

A. Associating FDOT LRS with the Unified Streets Basemap

Associating FDOT LRS with the Unified Streets Basemap

This section details the process building a Linear Reference System(LRS) on the NAVTEQ Street Network based on the FDOT LRS Routes defined in FDOT's Roadway Characteristic Inventory (RCI). The graphic below gives an example of the detail in the NAVTEQ street network.

- FDOT LRS Routes (FDOT Transportation Statistics Office (TSO) Planning Base Map) are shown in pink.
- The NAVTEQ street network is shown in blue.
- The FDOT Transportation Statistics Planning Base Map was used as the guide and source for tagging the NAVTEQ Street Network segments with Roadway Id, the FDOT route identifier.

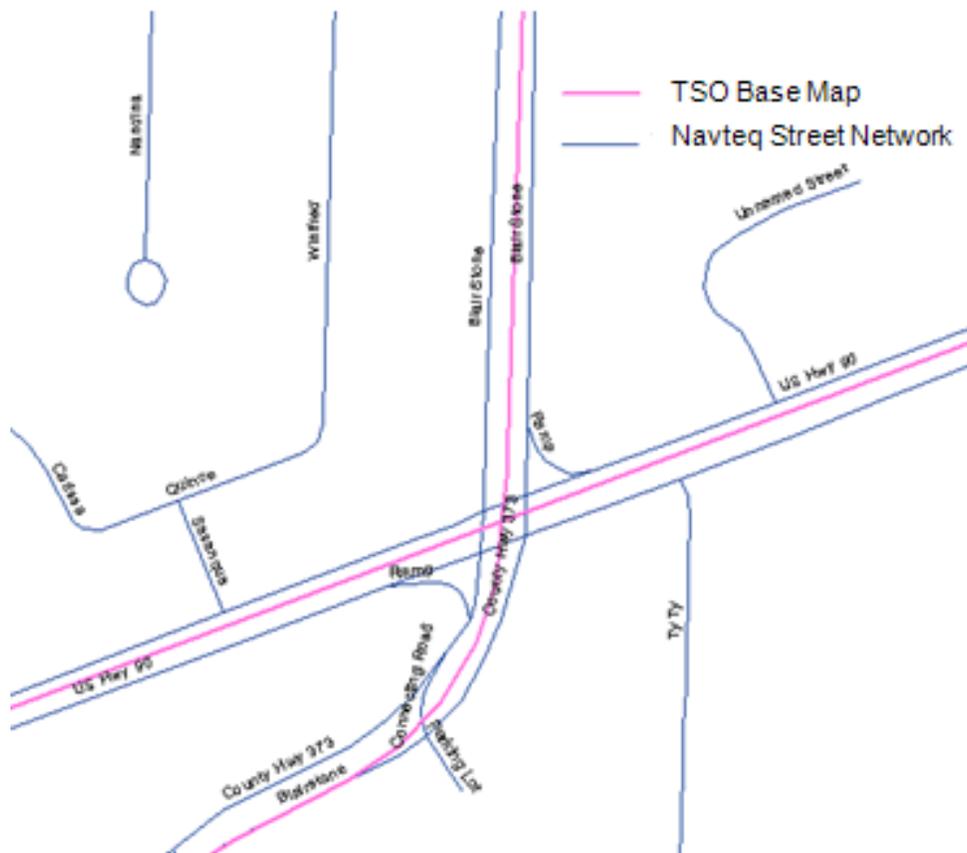


Figure A-1 TSO Basemap and Navteq

Fields necessary to build a LRS were appended to the NAVTEQ street network. Figure A-2 shows some of the fields that were essential for creating the LRS.

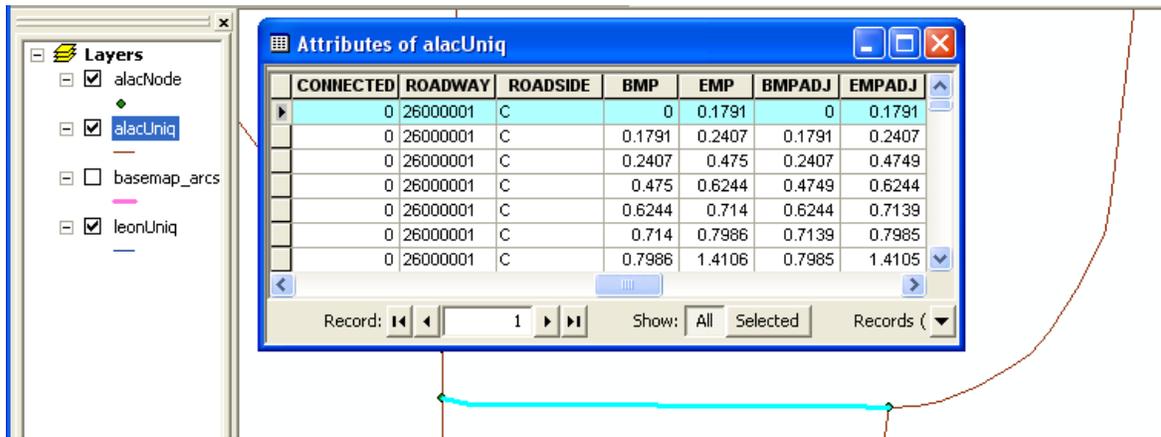


Figure A-2 Essential fields for creating the LRS

The first step is to transfer the FDOT Roadway Ids in the System Planning Base Map to NAVTEQ Street segments. Figure A-3 and Figure A-4 illustrate how roadway ids from the TSO basemap (shown in pink) were transferred. If a FDOT Route is represented in the NAVTEQ Street Network as a double alignment, both sides received the FDOT Roadway Id.

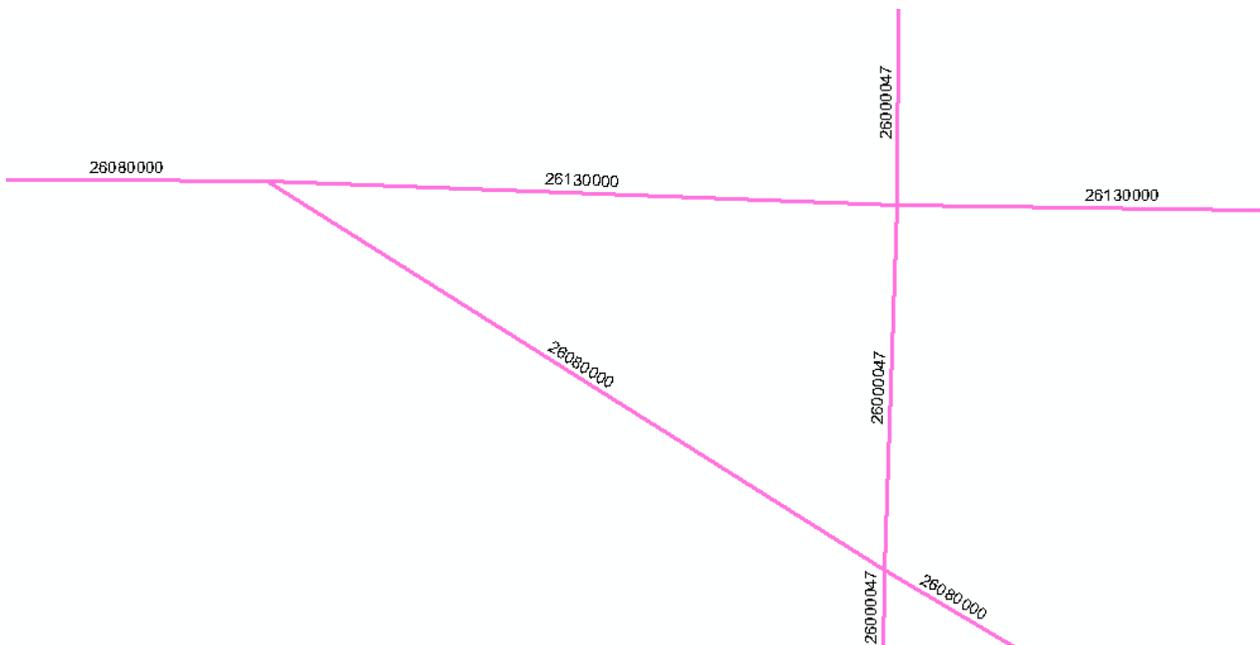


Figure A-3 TSO basemap

Since FDOT uses RoadwayID, milepost to locate any feature in RCI, FDOT maintains an intersection point dataset that stores official FDOT mileposts for key intersections. FDOT Straight line diagrams are a visual representation of these intersection points. FDOT assigns an official milepost to intersections along a route, and these mileposts may or may not agree with the linear length of the road as defined by NAVTEQ. To insure that FDOT mileposts will override mileposts calculated from NAVTEQ linear lengths, FDOT calibration points were snapped into the street network and GIS routines integrated these calibration points to populate another set of milepost fields: BMPADJ and EMPADJ. Figure A-6 below shows the relationship between BMP/EMP which are based on linear lengths of NAVTEQ segments and BMPADJ/EMPADJ which have been adjusted based on RCI information.

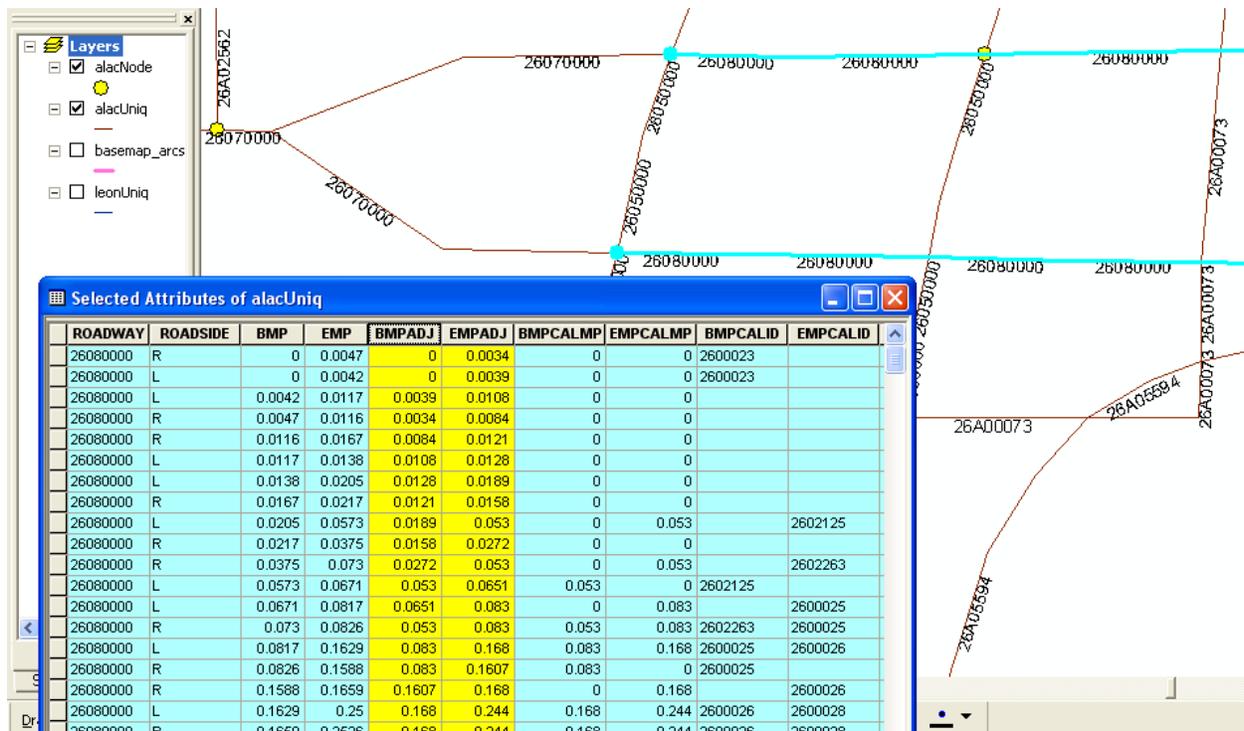


Figure A-6 Relationship between BMP/EMP and BMPADJ/EMPADJ

The effect of integrating these points into the LRS on NAVTEQ is illustrated in the following example.

In Tallahassee, at the intersection of Mahan/US 90 and Hi Lo, there is a traffic light (Figure A-7).

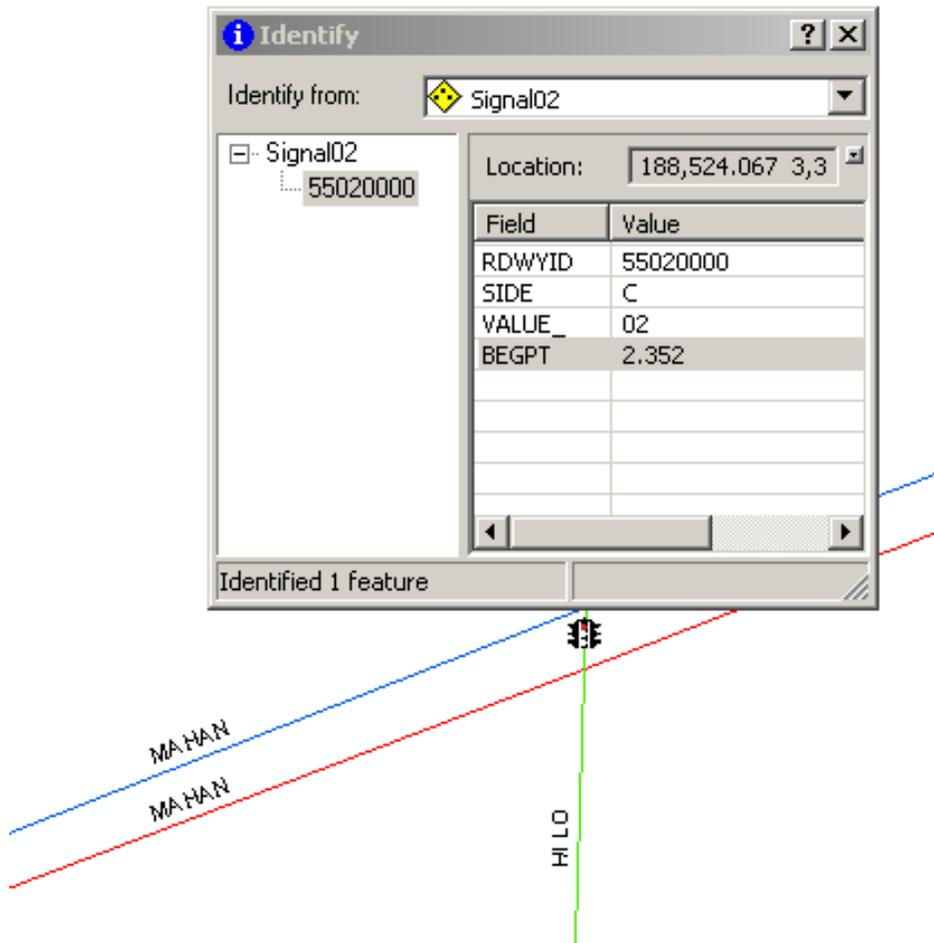


Figure A-7 Intersection of Mahan/US 90 and Hi Lo

In RCI, the location of the traffic light is defined as RoadwayId 55020000, Milepost 2.352.

Calibration nodes from RCI have been snapped to this location in NAVTEQ. The effect of these calibration nodes is shown Figure A-8 below.

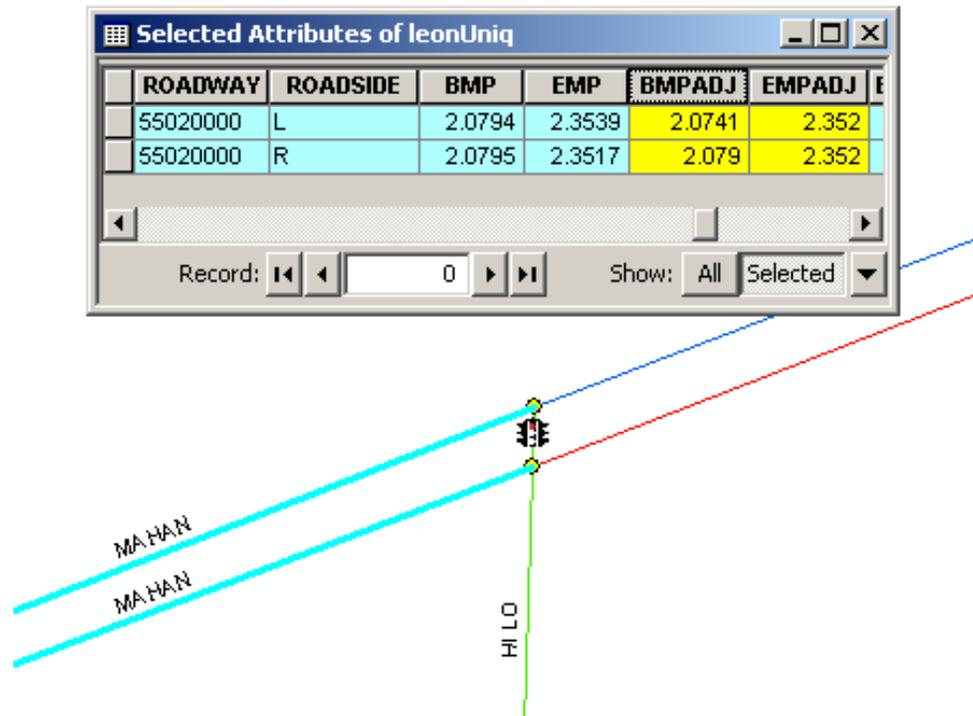


Figure A-8 Effect of calibration nodes

The calibration nodes have forced the EMPADJ of both the left and right sides of the Mahan (the two segments shown above that are selected in light blue) to be 2.352. The LRS is built using the BMPADJ/EMPADJ fields. When a user uses the RCI traffic light record as an event theme on the LRS on NAVTEQ the traffic light defined at RoadwayId 55020000, Milepost 2.352 will appear exactly at the intersection of Mahan and HiLo. Without the calibration node, the ending milepost on the north side is 2.3539 and on the south side it is 2.3517 (the BMP/EMP fields). If the LRS did not have access to the BMPADJ/EMPADJ information and used the BMP/EMP fields the traffic signal would be placed on either side of the intersection. With the calibration nodes, the signal will be at the intersection.

The final step is to build the routes using ESRI's ArcToolBox/CreateRoutes routine (Figure A-9).

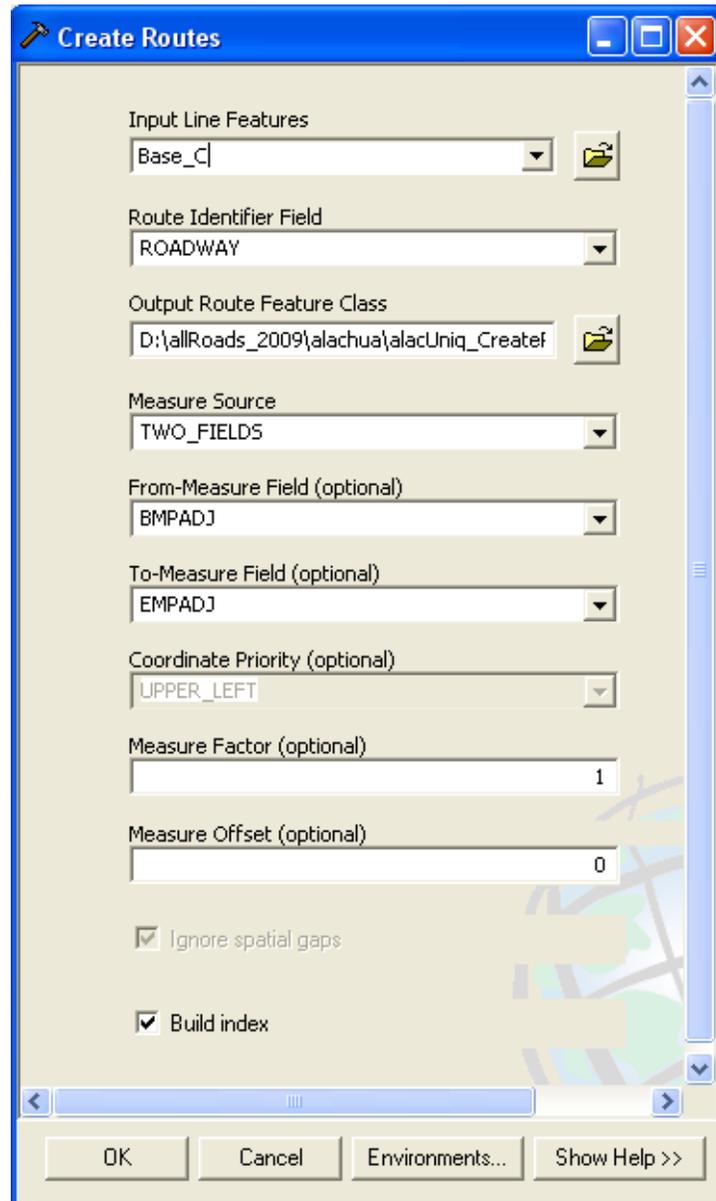


Figure A-9 Building the routes

- Three linear references are created.
- One for ROADSIDE="C" segments
- One for ROADSIDE="L
- One for ROADSIDE="R"

- For all three the Route Identifier Field is ROADWAY
- The From-Measure Field is BMPADJ
- The To-Measure Field is EMPADJ

Lessons Learned

The more calibration nodes that can be included the better. Once the FDOT calibration nodes are snapped to NAVTEQ segments, The FDOT calibration information can be transferred directly to the NAVTEQ zlevel nodes. This can help to migrate this information from NAVTEQ version to NAVTEQ version. Because divided roads have varying linear lengths on each side of the road, more calibration nodes placed on both sides of the road will help remove this variance.

Appendix

B. Conflation of TSM to the Unified Streets Basemap

Conflation of TSM to the Unified Streets Basemap

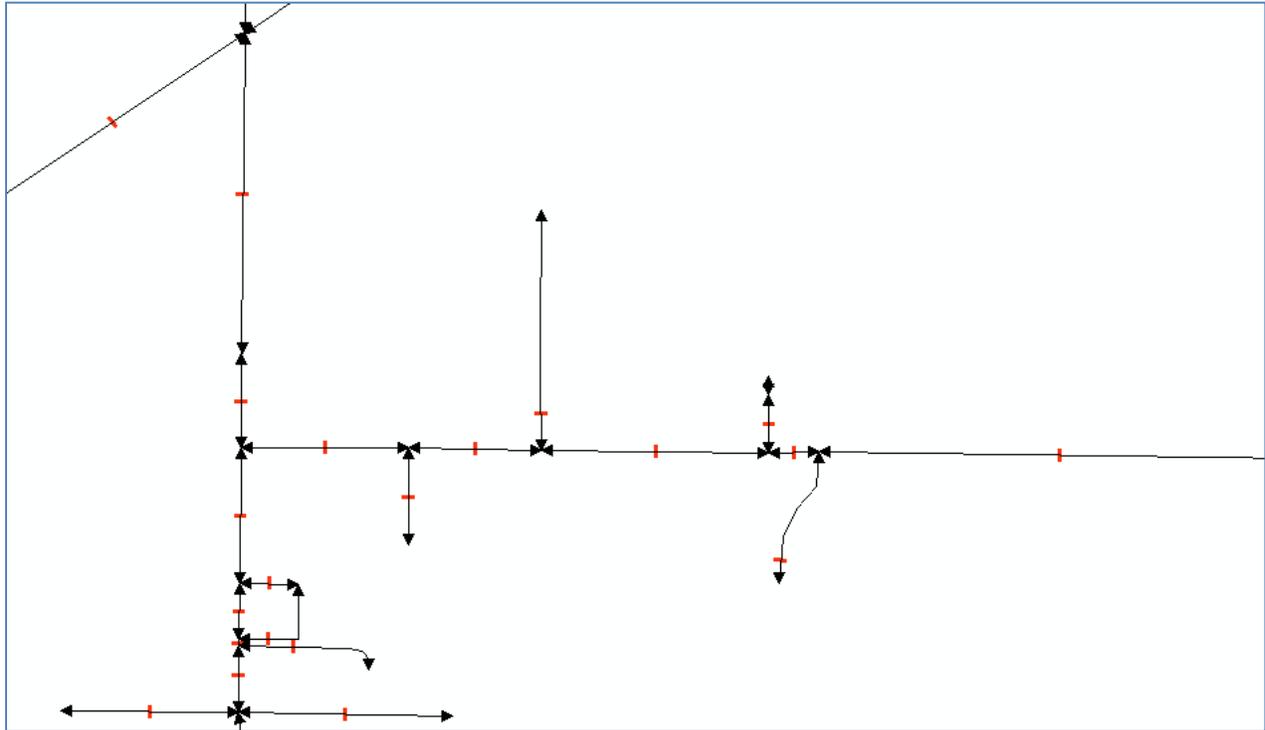
The purpose of this section is to describe the steps of conflating two GIS linear networks so that attributes can be transferred from one network to the other. This procedure is not dependent on a particular GIS network, and can be employed as long as the two GIS networks are spatially close to each other. The overall success of the conflation procedure is directly related to how close one network is spatially to the other, and how well features in one network are represented in the other.

The software requirements for this procedure are ArcMap and Microsoft Access. The GIS networks should be ESRI compatible (shapefile or geodatabase format).

One of the first requirements of the user is to identify which linear network will be the source and which will be the target. For each feature in the target network, this procedure will build a relationship table that defines which feature in the source network is linked to the target feature. If the requirement also includes transferring attributes from the target network back to the source, then this procedure can be rerun with the two networks swapping roles. In the second run, the source becomes the target and the target the source.

Overview of the Conflation Algorithm

For each segment in the target network a new “Seeker” line is created that establishes a bridge between the source and target networks. A “Seeker” line is created perpendicular to a segment in the target network.



- ←→ Target segments symbolized with arrowheads at start and end of segments
- “Seeker” line created perpendicular to target segment

Figure B-1 Target segments and seeker lines

Here is an example of the process to move attributes from the source network to one segment in the target network.

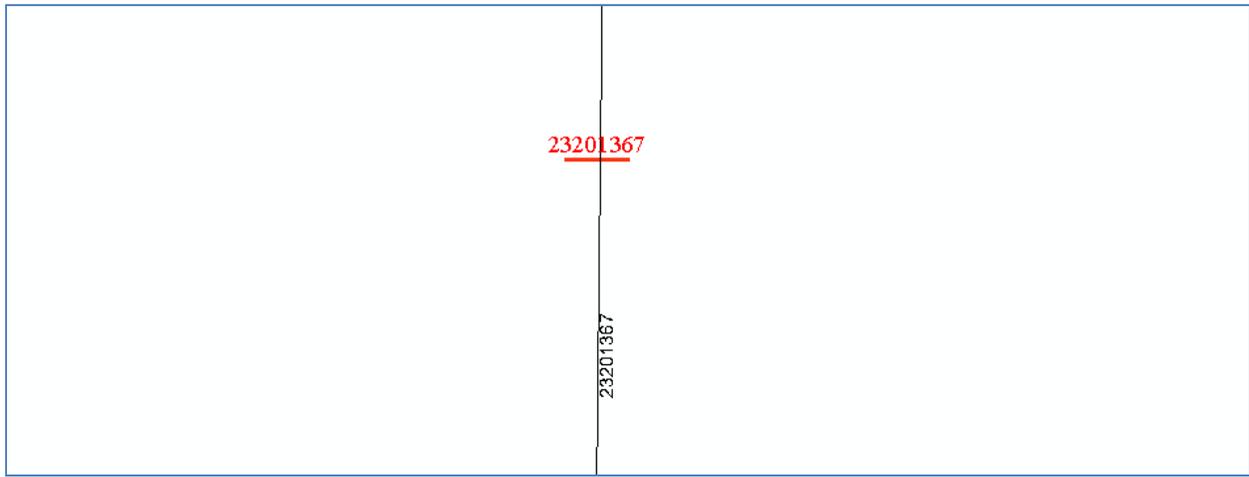


Figure B-2 Seeker line zoomed in

A Seeker line (shown in red) is created for segment #23201367 from the target network. The Seeker line is tagged with the id of the target segment, #2320167 (Figure B-2).

The Seeker line is buffered and intersected with the source network. The source network is shown in yellow (Figure B-3).

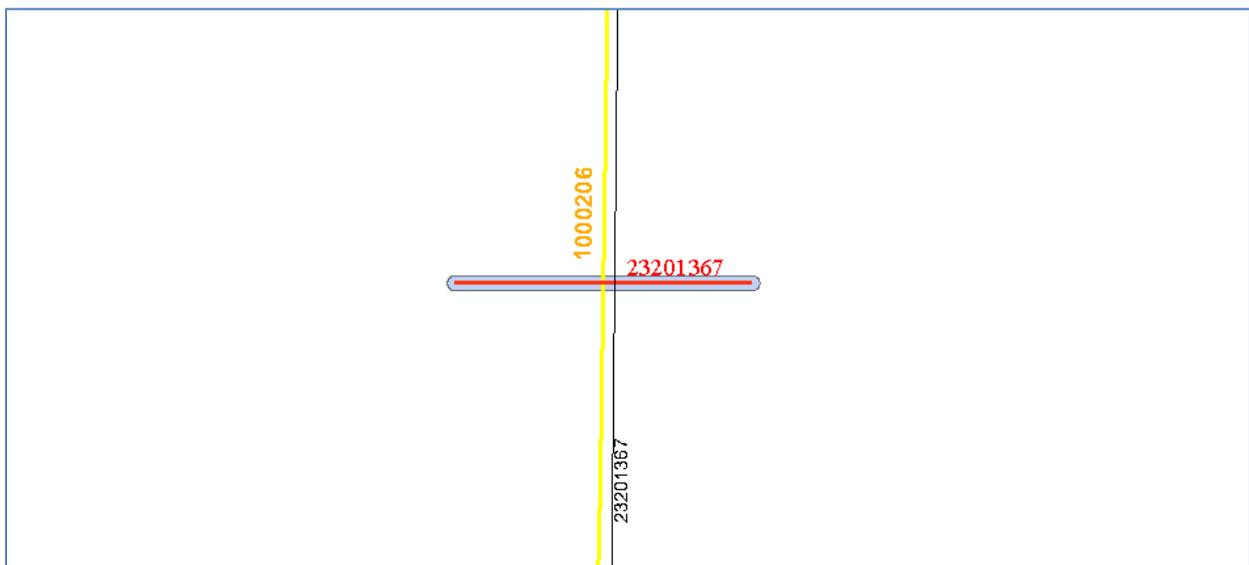


Figure B-3 Buffered seeker lines

After this process of buffering and intersecting is complete, a link has been established between the target and source network as shown in Table B-1.

Table B-1 Established link between the target and source network

Segment Id in Target Network	Id of segment in Seeker layer	Id of buffered segment in Seeker layer	Buffered Seeker Id and Source Segment Id retrieved from intersection file	Segment Id in Source Network
23201367	23201367	23201367	23201367/10000206	1000206

The information in the intersection file provides the link between the target and source network. Attributes from the #1000206 in the source network can now be transferred to #23201367 in the target network. The transfer of attributes is a simple database operation or a join/field calc operation in ArcMap.

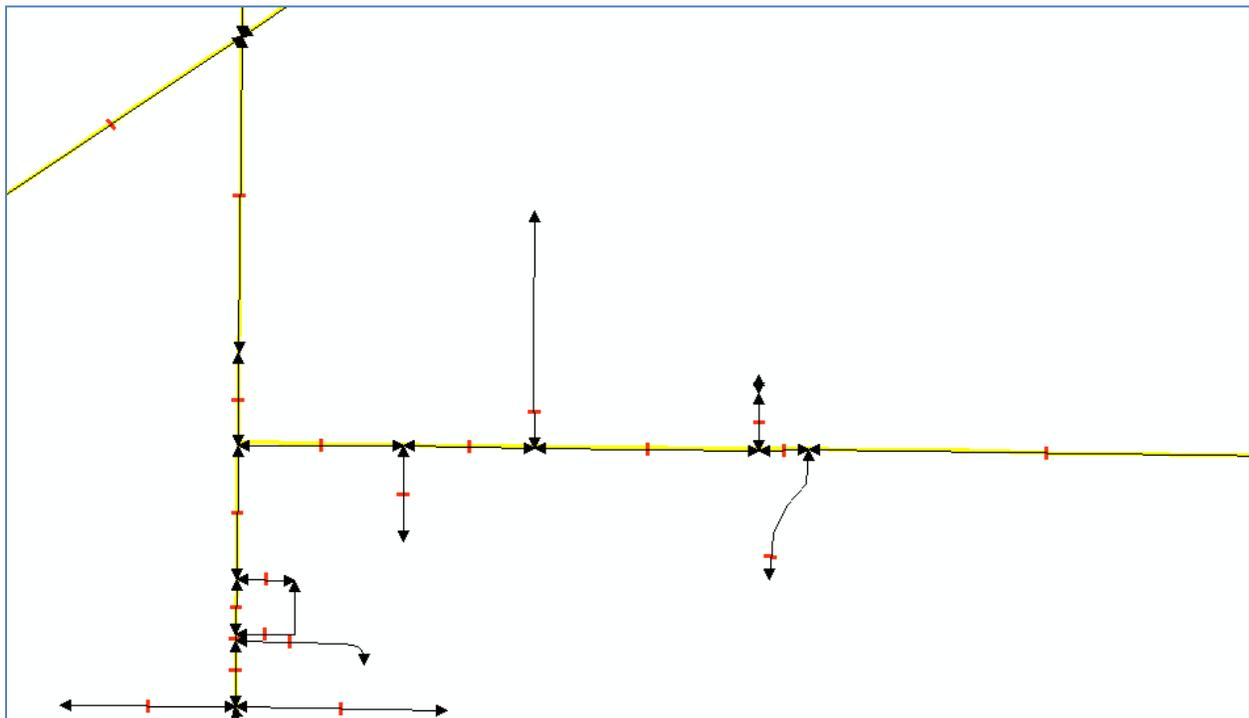


Figure B-4 Source network matched to target network

The source network is shown above in yellow. This is an example of when the geometry of the source network closely matches the geometry of the target network. If the geometry of the source network does not closely match the geometry of the target network, the Seeker lines/buffers will not intersect the source network, and no match will be made.

Any segments in the target network that are not matched to a segment in the source network by this process should be flagged for review by an editor. The editor will have to make a decision if a match can be made. The editors must be careful not to flag roads that should not participate in the network. There are routines in the modeling software that can be run to check the validity of the editors' work.

There are two scenarios that will arise in this process.

Scenario 1: When one segment in the target corresponds to more than one segment in the source.

If the goal is simply to transfer or tag the target with attributes from the source then the target segment need only be associated with one source segment. For this project this scenario occurred when TeleAtlas, the network source for original TSM network, created multiple segments between intersections and NAVTEQ only created one. Because the fundamental attributes (funclass, areatype, number of lanes, speed) of segments on the many side did not vary between intersections, it did not matter which of the source segments was used for the one target segment.

Scenario 2: When multiple segments in the target correspond to one segment in the source.

For this project this scenario occurred when NAVTEQ created multiple segments between intersections and TeleAtlas, the network source for original TSM network, only created one. This does not create any problem as multiple segments in the target can be associated with only one segment in the source. The multiple segments would all share the attributes from the one segment in the source.

Buffering the Seeker lines can be done with an ArcToolbox function. The intersection of the buffered Seeker lines and the source network can also be done with an ArcToolbox function.

Algorithm for creating Seeker lines

- Each segment in the target network (black line) is made up of a set of vertices
- The distance between each vertex is calculated.
- The pair of vertices that has the largest distance between them is found. By experimentation this was found to give the best chance of drawing the seeker line at a location that would make the best match. If the segment is curvy, this finds that most representative shape.
- Create a line that is perpendicular to the line between the pair of vertices found in the step above and passes through the midpoint between the vertex pair.

- There are two lengths of “Seeker” lines. One set extends 5 meters on both sides of the target line and the other set extends 10 meters.

Code for generating Seeker lines

The language of the following code is VB. This example assumes that the user has defined a feature class, has set a search criteria, and then populates pSelectionset.Search which is a selectionset of the results of applying the search criteria to the feature class.

```
Dim pFeatureCursor As IFeatureCursor
pSelectionset.Search Nothing, True, pFeatureCursor

Dim pEnumFeat As IEnumFeature
Dim pFeature As IFeature
Dim pGeometry As IGeometry
Dim pPolyLine As IPolyline
Dim pPointCollection As IPointCollection
Dim pPoint As IPoint
Dim X As Long, zDist As Double, prevDist As Double, lineId As Long

Set pFeature = pFeatureCursor.NextFeature
Do While (Not pFeature Is Nothing)
    Set pGeometry = pFeature.Shape
    If pGeometry.GeometryType = esriGeometryPolyline Then
        lineId = pFeature.Value(pFeature.Fields.FindField("DYNAMAP_ID"))
        Set pPolyLine = pGeometry
        Set pPointCollection = pPolyLine
        iCount = pPointCollection.PointCount
        Select Case iCount
            Case 0

            Case 1

            Case 2
                Set pPoint = pPointCollection.Point(0)
                x1 = pPoint.X
                y1 = pPoint.Y
                Set pPoint = pPointCollection.Point(1)
                x2 = pPoint.X
                y2 = pPoint.Y
                Call Perpendicular(lineId, pFeatureclass5, pFeatureclass10)

            Case Else
                prevDist = 0
                For X = 1 To pPointCollection.PointCount - 1
```

```

Set pPoint = pPointCollection.Point(X - 1)
x1b = pPoint.X
y1b = pPoint.Y
Debug.Print pPoint.X & ", " & pPoint.Y
Set pPoint = pPointCollection.Point(X)
x2b = pPoint.X
y2b = pPoint.Y
zDist = Sqr((x1b - x2b) ^ 2 + (y1b - y2b) ^ 2)
If zDist > prevDist Then
    x1 = x1b
    y1 = y1b
    x2 = x2b
    y2 = y2b
    prevDist = zDist
End If
Next X
' The vertex pair that has the greatest distance between them is in
' x1, x2, y1,y2.
Call Perpendicular(lineId, pFeatureclass5, pFeatureclass10)

End Select

End If
Set pFeature = pFeatureCursor.NextFeature
Loop
dbs.Close
End Sub

Public Sub Perpendicular(lineId As Long, pFeatureclass5 As IFeatureClass, pFeatureclass10 As
IFeatureClass)
Dim dbs As ADODB.Connection
Dim sql As String

Set dbs = New ADODB.Connection

dbs.Open sConStringCrawler_Master

Dim radius As Double

'*****
' reset x2,y2 to the midpoint of original x1,y1 x2,y2 line
'*****
x2 = (x1 + x2) / 2

```

$$y2 = (y1 + y2) / 2$$

```

*****
' sub calc_Perpendicular_coords will generate a line
' that is perpendicular to x1,y1 x2,y2 line
' that is radius*2 long
' and passes thru x2,y2
' The coordinates of the line are in px1,py1,px2,py2
*****

```

```

radius = 5
Call calc_Perpendicular_coords(radius)
Call Create_Line_from_XYdata(pFeatureclass5, lineId)
sstr = "INSERT INTO Perpendicular5 ( DYNAMAP_ID, x1, y1, x2, y2, " & _
      "px1, py1, px2, py2) " & _
      "SELECT " & lineId & " AS E1, " & x1 & " AS E2," & _
      y1 & " AS E3," & x2 & " AS E4," & y2 & " AS E5," & _
      px1 & " as E6," & py1 & " as E7," & px2 & " as e8," & _
      py2 & " as e9;"
dbs.Execute sstr

```

```

radius = 10
Call calc_Perpendicular_coords(radius)
Call Create_Line_from_XYdata(pFeatureclass10, lineId)

```

```

sstr = "INSERT INTO Perpendicular10 ( DYNAMAP_ID, x1, y1, x2, y2, " & _
      "px1, py1, px2, py2) " & _
      "SELECT " & lineId & " AS E1, " & x1 & " AS E2," & _
      y1 & " AS E3," & x2 & " AS E4," & y2 & " AS E5," & _
      px1 & " as E6," & py1 & " as E7," & px2 & " as e8," & _
      py2 & " as e9;"

```

```

dbs.Execute sstr

```

```

dbs.Close

```

```

End Sub

```

```

Public Sub calc_Perpendicular_coords(radius As Double)

```

```

  Dim pi As Double

```

```

  Dim slope As Double

```

```

  Dim xAngle As Double

```

```

  Dim xdiff As Double

```

```

  Dim xAngle_1 As Double

```

```

  Dim xAngle_2 As Double

```

```

' Xangle is the degree measure of the original line going from x1,y1 to x2,y2

```

' Create 90 degree angle on either side of this line.
' The line goes thru the x2,y2 pair, is perpendicular to the original
' and is Radius units long on either side of the original line.

' to convert slope to degrees, use arctan(slope)

If Abs(x1 - x2) < 0.00001 Then

 xdiff = 0.00001

Else

 xdiff = x1 - x2

End If

slope = (y1 - y2) / xdiff

Dim quad As Integer

If y1 < y2 Then

 If x1 < x2 Then

 quad = 3

 Else

 quad = 4

 End If

Else

 If x1 < x2 Then

 quad = 2

 Else

 quad = 1

 End If

End If

pi = 4 * Atn(1)

xAngle = (Atn(slope) * (180 / pi))

If xAngle < 0 Then

 If quad = 4 Then xAngle = 360 + xAngle

 If quad = 2 Then xAngle = 180 + xAngle

End If

If quad = 3 Then xAngle = 180 + xAngle

xAngle_1 = (xAngle + 90) * pi / 180

xAngle_2 = (xAngle - 90) * pi / 180

px1 = x2 + (radius * Cos(xAngle_1))

px2 = x2 + (radius * Cos(xAngle_2))

py1 = y2 + (radius * Sin(xAngle_1))

py2 = y2 + (radius * Sin(xAngle_2))

End Sub

```
Private Sub Create_Line_from_XYdata(pFeatureClass As IFeatureClass, lineId As Long)
    'http://forums.esri.com/Thread.asp?c=93&f=1149&t=121311
```

```
    Dim pFeatureCursor As IFeatureCursor
    Dim pFeatureBuffer As IFeatureBuffer
    Dim pFeature As IFeature
```

```
    Dim pPoint As IPoint
    Set pPoint = New Point
    Dim pPointCollection As IPointCollection
```

```
    ' create shapefile
    ' Set pFeatureClass = CreateShape("directory", "name", esriGeometryPolyline)
```

```
    ' create an insert cursor for the shapefile
    Set pFeatureCursor = pFeatureClass.Insert(True)
```

```
    ' create a featurebuffer (intermediate storage for the polyline)
    Set pFeatureBuffer = pFeatureClass.CreateFeatureBuffer
    Set pFeature = pFeatureBuffer
    pFeature.Value(pFeature.Fields.FindField("DYNAMAP_ID")) = lineId
```

```
    Set pPointCollection = New Polyline
```

```
        ' get first coordinate and store
        pPoint.X = px1
        pPoint.Y = py1
        pPointCollection.AddPoint pPoint
```

```
        ' get second coordinate and store
        pPoint.X = px2
        pPoint.Y = py2
        pPointCollection.AddPoint pPoint
```

```
        ' store the pointcolletion in the featurebuffer
        Set pFeature.Shape = pPointCollection
        ' store the featurebuffer in the shapefile
        pFeatureCursor.InsertFeature pFeatureBuffer
```

```
    pFeatureCursor.Flush
```

End Sub

Appendix

C. Correcting Conflation Errors

Correcting Conflation Errors

Introduction

This manual introduces the methods of creating a unified network based on Navteq network by integrating the transportation model information from the Turnpike State Model (TSM). The work is based on what the URS and Citilabs have done on the matching of Navteq network and TSM network, and the attribute transfer between these two layers. Since they used an automatic method in which the matching is not 100% correct, we need correct the errors and create a unified network. The work need to do mainly includes two parts: the first part is to eliminate the dangles and gaps, and the second part is to edit the Navteq attributes to make sure consistent with TSM network.

Network Matching Adjustment

Introduction

The purpose of the network matching adjustment is to correct the errors that happened during the automatic process to match the turnpike state model (TSM) network to Navteq network. The errors are in to classes. The first class is some Navteq links are matched to a TSM link, while it should not in real world. We call these links dangles and they should be eliminated. The second class is that some Navteq links should me matched to TSM links while not. We call these links gaps and they need to set matched to TSM links.

The input data for this task includes Navteq network that automatically matched with TSM network but with some errors, and the TSM network. These two layers are stored in a file geodatabase for the management convenience.

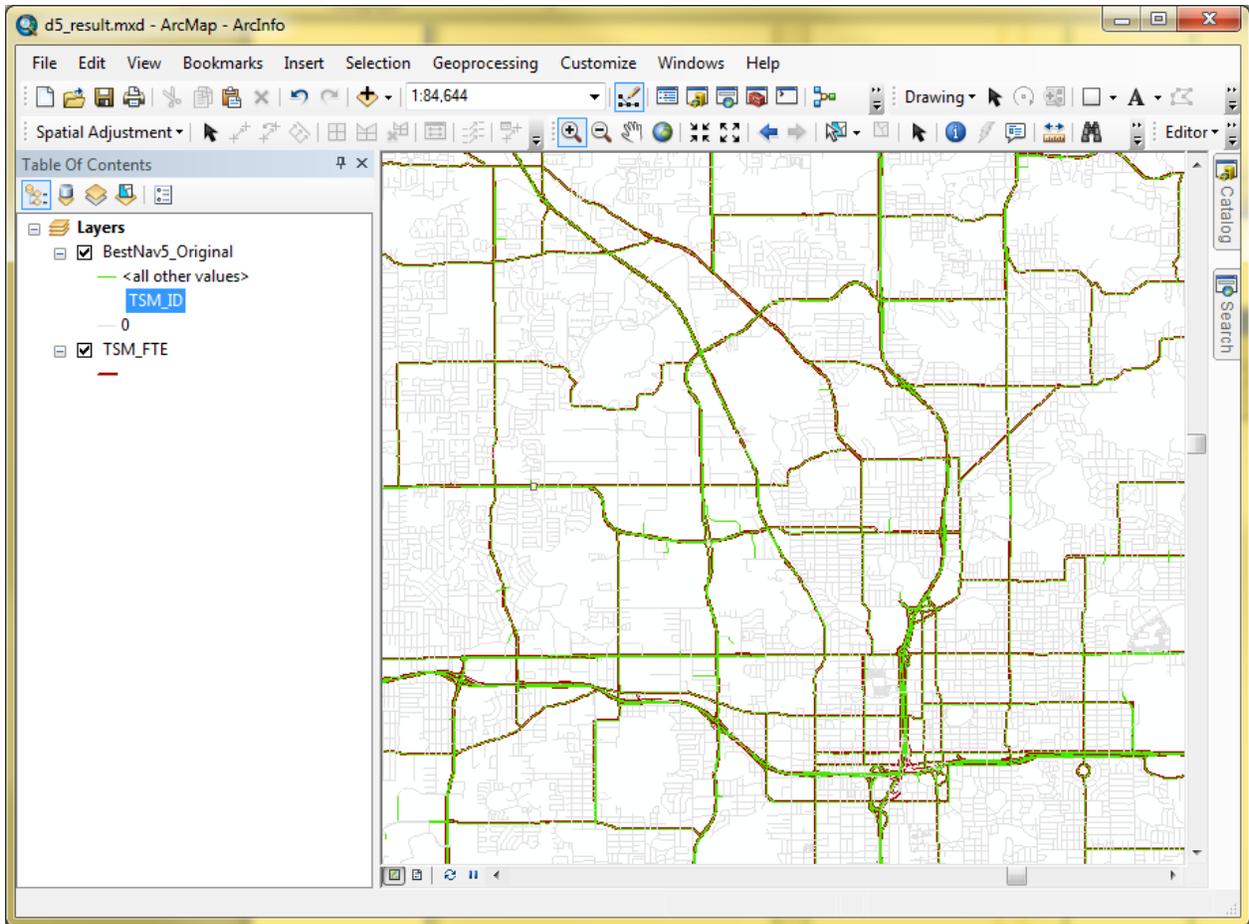


Figure C-1 ArcMap screen for network matching adjustment

Creating No Dangle Topology

The following steps are used to create a no dangle topology for the Navteq data (BestNav5_Original layer here).

Step 1. Create a new feature class data set with a name D5ORIGINAL_1 under the geodatabase in ArcCatalog (Figure C-2).

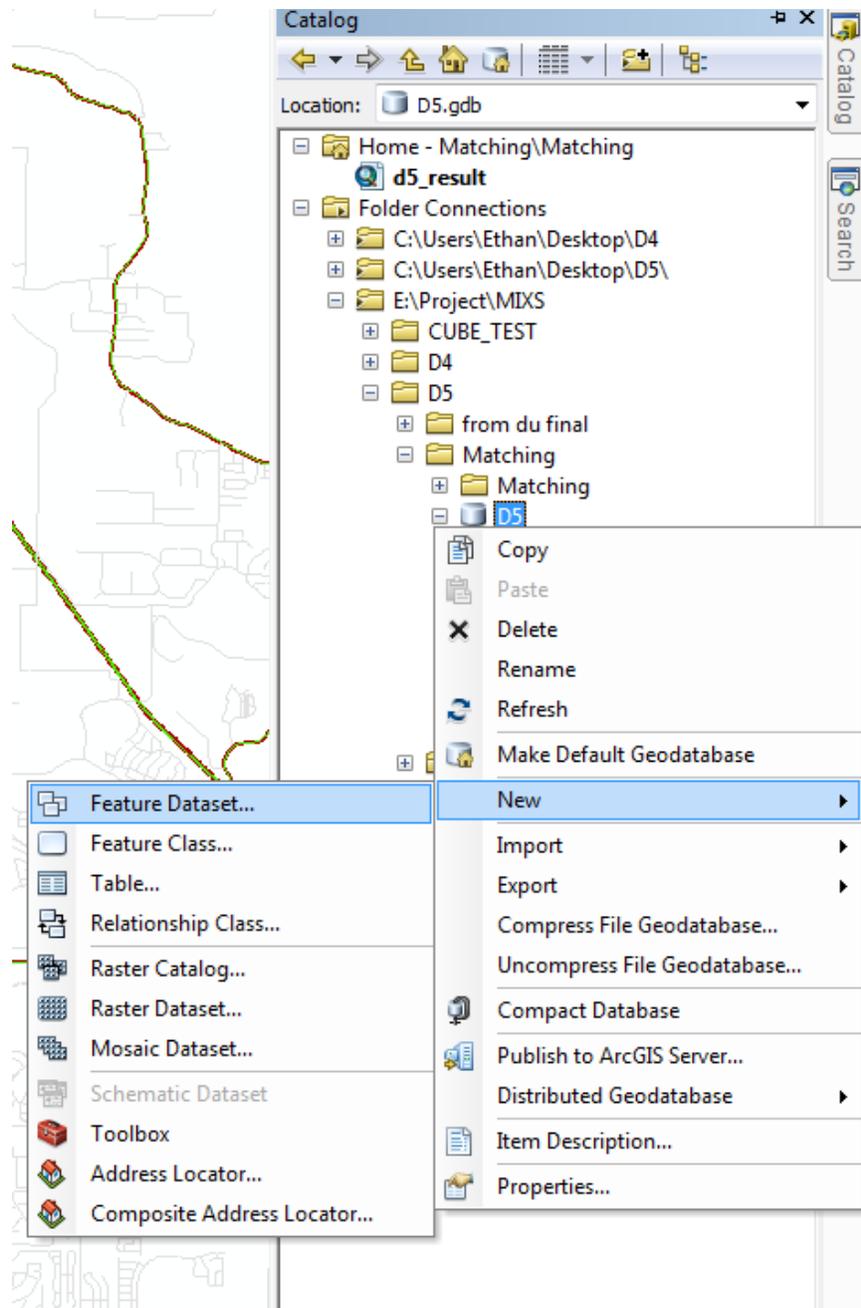


Figure C-2 Create a new feature class data set

Step 2. Import the Navteq network into D5ORIGINAL_1

Import the loaded BestNav5 into the new Feature Dataset as a feature class using the expression `TSM_ID <> 0` (Figure C-3).

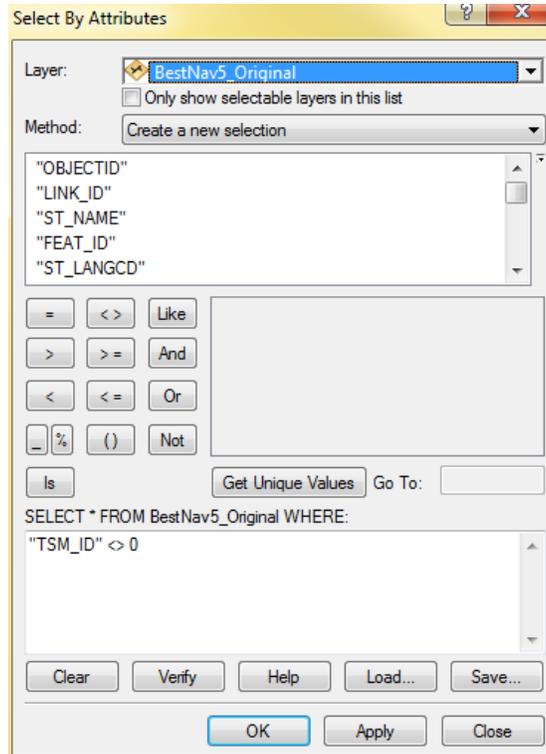


Figure C-3 Select from the Navteq network

The name of the feature class is defined as D5_1 (Figure C-4).

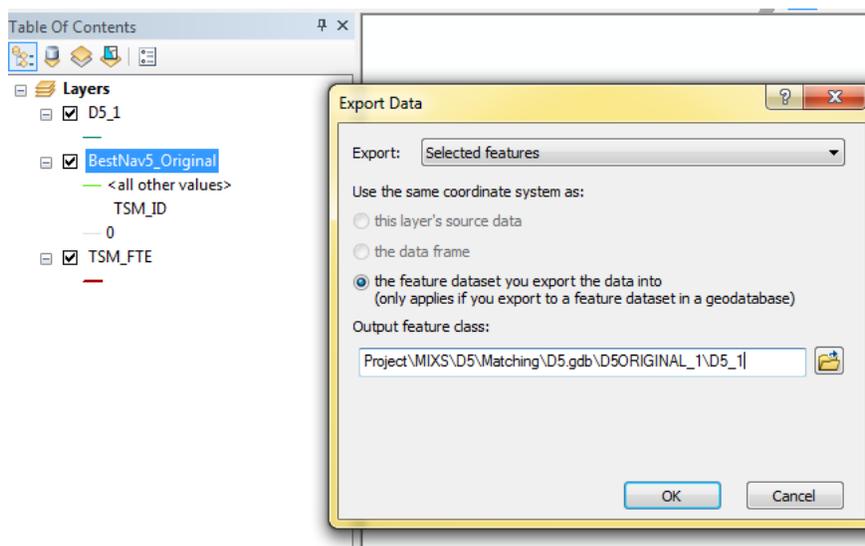


Figure C-4 Export selected features

Step 3. Creating No Dangle Topology

Right select the new dataset in ArcCatalog, and then select New -> Topology (Figure C-5).

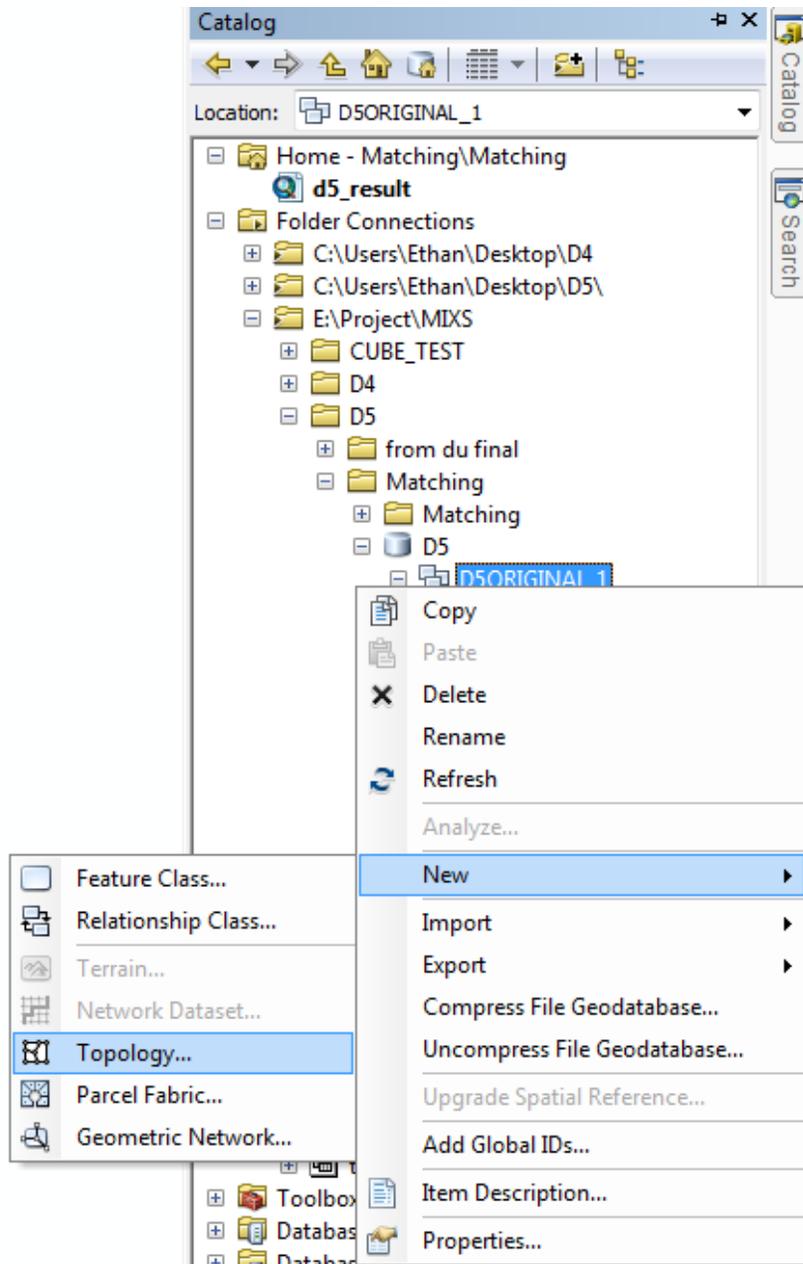


Figure C-5 Create new topology

Name the topology as D5ORIGINAL_1_Topology (Figure C-6).

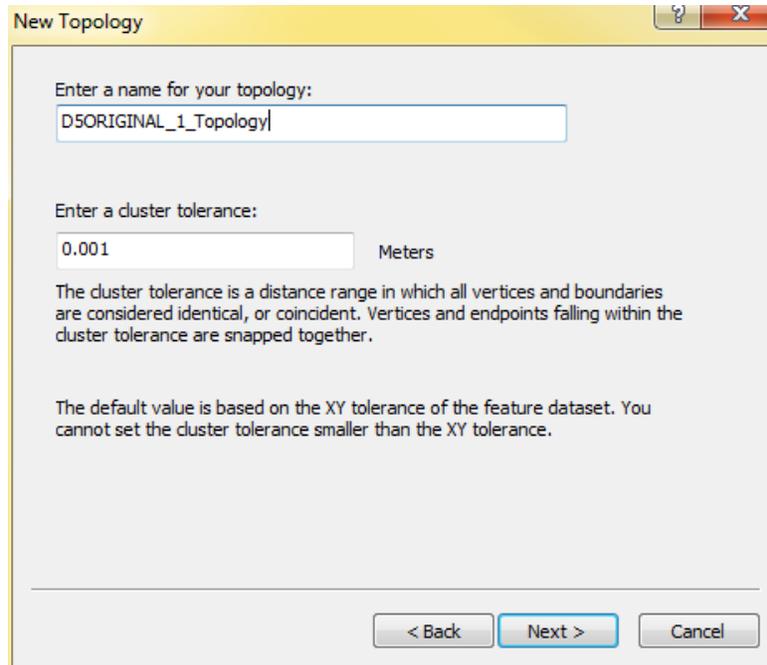


Figure C-6 Name created topology

Select the D5_1 as the layer that will participate in the topology (Figure C-7).

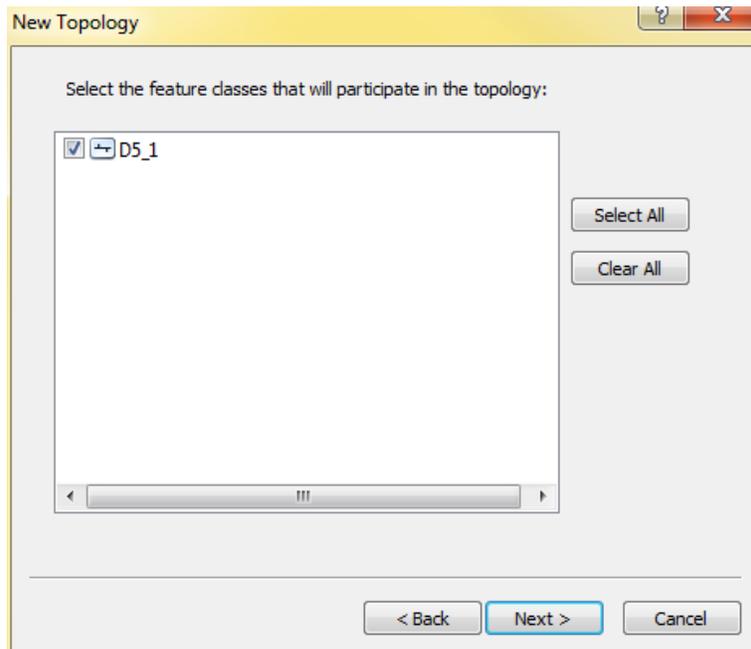


Figure C-7 Feature class participating in the topology

Add the rule “Must Not Have Dangle” in the process of specifying the rules for the topology (Figure C-8).

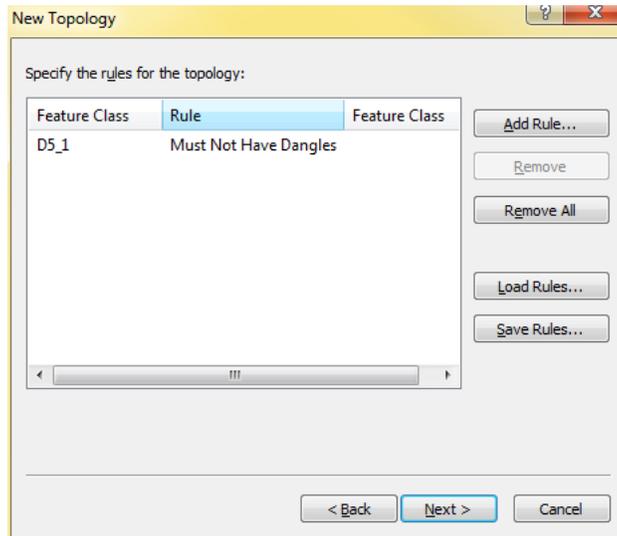


Figure C-8 Add rules

The result of the topology creating process is like the Figure C-9. The three kinds of topology errors (area, line and point) are the places where the dangles and gaps exist.

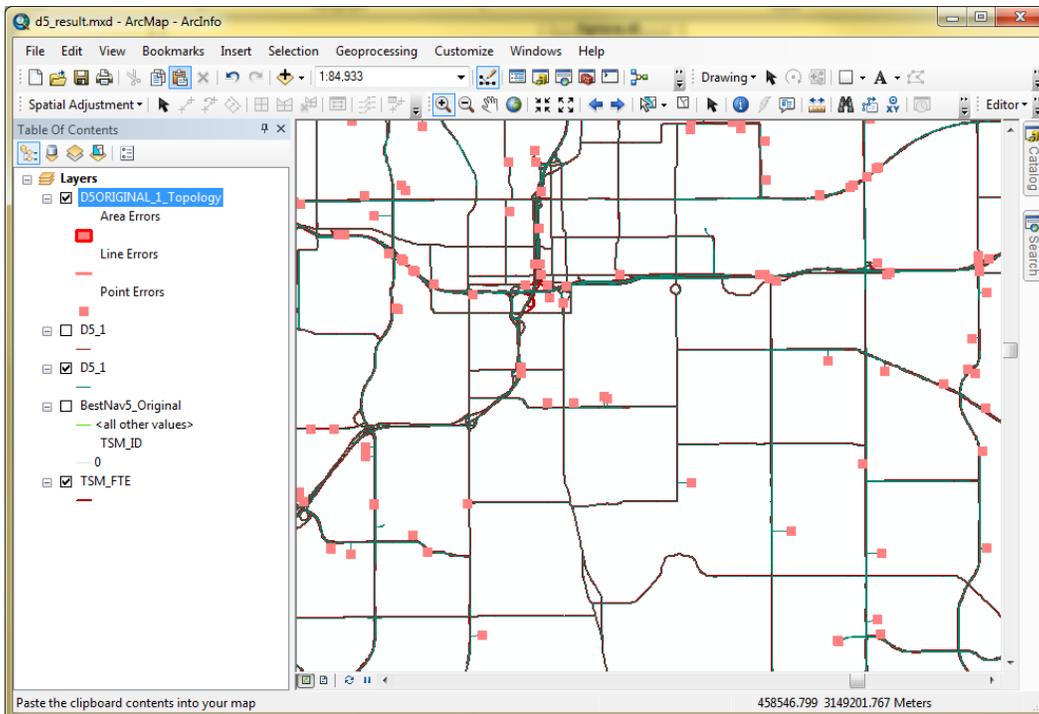


Figure C-9 Results of the topology creation

Preparation Work for Dangle and Gap Elimination

Step 1. Add fields TSM_ZERO, IS_DANGLE, DANGLE_ONE for BestNav5_Original. The type for the three fields is short integer. Assign 0 as value to TSM_ZERO, and 1 to DANGLE_ONE by using the field calculator. The IS_DANGLE is used to record whether the link is a dangle or not (Figure C-10).

	district	Shape_Length	TSM_ZERO	IS_DANGLE	DANGLE_ONE	IS_GAP
▶	5	16.647223	0	<Null>	1	<Null>
	5	409.845991	0	<Null>	1	<Null>
	5	29.928055	0	<Null>	1	<Null>
	5	58.72454	0	<Null>	1	<Null>
	5	204.701918	0	<Null>	1	<Null>
	5	64.285407	0	<Null>	1	<Null>
	5	23.264913	0	<Null>	1	<Null>
	5	199.399676	0	<Null>	1	<Null>
	5	91.197563	0	<Null>	1	<Null>
	5	21.600268	0	<Null>	1	<Null>
	5	21.343465	0	<Null>	1	<Null>
	5	19.403133	0	<Null>	1	<Null>
	5	24.395113	0	<Null>	1	<Null>
	5	369.115698	0	<Null>	1	<Null>
	5	45.368886	0	<Null>	1	<Null>
	5	46.268426	0	<Null>	1	<Null>
	5	177.014631	0	<Null>	1	<Null>
	5	13.583514	0	<Null>	1	<Null>
	5	19.532255	0	<Null>	1	<Null>
	5	20.272529	0	<Null>	1	<Null>
	5	21.512465	0	<Null>	1	<Null>
	5	20.511849	0	<Null>	1	<Null>
	5	17.44534	0	<Null>	1	<Null>
	5	15.611448	0	<Null>	1	<Null>
	5	258.909732	0	<Null>	1	<Null>
	5	106.789563	0	<Null>	1	<Null>

BestNav5_Original (0 out of 301658 Selected)

Figure C-10 Add fields TSM_ZERO, IS_DANGLE, DANGLE_ONE

Step 2. Add field GAP_ONE to TSM_FTE attribute table as the same method in step 1 (Figure C-11).

	LNCF	SPCF	Shape_Leng	GAP_ONE	Shape_Length
▶	4	35	146.267671	1	146.267671
	4	45	48.047249	1	48.047249
	4	65	63.428107	1	63.428107
	4	45	38.45916	1	38.45916
	2	45	51.717373	1	51.717373
	2	45	135.743076	1	135.743076
	2	45	134.871426	1	134.871426
	2	45	97.966994	1	97.966994
	2	45	179.705439	1	179.705439
	2	45	41.254363	1	41.254363
	2	45	81.702345	1	81.702345
	2	45	51.188971	1	51.188971
	2	45	95.789822	1	95.789822
	2	65	169.132658	1	169.132658
	2	55	240.905696	1	240.905696
	2	55	305.500796	1	305.500796
	2	65	162.701867	1	162.701867
	2	65	99.086489	1	99.086489
	2	65	303.099878	1	303.099878
	2	65	347.446952	1	347.446952
	2	65	346.671973	1	346.671973
	2	25	87.196739	1	87.196739
	2	25	138.907703	1	138.907703
	2	25	140.160611	1	140.160611
	2	35	22.251488	1	22.251488
	2	35	177.024087	1	177.024087
	2	25	18.563122	1	18.563122

Figure C-11 Add field GAP_ONE to TSM_FTE

Step 3. Open the Editor toolbar and “start editing” (Figure C-12).

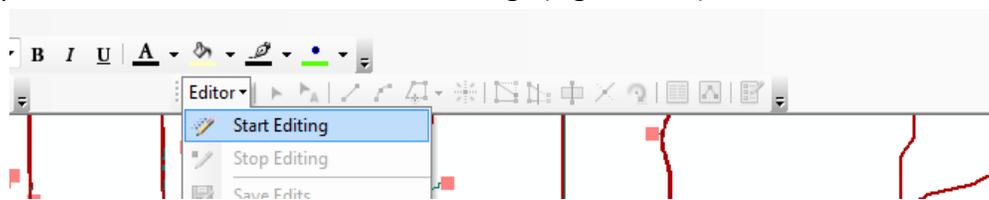


Figure C-12 Start editing

Dangle Elimination

Step 1. Open the Spatial Adjustment tool and set the Attribute Transfer Mapping rules (Figure C-13). Select the Attribute Transfer Mapping to set the rules (Figure C-14).

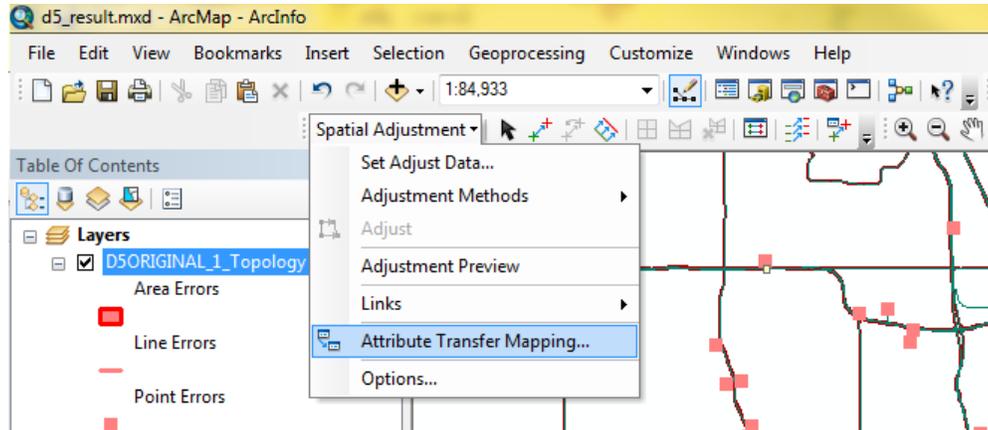


Figure C-13 Open the spatial adjustment tool

For the dangle elimination, we need transfer the attributes from a non-TSM matched Navteq link to a TSM matched Navteq but marked as dangles in the following way: TSM_ZERO to TSM_ID, and DANGLE_ONE to IS_DANGLE. The former is setting the TSM ID of a dangle to zero, and the latter one is marking the link is a dangle.

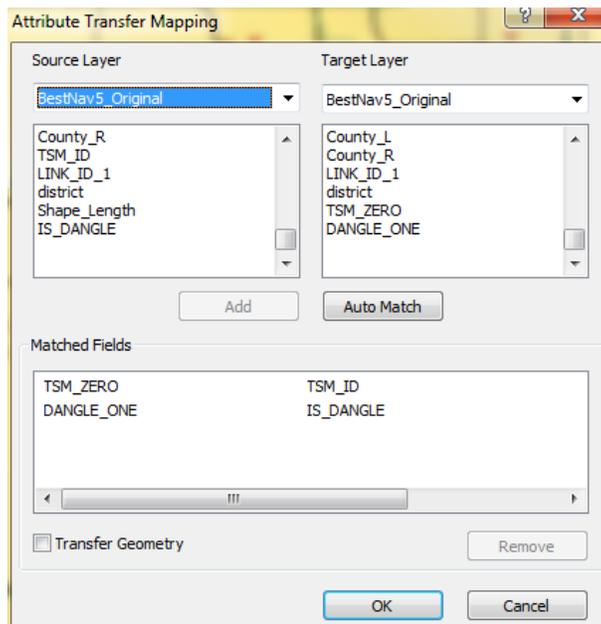


Figure C-14 Set the attribute transfer mapping rules

Step 2. Dangle Elimination

The process is as follows: first select the adjustment tool, then click a Navteq link in grey color (non TSM matched link), at last click the green link (dangle link) like to be eliminated (Figure C-15).

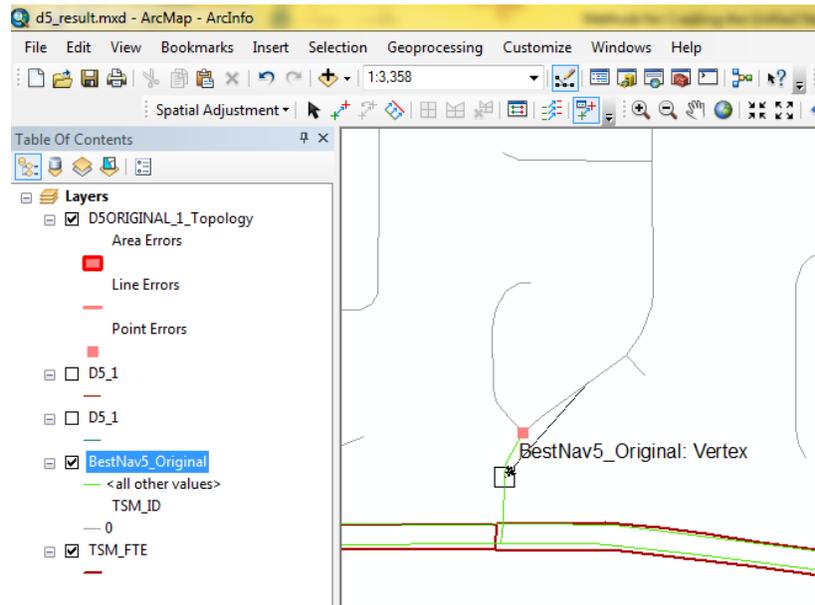


Figure C-15 Process of Elimination

Refresh the map, then found the green turned to grey which means the dangles is eliminated (Figure C-16).

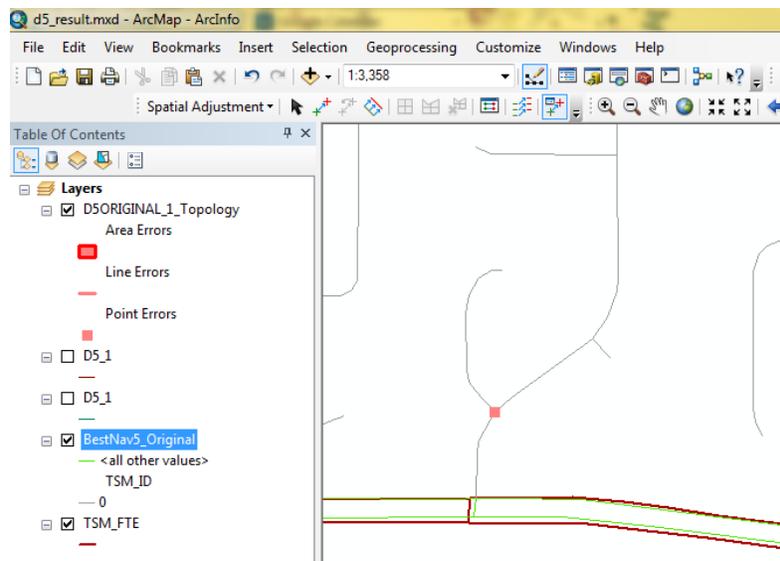


Figure C-16 Refreshed map

And, we can see the TSM_ID is 0 now, and the IS_DANGLE is 1 in the attribute table (Figure C-17).

County_R	TSM_ID	LINK_ID_1	district	Shape_Length	TSM_ZERO	IS_DANGLE	DANGLE_ONE	IS_GAP
75	0	22420201	5	68.247104	0	1	1	<Null>

Figure C-17 Attribute table after elimination

Gaps Elimination

Step 1. Set the Attribute Transfer Mapping rules

For the gap elimination, we need transfer the attributes from a TSM matched link to its potential matched Navteq link that marked as gaps in the following way: DYNAMAP_ID to TSM_ID, and GAP_ONE to IS_GAP. The former is setting the TSM ID of a gap to the DYNAMAP_ID of the matched TSM link, and the latter one is marking the link is a gap (Figure C-18).

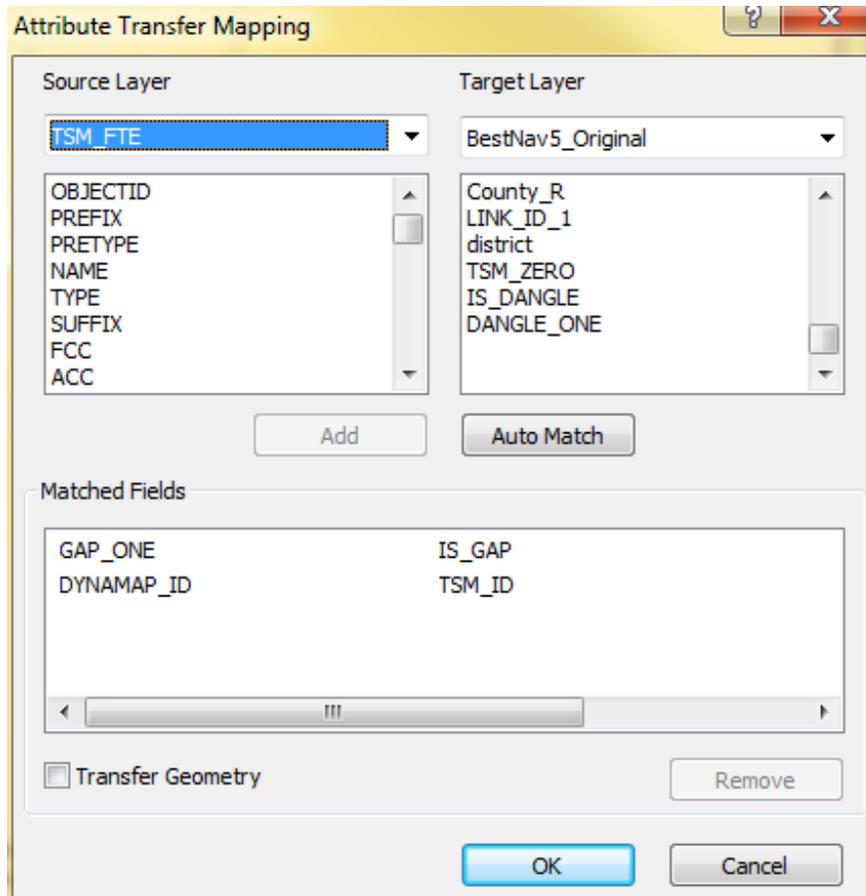


Figure C-18 Set the attribute transfer mapping

Step 2. Gap Elimination

Figure C-19 show there a gap existed between the top point topology error and the right bottom point topology error. There has a TSM link passes the two points while no green Navteq links.

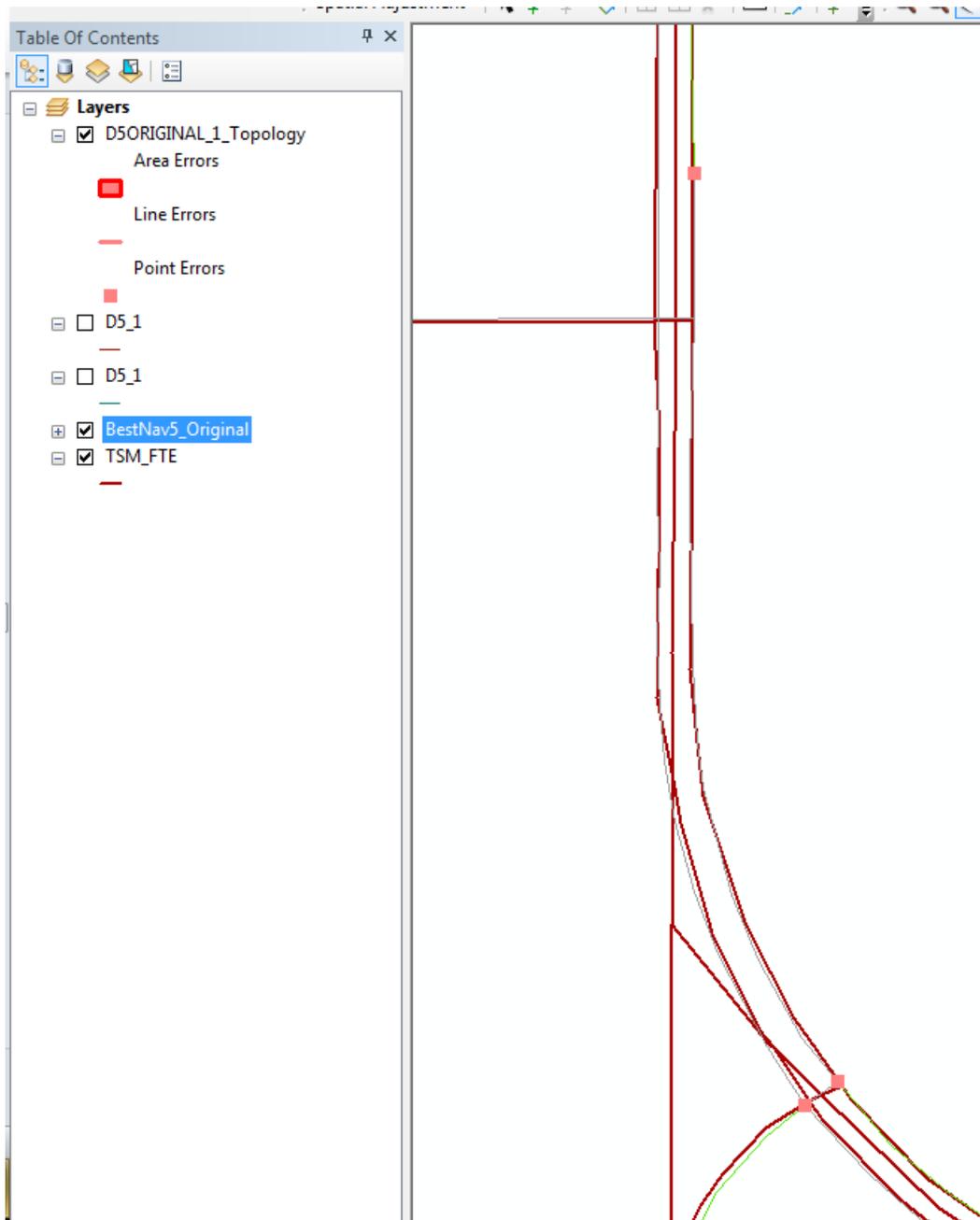


Figure C-19 Existing gaps in topology

Figure C-20 also shows the gap.

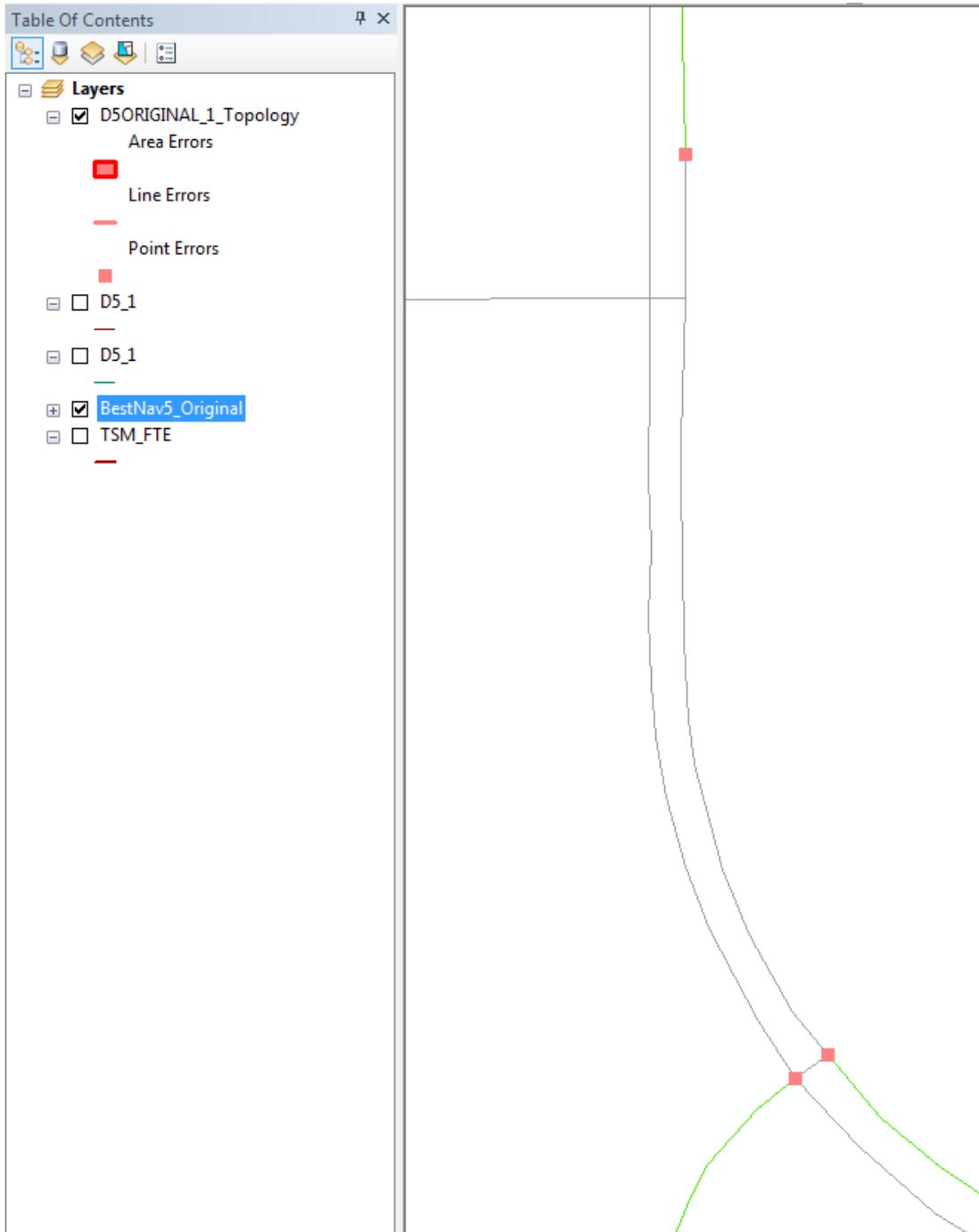


Figure C-20 Existing gaps (zoomed in)

The way to eliminate the gap is first select the links in the gap that belong to the TSM and then click on the grey Navteq link as shown in Figure C-21. Then the attributes will be automatically transferred.

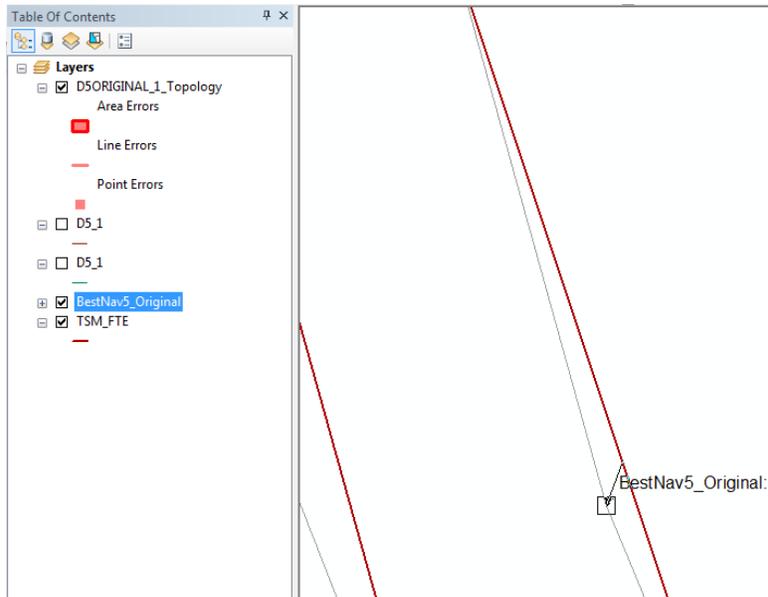


Figure C-21 Gap elimination process

After the attribute transfer, we can see the color of the gaps turns to green from grey (Figure C-22).

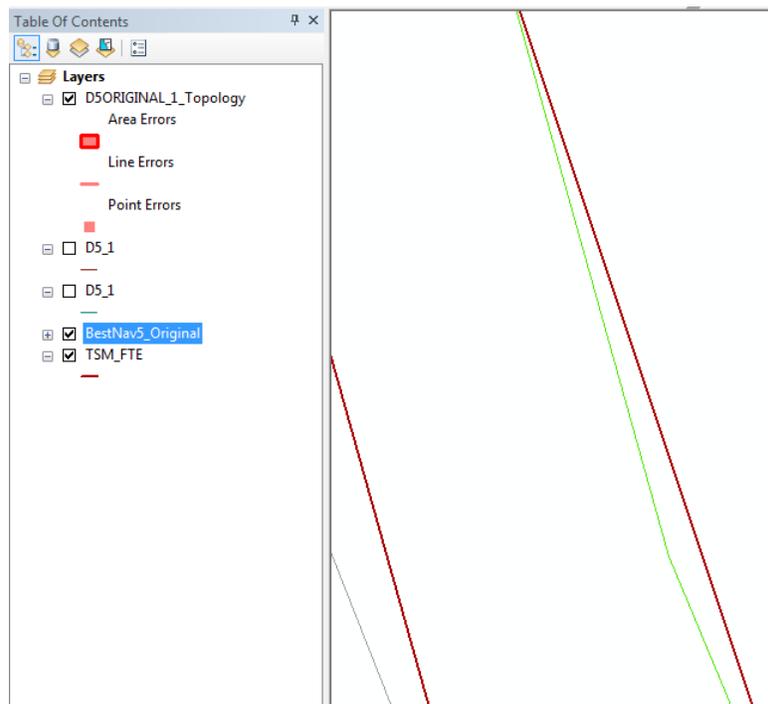
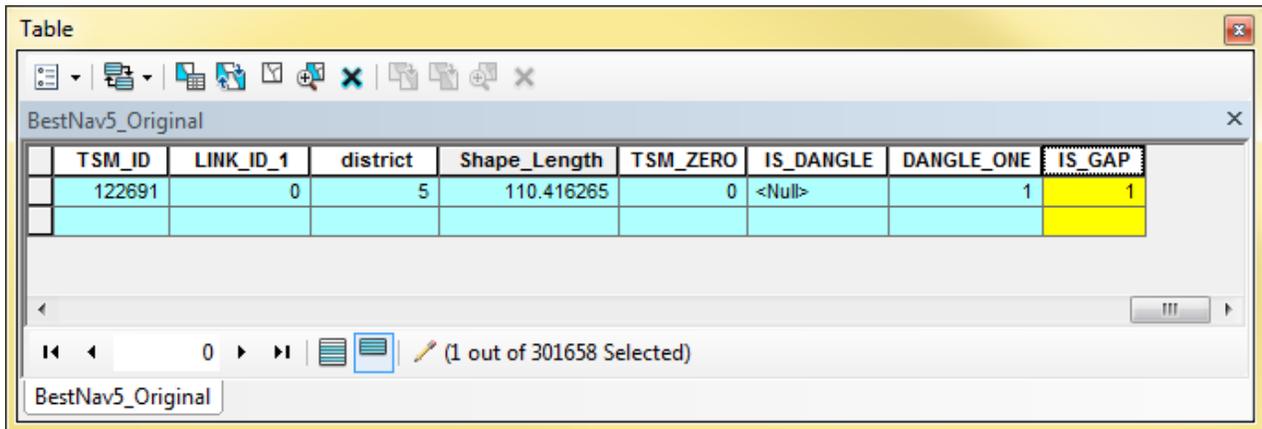


Figure C-22 Transferred attributes

And also, in the attribute table, we could see the TSM_ID is no longer zero and IS_GAP is marked with 1 (Figure C-23).



The screenshot shows a window titled "Table" containing a table with the following data:

TSM_ID	LINK_ID_1	district	Shape_Length	TSM_ZERO	IS_DANGLE	DANGLE_ONE	IS_GAP
122691	0	5	110.416265	0	<Null>	1	1

The table is displayed in a software interface with a toolbar at the top and a status bar at the bottom. The status bar indicates "(1 out of 301658 Selected)".

Figure C-23 Transferred results

Double Checking

After finish the first round of dangles and gaps elimination process, we need redo the whole process from 2.2.1 to 2.24. The reason is that we do the elimination work manually and it is very likely that some dangles and gaps still left after the first round. Usually need redo the whole process for three to four times to make sure all of the dangles and gaps are eliminated.

Network Attributes Editing

Introduction

The purpose of the network attributes editing process, also called network tagging, is to correct the value of some attributes of the Navteq network which had matched with the TSM network and inherited the attributes from the matched TSM link. The reason why this process is necessary is because of the mismatch between the original Navteq network and the TSM network. This mismatch results in the mismatch of some of the attributes values. Since the mismatch is the result of automatic process, this network attributes editing should be done manually.

The input data of this process are the matched Navteq network and the TSM network. The main work of this process is comparing the number of lanes (the attribute need keep consistent) between the Navteq network and the TSM network, and correcting value of the number of lanes in Navteq network if it is not consistent of the TSM network.

The following introduce the attribute editing process step by step and take district 5 as an example.

Network Attributes Editing Process

Data Preparation

Load TSM and Navteq network in ArcMap, and set the symbology of the TSM layer according to the value of the lane of lanes (LNE). The TSM network links are displayed in different colors as below (Figure C-24).

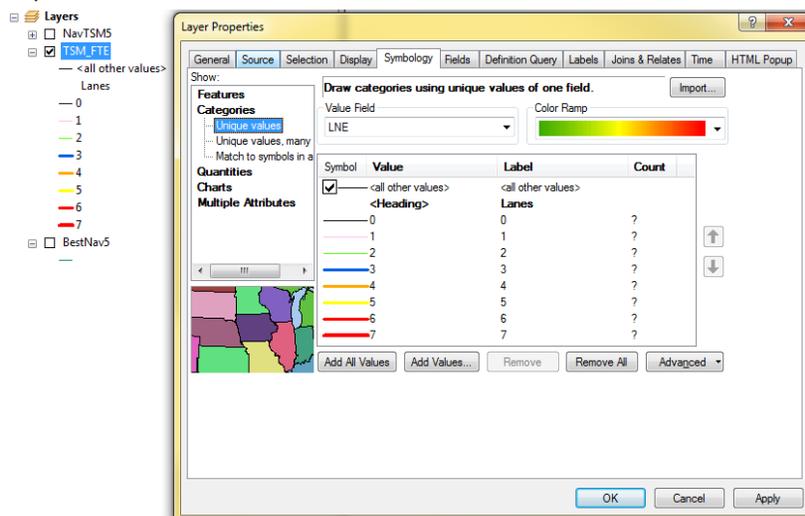


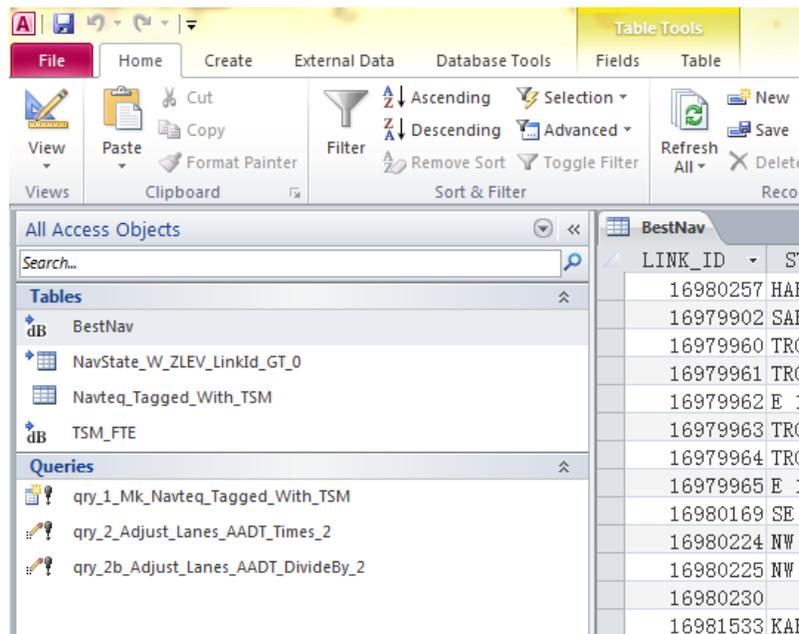
Figure C-24 TSM network symbology

Data Process in Access

Data preparation

The data preparation steps are as follows:

1. Open the database Tagging_NavBest_With_Attributes_D5 database in Access.
2. Load the table NavState_W_ZLEV_LNKID_GT_0 into Tagging_NavBest_With_Attributes_D5 database. This table includes the z level information and is contained in the database Zlev_Tagger_Z_Final_Table.
3. Load the attribute table of Naveteq layer (BestNav in this example: Figure C-25).
4. Load the attribute table of TSM layer (TSM_FTE here).



LINK_ID	ST
16980257	HAR
16979902	SAR
16979960	TRC
16979961	TRC
16979962	E 1
16979963	TRC
16979964	TRC
16979965	E 1
16980169	SE
16980224	NW
16980225	NW
16980230	
16981533	KAR

Figure C-25 Loaded attribute table

SQL Queries

After the data preparation for the Tagging_NavBest_With_TSM_Attributes_D5 database, there are three SQL queries need to be executed in order.

Query 1: qry_1_MK_Naveteq_tagged_with_TSM:

The purpose of this query is to get the TSM information from TSM table and the Z level information from NavState_W_ZLEV_LNKID_GT_0 to the Navteq network. The result will be displayed in a new table which called Navteq_Tagged_with_TSM.

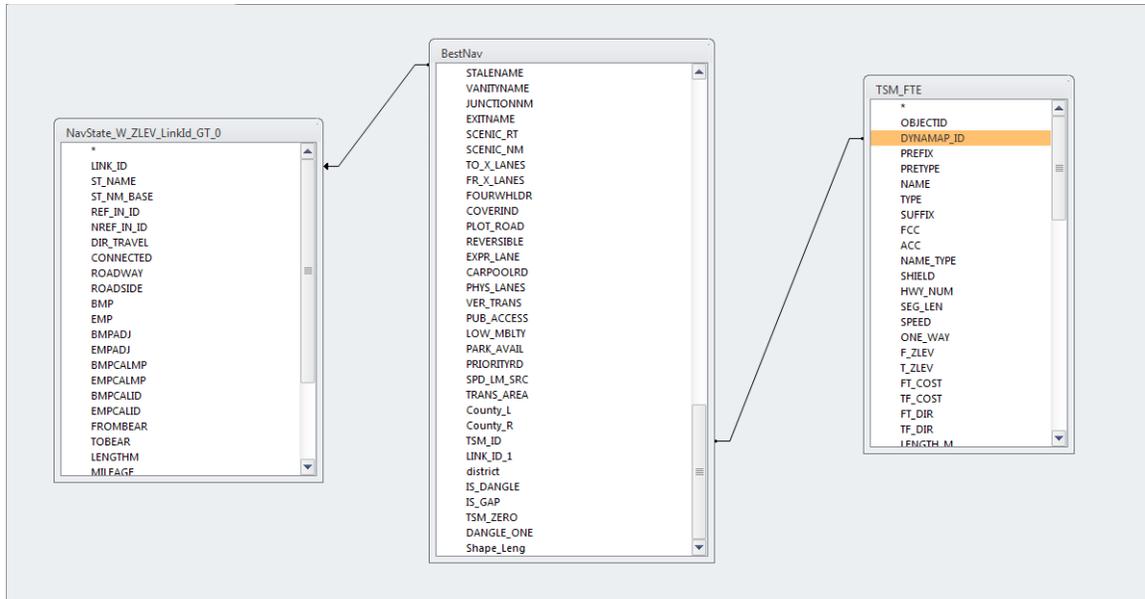


Figure C-26 SQL queries

Query 2: Qry2_Adjust_Lanes_AADT_times_2.

This query is to update the Navteq_tagged_with_TSM table where two road links in TSM are merged into one in Navteq. In this case, the value of all the AADT fields and the number of lanes field for the corresponding links in Navteq should be timed by 2.

Query 3: Qry2b_Adjust_Lanes_AADT_DivideBy_2

This query is to update the Navteq_tagged_with_TSM table where one road link in TSM is split into two links in Navteq. In this case, the value of all the AADT fields and the number of lanes field for the corresponding links in Navteq should be divided by 2.

Network Attributes Editing

Create New Layer NavTSM5

The following steps are to create a new layer NavTSM5 based on BestNav5 and table Naveteq_tagged_with_TSM. The NavTSM5 will be used to compare with the TSM network to keep the attributes in two layers consistent.

Step 1: Join BestNav4 with table Naveteq_tagged_with_TSM (Figure C-27).

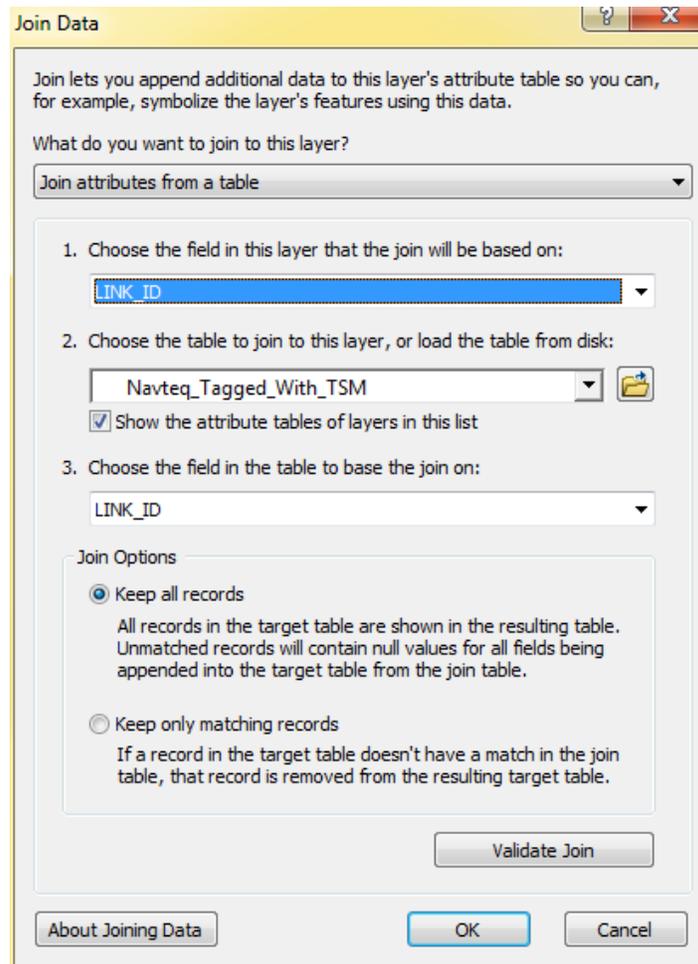


Figure C-27 Join tables

Step 2: Select by attributes from BestNav4 with condition: Navteq_tagged_with_TSM.Link_ID >0 (Figure C-28).

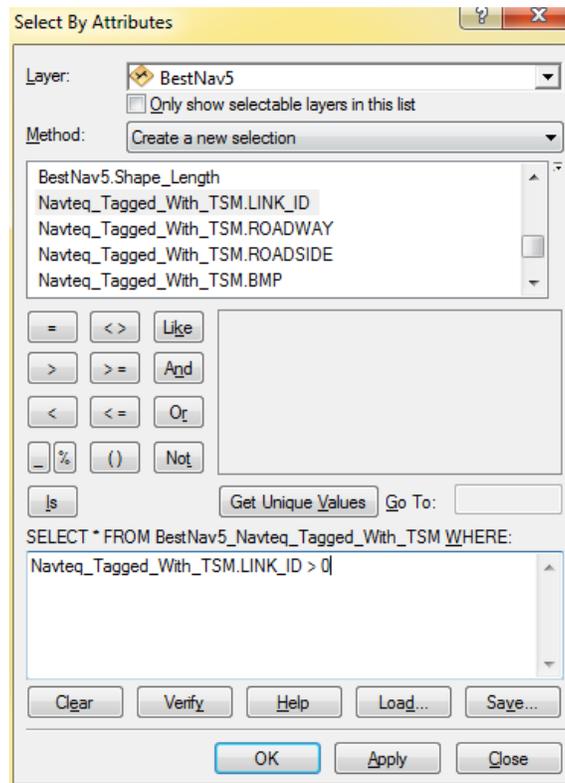


Figure C-28 Select attributes

Step 3: Export the selection to a layer: NavTSM4 (Figure C-29).

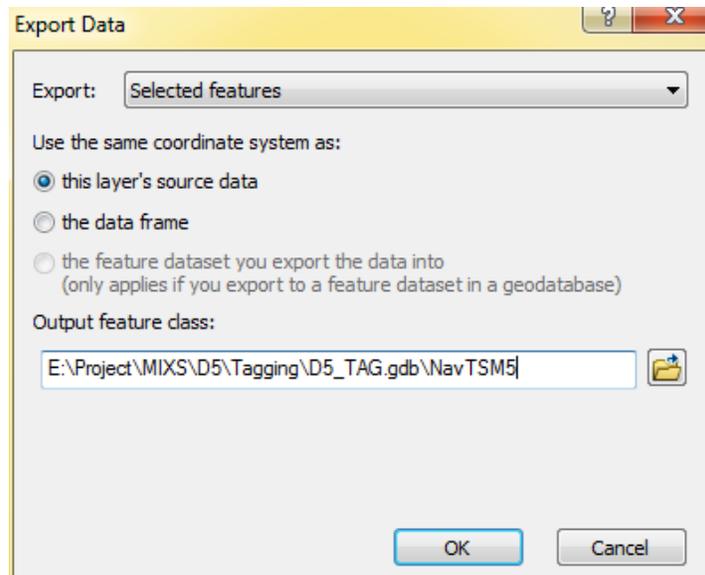


Figure C-29 Export selected data

Attributes Comparison and Editing

The following steps are used to compare the number of lanes attribute between the NavTSM5 and TSM_FTE two layers. If the value in NavTSM5 is different from the TSM_FTE, then edit it with the value from TSM_FTE.

Step 1: Loading the NavTSM5 in ArcMap and using the same symbology as the layer TSM_FTE (Figure C-30).

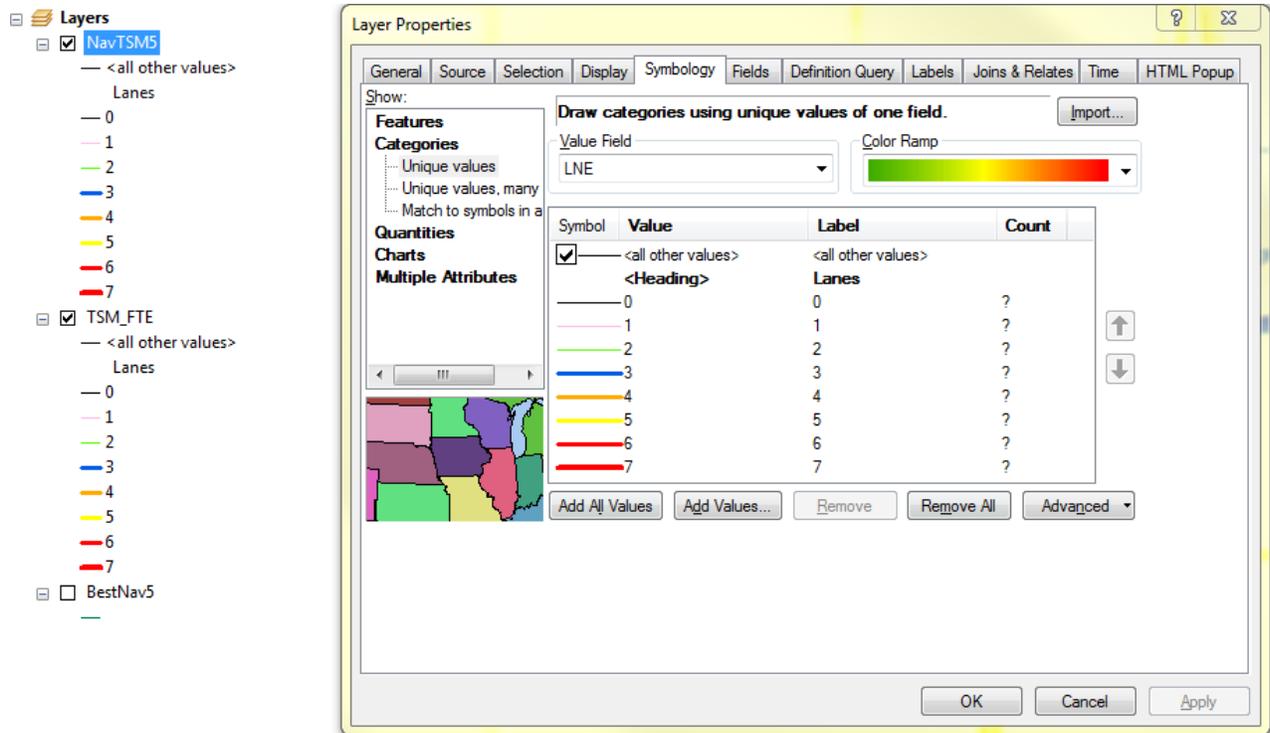


Figure C-30 NavTSM5 layer symbology

Step 2: Add a field "ORIGINAL_LNE" in the attribute table of NavTSM5 (Figure C-31) to record the original number of lanes that assigned to the Navteq layer during the matching process of TSM network and Navteq network. Then assign the value of ORIGINAL_LNE with value of LNE (Figure C-32).

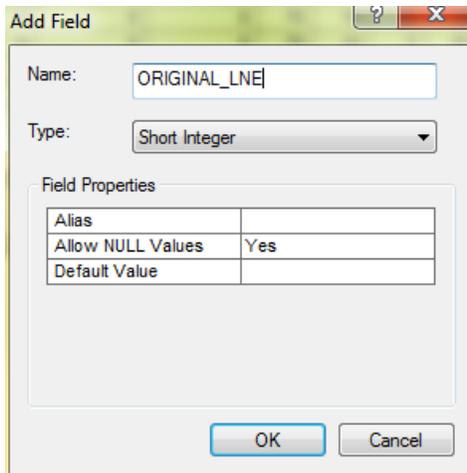


Figure C-31 Add field (ORIGINAL_LNE)

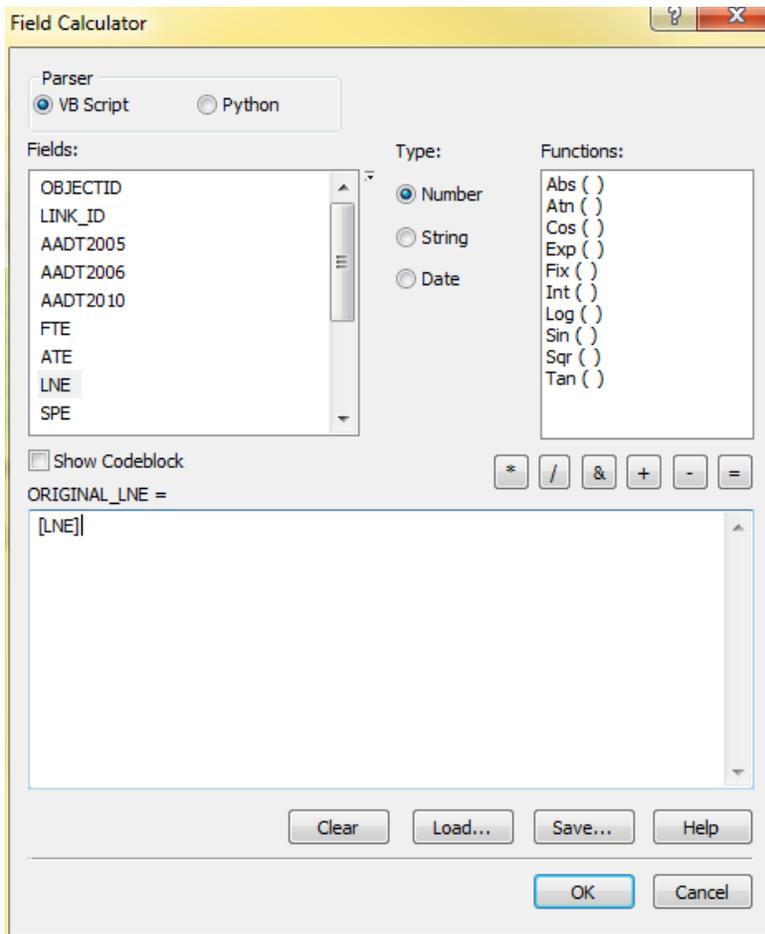


Figure C-32 Fill added field

Step 3: Compare and Edit Attributes

In this step, we compare the number of lane attributes between the NavTSM5 and the TSM_FTE for the whole area starting from the left-bottom. The comparison is finished manually by comparing the colors in different layers. If the colors are different, then it is very likely the attributes are not consistent. In this case, we need change the value of LNE and LNEC in NavTSM5 attributes table. The way how to do it is opening the attribute table, and conducting the “Field Calculator” for LNE and LNEC two fields (Figure C-33).

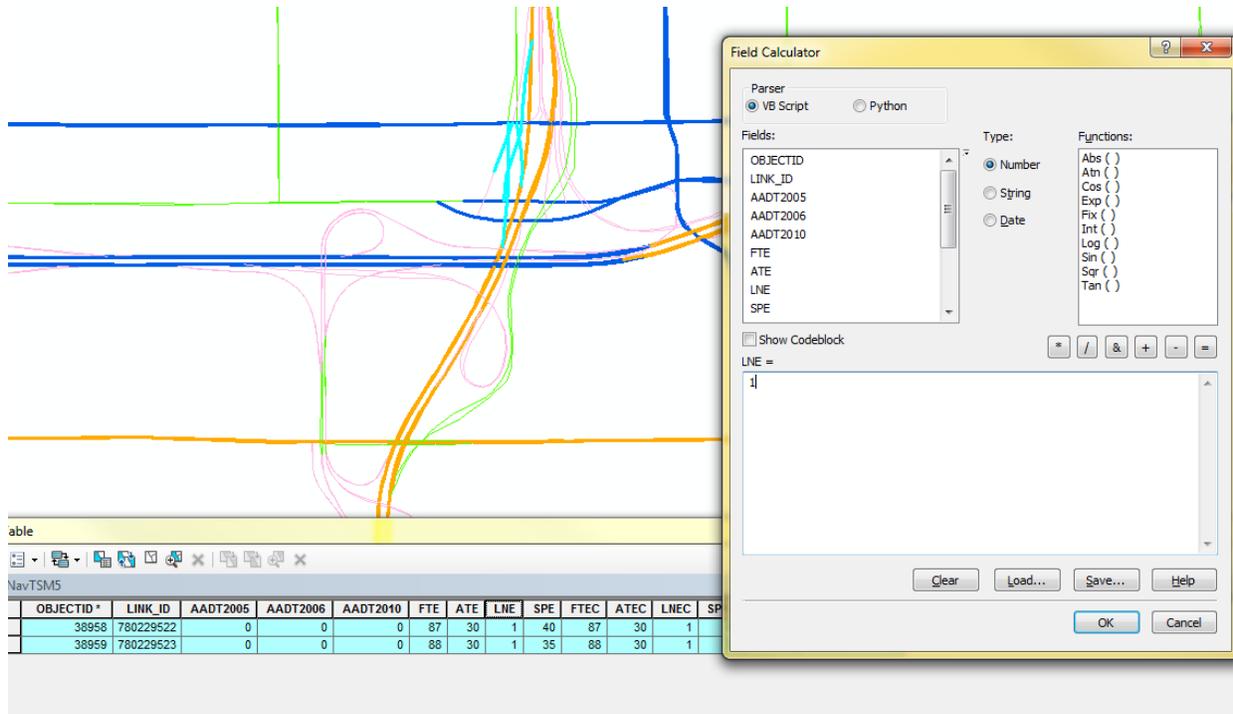


Figure C-33 Compare and edit attributes

Step 4: Double Check the Editing Result

Theoretically the attribute editing work is done when all of the links are compared as in step 3. While since all of the work is done manually, we need double check for editing result by redoing the step 3.

The final NavTSM5 is what we need.

Appendix

D. Managing the Unified Street Basemap Updates

Managing the Unified Street Basemap Updates

Crosswalk table shows the relationship between the different versions of the Navteq network of Florida. This relationship is built from the geometry perspective and try to create the matching of the Navteq links in different version.

Data Structure of Crosswalk Table

Figure D-1 is a part of the crosswalk table. It shows the relationship of the link between the 2010 1st quarter Navteq and the 2010 3rd quarter Navteq network. The crosswalk table is composed of several similar comparisons from 2009 to the newest version.

2010_Quarter1: is the link ID list of all the Navteq links in 2010 1st quarter.

Method_2010Q1_2010Q3: the description of what method used in building the relationship between the Navteq links and how well they are matched. The “exct” means the two links are exactly matched. The “prog” means the two links are matched through program, and the “hand” means the two links are matched through the hand work of editor. If the value is empty, it means no link in 2010 3rd quarter is matched with the link in 2010 1st quarter Navteq network.

2010_Quarter3: is the list of the link ID of 2010 3rd quarter Navteq network.

2010_Quarter1	Link_2010Q1_2010Q3	method_2010Q1_2010Q3	2010_Quarter3
16973829	16973829	exct	16973829
16973830	16973830	exct	16973830
16973831	16973831	exct	16973831
16973832	16973832	exct	16973832
16973833	16973833	exct	16973833
16973838	16973838	exct	16973838
16973839	16973839	exct	16973839
16973840	16973840	exct	16973840
16973841	16973841	exct	16973841
16973842	16973842	exct	16973842
16973843	16973843	exct	16973843
16973844	16973844	exct	16973844
16973845	16973845	exct	16973845

Figure D-1 Crosswalk table illustration

Creation of Crosswalk Table

There are three ways of matching between the Navteq links in different version for the crosswalk table.

1. Exactly Matched

In this situation, the link ID doesn't change in different version of the Navteq network (Figure D-2).

2010_Quarter1	Link_2010Q1_2010Q3	method_2010Q1_2010Q3	2010_Quarter3	Link_2010Q3
806534536	806534536	exct	806534536	806534536
806534535	806534535	exct	806534535	806534535
806534534	806534534	exct	806534534	806534534
806534533	806534533	exct	806534533	806534533
806534532	806534532	exct	806534532	806534532
806534531	806534531	exct	806534531	806534531
806534423	806534423	exct	806534423	806534423
806534422	806534422	exct	806534422	806534422
806534421	806534421	exct	806534421	806534421
806534420	806534420	exct	806534420	806534420

Figure D-2 Crosswalk table – exact match

2. Links Changed but Still Matched

Figure D-3 and Figure D-4 **Error! Reference source not found.** show the change of link in different versions of the Navteq. The crosswalk table tracks all of the information. From the crosswalk table we could see:

- 1) Links 80912942, 80912945, 80912946 entered the system in 2010, 3rd quarter.
- 2) These links replaced 781490015, and inherited its LRS/RCI attributes.

In this situation, the link in last version is split into three links. Thus these three links are all matched with the same link.

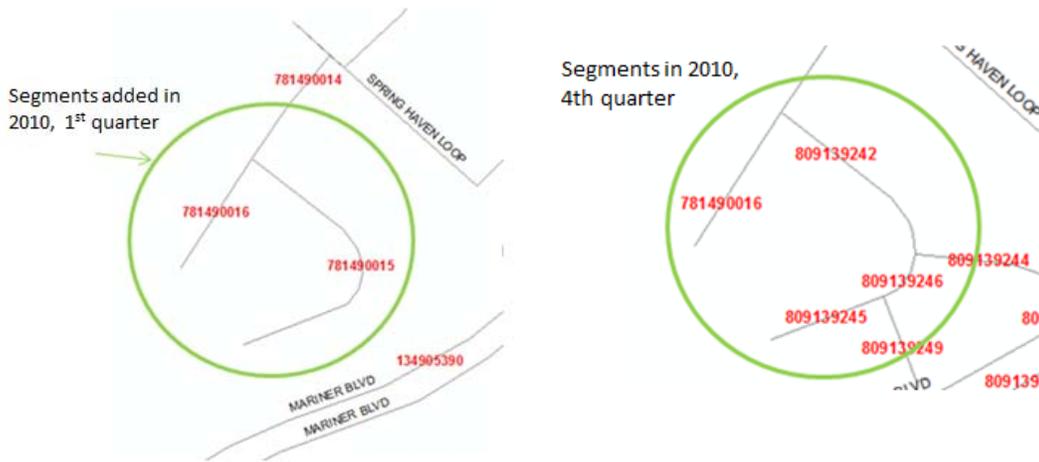


Figure D-3 Changes in Navteq versions

2009_q3	2009Link	2009M	2010_q1	2010q1Link	2010q1M	2010_q3	2010q3Link	2010q3M	2010_q4
	9	Hand	781490015						
				781490015	Hand	809139242	809139242	exct	809139242
				781490015	Hand	809139245	809139245	exct	809139245
				781490015	Hand	809139246	809139246	exct	809139246

Figure D-4 Crosswalk table before

3. New Links Added in New Version and Could not Be Matched with Pervious Version

Figure D-5 shows some links that are never appeared in 2010 1st quarter version but newly added in 2010 3rd quarter version, and kept in the following versions.

2010_Quarter1	Link_2010Q1_2010Q3	method_2010Q1_2010Q3	2010_Quarter3	Link_2010Q3	method_2010Q3	2010_Quarter4
		9 Hand	830595407	830595407	exct	830595407
		9 Hand	830652899	830652899	exct	830652899
		9 Hand	830648792	830648792	exct	830648792
		9 Hand	830644322	830644322	exct	830644322
		9 Hand	830644325	830644325	exct	830644325
		9 Hand	830648237	830648237	exct	830648237
		9 Hand	830648238	830648238	exct	830648238
		9 Hand	830648668	830648668	exct	830648668
		9 Hand	830648762	830648762	exct	830648762
		9 Hand	830652874	830652874	exct	830652874
		9 Hand	830648787	830648787	exct	830648787
		9 Hand	830653758	830653758	exct	830653758

Figure D-5 Crossway table after added links

The way that used to find whether a link in a Navteq version could be matched with a link in the previous version is a buffer method. A 0.5 meter buffer of the link will be done and then a comparison between the buffer and link in previous version need to be done. If the buffer contains the two end nodes of the previous link then they are exactly matched. If the buffer only contains one end nodes of the previous link then the link is the child of the previous link. While if no node of the previous link in contained, then the link is a new link and it could the

child of the previous link or a new link that appeared in the new version of Navteq. This usually needs the attention of editor.

Application of Crosswalk Table

Since the crosswalk table plays a role of bridge between different versions of Navteq network, thus it is useful to update the models that based on the Navteq network, and also transfer the attributes values from old version model to new version. Here are some possible applications of crosswalk table.

- 1) Help people to understand what has changed to the network.
- 2) Help to move the attributes in old model to new model that based on the Navteq network.
- 3) Help people get the latest RCI information because of the regular update of RCI tables and the association between the RCI and Navteq.
- 4) Help people to get the old user attributes.