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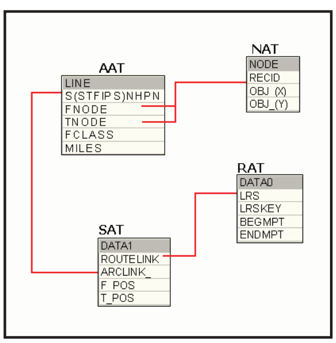
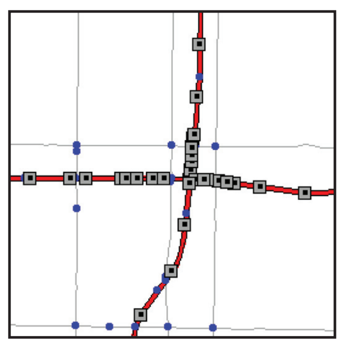
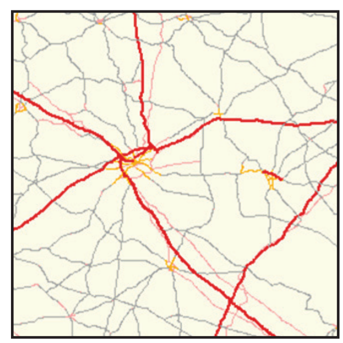
User Manual and Technical Documentation for the REDARS™ Import Wizard

by
Sungbin Cho, Shubharoop Ghosh, Charles Huyck
and Stuart D. Werner



Technical Report MCEER-06-0015

November 30, 2006

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NOTICE

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by

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Preface

The Multidisciplinary Center for Earthquake Engineering Research (MCEER) is a national center of excellence in advanced technology applications that is dedicated to the reduction of earthquake losses nationwide. Headquartered at the University at Buffalo, State University of New York, the Center was originally established by the National Science Foundation in 1986, as the National Center for Earthquake Engineering Research (NCEER).

Comprising a consortium of researchers from numerous disciplines and institutions throughout the United States, the Center's mission is to reduce earthquake losses through research and the application of advanced technologies that improve engineering, pre-earthquake planning and post-earthquake recovery strategies. Toward this end, the Center coordinates a nationwide program of multidisciplinary team research, education and outreach activities.

MCEER's research is conducted under the sponsorship of two major federal agencies, the National Science Foundation (NSF) and the Federal Highway Administration (FHWA), and the State of New York. Significant support is also derived from the Federal Emergency Management Agency (FEMA), other state governments, academic institutions, foreign governments and private industry.

The Center's Highway Project develops improved seismic design, evaluation, and retrofit methodologies and strategies for new and existing bridges and other highway structures, and for assessing the seismic performance of highway systems. The FHWA has sponsored three major contracts with MCEER under the Highway Project, two of which were initiated in 1992 and the third in 1998.

Of the two 1992 studies, one performed a series of tasks intended to improve seismic design practices for new highway bridges, tunnels, and retaining structures (MCEER Project 112). The other study focused on methodologies and approaches for assessing and improving the seismic performance of existing "typical" highway bridges and other highway system components including tunnels, retaining structures, slopes, culverts, and pavements (MCEER Project 106). These studies were conducted to:

- assess the seismic vulnerability of highway systems, structures, and components;
- develop concepts for retrofitting vulnerable highway structures and components;
- develop improved design and analysis methodologies for bridges, tunnels, and retaining structures, which include consideration of soil-structure interaction mechanisms and their influence on structural response; and
- develop, update, and recommend improved seismic design and performance criteria for new highway systems and structures.

The 1998 study, “Seismic Vulnerability of the Highway System” (FHWA Contract DTFH61-98-C-00094; known as MCEER Project 094), was initiated with the objective of performing studies to improve the seismic performance of bridge types not covered under Projects 106 or 112, and to provide extensions to system performance assessments for highway systems. Specific subjects covered under Project 094 include:

- development of formal loss estimation technologies and methodologies for highway systems;
- analysis, design, detailing, and retrofitting technologies for special bridges, including those with flexible superstructures (e.g., trusses), those supported by steel tower substructures, and cable-supported bridges (e.g., suspension and cable-stayed bridges);
- seismic response modification device technologies (e.g., hysteretic dampers, isolation bearings); and
- soil behavior, foundation behavior, and ground motion studies for large bridges.

In addition, Project 094 includes a series of special studies, addressing topics that range from non-destructive assessment of retrofitted bridge components to supporting studies intended to assist in educating the bridge engineering profession on the implementation of new seismic design and retrofitting strategies.

As REDARS™ moved from a methodology to a fully functional software program for seismic risk analysis of highway systems, a key element in encouraging widespread use was developing an import module that could process standard data formats into a format suitable for REDARS™. This report documents the development of an Import Wizard, including the base data, research, modeling assumptions, and user requirements, necessary for importing source data into the REDARS software. Data from several national and regional databases are able to be accommodated by the Import Wizard, such as the National Highway Planning Network (NHPN), Highway Performance Monitoring System (HPMS), National Bridge Inventory (NBI), National Earthquake Hazard Reduction Program (NEHRP) Soil, and Origin-Destination zones and trip tables (OD data) (available through local Metropolitan Planning Organizations). A complete user manual and technical documentation is included in the report. The REDARS methodology and software is presented in a companion MCEER special report, "REDARS 2 Methodology and Software for Seismic Risk Analysis of Highway Systems," by S.D. Werner, C.E. Taylor, S. Cho, J.P. Lavoie, C.K. Huyck, C. Eitzel, H. Chung and R.T. Eguchi, MCEER-06-SP08.

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The authors would especially like to acknowledge the exceptional leadership and guidance provided by Stuart Werner of Seismic Systems and Engineering Consultants. Without this vision, this project would not have been possible. In addition, the special efforts of Jean-Paul Lavoie and Chip Eitzel of Geodesy, Craig E. Taylor of Natural Hazards Management, Inc., and James E. Moore II of the University of Southern California are acknowledged by the authors. The authors would also like to thank Mandy Chu and her team in the Division of Research and Innovations, Caltrans for their thorough evaluation of the Import Wizard.

This research was conducted under MCEER master agreement DTFH61-98-C-00094 with the Federal Highway Administration.

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CHAPTER 1
INTRODUCTION TO REDARS™

1.1 Overview of REDARS™ 2.0

REDARS™ (**R**isks from **E**arthquake **DA**mage to Roadway **S**ystems) is a software program for deterministic and probabilistic seismic risk analysis of highway systems. Funded by the Federal Highway Administration funds the research and executed by the Multi-Disciplinary Center for Earthquake Engineering Research, REDARS™ estimates the economic impact of earthquakes on transportation networks by evaluating damage to bridges and modeling the subsequent impacts on traffic flow. During a validation study, Task B1-1 of FHWA/MCEER Project DTFH61-98-C-00094, several areas were identified for potential improvement. The objective of this report is to document the usability of REDARS™ achieved by creating a methodology for importing databases into REDARS™. The following sections introduce each task completed under this project and identify the location in the report where further documentation can be found.

Creating a REDARS™ study region in the initial REDARS™ demonstration product was a considerable challenge that required several months of data massaging. The user was tasked with developing a transportation network with full topology that integrated bridges and Origin/Destination (OD) data. As the REDARS™ prototype moved from a methodology to a fully functional software program, a key element in encouraging widespread use was developing an import module or methodology that processed standard data formats into a network suitable for REDARS™. This report documents the base data, research, modeling assumptions, and user requirements for running the REDARS™ *Import Wizard*, a software program for importing data into REDARS™.

Given the dependence on data provided in a standard, federally mandated format, the Import Wizard is limited in flexibility. Section 1.2 explores the limitations of the Import Wizard in detail. Data sources and critical steps required to develop a REDARS™ database are documented in a data flow diagram and data model presented in Sections 2.2 and 2.3. The Import Wizard requires data from two separate FHWA transportation networks, which are integrated with bridges and local OD data. Sections 2.4-2.8 examine the transportation network, bridge, local OD and soil data imported into REDARS™ through the Import Wizard. These sections also provide an overview of the many integration issues encountered during the automation of REDARS™ database development, and presents an overview of the solutions employed. The individual screens that constitute the import wizard are presented in Chapter 3, which serves as the Import Wizard user manual. Details of the modeling assumptions in the Import Wizard can be found in Chapter 4, where research challenges are presented along with samples and preliminary validation results. Additional reference information is available in the appendices: Appendix A provides answers to frequently asked questions; Appendix B presents a detailed outline of the programming steps within the Import Wizard; Appendix C provides FHWA network data fields referenced by the Import Wizard; and finally Appendix D provides a list of REDARS™ data table fields.

1.2 Limitations of the Import Wizard

The REDARS™ Import Wizard uses nationally available FHWA datasets to enable prompt creation of REDARS™ study regions. Although the program depends on FHWA data, the actual datasets are provided by the states themselves and vary in accuracy and completeness depending on interpretation of the requirements, and completeness of the transportation data available. These factors influence the usability of the REDARS™ study region for a given area. The following discussion explores various problems that may arise in a study region due to problems with base data. Where possible, solutions are recommended.

In a REDARS™ study region, bridges may be missing or misplaced. This is often due to problems in the Linear Referencing System (LRS) of the base data. Some state transportation agencies do not track subroute ID, or do so in a manor inconsistent with the National Bridge Inventory (NBI). Milepost markers are frequently incorrect, reversed, or in the wrong units, resulting in misplaced or omitted bridges. Possible solutions include correcting the LRS in a GIS system, or editing the data fields in the original data to be consistent with the NBI data. Additionally, the state DOT should be contacted directly and notified of the data inconsistencies.
The NBI, the National Highway Planning Network (NHPN) and the Highway Performance Monitoring System (HPMS) do not contain sufficient information for locating bridges that are freeway onramps. A freeform field in the NBI data does accommodate entering a general description (such as I-10 W to 405 NB), but this is rarely entered consistently enough to parse bridge location. At this time, REDARS™ conservatively assumes that damaged ramps impact traffic in both directions of the freeway.

Attribute data in the various databases may contain incorrect or no information regarding number of lanes, link type, the rural or urban designation, and route attributes. The user is advised that currently, the only way of resolving these issues is to fix these problems in the base data and rerun the Import Wizard. The problems will be fixed in the resulting REDARS™ study region.
The NBI only tracks state and federal bridges which are located primarily on freeways and highways. Users requiring detailed bridge and network data for analysis may obtain network data from their Metropolitan Planning Organization (MPO) and bridge data from the local jurisdictions. This data will vary by region and is not supported by the Import Wizard. Users can create a REDARS™ study region outside of the Import Wizard using the REDARS™ open database format.

Public transit is currently not supported within REDARS™. One-way routes are not distinguished in the NHPN data. Users can support one-ways by deleting the extra directional link record in the final REDARS™ study region.

CHAPTER 2

DEVELOPMENT OF THE REDARS™ DATABASE

2.1 Role of the Import Wizard

This chapter documents the development of the REDARS™ Import Wizard, a software program that streamlines the process of importing data into REDARS™. The Import Wizard depends on publicly available and federally distributed FHWA databases to minimize data collection and formatting tasks. Figure 2.1 illustrates the user tasks when running the Import Wizard. First, a series of dialogs guide the user through identifying databases on the computer hard drive. The user then enters several data parameters such as OD trip type and default soil type, and defines a REDARS™ study region by selecting a collection of TAZS. The Import Wizard verifies the selection, integrates the various data into a REDARS™ database, and calculates the external trip demand. These tasks executed by the Import Wizard require complex spatial and transportation modeling techniques, which are discussed from a technical perspective in Chapter 4.

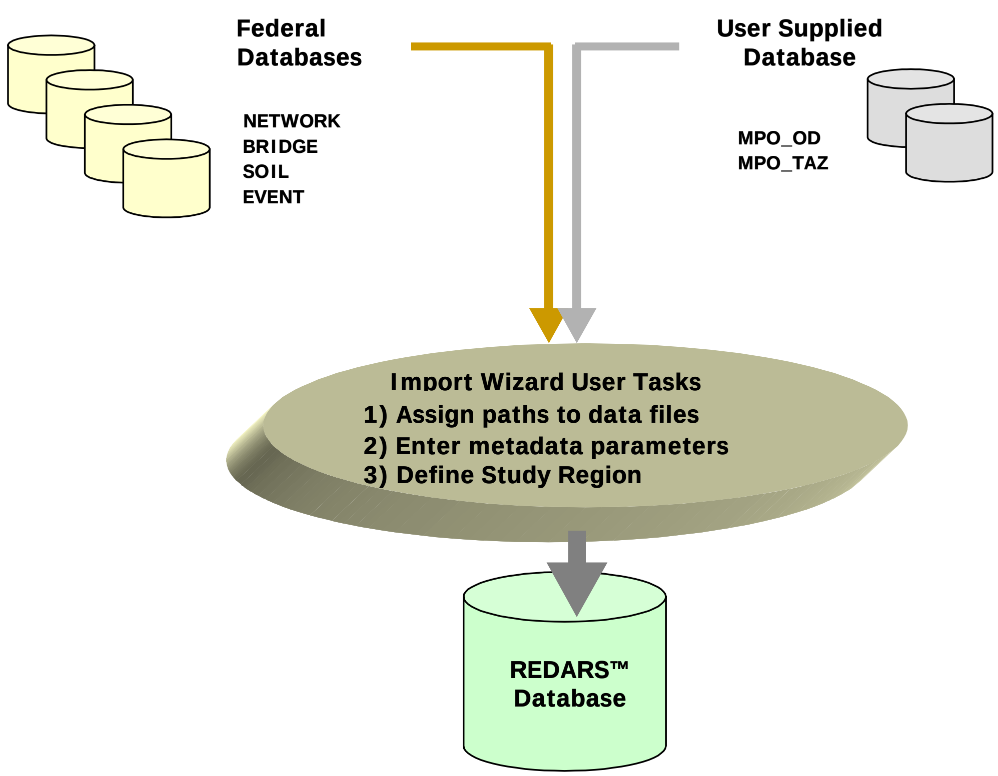


Figure 2.1 User tasks when running the Import Wizard

2.2 Conceptual Data Flow Diagram

This section summarizes the challenges in establishing the data relationships and joins within the data model during Import Wizard development. Figure 2.2 presents a conceptual data flow diagram that introduces a simplified version of the REDARS™ Import Wizard representing the data types and the REDARS™ tables. The left side of Figure 2.2 documents the data sources critical to develop the REDARS™ database in a conceptual data flow diagram. The following is a list of national databases that are discussed in this chapter:

i. National Highway Planning Network (NHPN)

ii. Highway Performance Monitoring System (HPMS)

iii. National Bridge Inventory (NBI)

iv. National Earthquake Hazard Reduction Program (NEHRP) Soil

v. Metropolitan Planning Organization (MPO) Origin-Destination zones and trip tables (OD data)

Items i) and ii) above are databases providing the transportation network and are discussed in detail in Sections 2.4 and 2.5. Item iii) provides bridges data, discussed in Section 2.6, and item iv) is the soil data discussed in Section 2.7. In addition to the publicly available federal databases, REDARS™ requires data on Origin Destination (O-D) that is available through local Metropolitan Planning Organizations. Item v) provides data on OD and is discussed in Section 2.8.

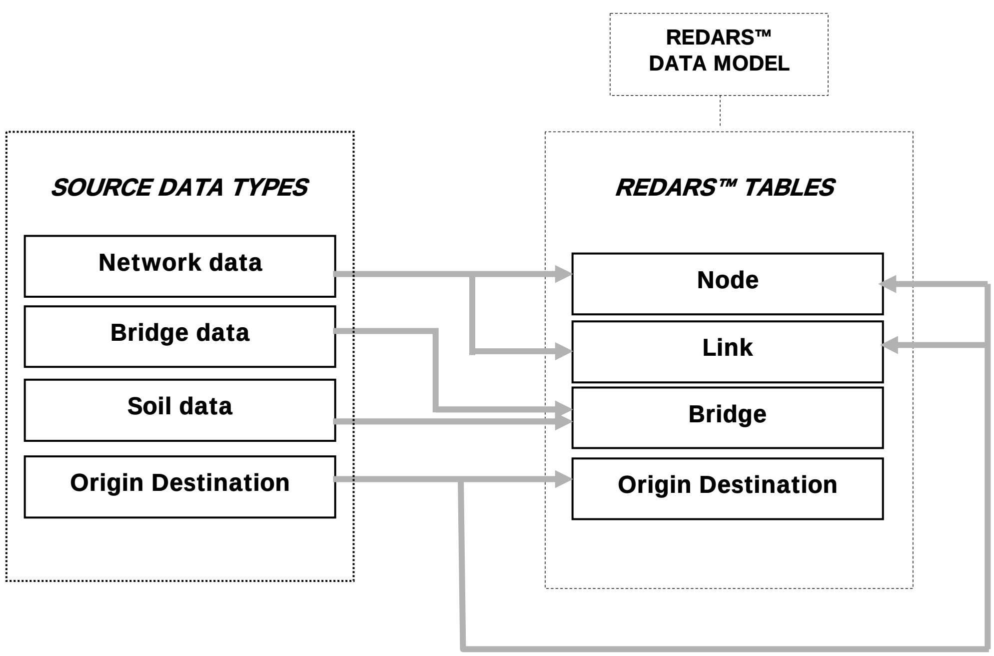


Figure 2.2 Conceptual Data Flow Diagram

2.3 The REDARS™ Data Model

Figure 2.3 introduces the REDARS™ data model. The data model is a 'blue print' for REDARS™ data development, and provides the framework for understanding how the base data is combined into a REDARS™ database. Subsequent sections of this chapter discuss key elements of the data model. For each data type, the base data is described along with the methods of joining the data to other data sources within the data model.

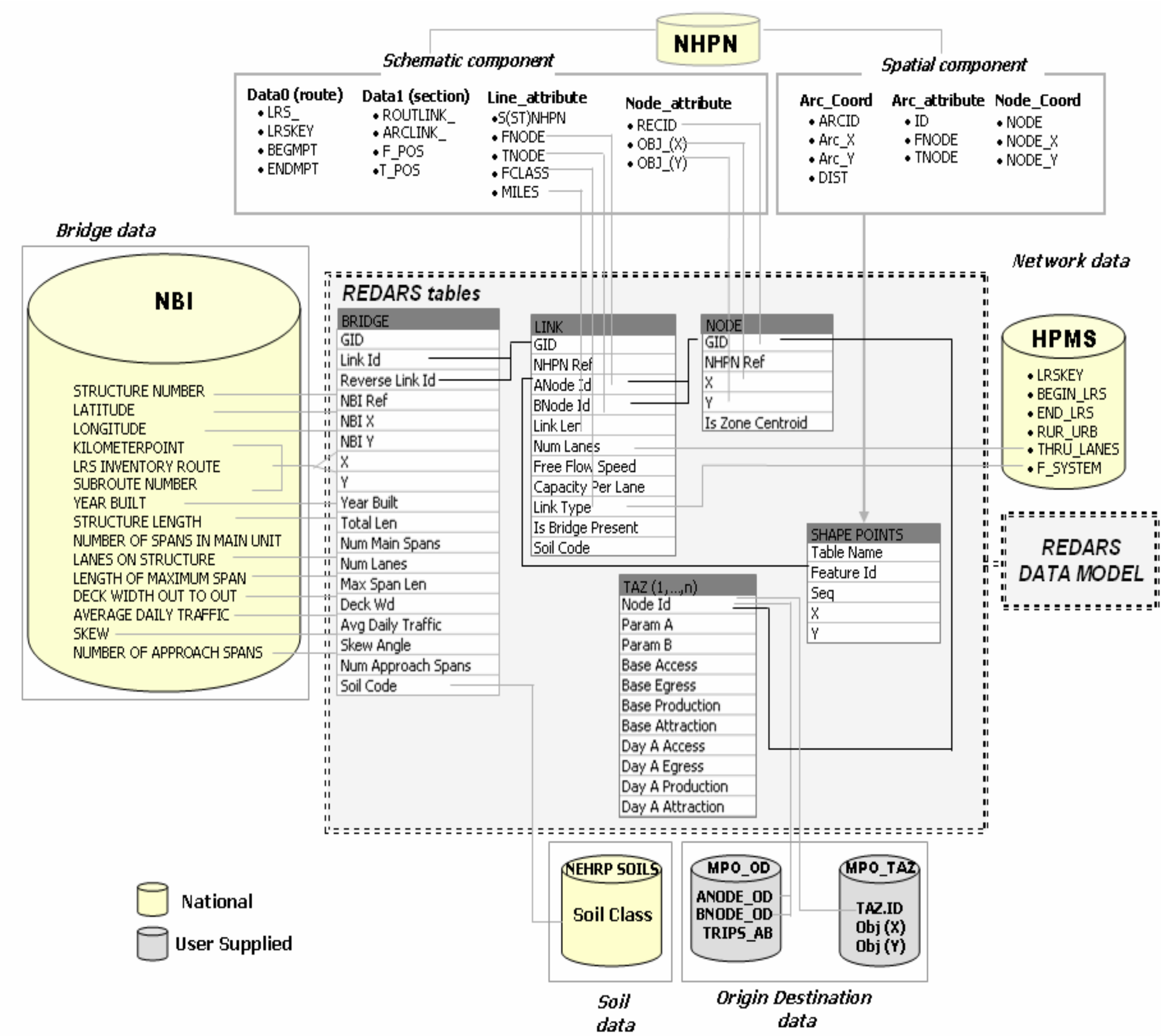


Figure 2.3 REDARS™ Data Model

The REDARS™ data model provides a framework for importing data into REDARS™. The data joins illustrated in the data model can not be established in a traditional database context because of incompatible linear referencing systems, and lack of common identifiers. Instead, these relationships must be forged with a series of GIS and transportation modeling tools, including proximity analysis, dynamic segmentation, weighted averages, and connectivity assessment.

Throughout this documentation, a *database* refers to a collection of tables. In some cases, there may only be one table, for example with the bridge database (National Bridge Inventory or NBI). A data *table* refers to tabular data consisting of *fields* (columns) and *rows* within a database. In some cases, in preparation for import or export, a data table may be kept outside a database in a single table file, such as with a delimited text file. Data in tables are connected through common identifiers, stored in an *ID fields*. The connections between tables are referred to as *relationships, relates* or *joins* between fields. The term "link" is avoided, due to frequent use in transportation terminology.

The REDARS™ database is comprised of five tables. Table 2.1 provides a summary of the REDARS™ tables.

Table 2.1 REDARS™ Tables within the Data Model

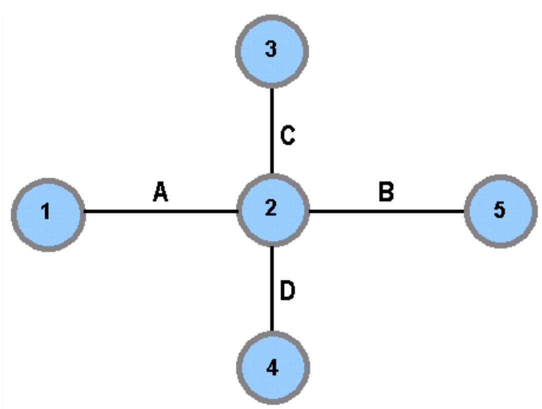
Tables populated by the Import Wizard	Description	Key Information
Node	Node location provides link connectivity. Nodes are either centroids of Origin Destination zones or endpoints of links. All entities in the transportation network or made from a collection of nodes.	Location, whether associated with an OD node or virtual link, node identifier
Link	A connection between two nodes. A collection of links constitute the road network. Network attributes are associated with links. Some links are referred to as "virtual links" in the text, because they are not associated with roadways, but connections between external network nodes or OD nodes and the transportation network.	Link identifier, "From" node identifier, "To" node identifier, link length, whether it is a virtual link or a link between external OD nodes, free flow speed, capacity, presence of bridge along the link.
Bridge	Bridge location, associated link identifier, database identifiers, structural characteristics, age, geometric data, structural classification, and condition. This table also includes tunnels.	Database identifiers for state name, bridge, and freeway route; latitude and longitude; number of spans, bridge length, width and skew angle
OD (Origin Destination)	Data derived from travel surveys used to quantify the traffic demand between zones in the network (defined as key nodes) includes the baseline travel time as calculated by the model	Node database identifier for "From" zone and "To" zone, travel demand, and travel time
Shapepoints	Points in addition to node endpoints that define the shape of a given link. These points are used to geographically represent links and to calculate distance. Are not used as features of the transportation network for routing purposes.	Link ID, distance along the link, position.

A transportation network represents the highways and roads via a system of linear features or "links" connected at intersection points or "nodes". Nodes are associated with map coordinates that define location. The REDARS™ Node table contains a unique identifier, the latitude and longitude coordinate fields, and a "node type" field that designates whether a node is associated with an OD centroid. The REDARS™ Link table provides the attributes of the transportation network, including the number of lanes, direction (unidirectional or bi-directional), and capacity per lane. Connectivity between links in the network is maintained through the Node table. Section 2.4 explores network connectivity in detail.

The Bridge table provides the structural characteristics to assess seismic vulnerability and the location of the bridge. There are many fields in this table that are not illustrated in Figure 2.3, that either are transferred directly from the National Bridge Inventory or are available for the user to update. A complete list of fields is available in Appendix D. Finally, the Origin Destination (OD) table provides information on origin destination or travel related zones and the demand for travel between these zones.

2.4 Network Data Topology within REDARS™

REDARS™ requires an integrated transportation network for analyzing post-earthquake traffic disruption and increased travel costs. An integrated transportation network refers to the spatial data that models the highway system using a set of links and nodes as discussed in Section 2.3 above. Nodes are point locations along the network where traffic flow originates, terminates, or transmits. Links are the conduits for flow between nodes. The attributes of the link database inform the transportation model if, and with what speed, traffic can be transmitted between nodes. Two adjacent links are connected when they share a common node, with a common identifier, allowing a transportation model to transfer traffic between links. Adjacency of links is not sufficient to route traffic in a transportation network. Network connectivity is a key data requirement for the REDARS™ database.



LINK	From	To
A	1	2
B	2	5
C	2	3
D	2	4

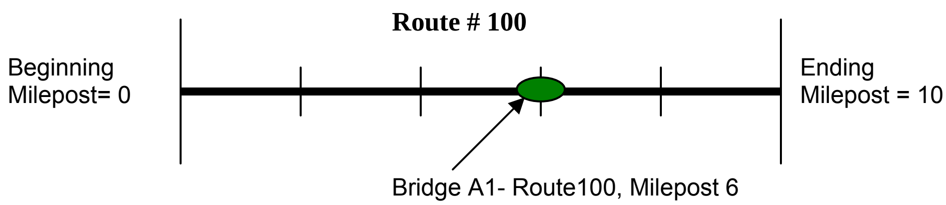
NODE	X_Coord	Y_Coord
1	-118.75	37.65
2	-118.65	37.65
3	-118.65	37.75
4	-118.65	37.55
5	-118.55	37.65

Figure 2.4 Topological Network and the Underlying Databases

Figure 2.4 illustrates how node-link connectivity is maintained in a network. Link "A" has a "from node" of *1*, and a "to node" of *2*, allowing traffic to flow from point *1* to *2*. This is illustrated in the graphic as well as the matrix in Figure 2.4. Node *2* is in the "from node" field of 3 separate links: "*B*", "*C*", and "*D*". This commonality enables the modeling of traffic flow from node *1* to nodes *2*, *3*, *4* and *5*. If node *2* represents an overpass and there is no connectivity between node *1* and nodes *3* and *4*, then either there would be no node *2* (which would result in the combination of links A and B, and the combination of links C and D), or there could be a node with a different ID number connecting links C and D. In this manner, connectivity would be cut off between node 1 and nodes 3 and 4. In this example, as the tables are populated, each link routes traffic in a single direction. To route traffic in the opposite direction, the links would be repeated, with new IDs, and the values in the *from* and *to* fields switched. Although intuitively, one could look at a map and deduce the flow of traffic at an intersection quite easily, this rigid table structure is required to address the flow of traffic programmatically.

A Linear Referencing System (LRS) is an integral part of a transportation network data structure. To spatially index and assign coordinates to the transportation infrastructure, transportation departments and Metropolitan Planning Organizations (MPOs) frequently use a LRS for transportation facilities. LRS support the storage and maintenance of "events" that occur on a transportation network, which might include: bridges and other structures, changes in pavement condition, or traffic accident sites. In a LRS, features are represented as occurring along the links that comprise the transportation network. Event locations are defined as a distance along a specified route from a reference point. If the reference point and the route are explicitly identified in the transportation network, then the linear-referenced feature can be located by calculating the distance along the segments comprising the specified route. Usually, this referencing system corresponds to the mile-marker and route name. In order to calculate the distance along a link, each segment in the transportation network must include a route identifier consistent with the naming convention of the linear-referenced feature and a distance (mile or kilometer) with respect to the start of the route. An ending reference distance with respect to the start of the route must also be included for the referencing of linear features.

Figure 2.5 below illustrates a bridge linearly referenced using a route number and milepost. The tabular data in figure includes the route identifier, a beginning milepost and an ending milepost for the segment. The sample bridge in Figure 2.5 is located by matching the route number and measuring 6 miles along the segment. The 6 miles corresponds to the beginning milepost subtracted from the milepost of the event. The following section applies these concepts to the databases used within REDARS™.



Route Attribute Table

Route	From Milepost	To Milepost
100	0	10

Event Table

Accident	Route	Milepost
A1	100	6

Figure 2.5 Linear Referencing System and the Underlying Databases

2.5 FHWA Transportation Network Data Sources

For transportation network data, the Import Wizard uses two nationally available databases distributed by the Federal Highway Administration (FHWA): the National Highway Planning Network (NHPN) and the Highway Performance Monitoring System (HPMS). The following sections discuss the use of these databases.

2.5.1 The National Highway Planning Network (NHPN)

NHPN is a nationally available transportation network that includes interstates, principal arterials, and rural minor arterials. The data is provided by the states and maintained by FHWA. It is a 1:100,000 scale network database that contains line features representing just over 450,000 miles of current and planned roads. Complete NHPN documentation including description, schema, and file structure of the NHPN Network can be obtained at: http://www.fhwa.dot.gov/planning/nhpn/docs/index.html. The latest version of NHPN data is 4.0 and is available for all 50 States, the District of Columbia, and Puerto Rico (http://www.fhwa.dot.gov/planning/nhpn/). These files are available as zipped ESRI ArcInfo Interchange (.e00) format.

The NHPN v4.0 database contains network topology and route attribute data. The network topology defines the geometry required for mapping in a GIS, and the route attribute data provides data on the road network. The geometry from the NHPN data is contained in a set of tables. These tables are 1) Node Attribute Table (NAT), 2) Arc Attribute Table (AAT), 3) Route Attribute Table (RAT), and 4) Section Attribute Table (SEC). These tables are all contained within an .e00 file, and can be examined individually if imported into ArcInfo or ArcGIS. The following section outlines the tables contained within the NHPN database and discusses the key fields used by the REDARS™ Import Wizard.

2.5.1.1 Node Attribute table (NAT)

The Node Attribute Table contains the geographic location of each node referenced by an arc end point. Nodes in the NAT table are not generally visible to the end user, and do not appear on the transportation network, but the nodes in this table comprise all of the geographic entities in the transportation network through database relationships.

2.5.1.2 Arc Attribute Table (AAT)

The AAT contains records for each arc in the NHPN database. Each arc, (corresponding to a network link) contains the following key attributes:

*S(STFIPS)NHPN_*	A unique identifier for the network link. "(*STFIPS*)" corresponds to the two digit state FIPS code. Each link identifier includes the state FIPS Code.
FCLASS	Identifies the functional class of each arc. Functional class designates roads as interstates, highways, arterials, or local rural roads.
MILES	The length of the arc in miles.
FNODE	The unique ID of the "from node", or starting node of the network link. This is a link to the unique ID stored in the NAT table, and is used to create a relational join between the Link and Node tables.
TNODE	The unique ID of the "to node", or ending node of the network link. This is a link to the unique ID stored in the NAT table, and is used to create a relational join between the Link and Node tables.

2.5.1.3 Route Attribute Table (RAT)

The RAT is a table that provides information on the route. There is one row in the RAT for each named interstate, highway, arterial, or local rural road. The following are key attributes of the RAT:

*LRS_*	A unique identifier for the interstate, highway, arterial, or local rural road.
LRSKEY	Standard route name for the LRS. For example, Interstate 10" has a value of "10".
BEGMPT	Value of the first mile marker in the route.
ENDMPT	Value of the last mile marker in the route.

2.5.1.4 Section Attribute Table (SAT)

The SAT tracks attribute information for a section of a route, which is comprised of a collection of arcs or portions of arcs. Key identifiers include:

ROUTELINK _	Links to the LRS_ field
*ARCLINK_*	Links to the S(STFIPS)NHPN_ unique identifier.

The REDARS™ data model requires spatial data (network topology and route information) for location and visualization, which is obtained from the NHPN database. The NHPN provides the data structures necessary to overlay dynamically segmented (see Section 2.2.2) state inventory databases, such as the Highway Performance Monitoring System (HPMS) and the National Bridge Inventory database (NBI). The attribute information for the highway system, however, can be incomplete or inaccurate in the NHPN database. Below, we discuss the data that can be linked to the NHPN from the HPMS.

2.5.2 The Highway Performance Monitoring System (HPMS)

The HPMS is a nationwide inventory distributed by FHWA that tracks public road mileage and is certified by state governors on an annual basis. Attributes that are collected include the extent, condition, performance, use, and operating characteristics of a given section of roadway. The database is not geographic, but contains a route number and a *from* and a *to* mile marker. This provides enough information to render the attributes of the HPMS on the NHPN through dynamic segmentation. Mapping the HPMS data using dynamic segmentation is discussed in Section 4.5. The REDARS™ Import Wizard references the following fields from the HPMS database:

LRSKEY	Linear Referencing System Unique ID. This ID corresponds to the LRSKEY field in the NHPN RAT.
BEGIN_LRS	The first mile marker for a given HPMS event segment. May or may not correspond to a node in the NHPN NAT.
END_LRS	The last mile marker for a given HPMS event segment. May or may not correspond to a node in the NHPN NAT.
RUR_URB	Indicates whether the route is in a rural, suburban or urbanized area.
THRU_LANES	Number of lanes in both directions combined.
F_SYSTEM	Functional class of road (Interstate interstates, highways, arterials, or local rural roads)

HPMS data and documentation is available from http://www.transtats.bts.gov/DataIndex.asp.

The HPMS field manual with data descriptions and coding instructions is available from http://www.fhwa.dot.gov/ohim/hpmsmanl/hpms.htm

The HPMS road inventory tracks more detailed attribute data for key fields such as the number of lanes, functional classification than the NHPN. Thus, the attribute information is more appropriate for REDARS™. However, REDARS™ needs the geographical location of the transportation network, which is provided by the NHPN. Linking the attribute data in the HPMS to the geographic data in the NHPN is a difficult process because the beginning and ending nodes of individual links do not always correspond. For example, a given link in the NHPN may have a beginning milepost of 2 and an ending milepost of 3, associated with highway 101. Covering the same length of road, the HPMS may have two segments. One might have a beginning milepost of 1.5 and an ending milepost of 2.25 with one set of attributes (for example

4 lanes, suburban), and the other might have a beginning milepost of 2.25 and an ending milepost of 3.1 with another set of attributes (for example 6 lanes, urban). Establishing the best attributes for the geographic link requires either splitting the link into 2 sections (milepost 2 to 2.25 and 2.25 to 3) or rebuilding the topology of the network, or using a rules-based approach to establish the best attributes.

2.5.3 Relationships between FHWA Network Data Sources

The primary purpose of the NHPN is to provide a method of visualizing the HPMS network attributes. This section describes the process by which the two data sets are joined. Table 2.2 provides a summary of the NHPN and HPMS data sources discussed thus far and includes a list of key fields, the benefits, and the drawbacks.

Table 2.2 Summary Table of FHWA Network Data Sources

Network Data from FHWA	Key Database Fields	Applicability for REDARS™
National Highway Planning Network (NHPN)	**Node (NAT):** *RECID* **Arc (AAT):** *S(STFIPS)NHPN_* *FCLASS* *MILES* *FNODE* *TNODE* **Route (RAT):** *LRS_* *LRSKEY* *BEGMPT* *ENDMPT* **Section (SAT):** *ROUTELINK _* *ARCLINK_*	• Can be mapped with GIS • Link-node network topology • A routing system suitable for LRS. • Can be used for locating bridges and tunnels through dynamic segmentation
Highway Performance and Monitoring System (HPMS)	*LRSKEY* *BEGIN_LRS* *END_LRS* *RUR_URB THRU_LANES* *F_SYSTEM*	• Tracks network attribute data such as route number, number of lanes, and functional class • No native geographic information • Can be visualized with the NHPN using dynamic segmentation • Inconsistent with the NHPN on a link by link basis. Unmatched beginning and ending nodes make it impossible to directly match attributes without reestablishing NHPN links or weighting link attributes.

The detailed network data model for the NHPN database presented in Figures 2.6 and 2.7 below illustrate the relationships between the NHPN data tables (Node Attribute Table (NAT), the Arc Attribute Table (AAT), the Route Attribute Table (RAT), and the Section Attribute Table (SAT). These relationships are key to joining the NHPN and HPMS databases. The key relationships in the NHPN can be summarized as follows:

- The Node Attribute Table contains a unique identifier (*RECID*) and geographic coordinates. These are used to georeference the endpoints of the links in the AAT. The unique identifier (*RECID*) corresponds to the value of *FNODE* and *TNODE* in the AAT.

- The Arc Attribute Table contains the unique identifier *S(STFIPS)NHPN_* referenced by *ARCLINK_* of the SAT (Data1). *ARCLINK_* is not a unique value field, and many arcs define a section. An arc is a linear segment between exactly two nodes. A given street between two intersections may contain many arcs to define curvature, but will usually have only one row of attribute information, which is stored in the SAT. A row in the SAT, or a section, will join to at least one row in the AAT, and a section is smallest unit for which attribute information is defined.

- The Route Attribute table (Data 0) contains a unique identifier (*LRS_*), referenced by *ROUTELINK_* in the SAT. Routes are a collection of sections. In some cases, they correspond to the entire length of a named roadway within a state.

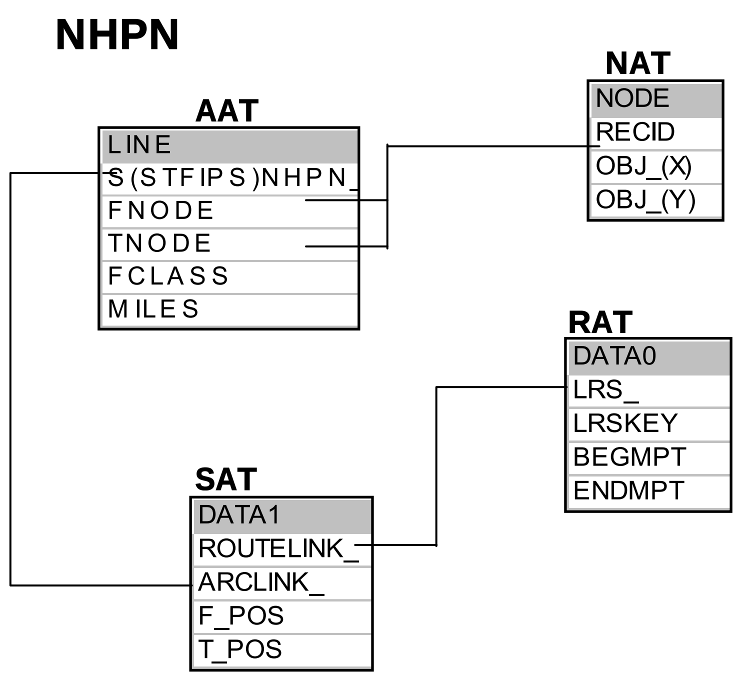


Figure 2.6 Joins between Attribute Tables in NHPN Database

Figure 2.7 illustrates the relationships between the NHPN and HPMS databases. The HPMS contains network attributes which can be linked to the NHPN data using a linear referencing system. The *LRSKEY* in HPMS matches the *LRSKEY* in NHPN, and the milepost fields can be used to locate the attributes on a portion of the NHPN data. *BEGIN_LRS*, *END_LRS* in HPMS usually use the same linear reference as *BEGMPT* and *ENDMPT* in the NHPN. Using the same linear reference necessitates that the same milepost markers apply to the same length of roadway, and using the same key necessitates that Highway 101 is referenced with the exact same notation, and that both datasets are populated for this length of roadway. In practice, the databases do not always use the same linear reference or LRS key, but these fields are the only method of joining the attributes in the HPMS to the geographic data in the NHPN. Even with the same linear reference, the beginning and ending modes used for the same length of road may not match, so the attributes can not be linked directly.

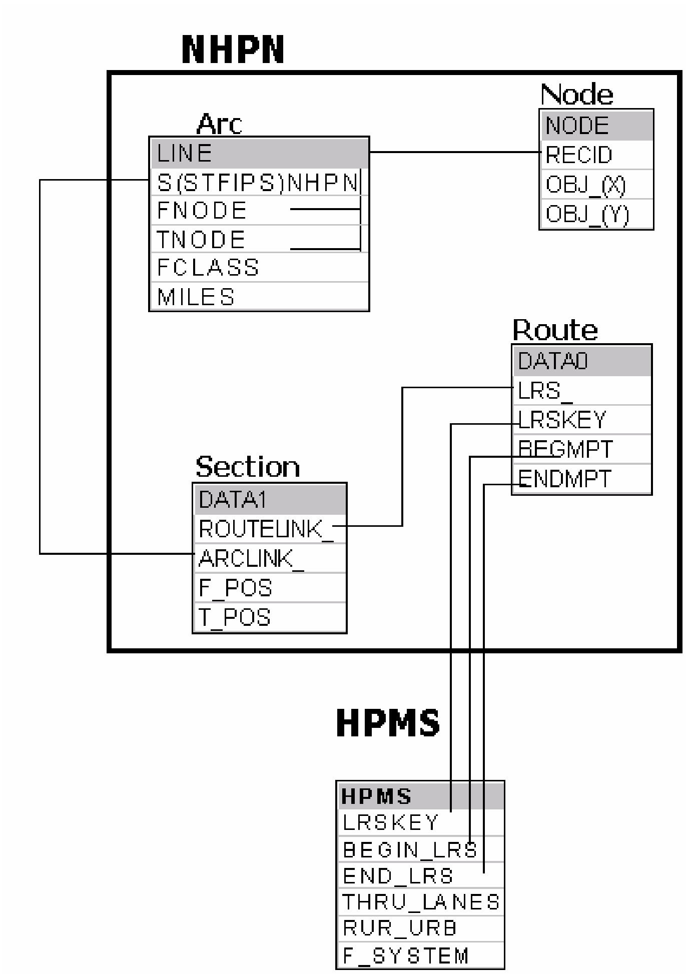


Figure 2.7 Database Joins between HPMS and NHPN

NHPN and HPMS contain crucial data that must be joined into one database for use in REDARS™. Although both data sets have a linear referencing system, there are connectivity issues with matching the data sets. Individual links in the two databases pertaining to a given stretch of road can not be joined through a database because the beginning and end points of individual segments tracked by NHPN and HPMS frequently do not match. Section 4.4 discusses the issues resolved while importing the data from FHWA into REDARS™. The next section discusses integrating bridges into the REDARS™ transportation network.

2.6 Bridge Data

2.6.1 Bridge Data within REDARS™

The REDARS™ data model requires bridge data that is integrated into the REDARS™ transportation network. Bridges and links must be joined by a common ID. Incorporation of bridges into the network is required to analyze post-earthquake traffic routes and the increase in travel costs due to bridge damage. REDARS™ uses the National Bridge Inventory (NBI) distributed by FHWA to incorporate location, structural type, year built, and number of lanes. As with the HPMS data, the route and milepost field within the NBI make it possible join the bridges to the network through dynamic segmentation. This section discusses the key data fields in the bridge data and explains how the bridges are spatially located through dynamic segmentation. Data fields which track bridge damage and ground shaking are not necessary for building network topology in REDARS™ data model, and thus, are not discussed in this document.

The REDARS™ data model incorporates both the geographical data and attributes from the NBI database. Although locations of the bridges are maintained in the latitude and longitude fields, these fields are not used. The Import Wizard locates the bridges using the LRS data, which allows the bridges to be joined to individual segments in the transportation network, allowing REDARS™ to assess disruption in network connectivity. Additionally, locating the bridges through LRS can provides very accurate bridge coordinates, if the milepost markers in both databases are correct. Using the location provided by the latitude and longitude can result in ambiguity, particularly in cases where the data is not provided with enough precision or at major intersections where the closest link may not correspond to the appropriate freeway.

The process of locating bridges from the LRS is called "dynamic segmentation." Dynamic segmentation generates points for events referenced by distance along a linear feature. For example, through dynamic segmentation using the milepost marker and the highway route, information stored in a bridge table can be assigned a coordinate and plotted on a map as well as linked to the highway segment in the underlying database.

Figure 2.8 illustrates how the LRS in network and bridge databases is used to establish location. Data for a bridge with the unique identifier "53 1059" has a "route identifier" (405), and milepost data (215.6). Dynamic segmentation converts the linearly referenced bridge data stored in the database into a GIS point that is displayed on the base network between the "From Milepost" (215) and the "To Milepost" (216). This process of locating bridges generates a greater accuracy than recorded latitude and longitude, and connects bridges to network attributes for transportation modeling.

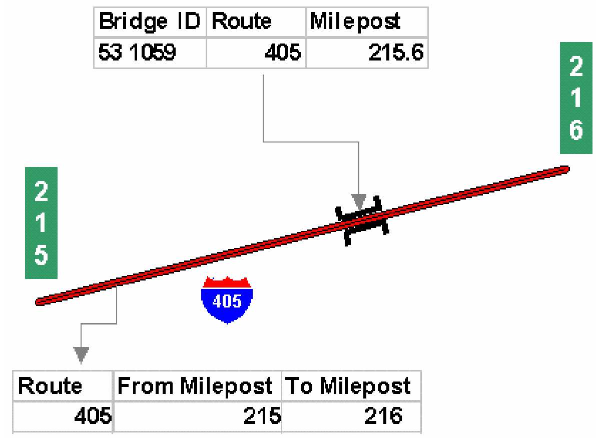


Figure 2.8 An Example of Locating a Bridge Through Dynamic Segmentation

2.6.2 Bridge Data Source

The NBI is a compilation of data supplied by State DOTs as required by the National Bridge Inspection Standards for bridges located on public roads. The NBI database is prepared for use by State and Federal governments, as well as other agencies. The database model for the NBI is established by the "Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges." The NBI data is made available to the public, usually in a delimited text file format, through the FHWA Office of Bridge Technology.

The following fields are key identifiers and locational information:

Structure Number The structure identifier recorded by the state transportation agency. This frequently serves as a unique identifier, but not for all states. Ideally, this identifier provides a method of linking to the State DOTs internal bridge databases.

State Name A two character code that identifies the state (i.e. AL, AK, AR). Not a FIPS code.

Mile Point The linear referencing system (LRS) milepost marker is used to establish the location of the bridge on the base highway network. Uses the same LRS as the NHPN and HPMS.

Inventory Route LRS inventory route and numbers reported by the state. Typically corresponds to the HPMS and NHPN route numbers, but not always.

Inventory Subroute LRS inventory subroute numbers reported by the state. Typically corresponds to the HPMS and NHPN route numbers, but not always. The subroute is an important component for dynamic segmentation.

Latitude/Longitude Coordinates of the bridge in degrees. Datum and precision vary from state to state. Not used for bridge location within REDARS™.

The following fields provide structural information or data used to assess fragility:

Number of Spans	The number of bridge spans in the main section of the bridge.
Number of Approach Spans	The number of spans before the first abutment.
Year Built	Year of construction. This field is not updated for retrofitting or reconstruction.
Lanes on the Structure	Lanes being carried by the structure, for the full length of the bridge, in both directions.
Length of Maximum Span	The length of the maximum span along the center of the bridge in meters.
Structure Length	Length of the road supported by the bridge structure in meters. Corresponds to the main section of the bridge as coded in the "number of spans" column.
Deck Width, Out-to-Out	The width of the bridge deck in meters.
Skew	The skew angle between the centerline of a bridge pier and a line normal to the roadway centerline. Measured in degrees.

2.7 Soil Data

2.7.1 Soil Data within REDARS™

The REDARS™ data model requires NEHRP soil classification. The status and availability of soil databases from NEHRP can be obtained from the website: http://www.fema.gov/hazards/earthquakes/nehrp/. To import soil data into REDARS™ the user provides an ESRI Shapefile in decimal degrees with the NEHRP soil class in a single column.

2.7.2 Soil Data Sources

For studies in California, this data is available from the California Geological Survey (CGS). The REDARS™ Import Wizard will accept a default NEHRP soil type if soil is not available in GIS format. If a soil survey or soil classification map is available that does not conform to the NEHRP classifications, a geologist will be able to convert the classification to the required NEHRP classification scheme.

2.8 Origin Destination (O-D) Data

2.8.1 Origin Destination (OD) Data Within REDARS™

Origin and Destination (OD) data estimates travel origins and destinations from periodic public surveys. The location of travel origin and destinations in OD data are aggregated by Traffic

Analysis Zones (TAZs), which are approximately the size of a census tract. OD data contains three fields, a “from” TAZ identification number, a “to” TAZ identification number, and the estimated number of trips, or travel demand, between the two zones. In REDARS™ the OD data must be joined geographically to the transportation network, in order to load the demand on the network. The TAZs are connected to the network through a series of automated processes. First, a point object is created at the center of each TAZ. These points are added to the REDARS™ Node table, and are distinguished from the transportation network nodes by the “True” value in the “*Is Zone Centroid*” column of the Node table. A “virtual link” is established between each TAZ node and the closest node on the transportation network. This link is called a “virtual link” because it does not correspond to a real world physical feature. The virtual links are appended to the REDARS™ Link table, and are distinguishable from transportation network links by the values “0” or “1” in the “Type” field (see Appendix D for a list of fields).

To import the OD data into REDARS™, the user must provide OD data in a delimited text file with three columns. The first column must be the TAZ “from” field, the second field must be the TAZ “to” filed, and the last field is the traffic demand. The Import Wizard Dialog where the user locates the OD data on drive requires two additional parameters. The first parameter is the number of hours that the OD demand represents, and the second parameter is the factor for converting the system-wide travel time into a daily value. Although default values are provided, the user must inquire directly with the MPO or transportation agency providing the data to establish these factors.

In addition to the OD transportation matrix, the user must supply an ESRI Shapefile in a geographic projection of the TAZ boundaries. The datum of the file must match the datum of the transportation network. The user is prompted to identify the field in the shapefile that contains the unique identifier, so that the data can be joined to the OD matrix.

2.8.2 Origin Destination (O-D) Data Sources

A primary goal of the Import Wizard is to enable the user to create a REDARS™ study region with as little effort as possible. The Import Wizard saves the end user time in both data manipulation and data acquisition. A key element in the automation of REDARS™ data creation is the dependence on federally available database. The data provided by FHWA will remain relatively consistent from state to state in regards to the format of geographical and linear referencing data, data projection, field names, field types, and data provided. Supporting and anticipating the various data formats used by state and local governments would require a much greater effort. However, the OD and TAZ data are not available federally. Luckily, the format of these databases is relatively simple, as described in the previous section. If the data is not in the format described above, it can usually be exported to the required format directly from the commercial transportation package. Both TAZ and OD file are developed and maintained by Metropolitan Organizations (MPO), Regional Transportation Planning Agencies (RTPA), or state department of transportation. To get a TAZ and OD file, contact the local MPO, RTPA, or state DOT and ask for the Senior Planner in the planning department.

CHAPTER 3
IMPORT WIZARD USER MANUAL

The Import Wizard enables the creation of a REDARS™ study region with minimal effort. The Import Wizard tasks the user with simple steps to identify data sources and a few key variables. The following sections outline the steps involved in running the Import Wizard.

3.1 Opening the REDARS™ Import Wizard program

The Import Wizard is opened by starting the REDARS™ program and navigating to the "Start Import Wizard" menu option. When the REDARS™ Import Wizard is opened, the introduction screen in Figure 3.1 is displayed.

3.2 REDARS™ Import Wizard Screens

3.2.1 Screen 1: Introduction

The "Introduction" screen is the first screen a user sees when REDARS™ Import Wizard is opened. The "Introduction" screen provides a brief description of the steps required to create a REDARS™ study region.

Screen 1 has the following options:

1. Click the "Cancel" button to quit the Import Wizard program.
2. Click the "Next" button to go to the next screen of the Import Wizard program.

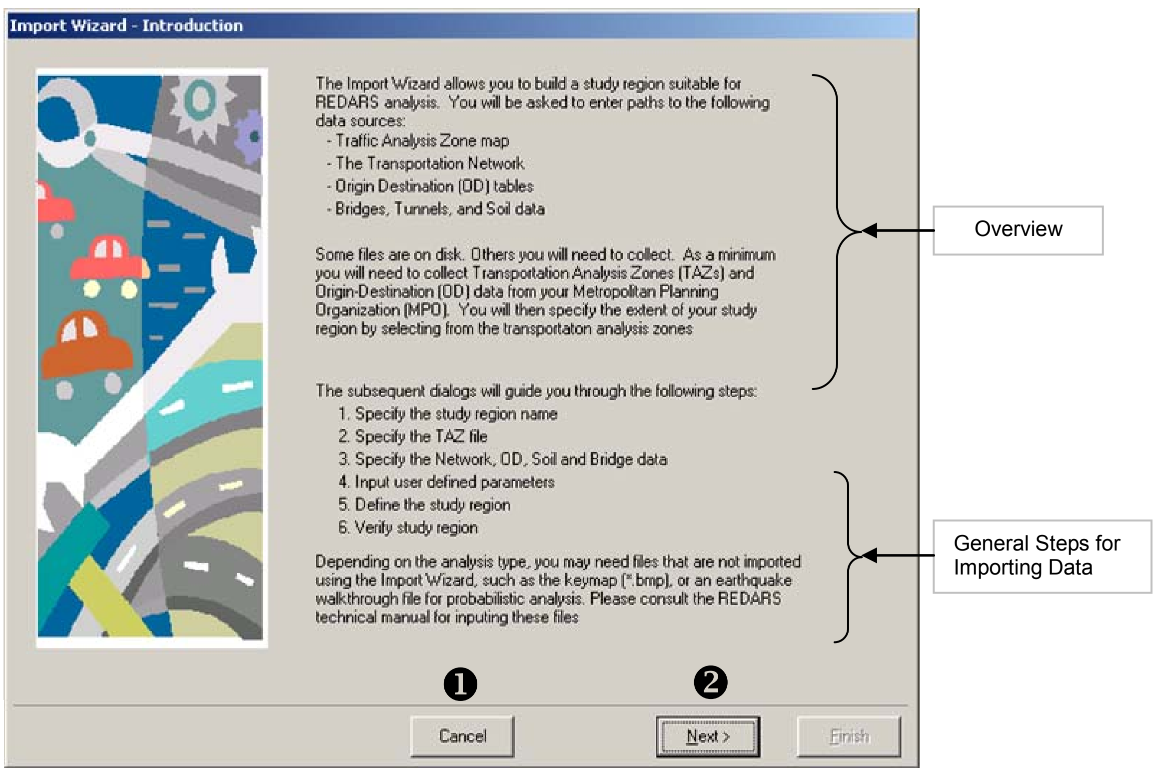


Figure 3.1 REDARS™ Import Wizard Introduction Screen

3.2.2 Screen 2: Specify the Study Region Name and REDARS™ Filename

Screen 2, illustrated in Figures 3.2, allows the user to specify a name for the study region. The user specified name is used for the names of folders, REDARS™ database file (*.RDF) and Binary file for OD matrix *.BOD).

This screen has the following options illustrated in Figure 3.2:

1. The "Cancel" button exits the Import Wizard program.
2. The "Back" button navigates to the previous screen of the Import Wizard program.
3. The "Next" button navigates to the next screen of the Import Wizard program. The "Next" button becomes active after a user specifies the name for the REDARS™ database file and the study region name.

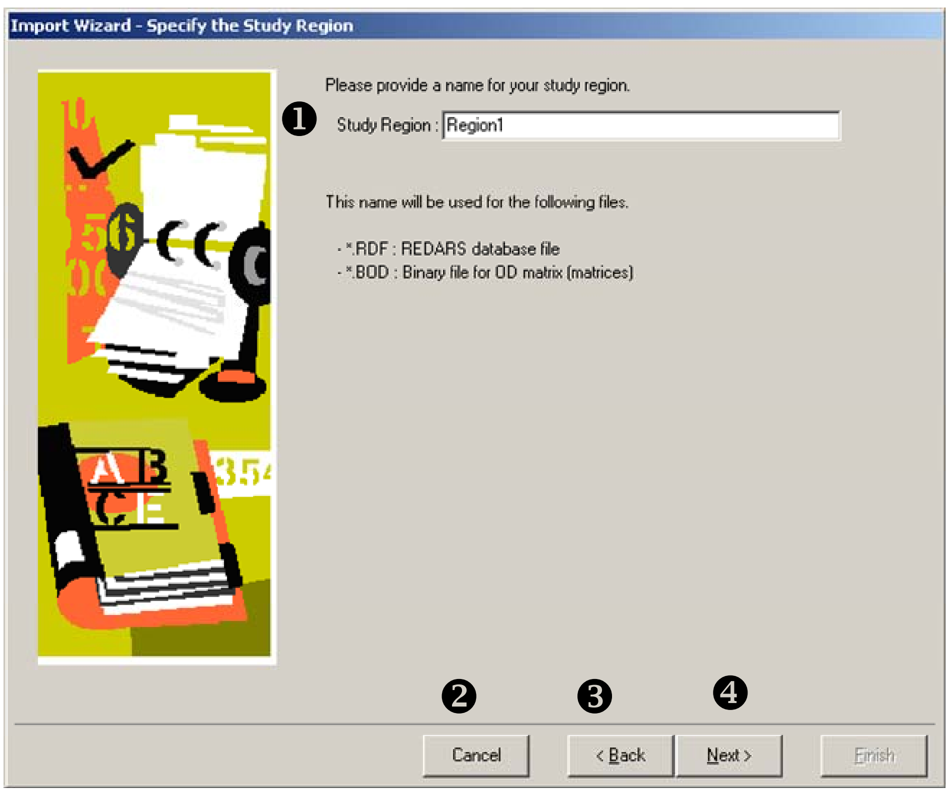


Figure 3.2 Study Region Name, REDARS™ Database Filename and Binary Filename for OD matrix (matrices)

3.2.3 Screen 3: Specify Paths to Transportation Network Data- NHPN & HPMS

Screen 3, illustrated in Figure 3.3, allows the user to specify the location of NHPN and HPMS data files on disk. The Import Wizard reads and converts NHPN and HPMS data files to create a transportation network for use with REDARS™. Import Wizard requires the NHPN data in uncompressed E00 format, and HPMS in TXT format (with SCH or Schema file) with a valid number of columns or fields. The Import Wizard checks the validity of the user specified files. If the user specified NHPN and HPMS files are not in a valid file format, an error is reported. The data must be in a geographic projection.

Figure 3.3 illustrates the following functionality:

1. Click the “Browse” button and navigate to the folder on your local drive where you have the NHPN file in uncompressed E00 format. Select the file and click open.
2. Click the “Browse” button and navigate to the folder on your local drive where you have the HPMS file in TXT format (with SCH or Schema file). Select the file and click open.
3. The “Cancel” button exits the Import Wizard program.
4. The “Back” button navigates to the previous screen of the Import Wizard program.
5. The “Next” button navigates to the next screen of the Import Wizard program.

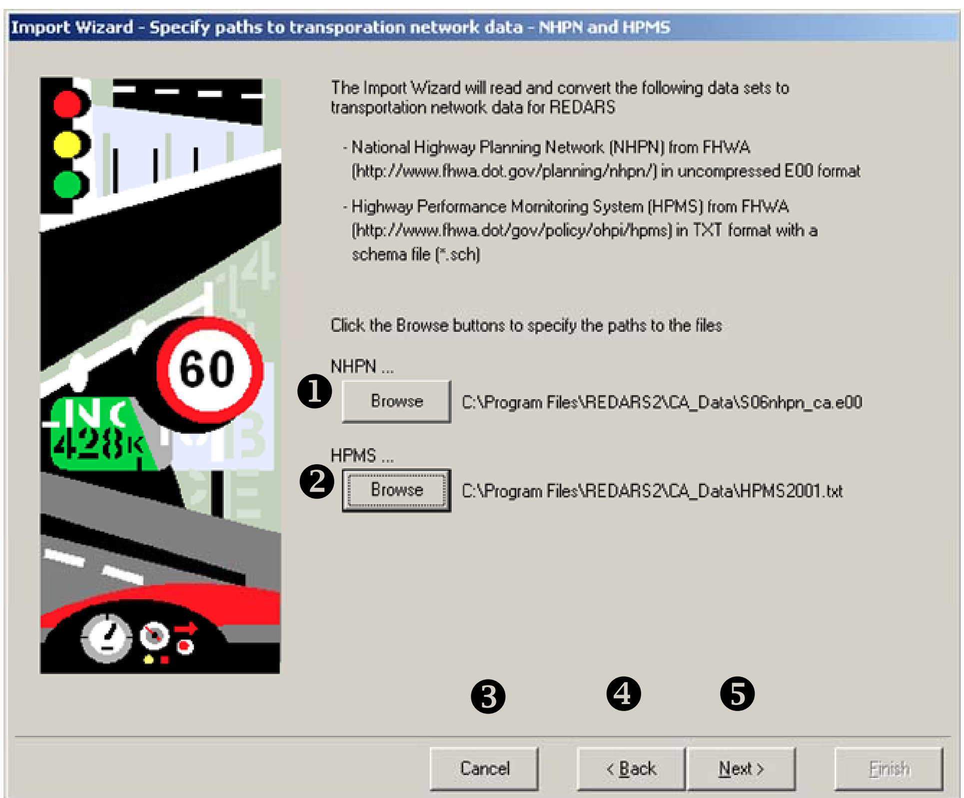


Figure 3.3 Specifying Paths to NHPN and HPMS Data

3.2.4 Screen 4: Specify Paths to Bridge and Soil Data

Screen 4, illustrated in Figures 3.4, allows the user to specify the paths to the NBI bridge and NEHRP soil data files on disk. The Import Wizard reads the NBI bridge data file and locates the bridges on the transportation network for use with REDARS™. The Import Wizard requires the NBI data in delimited TXT file format. The user must provide NEHRP soil data in ESRI Shapefile format and specify the field for NEHRP soil class. The Import Wizard checks the validity of the user specified NBI and NEHRP files. If the user specified files are not in a valid file format, an error is reported. If the NEHRP soil data is not available in shapefile format, the user can define a default soil type for the study region. All shapefiles must be in a geographic projection. The datum must match the NHPN base data, currently in NAD 1927.

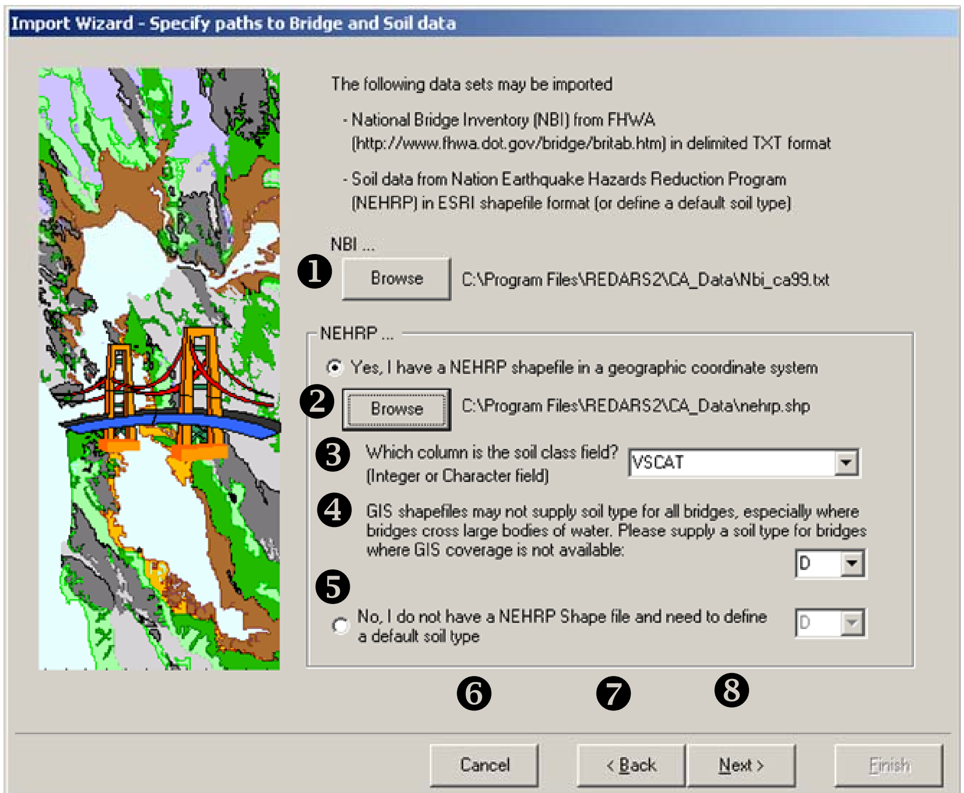


Figure 3.4 Specify Paths to Bridge and Soil Data

Figure 3.4 illustrates the following options:

1. Click the "Browse" button and navigate to the folder on your local drive where you have the NBI file in TXT format. Select the file and click open.
2. Click the "Browse" button and navigate to the folder on your local drive where you have the NEHRP soil file in ESRI Shapefile format. Select the file and click open.
3. Once you open the NEHRP soil file, a text box with a drop down list of field names become active. You have to specify the soil class field from the dropdown list (See Figure 3.5).

4. You will need to specify the soil type value in the soil class field that defines water.
5. If NEHRP soil data is not available in GIS file format, you have to specify a default NEHRP soil class for the study region using the dropdown list (See Figure 3.6).
6. The "Cancel" button exits the Import Wizard program.
7. The "Back" button navigates to the previous screen of the Import Wizard program.
8. The "Next" button navigates to the next screen of the Import Wizard program.

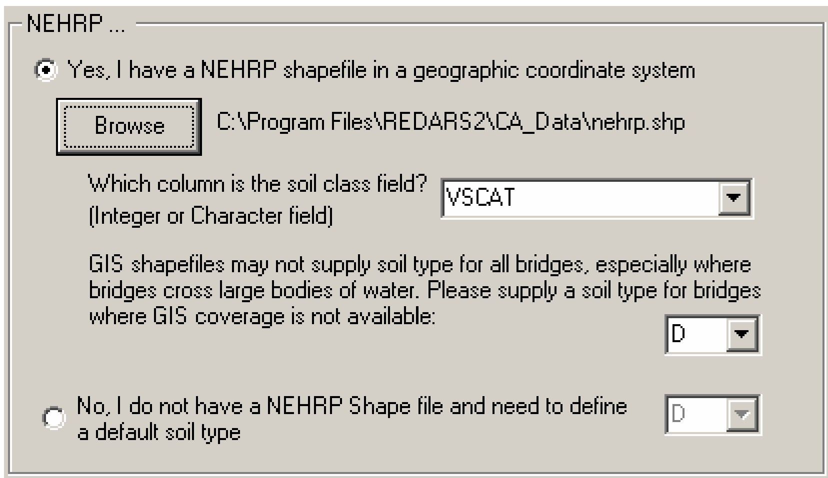


Figure 3.5 Specifying Soil Class Field and Soil Type value for Water when NEHRP Soil File is Available

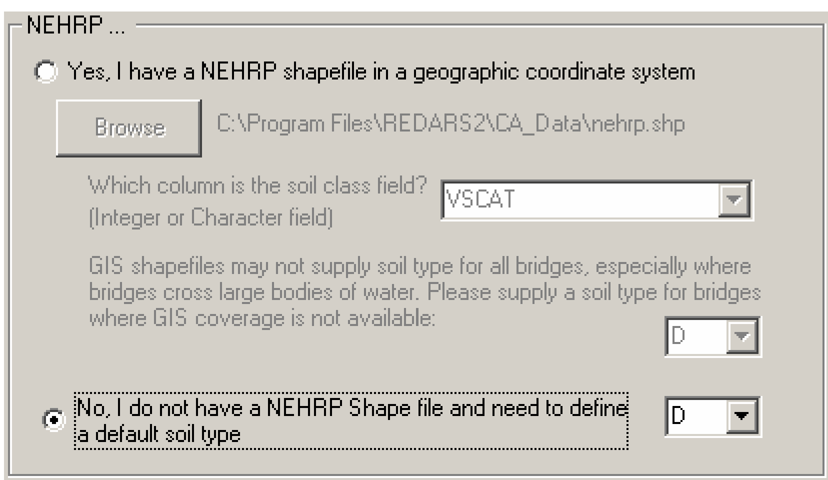


Figure 3.6 Specifying Soil Class Field when NEHRP Soil File is Not Available

3.2.5 Screen 5: Specify Path to Traffic Analysis Zone Data and Identify TAZ Id Field

Screen 5, illustrated in Figure 3.7 allows the user to specify the path to the Traffic Analysis Zone (TAZ) data file on disk. Traffic Analysis Zone (TAZ) files are usually available from the local Metropolitan Organizations (MPO). For more details on how to obtain TAZ files, refer to Appendix A Frequently Asked Questions. The Import Wizard requires the TAZ file in ESRI Shapefile format in a geographic coordinate system. Once the path to the TAZ file is specified, the user must identify the field containing the TAZ ID. All shapefiles must be in a geographic projection. The datum must match the NHPN base data, currently in NAD 1927.

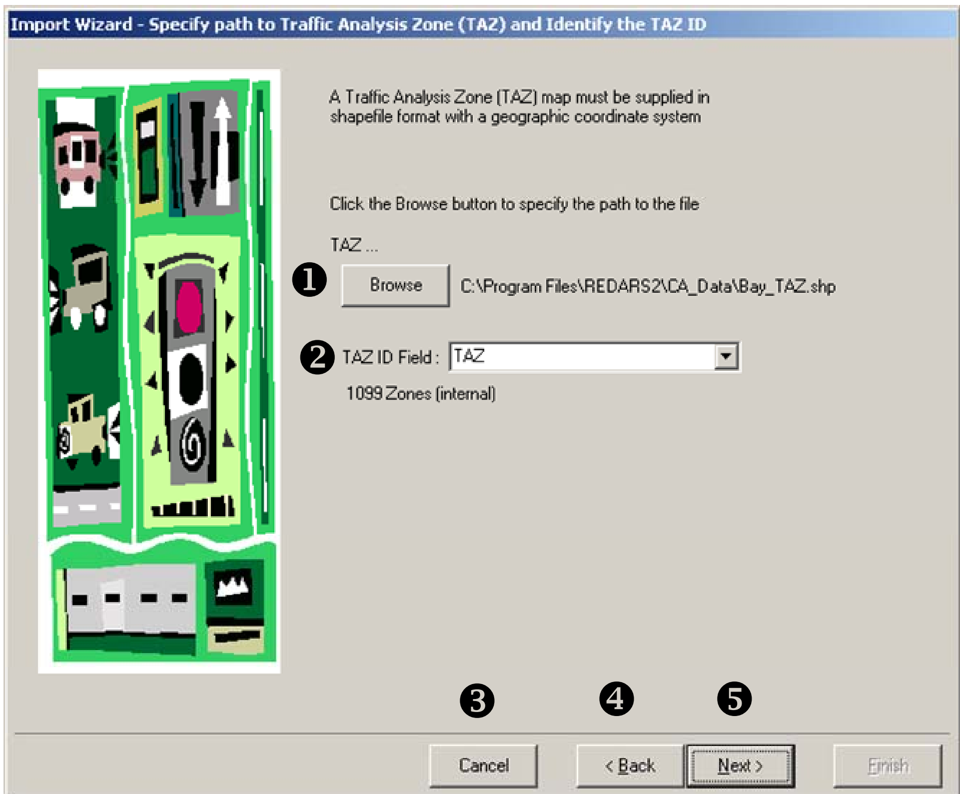


Figure 3.7 Specify Path to TAZ Data and Identify the TAZ ID Field

Figure 3.7 illustrates the following:

1. Click the "Browse" button and navigate to the folder on your local drive where you have the TAZ file in ESRI Shapefile format in a geographic coordinate system. Select the file and click open.
2. Once you open the TAZ file, a text box with a drop down list of field names become active. You have to specify the "TAZ ID" field from the dropdown list.
3. The "Cancel" button exits the Import Wizard program.
4. The "Back" button navigates to the previous screen of the Import Wizard program.
5. The "Next" button navigates to the next screen of the Import Wizard program.

3.2.6 Screen 6: Specify Path to the Origin Destination (OD) File

Screen 6, illustrated in Figures 3.8 and 3.9, allows the user to specify the Origin Destination (OD) file on disk. OD files are usually available from the local Metropolitan Organizations (MPO). For more details on how to obtain OD files, refer to Appendix A Frequently Asked Questions. The Import Wizard requires the OD file to be a tab, comma or space delineated TXT file with the following columns:

- Column 1: Origin Zone ID
- Column 2: Destination Zone ID
- Columns 3, 4, 5…→n: Trips between the zone-pair by trip type

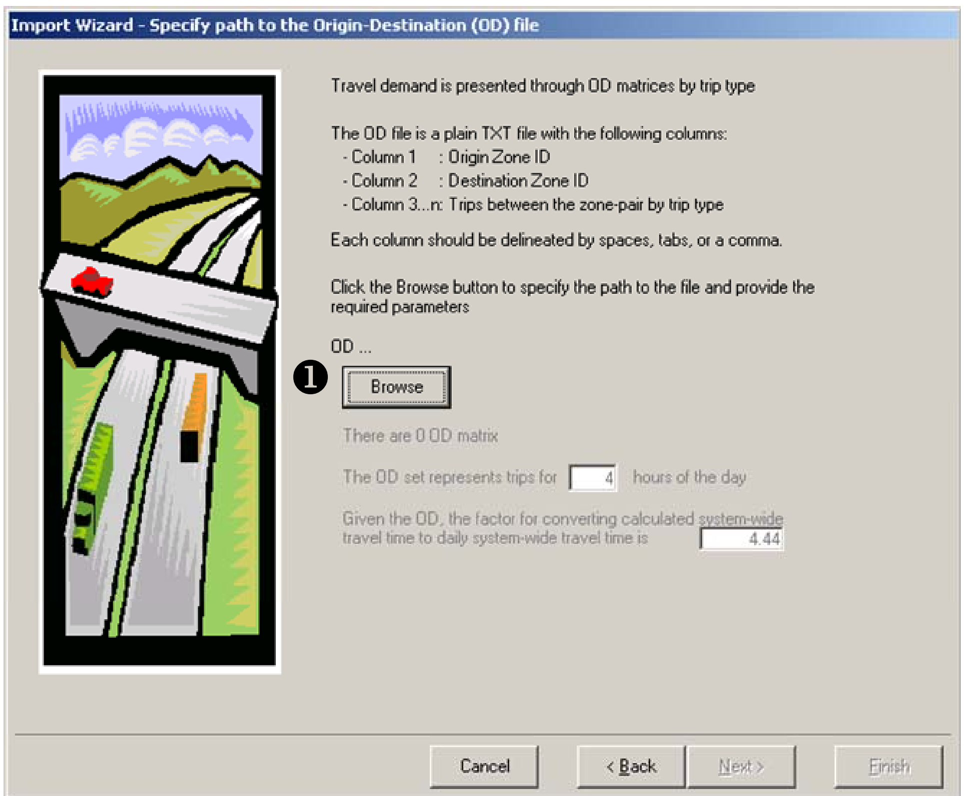


Figure 3.8 Specify Path to OD Data

Figures 3.8 and 3.9 illustrate the following functionality:

1. Click the "Browse" button and navigate to the folder on your local drive where you have the OD file in a tab, comma or space delineated TXT file. Select the file and click open.
2. Once you open the OD file, the text box 1 becomes active where you have to specify the number of hours that the OD file represents (see Figure 3.9).
3. Once you open the OD file, the text box 2 becomes active where you have to specify the factor to convert calculated travel time (using OD) to daily travel time (see Figure 3.9).

4. The "Cancel" button exits the Import Wizard program.
5. The "Back" button navigates to the previous screen of the Import Wizard program.
6. The "Next" button navigates to the next screen of the Import Wizard program.

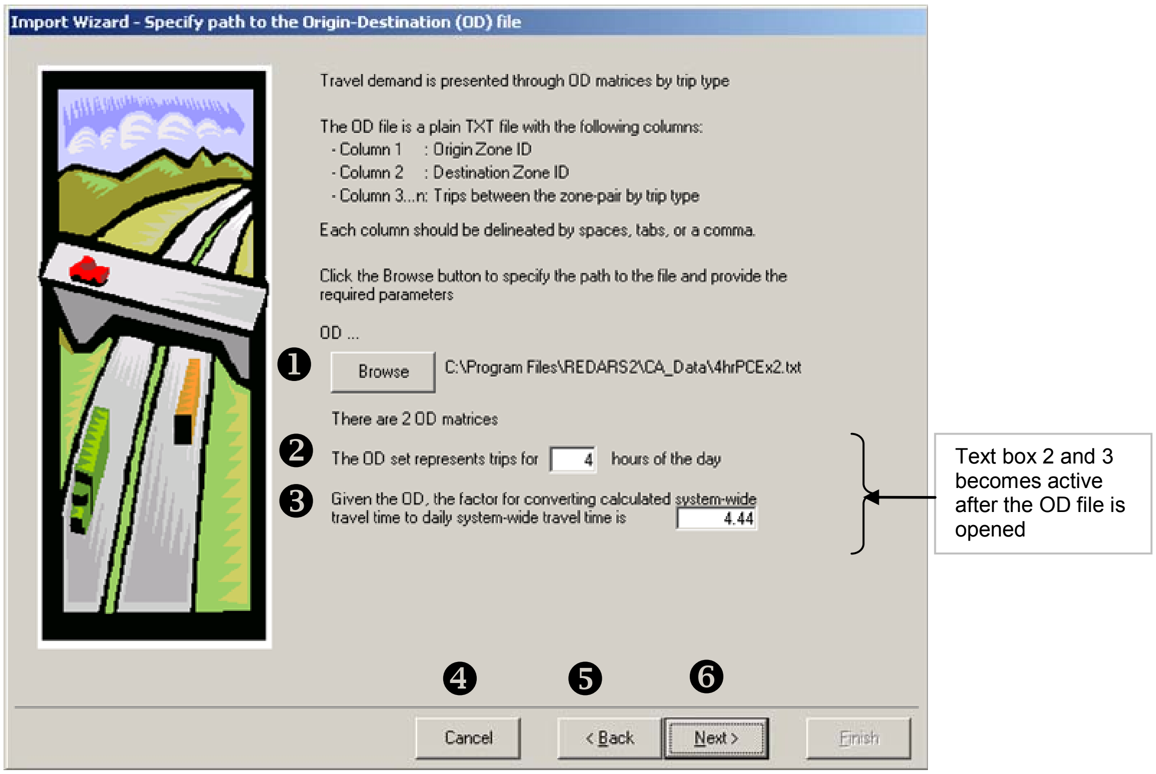


Figure 3.9 Specify Factors to Covert the OD to Daily Trips

3.2.7 Screen 7: Specify OD Parameters

Screen 7, illustrated in Figure 3.10, allows the user to enter information on the Origin Destination (OD) parameters. For detailed description of the OD parameters VOT (Value Of Time) and PCU (Passenger Car equivalent Unit), refer to Appendix A Frequently Asked Questions. The Import Wizard requires information on the following OD parameters:

- Name: User defined OD description
- Group: Passenger or freight
- VOT: Value in dollars ($)of one-hour of travel time
- PCU: Number of passenger car equivalent for 1 OD unit

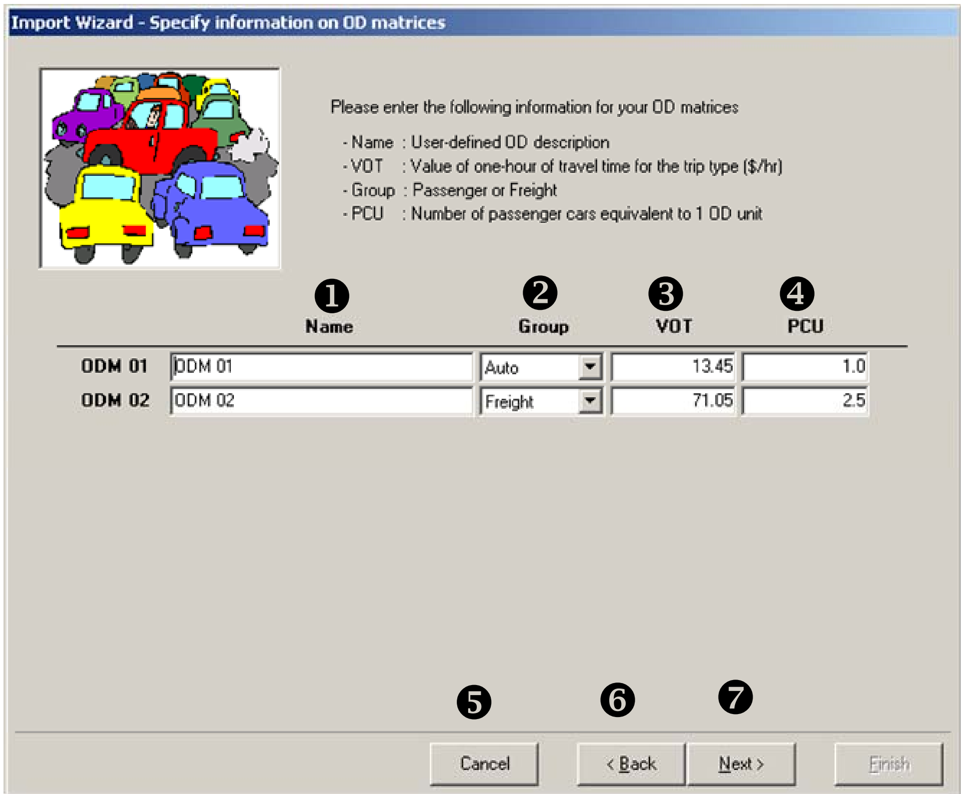


Figure 3.10 Screen to Specify Information on OD Matrices

Figure 3.11 illustrates the following functionality:

1. Specify “Name” for the OD matrix in this text box.
2. Specify “Group” for the OD matrix in this text box using pull down list.
3. Specify “VOT” for the OD matrix in this text box.
4. Specify “PCU” for the OD matrix in this text box.
5. The “Cancel” button exits the Import Wizard program.
6. The “Back” button navigates to the previous screen of the Import Wizard program.
7. The “Next” button navigates to the next screen of the Import Wizard program.

3.2.8 Screen 8: Define Study Region

Screen 8, illustrated in Figure 3.11, allows the user to specify the TAZs that will define the study region. The initial screen shows the transportation network overlaid on the TAZ map. The user has the option of turning the transportation network layer "on" or "off". Additionally, the dialog is expandable by dragging the right hand corner. Figure 3.12 illustrates a toolbar with standard GIS tools (zoom, pan, select) is available to the user to navigate the map and select the study region interactively. The selection of TAZs is made by drawing a polygon on the interactive map using the "Select TAZ" tool, as illustrated in Figure 3.13. After drawing the study region, the user clicks the "Finish" button to start the data import process. This is the most complicated of the import wizard dialogs, and each option will be described in detail below. Section 3.2.9 troubleshoots common problems encountered while defining the study region.

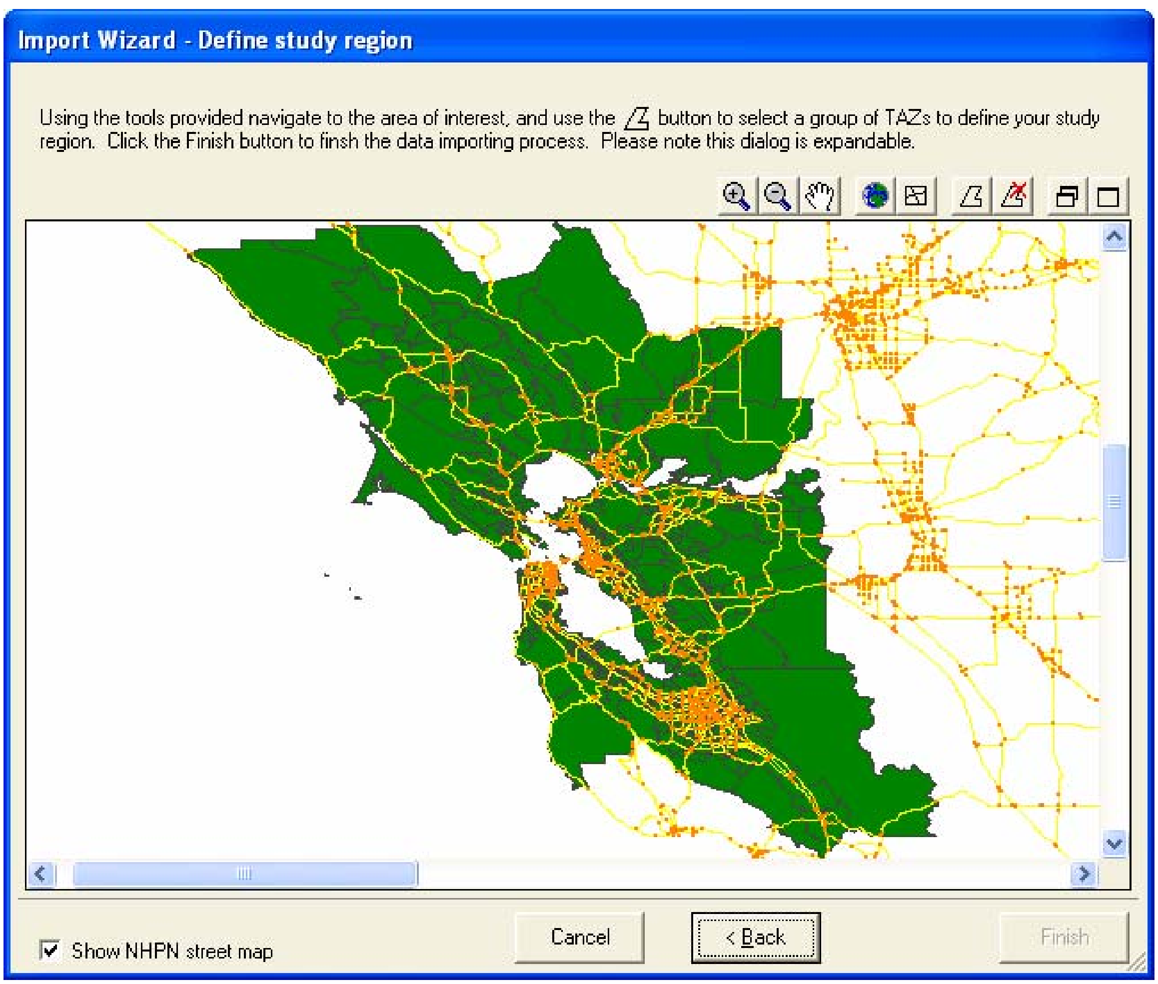


Figure 3.11 Screen to Define Study Region Boundary

The tools illustrated in Figure 3.12 are used to navigate the map and draw the polygon to select the TAZs that define the study region. The zoom-in tool allows the user to click and drag the mouse on the map to define a rectangle. The map will then change scale to fit the new rectangle. The zoom-out tool changes to a larger scale map with the center at the location the user has clicked. The full extent button will modify the scale of the map to display the extent of the entire transportation network, which is usually the state. The extent of TAZs button changes the scale to the entire TAZ shapefile, or the MPO coverage area. The select TAZs button allows the user to select the TAZs that define the study region. The clear selection button allows the user to reselect the TAZs if the original selection is unsatisfactory. The last two buttons allow the user to see the dialog either full screen or as a smaller dialog.

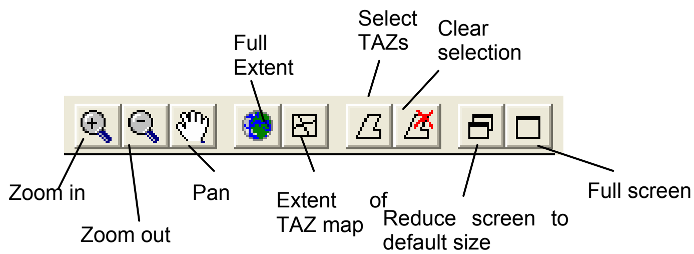


Figure 3.12 GIS Tools to Navigate and Select Study Region

To select the TAZs that will define the study region, the user clicks on the Select TAZs button and draws a polygon on the map, as illustrated in Figure 3.13. The polygon will expand to include each node added by the user. To end the process of ending nodes, the user clicks twice in rapid succession.

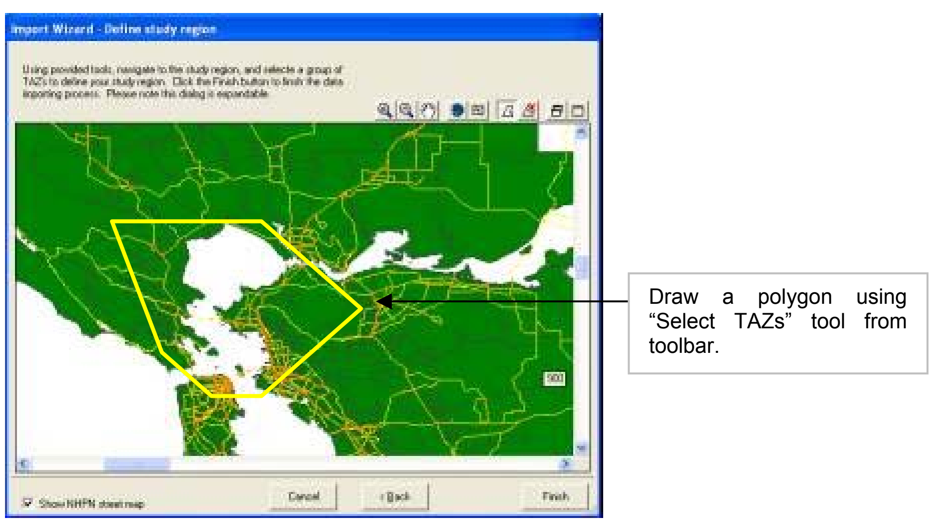


Figure 3.13 Selecting the TAZs

The TAZs that intersect the polygon drawn by the user are shown with a red hatching pattern, as illustrated in Figure 3.14. If the user is satisfied with the selection, the Finish button is selected. If the selection is not satisfactory, the user selects the "Clear selection" button and draws a new polygon.

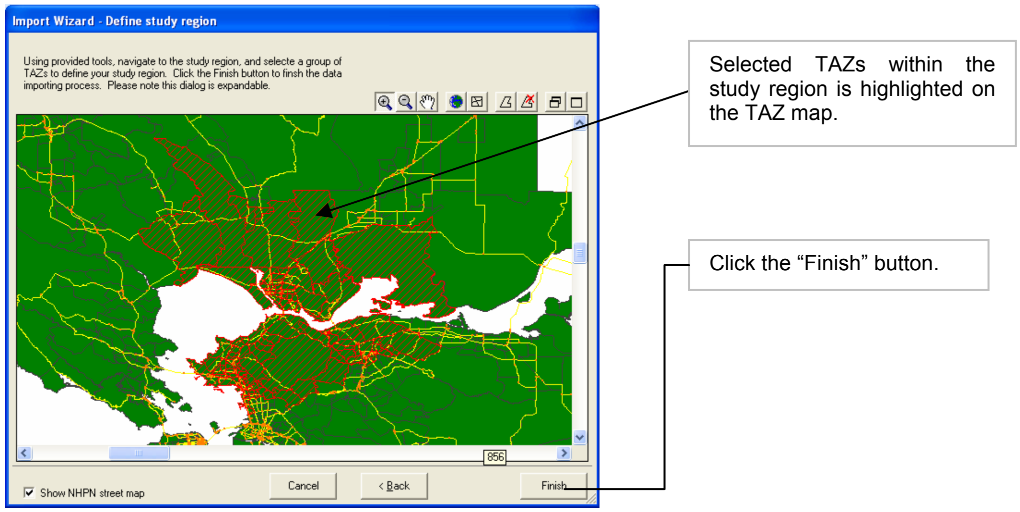


Figure 3.14 Selected TAZs

The Import Wizard must complete a lengthy process of verification and subsetting before a REDARS™ study region is completed. Several checks are incorporated into REDARS™ to make sure that the study region consists of contiguous zones and that the region is satisfactory to the user. Figure 3.15 illustrates the next dialog that notifies the user of the verification process.

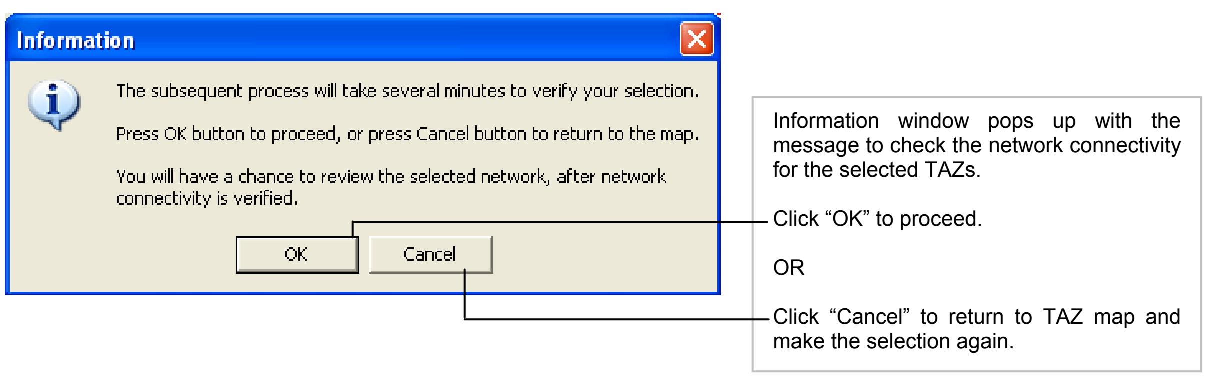


Figure 3.15 Verification of the Study Region

If the user selects a study region that consists of a single subnetwork, the Import Wizard displays the message in Figure 3.16. The user clicks OK to verify the selection and proceeds to process the study region.

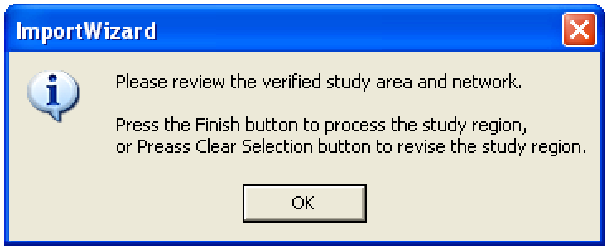


Figure 3.16 Single Region in a Network Selection

However, if the user selects a study region that consists of multiple subnetworks, then the Import Wizard will notify the user of the number of subnetworks, and corresponding nodes that are in the primary and secondary regions, using the dialog illustrated in Figure 3.17. The user has the opportunity to modify the selection by selecting again, or proceeding with the primary region in the current selection.

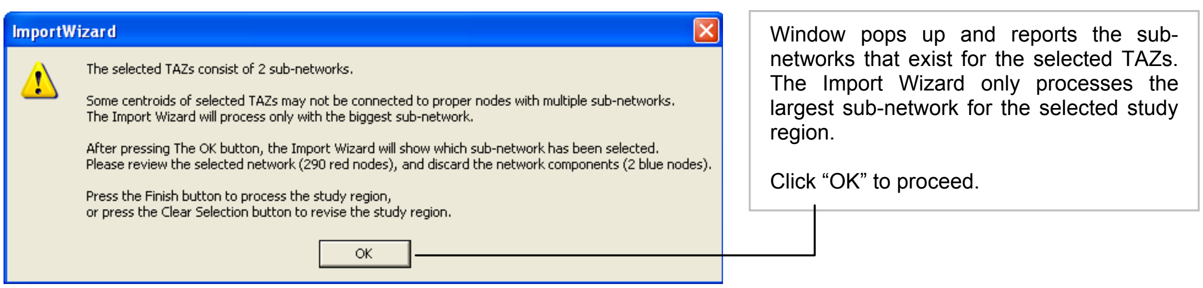


Figure 3.17 Multiple Regions in a Network Selection

To illustrate the selected network, the Import Wizard displays the "Define Study Region Screen" once again, this time with the selected zones in red, the selected nodes in red, and the transportation network in black. The nodes that are not included in the primary network are in blue. This version of the study region selection dialog is illustrated in Figure 3.18.

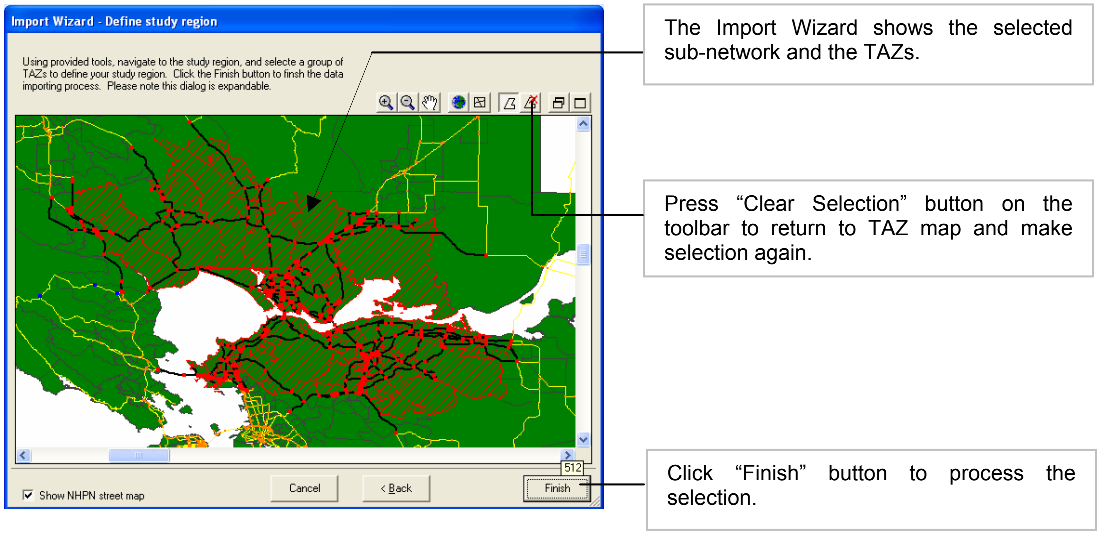


Figure 3.18 The Selected TAZs and Transportation Network

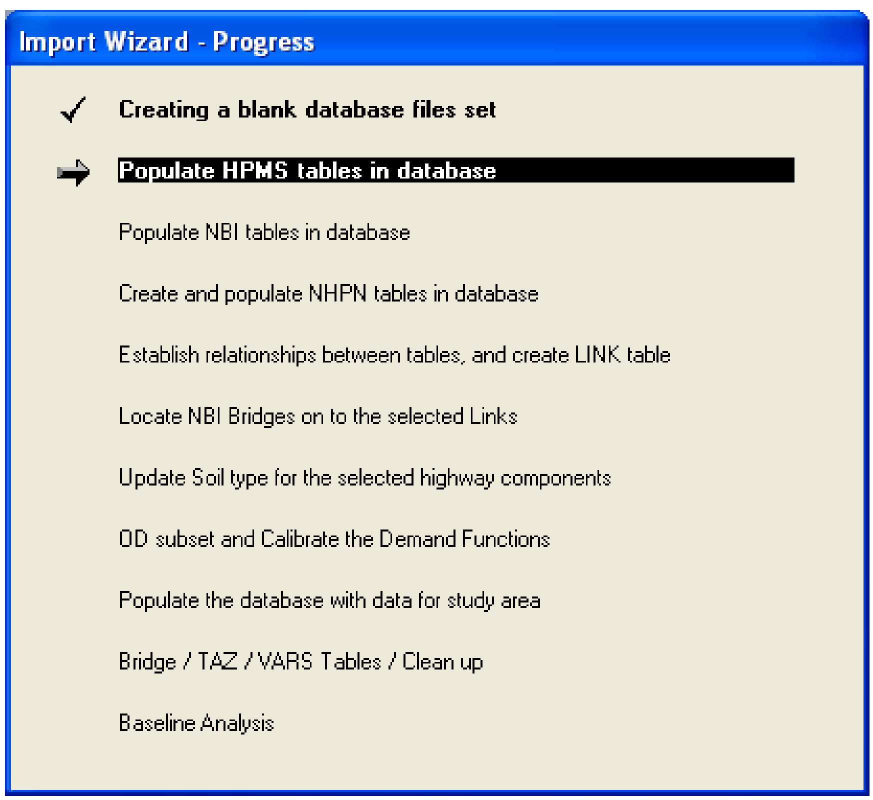


Figure 3.19 Study Region Creation Progress Bar

Once the user indicates that the study region is satisfactory, the study creation progress bar tracks the progress of the individual tasks. During the previous Import Wizard dialogs, there is very little processing. All options and selections are stored in an underlying file so that the processing will occur all at once, leaving the user to attend to other tasks. The process can take as long as an hour to complete, and the progress bar allows the user to examine what tasks have been completed and also, if the program were to crash, what module the problem is in. Appendix B discusses the various processing steps of the Import Wizard in detail.

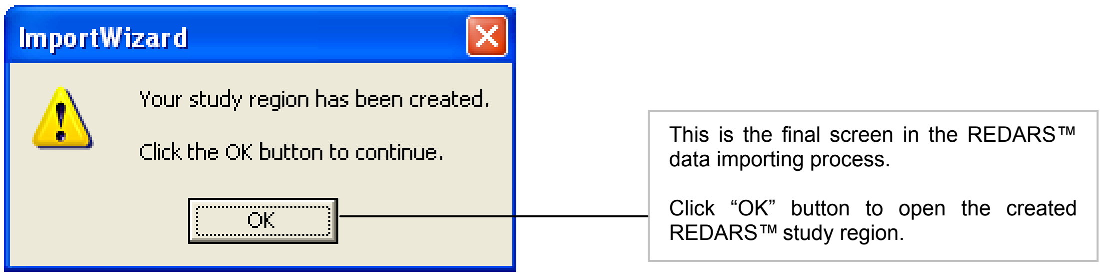
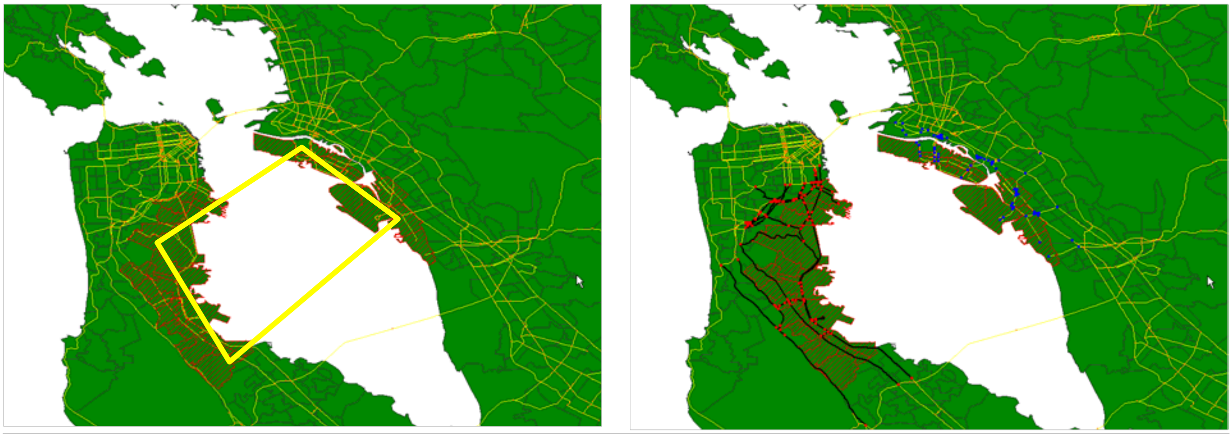


Figure 3.20 Successful Study Region Creation

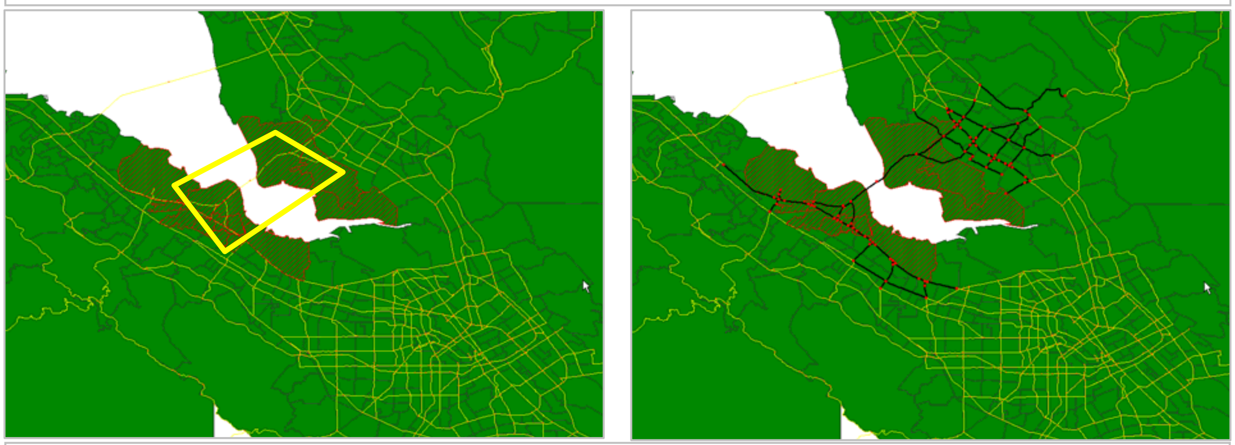
Once a study region has been successfully created, the user clicks "OK" in the final Import Wizard screen at the end of the data import steps. The next section discusses some of the unique conditions that the Import Wizard resolves during the study region selection based on the user defined polygon. For example, it is possible for the user to select disconnected TAZs or networks when drawing a polygon.

3.3 Understanding the Study Region Selection Results

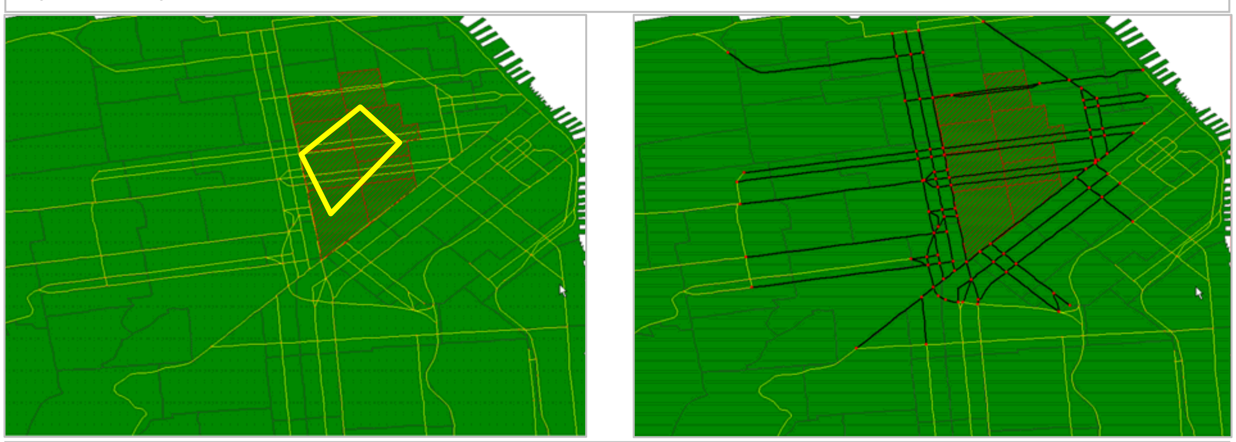
Various unique network and TAZ conditions are possible when a user draws a polygon to select a study region. The Import Wizard identifies such conditions, reports it to the user and resolves them during the network generation process. The user has the option of re-selecting the TAZs if he is not satisfied with the selection. Figure 3.21 illustrates and discusses some of these conditions and the resulting selection of network/ TAZ. Section 4.7 discusses the algorithms used to detect the problems illustrated below.



CONDITION 1: When 2 sets of disconnected TAZs and sub-networks fall within a selected study region (yellow polygon in the left figure) i.e. there are no transportation links between the TAZs or the sub-networks, or the TAZs do not share any common boundary, the Import Wizard processes the larger sub-network. The resulting selection of sub-network is shown on the figure to the right.



CONDITION 2: When 2 sets of connected TAZs and sub-networks fall within a selected study region (yellow polygon in the left figure), the Import Wizard processes both the sub-networks. The resulting selection of sub-network is shown on the figure to the right.



CONDITION 3: When a selection (yellow polygon in the left figure) is made for a set of TAZs that are traversed by a dense network of streets that go in and out of the selected region, the resulting sub-network may look like the figure on the right. Some of the links which are completely outside the selected TAZs may be a part of the selected network. This is because, when selecting a sub-network, the Import Wizard draws a rectangular buffer around TAZs and all links that intersect the buffer are considered a part of the selected sub-network.

Figure 3.21 Study Region Selection Results

CHAPTER 4
IMPORT WIZARD TECHNICAL MANUAL

4.1 Introduction to Import Wizard Research

Sections 2.1 and 2.2 briefly introduced the complex data manipulation tasks involved in processing disparate federal databases into a single transportation network suitable for SRA analysis in REDARS™. Each independent task, including network data conversion, bridge location and sub-setting OD matrices, presented a set of challenges. This chapter provides documentation of each of these challenges and the solutions implemented in the final REDARS™ Import Wizard software package.

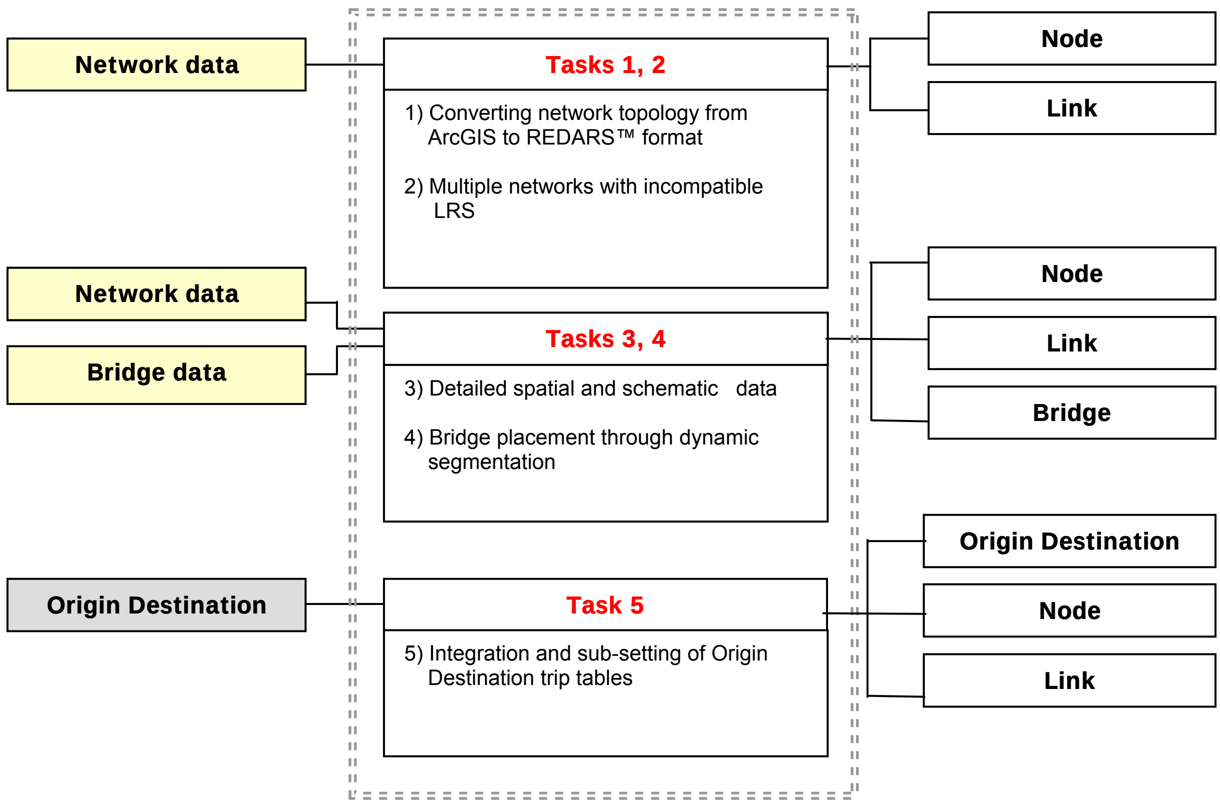


Figure 4.1 Problems encountered during development of Import Wizard

Figure 4.1 is a conceptual flow of information from the raw, independent data types into REDARS™ tables. The task statements in the middle provide a description of the issues associated with each general data transformation task. Issues encountered during the development of the import wizard range from mundane file translation issues to complex modeling of topology in the absence of complete data sets. Section 4.2 address task 1, converting network topology from ESRI ArcInfo e00 into REDARS™ format. Although the ESRI file format is open, it is not well documented, particularly with regard to network topology. In order to read the data from the format provided by FHWA, a custom module had to be developed that extracted the required data tables. Section 4.3 addresses task 3, maintaining schematic and geographic network data. This is import in order to streamline computationally intensive transportation analysis and to maintain the spatial accuracy required for SRA. Section 4.4, resolving multiple network dependency addresses task 2. REDARS™ requires network data from two separate transportation networks: NHPN and HPMS. Although both data sets have a Linear Referencing System (LRS), only one data set includes geographic objects, and there are connectivity issues between the datasets. This section addresses combining the two separate sources of transportation data into an integrated transportation network, with a detailed description of how each individual field is addressed and the results of a validation for the State of South Carolina. Section 4.5 addresses task 4, the development of a customized dynamic segmentation algorithm. Section 4.6 discusses the topological complexities posed by bridges that are freeway onramps or freeway offramps. Ultimately, this issue could not be resolved with the data at hand. Section 4.7 provides documentation of specific topological idiosyncrasies that arise given specific network-study region interactions, particularly in areas with sparse roads represented with long individual segments. Finally, section 4.8 addresses task 5, which addresses the sub-setting and recalculation of OD data to account for external and transverse traffic.

4.2 Converting network topology from ArcInfo to REDARS™ Format

The Import Wizard uses federally distributed NHPN data as the source for network information. These data files are distributed in an uncompressed ArcInfo Interchange or E00 format. This format can not be directly imported into REDARS™. Converting NHPN data from E00 to REDARS™ while maintaining topology is key to assuring that REDARS™ can be used without importing local transportation network data.

ESRI developed the E00 format specifically to enable users to transfer data between GIS platforms. The E00 format is an ASCII text file that can be opened and viewed using common text editors like Microsoft Word or notepad. The NHPN consists of an arc-node network topology and a route system, as discussed in Chapter 2, and this structure is maintained within the text of an E00 file. An E00 file that maintains topology consists of several separate, undocumented sections describing arc topology and attributes of network entities. Each section begins with a section header. The Arc topology data starts with the "ARC" header. For the NHPN data, this section stores the geographic lines using a series of latitude and longitude coordinates for all of the points on the line. "AAT" is the header for the section containing the line attributes. The number of records in this section is identical to the number of lines in the "ARC" section. The node attributes are stored in "NAT" section. Since the beginning and ending nodes are included in the geographic representation of lines, the node coordinates are not provided separately in the E00 file. The "RATLRS" section contains route information such as the LRSKEY and beginning and ending milepost data. The "SECLRS" section is the event table that associates route information in the "RATLRS" section to lines in the "ARC" and "AAT" sections. Figure 4.2 illustrates the data fields that can be extracted from the separate sections of the E00 file.

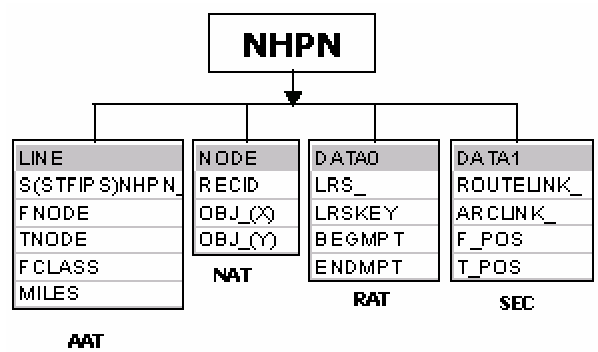


Figure 4.2 Internal Structure of the E00 file containing NHPN network data

Creating network topology from the complex structure of the E00 file in a usable REDARS™ format is possible in a number of different ways, all of which involve the use of external software programs. Programs like "IMPORT71" included with ArcView 3.2, 'ArcLink', a program that runs within MapInfo, and ArcInfo can covert these files into a format which could manually be incorporated into REDARS™. However, this introduces another layer of complexity into the creation of a REDARS™ study region through the requirement for utilities, programs and GIS specialists. Additional utilities or programs may be prohibitive to the development and implementation of the Import Wizard. The ideal solution is to generate the required REDARS™ tables in a manner that evades the use of any special utilities or programs. Additionally, since the incorporation of a network requires several data checking steps, including this portion of the data import process with the other automated tasks reduces the number of tasks placed on the end user and simplifies the process of running the program.

A customized software module was developed in Visual Basic to convert the uncompressed E00 file to multiple Microsoft Access database tables. Figure 4.3 shows the process for converting the E00 NHPN network file into REDARS™ Link and Node tables. The original transportation network data within ArcInfo is stored in a simple ASCII file, and the custom application reads the attribute data required for REDARS™ and populates the Line and Node tables in the REDARS™ database.

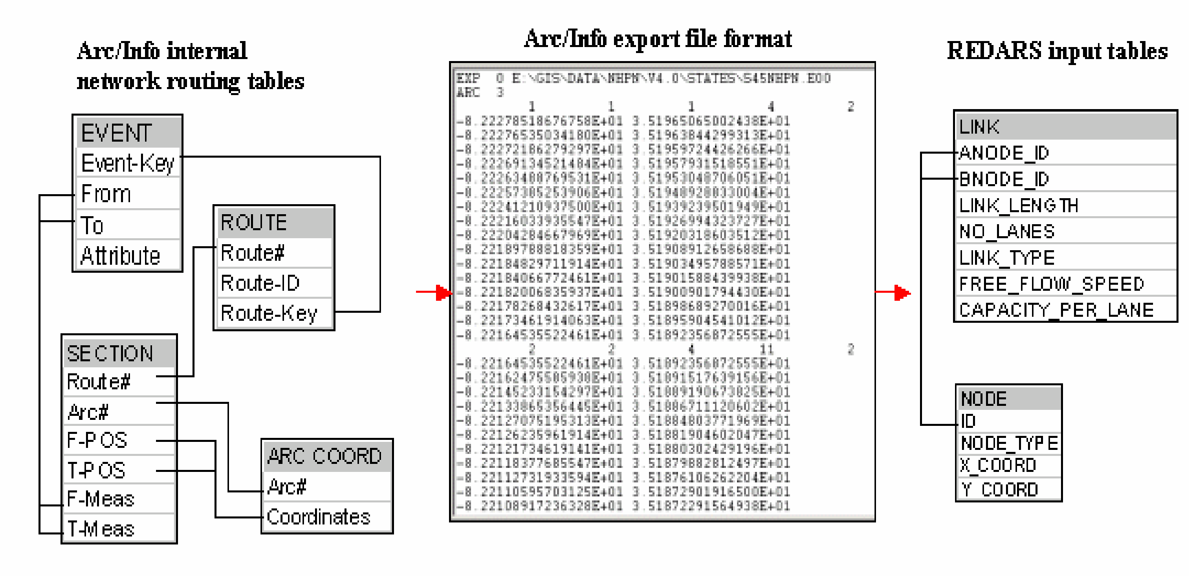


Figure 4.3 The Process of Converting ArcInfo .e00 File Into REDARS™

4.3 Maintaining Schematic and Geographic Network Data

The REDARS™ Import Wizard requires both schematic and geographic network data to allow both efficient modeling and accurate representation of the transportation network. A schematic transportation network is constructed of links and nodes and has a simple node-link topology, where the geographic location of a given link is defined solely by the start and end nodes. Typically, these nodes correspond to street and freeway intersections. The shape of a road segment is not maintained in a schematic network. All street segments are recorded as straight lines. By storing only the geographic objects required to route traffic, a schematic network is efficient for routing algorithms. Like a schematic network, a geographic network is also a topological network, but in addition to the locations of the start and end nodes, additional nodes are stored to define the shape of the line segment (see Figure 4.4). In REDARS™, these nodes are kept in the Shapepoints table.

Both the schematic and geographic data have advantages and drawbacks that affect the adoption of a single network model within REDARS™. One significant advantage of schematic data is the faster calculations for transportation modeling. The advantage of geographic network data is the accurate spatial representation, which allows for more accurate location of bridges through dynamic segmentation, more accurate ground motions for SRA, and a better visual presentation.

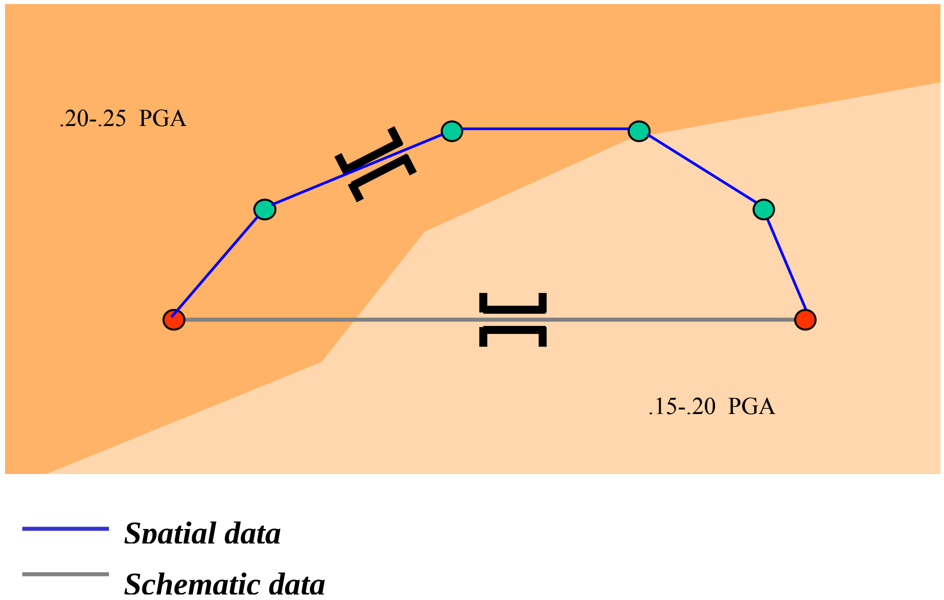


Figure 4.4 Conceptual Comparison of Schematic and Geographic Network Data

The REDARS™ Import Wizard creates a network that combines the advantages of both data models. The geographic data allows for visualization of the network, and bridge location. Ground motion is assigned to the network and bridges based on the spatial location derived using this network. The schematic data is used for transportation modeling. In addition to locating bridges on the geographic network, bridges are also integrated into the schematic data for analyzing the effects of bridge damage on traffic disruption.

To implement the dual network model, both networks are derived from the NHPN data in E00 format. The spatial objects of the network are the nodes and links. The node locations and connectivity from links in the NHPN network form the schematic data used for modeling. Additional geographic nodes are maintained in a separate table. These nodes are used by the map interface to represent the geometry of the network and the dynamic segmentation module to accurately locate bridges.

Figure 4.5 illustrates the results for an actual portion of the Los Angeles transportation network, and displays both the schematic transportation network used for modeling and the geographic network used for visualization and bridge location. For illustration, the geographic and the schematic network have been separated physically and both networks have been displayed graphically. The schematic network has fewer nodes, displayed as small circles. Each of these circles also represents a location of a node on the geographic network. The additional nodes, not shown, give the geographic network the smooth, curved shape, and allow for the more accurate location of bridges, represented as squares.

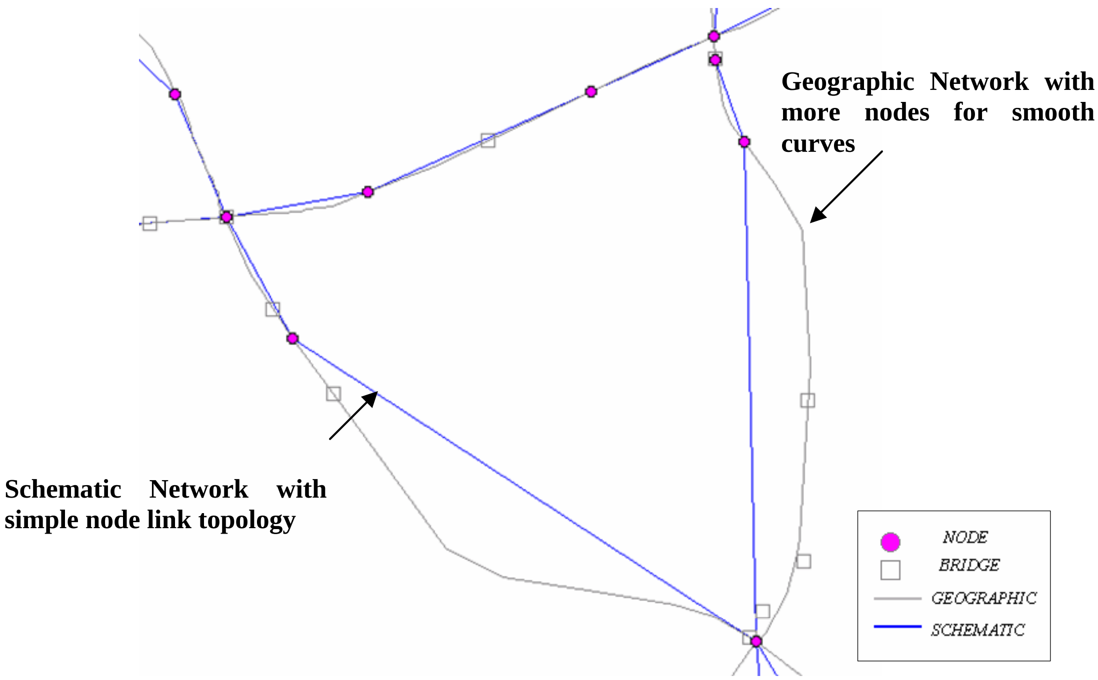


Figure 4.5 Presented Schematic and Geographic Network in Database

4.4 Resolving Multiple Network Dependency

REDARS™ requires two FHWA network databases, HPMS and NHPN, which must be combined. HPMS tracks attribute data for key fields such as the number of lanes, and functional classification. NHPN provides the geographical location of the transportation network. Linking the attribute data in the HPMS to the geographic data in the NHPN is complicated by mismatched beginning and ending nodes within the databases. In a full GIS program such as ArcIno, the attributes of HPMS can be viewed on top of the NHPN database using dynamic segmentation. However, this visualization of the HPMS data does not provide the link attribute data structure required for REDARS™ to analyze the attributes in the transportation module. For REDARS™, the HPMS and the NHPN must be combined into one database.

The two databases, NHPN and HPMS share a common route naming convention, or LRS, through the *LRSKEY* field. Although both data sets have the same LRS, the beginning and ending points in the milepost data (*BEGIN_LRS* and *END_LRS* in HPMS, *BEGMPT* and *ENDMPT* in NHPN) frequently do not match. This problem is illustrated in Figure 4.6 below. Mile-markers in the NHPN database (*BEGMPT* and *ENDMPT*) begin and end at different locations when compared with the HPMS mile-markers (*BEGIN_LRS* and *END_LRS*). The individual links between the mile-markers in NHPN (gray solid) do not correspond to the HPMS link (black dotted).

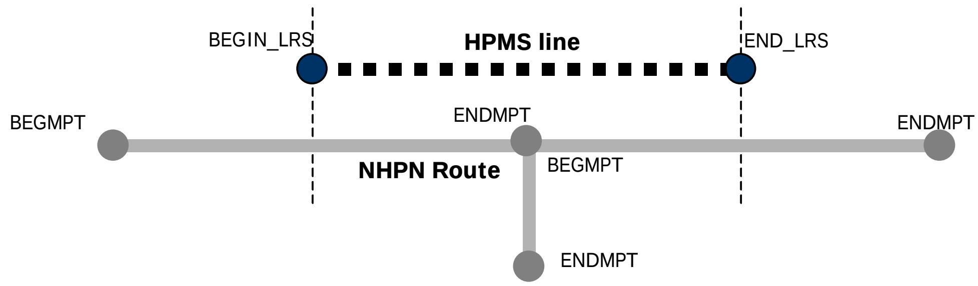


Figure 4.6 Mismatched beginning and Ending Nodes in the HPMS and NHPN Data

A methodology for creating a REDARS™ compatible transportation network model with NHPN topology and HPMS attributes is discussed below. Two options (Figure 4.7) are identified to resolve the problem of multiple network dependency. One option is selected based on the ability to program or automate the solution.

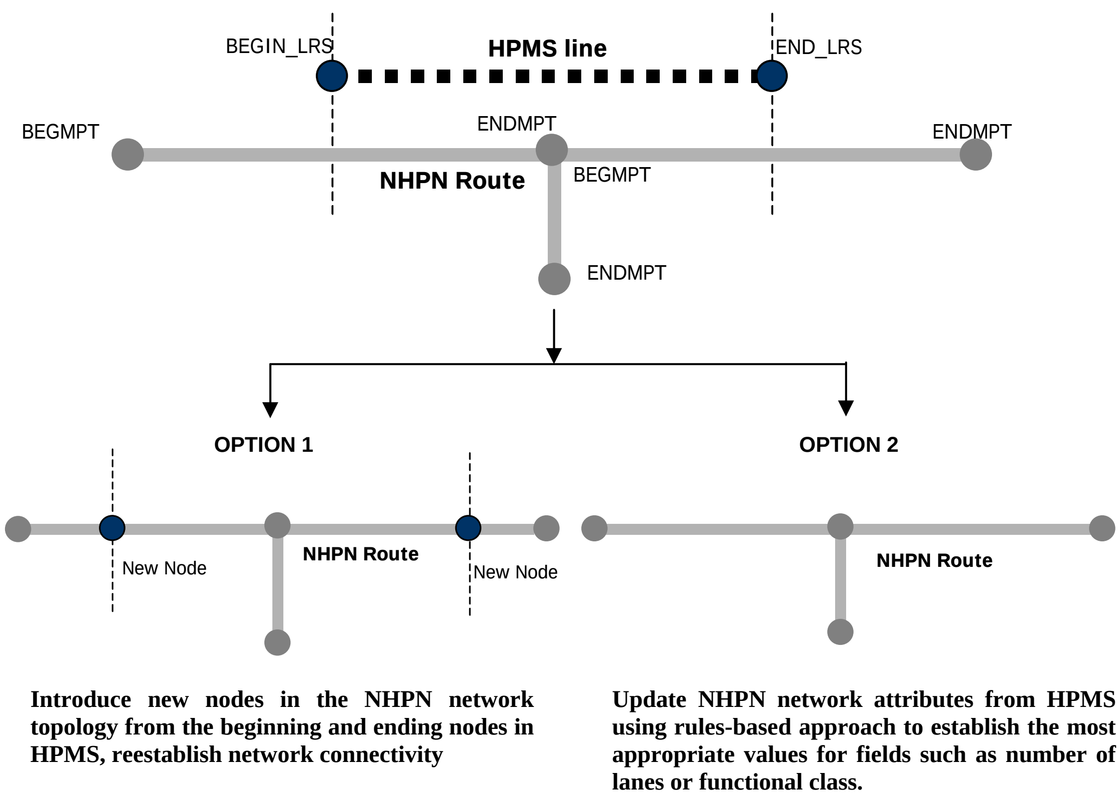


Figure 4.7 Matching NHPN and HPMS Data in Import Wizard

Figure 4.7 illustrates the two proposed options for resolving multiple network dependency. Option 1, illustrated on the left side of the Figure 4.7, is to introduce new nodes in the NHPN network topology, taken from the beginning and ending nodes in HPMS where the two networks do not have the same nodes. This option would require the connectivity of the network to be reestablished. Individual line segments can not be split, given a new node. Two new links must be created, and the nodes must now establish the flow between these two links and any other linear segments that come into contact with the link. Option 2, illustrated on the right side of the Figure 4.7, is to update the NHPN network attributes from HPMS using rules-based approach to establish the most appropriate values for fields. However, it would not be possible to automatically rebuild the transportation network and guarantee a satisfactory result. The following sections discuss these options in detail.

Option 1: Reestablish Node Topology and Recreate Network In order to discuss the method for creating a REDARS™ network using the first option, a hypothetical intersection is used (Figure 4.11). The dotted lines in Figure 4.8 represent the HPMS data and the solid lines represent NHPN lines. The lines are staggered for visualization only. The horizontal lines represent street segments corresponding to the same street. The vertical lines represent a cross street.

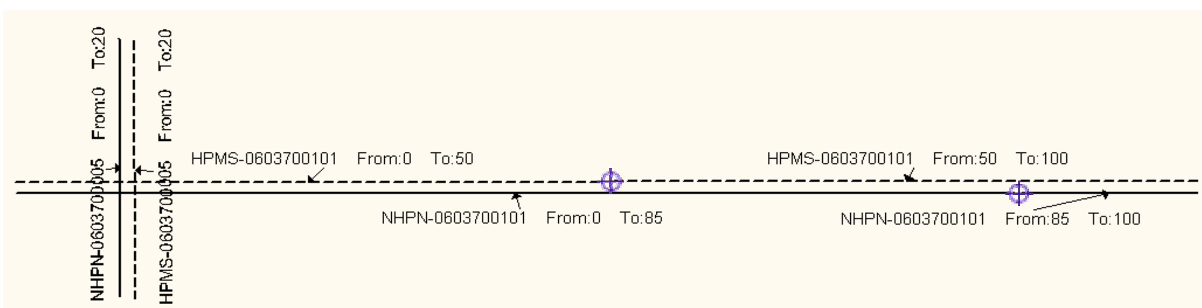


Figure 4.8 LRS from NHPN and HPMS

The visual representation of the HPMS table is generated from the NHPN network through dynamic segmentation. During dynamic segmentation, the user must specify the "LRS key" field, which is a text field to match the highway or freeway name, and the "from" and "to" fields, which identify the bounding milepost markers. The attribute data associated with the lines in Table 4.1 and Table 4.2 demonstrates how these segments may disagree. By comparing the dotted line to the solid line in figure 4.11 and examining the corresponding data tables, it becomes evident that the first segment of the solid line overlaps the two dotted lines, and that these two dotted lines have two distinct sets of attribute information.

Table 4.1 LRS in HPMS

LRSKey	From	To	Lanes
0603700101	0	50	6
0603700101	50	100	4
0603700005	0	20	2

Table 4.2 LRS in NHPN

LRSKey	From	To	Lanes
0603700101	0	85	4
0603700101	85	100	4
0603700005	0	20	2

To transfer the HPMS attribute data to the NHPN segments based on the length of overlap, the NHPN solid lines would have to be split using the HPMS dotted lines. This would create additional segments and introduces new nodes. The network would be updated to include each of the new segments and the nodes. Creating the topology that would enforce the traffic flow while recreating the links would be very difficult to automate.

Option 2: Maintain Topology and Update Attribute The second option maintains the NHPN arc as the unit of transportation analysis in REDARS™, and updates the important attributes using a rules-based approach. The following paragraphs provide a list of the rules used to match the HPMS and NHPN links in the import wizard. A detailed data model is presented to illustrate the process by which the HPMS attributes are transferred to the NHPN network.

Figure 4.9 illustrates the universe of possible relationships between the beginning and end points of the NHPN and HPMS line segments. In an ideal condition, the beginning and end mile points would match in NHPN and HPMS databases (situation *i.*). However, this is not the case in majority of the line segments. As illustrated the HPMS and the NHPN links below can be mismatched in a number of different ways (situation *ii.* through *vii.*).

i. BEGIN_LRS equals BEGMPT and END_LRS equals ENDMPT
ii. BEGIN_LRS is less than BEGMPT and END_LRS is greater than ENDMPT
iii. BEGIN_LRS is less than BEGMPT and END_LRS is less than ENDMPT
iv. BEGIN_LRS is greater than BEGMPT and END_LRS is greater than ENDMPT
v. BEGIN_LRS equals BEGMPT and END_LRS is less than ENDMPT
vi. BEGIN_LRS is greater than BEGMPT and END_LRS is less than ENDMPT
vii. BEGIN_LRS is greater than BEGMPT and END_LRS equals ENDMPT

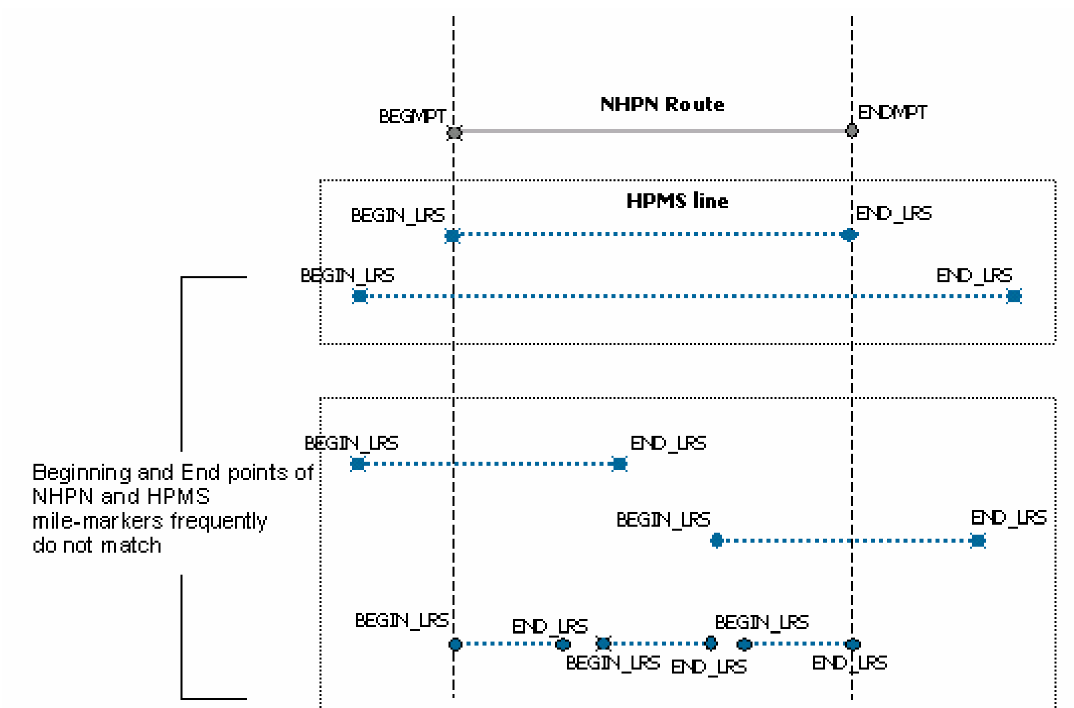


Figure 4.9 Matching NHPN Route and HPMS Line

Figure 4.10 is a schematic diagram that illustrates the tables in the NHPN and HPMS databases and how specific fields feed into the REDARS™ tables. The NHPN network topology provides the geographic objects of links and nodes. Attribute data from the HPMS populate the REDARS™ Link and Node tables. The figure also illustrates the joins between data fields referenced in the matching of the NHPN and HPMS (for example, *LRSKEY*, *BEGMPT*, BEGIN_LRS, etc). The key fields in the REDARS™ Link table that are updated include *number of lanes*, *rural or urban* classification, *link type*, *free flow speed*, and *capacity*. The REDARS™ Node table includes only the schematic end points of the links and the attribute information for the Node table is derived from the Link table and the spatial component of NHPN data.

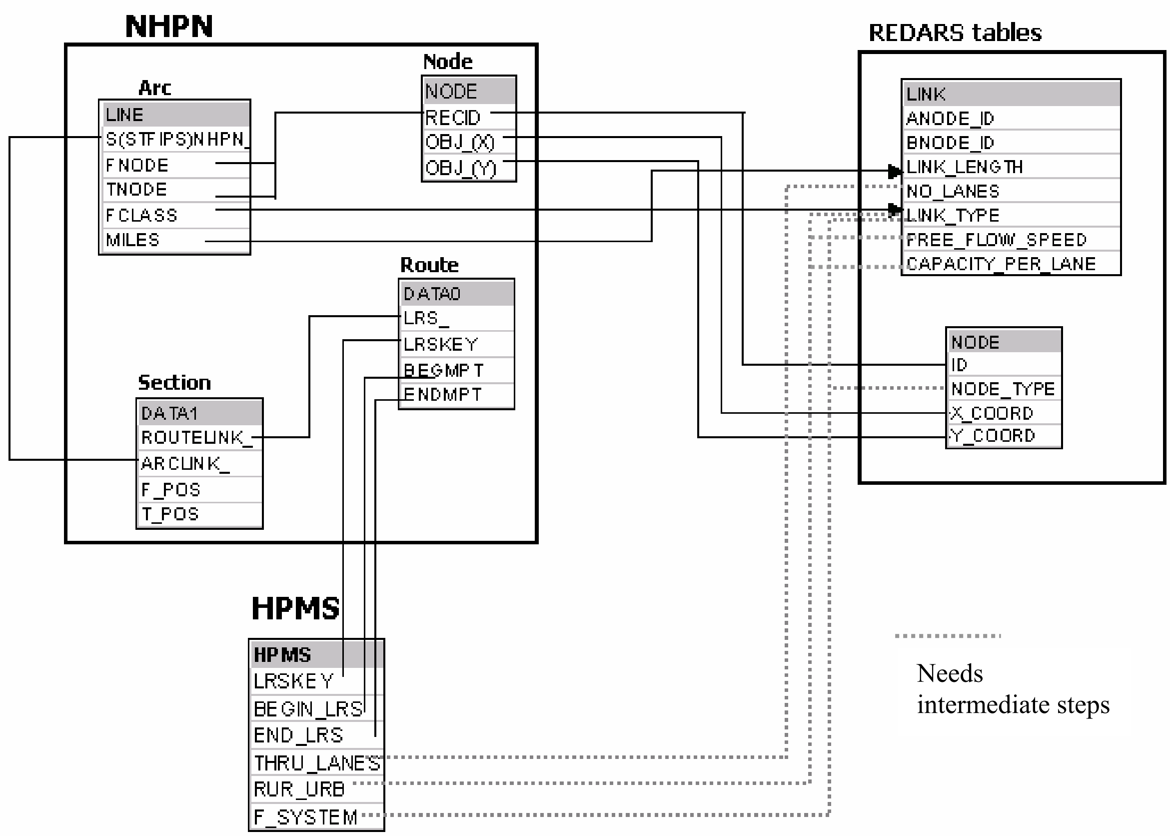


Figure 4.10 Detailed Data Model for REDARS™ Network

The matching procedure of polyline objects in the NHPN data with the HPMS data is developed through a series of geographic operations that estimate attributes based upon proximity and distance weighted functions. The next few sections discuss the methodology employed to update the following fields of the REDARS™ network tables: *Number of Lanes, Rur_Urb, Link_Typ, Free Flow Speed and Capacity.*

4.4.1 Updating Number of Lanes

The number of lanes on freeways is estimated from the HPMS Thru_Lanes field. The lane information available in the NHPN data is not accurate or is blank. The number of lanes in the REDARS™ Link table is updated with the HPMS (*Thru_Lanes*) values directly or using a measure of weighted average of the lanes depending on the manner in which the NHPN and HPMS mile markers are matched. If the nodes are co-located or span the NHPN link, then the number of lanes is simply accepted (conditions *i.* and *ii*.). For these two conditions, it is reasonable to directly update the lane information using HPMS values. This is because NHPN arc is the unit of our network. So, if a particular NHPN arc corresponds exactly with, or is totally spanned by a HPMS link, it is logical to directly transfer the HPMS attribute data to the NHPN link. For the remaining conditions *iii.* through *vii.* where there are partial overlaps between the NHPN and HPMS links, a weighted average for the lanes is calculated. The weight is calculated using the proportion of HPMS segment that overlap the NHPN arc. The process of updating the lanes is illustrated in the Figure 4.11 followed by two numerical examples.

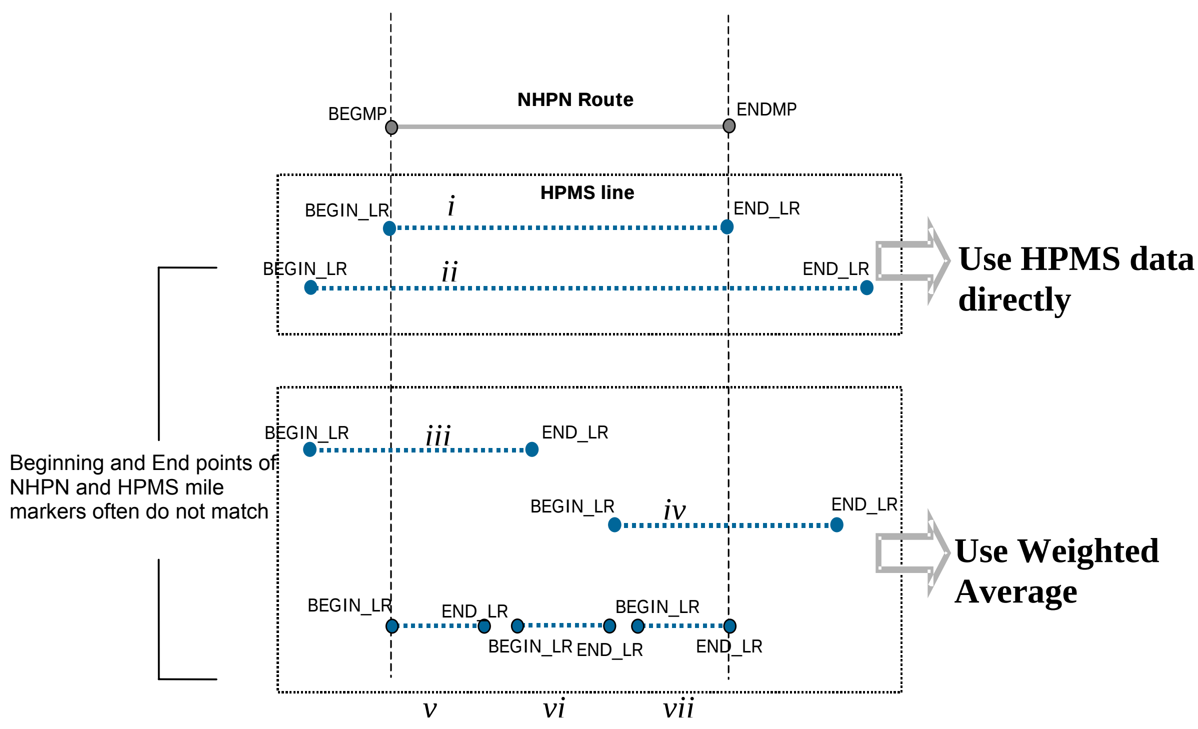
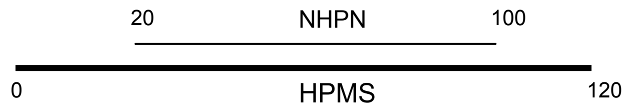


Figure 4.11 Updating REDARS™ Network Table with HPMS Attributes

Example 1:

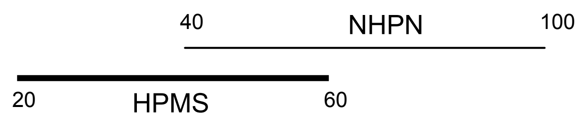
Source	BEGIN	END	LANES
NHPN	20	100	4
HPMS	0	120	5



This case reflects condition *ii* in Figure 4.11. The HPMS link completely spans the link topology derived from NHPN. Hence it is logical to update the number of lanes for this particular network link directly using the HPMS lane value which is 5.

Example 2:

Source	BEGIN	END	LANES
NHPN	20	100	4
HPMS	0	120	5



This case reflects condition *iii* in Figure 4.11. The HPMS link partially overlaps the link topology derived from NHPN. The start node (20) of the HPMS link is located before the NHPN link start node (40), and the HPMS link end node falls between the start and end nodes of the NHPN link (between 40 and 100). In this case, the number of lanes is calculated using the proportion of NHPN segment that overlap the HPMS link.

X = Proportion of overlap of NHPN segment = (60 - 40) / (100 - 40) = 0.33

Y = NHPN segment with no overlap = 1.0 - 0.33 = 0.66

Calculated Lane value = Integer(6*X + 2*Y) = Integer(6*0.33 + 2*0.66) = 3

4.4.2 Updating the Urban/Rural Designation

The *Rur_Urb* field in the HPMS database determines whether a roadway segment is in a rural area or an urban area. The information in the field is required to populate the *Free Flow Speed* and *Capacity* for the roadway link in the REDARS™ Link table. Using database queries, the HPMS *Rur_Urb* field attributes are combined with the network topology of links derived from the NHPN database. This is achieved by matching the HPMS and NHPN databases with the common LRSKEY field and any overlapping node condition. However, *Rur_Urb* classification for links in the NHPN database without a matching HPMS *LRSKEY* cannot be updated directly. *Rur_urb* classification for such links is updated by an iterative process involving proximity analysis of the neighboring links. Figure 4.12 illustrates this process showing two adjacent links, one with *Rur_urb* data and the other without the *Rur_urb* data.

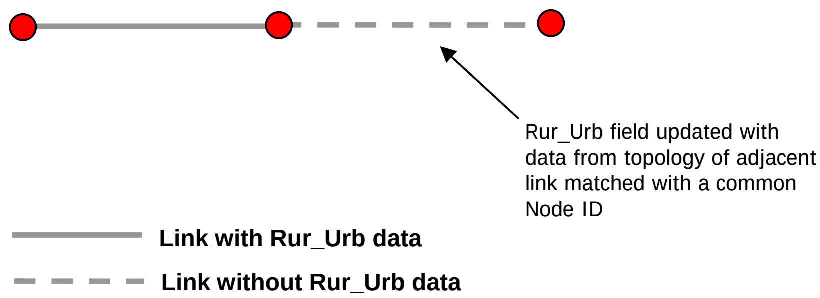


Figure 4.12 Updating the *Rur_Urb* Field

4.4.3 Updating Link Type

The *Link_Type* field in the REDARS™ Link table classifies the network links into the various roadway types such as urban or rural freeways, arterials and collectors. Each roadway type is associated with a *Link_Type* value (see Table 4.3). For example, rural and urban interstates are assigned a *Link_Type* value of 1. This classification is based individually on or as a combination of the following fields HPMS functional system, NHPN functional class, and the HPMS rural/urban classification. A three-step process involving database queries is used to update the *Link_Type* field

- First, the HPMS functional system (F_SYSTEM) is used to update the *Link_Type* field for links that have a matching HPMS and NHPN LRSKEY.
- Next, the links in the NHPN database without functional system (links without a matching HPMS LRSKEY) are updated using the NHPN functional class (FCLASS).
- Finally, the remaining links in the NHPN database (that do not have a matching HPMS LRSKEY and missing NHPN FCLASS) are updated using the rural/urban classification obtained through the topology of the neighboring links.

These 3 steps ensure that all the links are assigned a *Link_Type* value. Table 4.3 provides a list of the REDARS™ link types that are assigned for analysis.

Table 4.3 HPMS *F_SYSTEM* Values Corresponding to *Link_Type* Values in EDARS™ Link table

LINK_TYPE	Description	HPMS F_SYSTEM
1	TAZ Connector	-
2	Rural and Urban: Interstates	1,11
3	Urban: Freeways or Expressways	12
4	Urban: Principal Arterial	14
5	Urban: Minor Arterial	16
6	Urban: Collector	17
7	Rural: Principal Arterial, Minor Arterial, Major Collector	2,6,7
8	Rural: Minor Collector	8
9	Rural: Local	9
10	Ramps & Junctions	-

4.4.4 Updating Capacity and Free Flow Speed

In general, the free flow speed and capacity for transportation networks are determined through a combination of roadway types and location factors. To estimate the link capacity and free flow speed, we use the assumptions outlined in the 1997 SCAG report (SCAG, 1997). This report is used to determine the "area type," or distinguish between urban, and rural conditions. Table 4.4 summarizes the redefined Rur_Urb factor for freeflow speed and capacity designation. The roadway code is established from the HPMS field *F_SYSTEM*, or functional system. The capacity and free flow speed fields are updated based on the *F_SYSTEM* and SCAG area types. Table 4.5 and 4.6 are the look up tables.

Table 4.4 HPMS *Rur_Urb* Classification Based on Population

Rur_Urb Code	Description
1	Rural Area
2	Small Urban Area (Population 5,000 to 49,999)
3	Small Urbanized Area (Population 50,000 to 199,999)
4	Large Urbanized Area (Population 200,000 or More)

Note. AT = SCAG Area Type; For RUR_URB values 1-4 used corresponding SCAG area types: AT6 Rural = Rural Area; AT5 Suburban = Small Urban Area; AT4 Urban = Small Urbanized Area; AT3 Urban business District= Large Urbanized Area.

Table 4.5 Free Flow Speed by *Rur_Urb* Classification (MPH)

F_SYSTEM	RUR_URB			
	1	2	3	4
9	25	25	25	25
8	30	30	30	27.5
2,6,7	35	35	32.5	30
17	40	40	35	32.5
16	45	42.5	40	37.5
14	50	47.5	42.5	40
12	55	52.5	47.5	45
1,11	60	57.5	52.5	50

Table 4.6 Capacity by *F_SYSTEM* (PCU/Hour)

F_SYSTEM	RUR_URB			
	1	2	3	4
9	1,000	800	600	500
8	1,100	900	700	600
2,6,7	1,200	1,000	800	700
17	1,300	1,100	1,000	900
16	1,400	1,200	1,100	1,000
14	1,600	1,500	1,400	1,300
12	1,800	1,700	1,600	1,500
1,11	2,500	2,300	2,100	2,000

Presented below is a summary of the steps used to process the two network databases (NHPN and HPMS) and creates the REDARS™ Link and Node tables:

1. Establish links among NHPN Route, Section, Arc, and Node tables in the NHPN database.
2. Match NHPN route table to the HPMS database using the *LRSKEY* field.
3. Evaluate all the conditions that might arise when NHPN and HPMS data are matched.
4. Calculate weighted average for lanes.
5. Update the lanes field using calculated weighted average, and/ or *THRU_LANES* from HPMS.

6. Make Link table with matched NHPN & HPMS database and include *FREE_FLOW_SPEED*, *CAPACITY_PER_LANE* and *LINK_TYPE* fields.
7. Update the *FREE_FLOW_SPEED*, *CAPACITY_PER_LANE* and *LINK_TYPE* fields in the Link table.
8. Extract the node information from the Link table and update Node table.

The above steps illustrate the process by which HPMS and NHPN databases are combined to generate REDARS™ Link and Node tables. The relationships are established through database queries and software code. As such, the process is easily automated and wrapped into the framework of the Import Wizard. In summary, *Option 1(Reestablish Node Topology and Recreate Network)* involves complex spatial operations that is difficult to automate. *Option 2 (Maintain Topology and Update Attribute)* generates the same results as *Option 1* using an approach that is easily automated.

4.4.5 Testing the Preliminary Import Wizard Software Routine for South Carolina

The solution for resolving multiple network dependency discussed in Section 4.4.1 was tested using data for the State of South Carolina. NHPN data for South Carolina was obtained from FHWA in uncompressed ArcInfo Interchange (E00) format and imported into a REDARS™ Access database using the preliminary Import Wizard software routines. HPMS data was also downloaded from the FHWA website in a delimited text file format and imported into the same database. The Link and Node data tables are generated using *Option 2* discussed in the previous section.. Statistics on the completeness of this match are presented below.

Figure 4.13 shows the number of records in the NHPN and HPMS datasets for South Carolina and the number of records with matching IDs (*LRSKEY*s) in the two datasets. The HPMS data for South Carolina consists of 9,123 records representing approximately 6,720 miles of roadway. The NHPN database records 2,581 arcs totaling 7,539 miles of roadway. Approximately 82% of the NHPN segment length has matching coverage in the HPMS data. Approximately 18% of the NHPN segment length has no matching HPMS coverage or common *LRSKEY*. The attribute information for the 18% of NHPN data with no match is updated through proximity queries or given default values.

Figure 4.14 below shows the results of overlaying NHPN and HPMS data. The NHPN records which do not have matching HPMS records are shown as pink lines. The data displayed in Figure 4.14 matches the NHPM and HPMS databases outside of REDARS™ using a standard GIS program. The NHPN network was converted to shapefile format and plotted using ArcView. The HPMS data is mapped through dynamic segmentation, using an event theme in the NHPN database and indicating the matching route and mile marker data in the HPMS table. The HPMS data layer is overlaid on top of the NHPN data layer to highlight areas where the data does not match. The NHPN lines that do not have matching HPMS attributes are shown in the map as the pink lines.

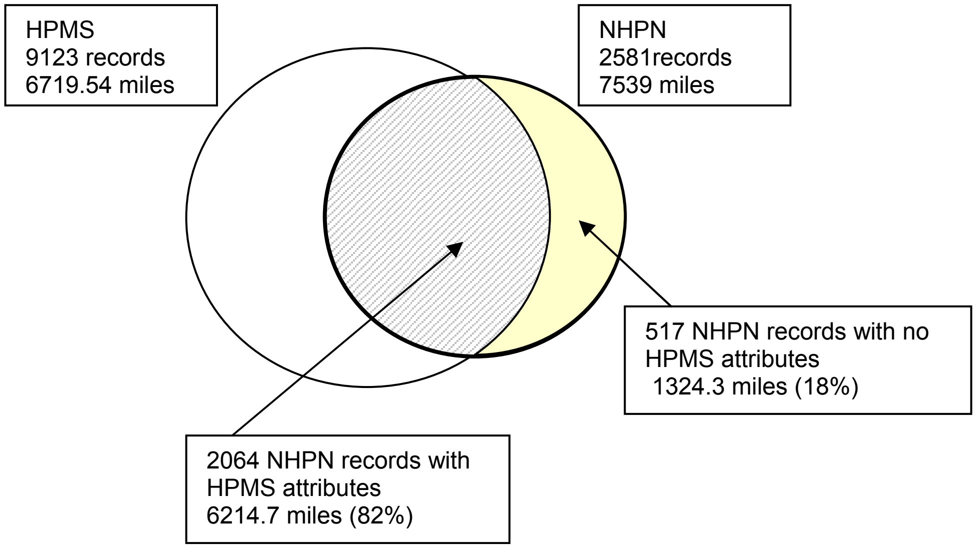


Figure 4.13 LRSKEY Join of the NHPN and HPMS Data for South Carolina

The matching of the NHPN and HPMS through dynamic segmentation within ArcView represents a baseline condition. The matching of the data within ArcView will store the best match in memory, but will not translate the data to the underlying data topology in a manner that can be used within REDARS™ to route traffic. The success of the match within ArcView represents the best match possible given the completeness of the data. The Import Wizard routines use an estimation process to match the success of this match, and supplement these results with assumption.

Three maps are used to compare the baseline data with the data created using the Import Wizard. These maps illustrate the success of the following Import Wizard procedures:

- The number of lanes in HPMS table plotted using dynamic segmentation and the number of lanes in the Link table.
- The *Rur_urb* classification in HPMS table plotted using dynamic segmentation and the *Rur_urb* field in the Link table updated based on proximity of the neighboring links.
- The *F_System* in HPMS table plotted using dynamic segmentation and the REDARS™ *Link_Type* in the Link table.

Figure 4.15 illustrates a comparison of the lane information from the REDARS™ Link table compared with the baseline condition. Figure 4.15(a) maps the lane information directly from HPMS table onto the NHPN using dynamic segmentation. The thickness of the gray lines thematically illustrates the number of lanes. The pink lines indicate the NHPN segments without matching HPMS data. Figure 4.15(b) maps the lane information stored in the REDARS™ Link table as calculated by the weighted average method described in option 1, Section 4.4.1.

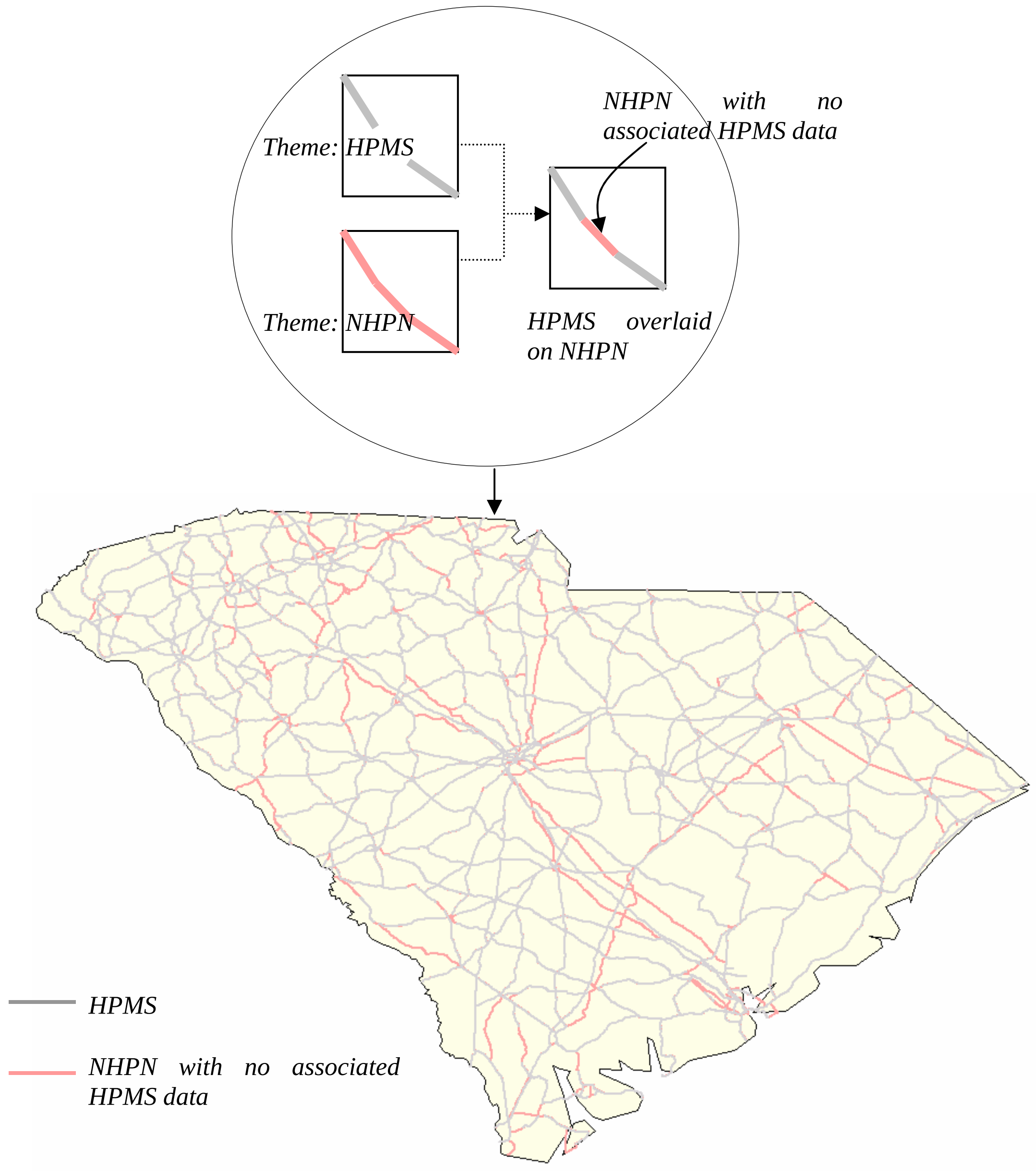


Figure 4.14 Overlaying NHPN and HPMS Data in ArcView

(a)

(b)

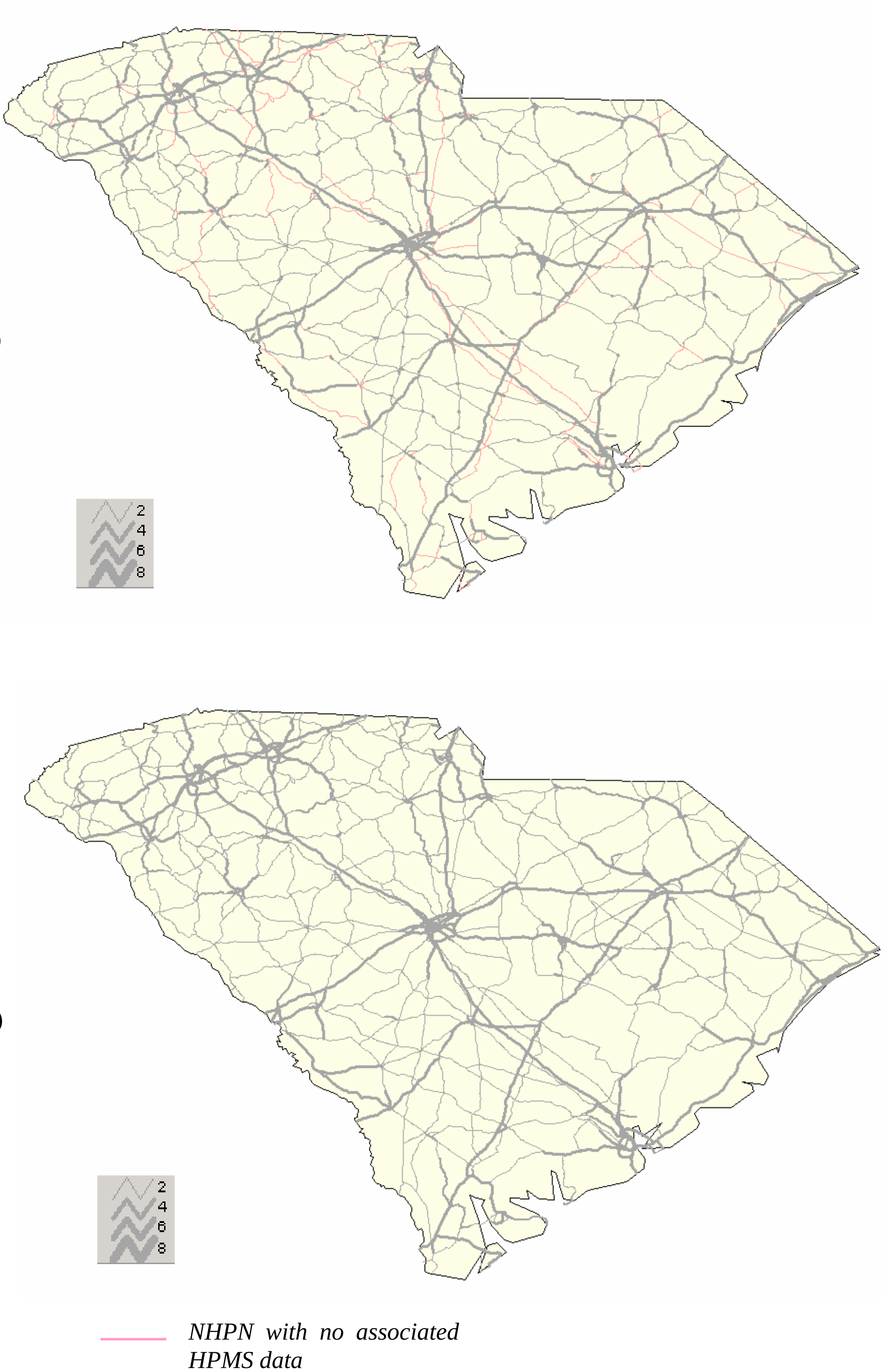


Figure 4.15 Updating the Lane Data in the REDARS™ Network Table

Table 4.7 Import Wizard Test for Accuracy of the Lane Attributes

Field tested	Steps	Conclusions
Lanes	- A baseline network indicating the missing lane information was created by matching the polyline objects in the NHPN with the HPMS data with ArcView. - The Import Wizard was used to update values for the lanes field using a weighted average	76% of the roadway length has a matching number of lanes in the updated Link table. 6% of the roadway length has inconsistent lane values. 18% of the roadway length could not be matched due to insufficient data.

Table 4.8 shows a matrix illustrating the updated lane values in the REDARS™ Link table. It tabulates the number of lanes in the REDARS™ table along the vertical axis and the number of lanes in the data matched through dynamic segmentation along the horizontal axis. The values deviating from the diagonal line indicate that there is a discrepancy between the two methods. Table 4.7 summarizes the results of the test. Based on the total link lengths of roadway that have the number of lanes consistent with the HPMS data, we conclude that the Import Wizard generates a reasonable estimate for the lanes. About 76% of the roadway has the same number of lanes in the updated Link table and the baseline HPMS table. Only about 6% of the roadway has inconsistent lane values. The remaining 18% of the roadway does not have HPMS attribute associated with it, and thus it was not possible to match the data. As such, these links are updated using default NHPN lane values and are not used in the comparison.

Table 4.8 Comparison of Updated Lane Values in Link Table with HPMS lanes

Link Lanes	HPMS Lanes							No HPMS attributes	Link Table
	2	3	4	5	6	7	8		
2	3681.79	0.99	37.98					1139.20	4859.96
3	221.35	76.72	166.49		1.55			185.08	466.11
4	10.54		1844.59	1.8					2042.01
5			22.48	22.52	11.83	2.89			59.72
6			2.55		102.23	1.63			106.41
7					1.05	0.04	1.1		2.19
8							3.5		3.5
Sum								1324.28	7539.90

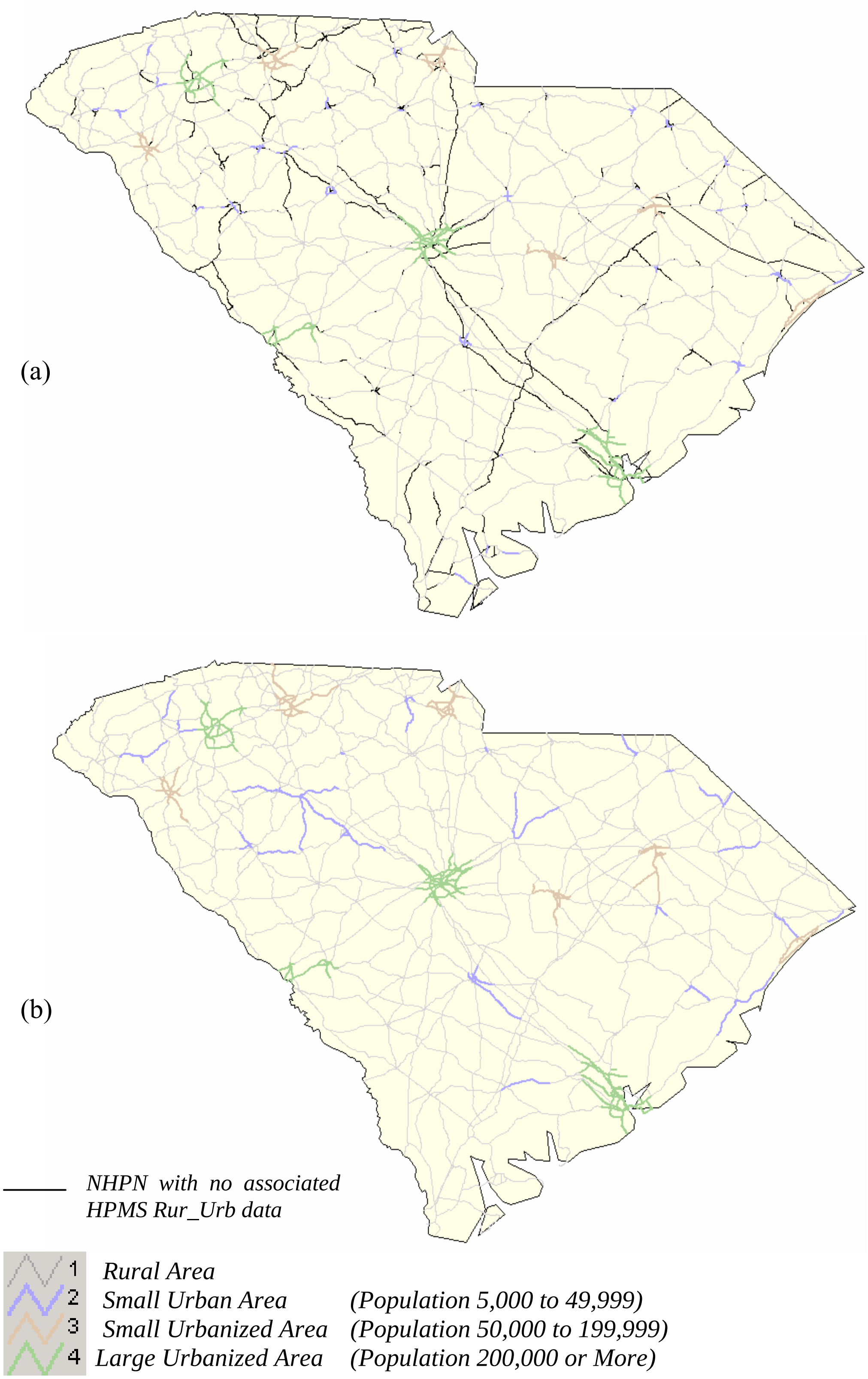


Figure 4.16 Updating the *Rur_Urb* Data in the REDARS® Network Table

The rural/urban classification within the HPMS data is sometimes blank, and sometimes can not be matched to the NHPN data through the *LRSKEY* field. In REDARS, these values are required to estimate other fields, so the Import Wizard approximates the values through a proximity analysis based on node connectivity. Figure 4.16 illustrates the transportation network with the missing *Rur_urb* classification, which has been created by matching polyline objects in the NHPN data with the HPMS table through database queries. The black lines indicate the missing *Rur_urb* data. The Figure 4.16(b) is a plot of the network with complete *Rur_urb* classification information after the import wizard routines are run. The missing *Rur_urb* information is completely updated. An inspection of the results presented in Figure 4.16(b) indicates a reasonable classification for the street network for South Carolina, with the populated values corresponding to the surrounding, known values.

Table 4.9 Import Wizard test for Accuracy of the Urban/Rural designation

Field tested	Steps	Conclusions
Rur_Urb	- A baseline network indicating the missing urban/rural classification was created by matching the polyline objects in the NHPN with the HPMS data with ArcView. - The Import Wizard was used to update values for the Rur_urb field using a proximity analysis through node topology.	All the missing Rur_urb information corresponding to the 18% of roadway that could not be matched is updated using the proximity analysis based on the topology of the neighboring links

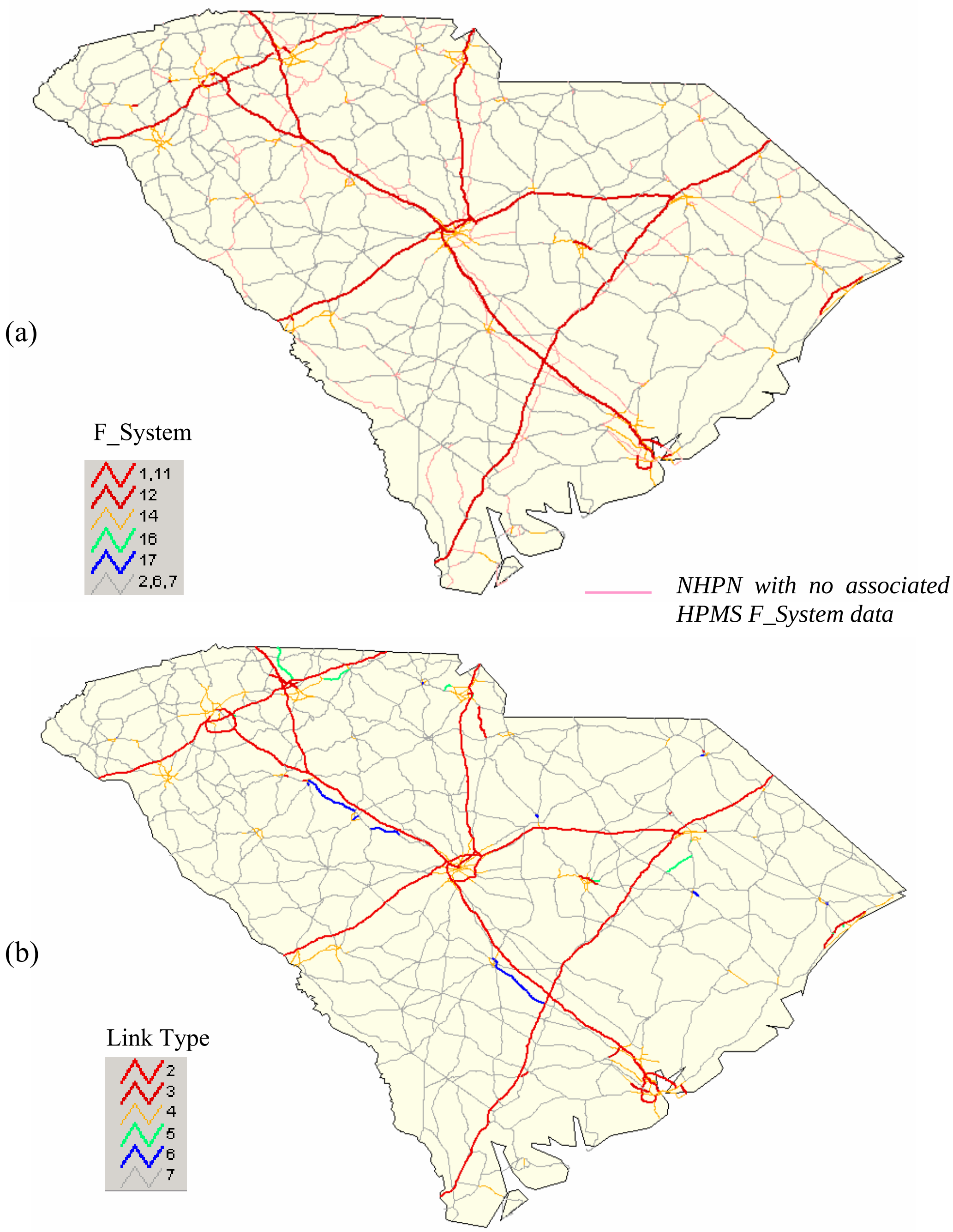


Figure 4.17 Updating *Link_Type* Data in the REDARS™ Network Table

The *Link_Type* information in the Link table is derived using data from one or more of the following fields: HPMS functional system, NHPN functional class, and the HPMS rural-urban classification. Based on these fields, each row in the Link table is assigned a *Link_Type* value. Figure 4.17(a) maps the HPMS F_System values directly and overlays it on NHPN topology. This map thematically illustrates the various functional classes of the streets (for example, Urban or rural interstates, highways, or arterials). The NHPN arcs without HPMS data are indicated as pink lines. Figure 4.17(b) maps the same network with Link_Type information from the Link table. Link_type values in this map uses a combination of the HPMS F_System values, default NHPN functional class (FCLASS) values, or a combination of lanes and rural/urban classification values to update the Link_Type information. Every F_System and Fclass value is assigned a corresponding *Link_Type* value. Links without associated F_System or Fclass values are updated using a combination of lanes and rural/urban classification values through proximity analysis. Figure 4.17 illustrates the results of transferring the *Link_Type* information between the two incompatible networks. The color-coding of the HPMS F_System classification and the *Link_Type* classification in Figure 4.17 have been maintained to illustrate the one-to-one relationship that exists between the two. With the exception of specific high volume links, the Import Wizard matches the observed data.

4.5 Integrating Bridges into the Transportation Network through Dynamic Segmentation

A key requirement for a REDARS™ is a transportation network with information on bridge attributes integrated into it. The REDARS™ data model requires bridge data to analyze post-earthquake traffic routes and travel costs due to bridge damage. The integration of bridges into the transportation network is a complex task. The national bridge database (NBI) contains fields for the latitude and longitude, the mile marker, and the highway route number of each bridge, but this is not suitable for directly associating the bridge with a specific roadway link. If a damaged bridge is incorrectly associated with a neighboring network link, it results in inaccurate estimation of travel time and cost in a post earthquake situation. The Import Wizard uses a custom dynamic segmentation algorithm to locate bridges along a route based on LRS data fields (mile marker and route identifiers). This creates an integrated system of bridges and the underlying network.

The dynamic segmentation algorithm in the Import Wizard is programmed in Visual Basic (VB). The Import Wizard uses the federally distributed NHPN data in E00 format discussed in Chapter 2 as the source of the network data. For bridge data, the Import Wizard uses the National Bridge Inventory (NBI) in delimited text format. The VB code uses the following fields for locating the bridges:

- *ID*
- *LRSKEY*
- *ArcID*
- *FNODE*
- *TNODE*

Figure 4.18 schematically illustrates the process for locating bridges through dynamic segmentation. The Visual Basic code reads the NBI table and the ArcInfo routing table DATA0 and matches the LRS information in the two tables. The *LRSKEY* field in the NBI table was created by combining three fields *LRS Inventory Route*, *Subroute Number*, and *County (Parish) Code*. The DATA0 table has an existing *LRSKEY* field. After the matching procedure, the bridges are separated based on an "unmatched" or "matched" *LRSKEY*. Bridges with unmatched *LRSKEY* use default latitude, longitude values in the NBI table as bridge location attributes. Bridges with matched *LRSKEY* are selected by *RouteID* field. Since there are multiple bridges with the same *LRSKEY* in different locations, each bridge is uniquely selected using the milepost data that falls between the beginning and end mile markers of the route table (DATA0).

The next step in the process is to associate the bridges with particular links. Although the LRSKEY matching routine establishes a relation between the bridge and route, it does not pinpoint the bridge location on a link. DATA1 table contains the field *Routelink_* that corresponds to the *RouteID* field in the DATA0 table. Using this relation and the fields *F_Meas* and *T_Meas* the code selects links (*Arclink_*) to locate the bridges. There are a number of such *Arclink_* for each bridge location. The dynamic segmentation algorithm then uses the Arc_Coord table to compare node locations with the bridge milepost. Finally, the link between the node pairs containing the bridge milepost is selected and the bridge location is generated using linear interpolation. The Import Wizard uses this bridge location coordinates to update *X_Coord* and *Y_Coord* (location fields) in the REDARS™ Bridge table.

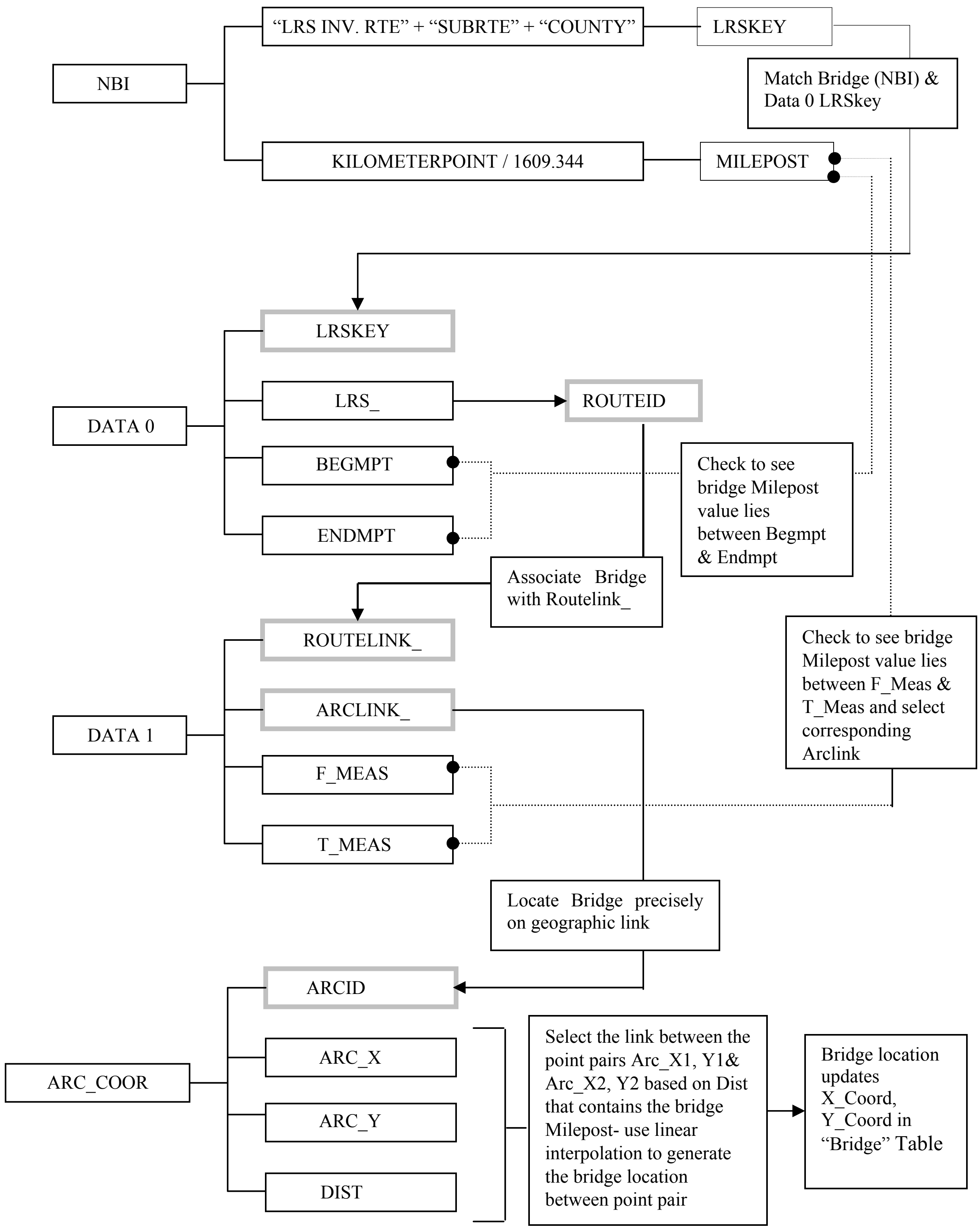


Figure 4.18 Dynamic Segmentation to Locate Bridges on Network

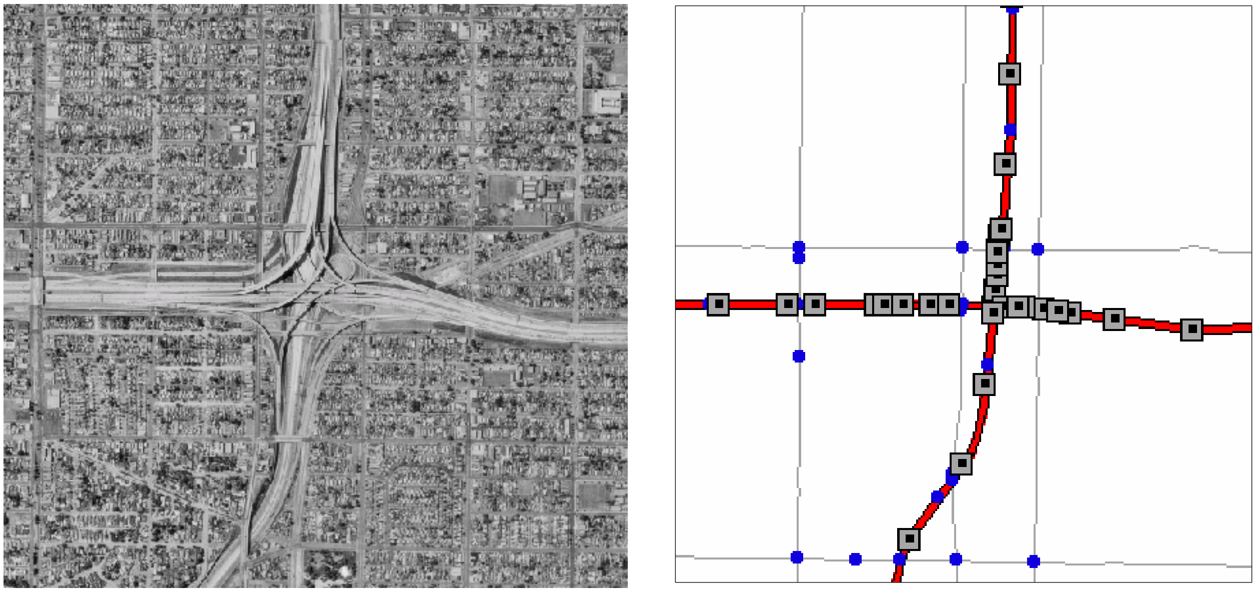
4.6 Topological Representation of Bridges Associated with Freeway Ramps

Bridges which serve as ramps to highways, or connectors at highway interchanges present a challenge in terms of topological representation and modeling bridge collapse. Damage to such bridges can simply close a freeway entry /exit or impede traffic flow on both directions on the freeway, depending on the configuration of the ramp. In each case, that is, whether a bridge is simply an on/off ramp, or it is a connector, the effect on the level of highway traffic congestion could be quite different. REDARS™ currently does not distinguish between bridges on main freeway links from bridges on ramps or connectors. Failing to differentiate between the two may result in overestimation in the overall economic loss due to an earthquake event. Incorporating bridges associated with ramps or connectors would improve modeling accuracy. In the next few paragraphs, we discuss issues associated with the topological representation of ramps and connectors and assess the ability to model traffic congestion due to collapsed ramps or connectors.

Several options were investigated to model ramps and connectors. The following issues were identified as challenges:

- The NBI database does not identify which bridges are ramps or connectors.
- The NHPN database does not include links to represent junctions.
- In many cases, ramps are stacked on top of each other and damage to one ramp may close others.

Theses issues are illustrated in the Figure 4.19(a) and 4.19(b). Figure 4.19(a) is an aerial photograph of the I-105/I-110 freeway interchange in Los Angeles. Figure 4.19(b) is the corresponding GIS representation with NBI bridges located on the NHPN network via the dynamic segmentation routine. As can be seen in the aerial photograph, there are several individual bridges associated with this single interchange. The NHPN however, represents this interchange as the simple intersection of two highways (I-105 and I-110). All the bridges, ramps, and connectors around the intersection appear as points based on mile-marker information in the NBI database, and as such do not represent the actual topology of the ramps or connectors. If the connector ramp from I-110 north (N) to I-105 east (E) were to collapse, deciding which link should be removed from the network is a matter of conjecture. Removing any of the existing links in this example may exaggerate the effect of the collapsed bridge, as it would prevent traffic from flowing in either direction along one (or both) of the highways.



(a) Aerial Photo

(b) NHPN network with NBI bridge locations

Figure 4.19 I-105 and I-110 interchange, Los Angeles, California

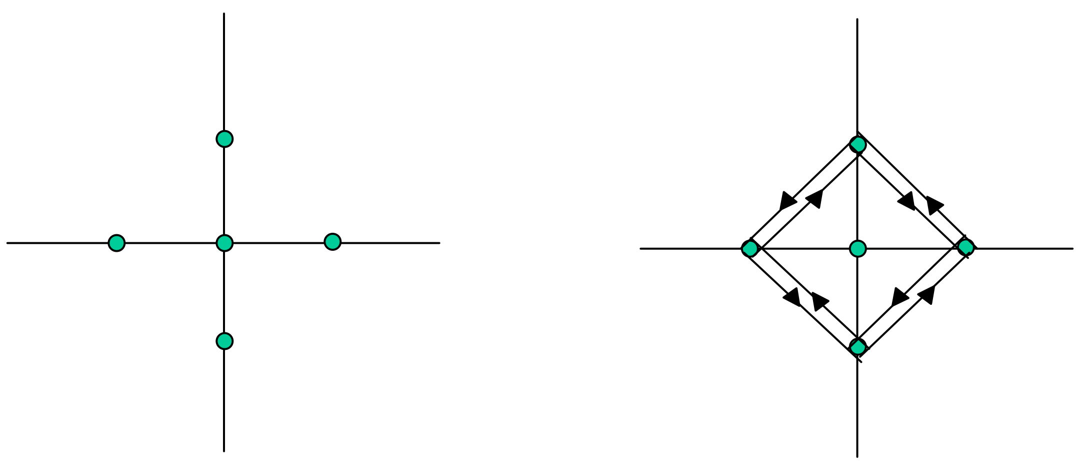
An attempt was made to locate ramps and connectors using a combination of quantitative and qualitative comment fields in the NBI database. These include the "Designated Level of Service," "Route number," "Facility carried by structure," and "Features intersected by structure" (See Figure 4.20). The hypothesis was that it may be possible to parse the descriptive fields in the NBI database to characterize ramps or connectors. This was not feasible due to the following reasons:

- The description for ramps/connectors was not consistent across the different states. There were no "rules" for the description, and as such, it was not possible to create parsing routines.
- Even from reading the descriptive fields it was difficult to discern which of the bridges are freeway-to-freeway connectors and which bridges were on or off ramps.
- It was not possible to establish the "to" or the "from" directionality of the highway or street segments, and hence the directionality of the ramps or connectors.
- Many of the descriptive fields are left blank

Structure Num	Designate	County	Features Intersected	Facility Carried By Structure
53 2670G	1	37	N405-N110 CONNECTOR RAMP	N405-N110 CONNECTR
53 2671H	7	37	S110-S405 CONNECTOR RAMP	S110&W91-N405 CONN
53 2671H	7	37	S110&W91-N405 CONNECTOR	S110&W91-N405 CONN
53 2672	7	37	HOOVER STREET	HOOVER STREET
53 2675K	7	37	S110-W105 CONNECTOR RAMP	W105-VERMONT OFFRP
53 2675K	7	37	W105-VERMONT AV OFF RAMP	W105-VERMONT OFFRP
53 2676F	7	37	BROADWAY, IMPERIAL HWY	W105-N110 CONNECTR
53 2677F	1	37	S110-E105 HOV CONN	S110-E105 CONNECTR
53 2677F	7	37	S110-E105 HOV CONN	S110-E105 CONNECTR
53 2677F	7	37	S110-E105 HOV CONN	S110-E105 CONNECTR
53 2677F	7	37	S110-E105 HOV CONN	S110-E105 CONNECTR
53 2677F	7	37	S110-E105 HOV CONN	S110-E105 CONNECTR
53 2677F	7	37	I 110, N110-W105, HOV	S110-E105 CONNECTR
53 2679F	1	37	BROADWAY STREET	S110-E105 HOV CONN
53 2680F	1	37	W105-N110 HOV (110 NBND)	W105-N110 HOV CONN
53 2680F	1	37	W105-N110 HOV (105 WBND)	W105-N110 HOV CONN
53 2680F	7	37	W105-N110 HOV(W105-S110)	W105-N110 HOV CONN

Figure 4.20 Sample Descriptive Data for Ramps in the NBI

A more possible way to integrate ramps or connectors at freeway interchanges may have been to introduce eight new links at each interchange, for example in Figure 4.21(a) to represent the connectors. As shown in Figure 4.21(b), this option represents the topology of the connectors and maintains directionality. However, it does not represent the topology correctly, as it fails to adequately restrict the flow of traffic in the event of a connector collapsing. Traffic might flow in unrealistic ways to avoid the damaged link, for example, make freeway u-turn (See Figure 4.22).



(a) NHPN representation of link, node, and freeway interchange

(b) Freeway interchange with connectors

Figure 4.21 Topology of Connectors at Freeway Interchanges

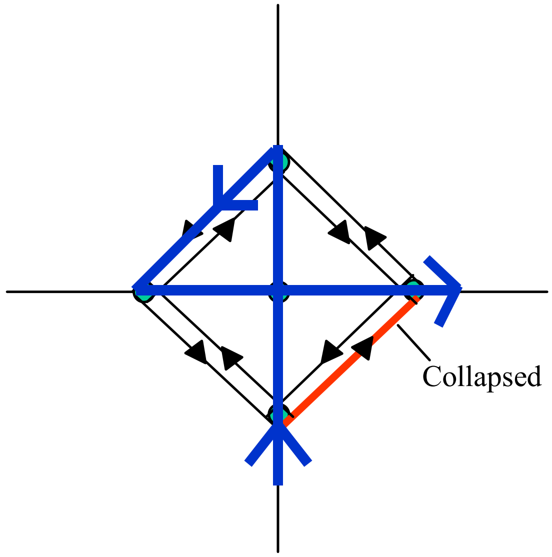


Figure 4.22 Collapsed Connector and Unrealistic Traffic Flow

In order to prevent topological anomalies such as freeway u-turns, and allow bi-directional traffic flow the following hypothetical interchange was investigated. This option included mirrored network links and nodes for each direction of traffic flow. This method was devised to accurately model traffic flow around freeway intersections. Using this model, flow of traffic is restricted to realistic routes once a connector is closed due to damage.

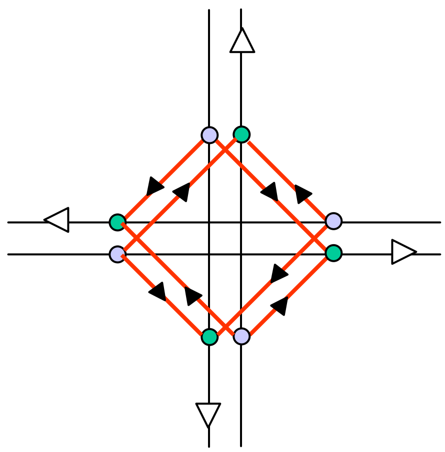


Figure 4.23 Hypothetical Freeway Interchange and Connector Topology

In order to realistically model a collapsed connector or a ramp a more detailed topology for the entire network is required. Directionality must be maintained along each link and only those links that truly connect in the real world should share a common node in the network. After further examination of the NHPN data overlaid on high resolution aerial photography it is clear that the NHPN only approximates the geometry of the real world highways. Therefore, it is concluded that while the NHPN is well suited for regional level analysis it is too crude to be used as a basis for modeling detailed features such as freeway interchanges using the methods discussed above.

4.7 Resolving Topological Idiosyncrasies in the Transportation Network

After the creation of the preliminary Import Wizard, the program was tested using many study regions throughout California. Various topological conditions are discussed below that lead to an incorrect network representation. The Import Wizard was modified to identify and resolve such conditions during the network generation process.

Inclusion and connection of links following zone boundaries Often Traffic Analysis Zone (TAZ) boundaries follow roadway center lines. Small differences between the traffic analysis zones and the NHPN network data as depicted in the GIS layer will cause a discontinuous route along the study boundary. The Import Wizard buffers the study region before sub-setting the network to resolve this condition.

Disconnected network polygons It is possible for the user to select a study region that captures disconnected TAZs, especially in sparse areas or if a body of water is present. This operation is programmed to select TAZs that intersects the user-drawn polygon, rather than only the zones where the center is within the polygon (see Figure 4.29). Additionally, when disconnected regions are drawn, the program will discontinue the processing and alert the user.

Isolated link segments or disconnected internal link: In some cases, links are disconnected from the main body of the network near boundaries. The Import Wizard will detect disconnected links and determine whether the links should be connected or discarded.

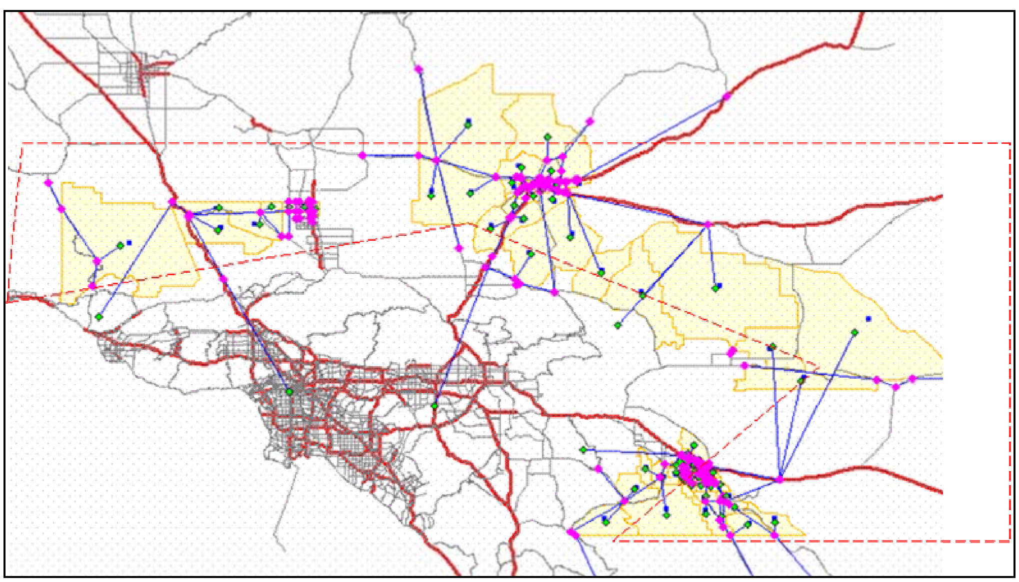


Figure 4.24 Disconnected TAZs from a User Selection

4.8 Sub-setting the OD Trip Tables

The Import Wizard creates a REDARS™ database for a user selected study region. This involves the sub-setting of the regional OD into a local subset ODs for the selected region. Sub-setting a smaller OD from a regional OD is a complex task as it addresses the following conditions:

- There is travel demand which traverses through the selected sub-region
- There exists travel demand associated with the selected sub-region and regions external to the selected sub-region

The Import Wizard incorporates a method using the User Equilibrium (UE) model for generating the subset OD with no network conductivity problems and consistent link volume with new external OD. This is discussed below:

The User Equilibrium (UE) paradigm equilibrates traffic volume and time based on competitions between routes. The UE model solves the following system of equations:

$$\min\ Z = \sum_a \int_0^{x_a} C_a(w)\,dw$$

s.t.

$$x_a = \sum_{r \in R} \delta_{ar} h_r \qquad \forall a \in A$$

$$\sum_{r \in R} h_r = T_{ij} \qquad \forall i \in I,\ j \in J$$

$$T = \sum_i O_i = \sum_j D_j = \sum_{ij} T_{ij} \qquad \forall i \in I,\ j \in J$$

$$h_r \geq 0 \qquad \forall r \in R$$

where x_a : the traffic flow on link *a*.

C_a : the performance (volume-delay) function on link *a*.

δ_{ar} : link-path incidence variable; 1 if link *a* belongs to path *r*

h_r : traffic flow on path *r*

$r,\ r \in R$: a network path

$i,\ i \in I$: origin zone,

$j,\ j \in J$: destination zone

T : total travel demand

T_{ij} : demand from zone *i* to zone *j*

Through out the iterative solution process, link volumes are adjusted. UE model builds all-to-all path in each iteration, and loads the demand in regional OD to the paths.

The following procedure solves the UE model:

Step 0. Initialization

Set iteration index k=0

Set link volume $x_a^k = 0, \forall a \in A$, and update link travel time $t_a^k = C_a\left(x_a^k\right)$

Set "small" OD $T_{ij}^k = 0, \forall i \in I, j \in J$

Step 1. All-or-Nothing Assignment

Search MTP based on updated link travel time t_a^k

Calculate auxiliary link volume; y_a^k, by loading all traffic demand to the searched MTP

Calculate auxiliary OD; U_{ij}^k, for the following possible alternative demand conditions defined by tracing MTP for each link:

- If the root (origin of the path) and destination is inside the selected sub-region, the demand is inside-to-inside.
- If the path has odd number of labeled cordon links, and the root is inside the selected region, the demand is inside-to-outside.
- If the path has odd number of labeled cordon links, and the root is outside the selected region, the demand is outside-to-inside.
- If the path has even number of labeled cordon links, and the root is outside the selected region, the demand is outside-to-outside. But the demand passes through some of the links in the selected sub-region.
- If the path has no labeled cordon link, and the root is outside the selected region, the demand would not pass through the selected sub-region.

Step 2. Search updating step size

Solve the following optimization problem against λ (0≤λ≤1)

$$\min_{\lambda} \sum_a \int_0^{x_a+\lambda(y_a-x_a)} C_a(w)dw$$

Step 3. Convergence test

Stop the algorithm if $0 \le \lambda < \varepsilon$ (ε is an arbitrary small tolerance)

Otherwise go to next step

Step 4. Update

Set iteration index k:=k+1

Update link volume $x_a^k := x_a^k + \lambda\left(y_a^k - x_a^k\right)$

Update link travel time $t_a^k = C_a\left(x_a^k\right)$

Update "small" OD $T_{ij}^k := T_{ij}^k + \lambda\left(U_{ij}^k - T_{ij}^k\right)$

Go to step 1.

CHAPTER 5

REFERENCES

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APPENDIX A
FREQUENTLY ASKED QUESTIONS

Q. What is a Traffic Analysis Zone (TAZ)?

A. A Traffic Analysis Zone (TAZ) is an area unit like zip codes or census tracts used for tabulating traffic-related data, especially journey-to-work and place-of-work statistics. See Section 2-1.

Q. What is an Origin Destination (OD) file?

A. An Origin Destination (OD) file is a two-dimensional matrix of elements whose cell values represent the number of trips made between various O-D zone pairs. See Section 2-1.

Q. Where do I get TAZ and OD data?

A. Both TAZ and OD file are developed and maintained by Metropolitan Organizations (MPO), Regional Transportation Planning Agencies (RTPA), or the state department of transportation. To get a TAZ and OD file for your community, contact your local MPO, RTPA, or state DOT. Ask for the Senior Planner in the planning department.

Q. How do I figure out my MPO or RTPA?

A. The Metropolitan Planning Organization (MPO) is a transportation policy-making board comprised of representatives from local government and transportation authorities. Regional Transportation Planning Agencies (RTPAs) are local transportation commissions, county transportation commissions, councils of government, and associations of government. Use a web search engine to determine the MPO or RTPA for your area, or contact the Association of Metropolitan Planning Organizations at http://www.ampo.org/

Q. What are the OD parameters and how do I figure out what parameter to use?

A. OD data incorporates a parameter or a measure of time over which the trips take place in a day for a region. For example, it can be trips taking place within an hour, or 4-hour morning peak, or even the whole day. REDARS™ requires this OD parameter for transportation analysis. The primary source of this information is your local MPO or RTPA. When contacting your local agencies for this information, ask for the time unit which the OD data represents (1hr, 4-hr morning peak, etc). In addition, based on the duration of the OD data, you need a conversion factor to estimate daily travel cost. If the OD data represents 1 day, the conversion factor is 1. For durations shorter than 1 day, you need a factor to scale the OD. The conversion factor is also available from your local MPO or RTPA.

Q. What is PCU?

A. PCU or Passenger Car-equivalent Unit is a measure of trips for vehicle OD (car or freight) considering the relative congestion effect of 1 trip. For example, the Highway Capacity Manual reports, 1 truck trip generates 1.8 ~ 2.5 times congestion than a passenger car trip. REDARS™ converts the OD to passenger car equivalent using PCU to estimate consistent congestion effect.

Q. What is Value of Time (VOT) and how do I figure out the value in dollars of one hour of travel time?

A. Value of Time for a vehicle is determined by a set of factors that are specific to the driver, passengers and cargo of that vehicle. In general, trucks have a higher VOT than passenger cars. The primary source of this information is your local MPO or RTPA. When asking your local agencies for this information ask for "what value of time are you using?" Also, the Rand corporation (http://www.rand.org/) provides VOT information.

Q. If my GIS data is in the wrong format, what can I do to get it in right format?

A. There may be 2 common types of problems with the GIS data format. These are discussed below:

- The data is not in shapefile format: Use any standard translating tool (e.g. MapInfo Universal translator, MIFSHAPE, ArcToolbox, FME Translator) to convert the data into ESRI shapefile format.
- The data is not in a geographic coordinate system: If you already know the projection of the data, use ArcView Projection Utility Wizard or a similar tool to convert the file into geographic coordinate system. If you do not know the projection, contact the data provider to obtain this information. Make sure all datums match the datum used for the NHPN.

Q. What if I have newer NBI, NHPN or HPMS data?

A. NBI and NHPN files include metafile when distributed by FHWA. Replace the old files with the new files. HPMS files are distributed with schema files. Replace the old HPMS and schema files with the new files.

Q. Where do I get the NEHRP Soil Data?

A. Contact the National Earthquake Hazards Reduction Program (NEHRP) and inquire if the NEHRP soil data is available for your area.

Q. What if NEHRP Soil is not available in my area?

A. If the NEHRP soil data is unavailable, a conversion from other soils data or a default value may be necessary. Otherwise, the Import Wizard allows users to define a default value.

APPENDIX B
IMPORT WIZARD PROCESSING STEPS

The following data importing steps are implemented when a user creates a study region using the Import Wizard:

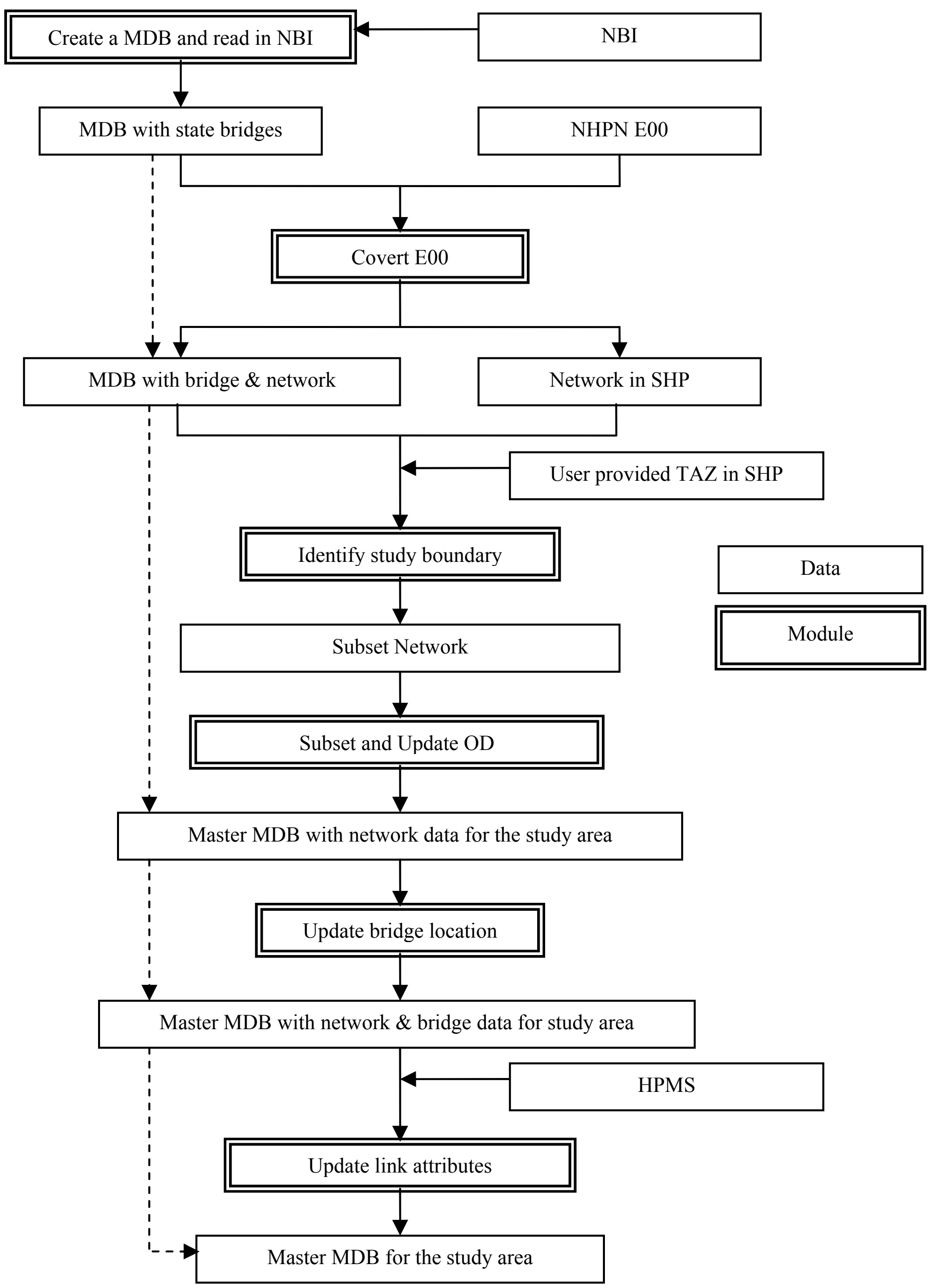

Figure B.1 Import Wizard Processing Steps

Create blank database files set As the first step in the database creation process, Import Wizard creates five Access MDB files. REDARS™ uses three distinctive MS Access database files, named RDF (REDARS™ Data File), and RVB (REDARS™ Visual Basic for Application), RPR (REDARS™ Probabilistic analysis). In addition, Import Wizard uses two temporal MDB files for the procedure. Instead of relying on ADOX (Active Data Object Extension) for manipulating MDB file structure (including creation of the files), the individual files are created by "melting" binary files that contains all the required data structure. It is convenient because "melting" method does not require modification of the program code to accommodate changes in data or database structure during development of REDARS™.

Populate HPMS tables HPMS (Highway Performance Monitoring System) files are comma delimitated text file with a metadata in a schema file (a text file). Import Wizard reads the metadata file to capture the data structure, including data field name and field length. A text parser in Import Wizard reads the required data and populates tables in the temporary Import Wizard file.

Populate NBI tables NBI (Nation Bridge Inventory) is also delivered in a column-based text file without delimiting characters. A text parser in the Import Wizard reads the file according to a pre-defined structure.

Create and populate NHPN tables NHPN (National Highway Planning Network) is delivered in an uncompressed ArcInfo export file, e00. Import Wizard reads state-wide NHPN file, and populates temporal Import Wizard tables for arc geometry, arc attributes, node attributes, route information, and linear referencing system.

Establish relationships between tables and create Link table Import Wizard creates two separate Link tables: One Link table is for region-wide network analysis, and the other Link table is for the study area specified by user. Region-wide Link table is created by a series of queries summarized below:

- Identify nodes within Traffic Analysis Zone Map (TAZ)
- Identify links, of which any end-node is included in the node set identified in previous step
- Identify "outside" nodes which are not within the TAZs, but are end-nodes of the selected links
- Update attributes of the selected links using HPMS attribute data
- Add virtual links to connect the TAZ centroids to the selected nodes

Link table for selected study area is created based on HPMS-updated region-wide Link table as follows:

- Identify nodes within user drawn boundary
- Additionally, identify nodes in the selected TAZs from user drawn boundary

- Identify links, for which any end-node is included in the node set identified in the two previous steps
- Identify "outside" nodes those are not within the user drawn boundary, or within selected TAZs, but are end-nodes of the selected links
- Add new virtual links to connect centroids of selected TAZs to the nodes in the study area
- Create virtual links to connect adjacent "outside" nodes
- Update the external virtual links between adjacent "outside" nodes to represent boundary conditions

***Locate NBI bridges on to the links in Link table*:** Data records in NBI are addressed for bridges and tunnels separately. Location of each bridge or tunnel is calculated through dynamic segmentation using a linear referencing system.

***Update Soil type for the selected highway components*:** Bridge and Tunnel tables in RDF file are updated for soil type, using point-to-polygon relationship.

***OD subset and Calibrate the Demand functions*:** This step includes several time- consuming calculations:

- Run fixed-demand user equilibrium model with region-wide network and OD matrices obtained from planning organizations. This will result in zone-to-zone travel time matrix and partial travel demand between outside zones, part of which demand is going through the selected study network. This step is especially time consuming because it involves huge network and OD matrices, and traces all routes for counting partial demand.
- Set travel times infinite to the links within the study area, and calculate travel time between "outside" nodes. This gives the travel times on virtual links between "outside" nodes.
- Regress the OD matrices against the travel matrix, using exponential function. This gives the distance-decay function
- Apply Deming-Stephan-Furness balancing algorithm for gravity model with the distance-decay function to calibrate required parameters for the demand function.

***Populate the database with data for study area*:** All processes up to this current step are done using the temporal MDB file. The current step populates the Link, Node, ShapePoints tables considering virtual links, new node ID, new link ID, and geographic objects.

***Bridge / TAZ / VARS tables / Clean up*:** The remaining tables are populated by importing selected data from the temporal MDB file. Actual updating of link attributes is done through data transaction. Scratch tables, and files are cleaned up. TAZ tables are created according to the OD file.

***Baseline Analysis*:** With the created RDF file, Import Wizard performs network analysis for the baseline case, for which network and component capacity is intact. Link and TAZ tables are populated with the baseline analysis results.

The overall running time of the Import Wizard is dependent on the size of region-wide TAZ, since it defines the time for OD subset for region-wide transportation analysis. Also, the size of study area (number of TAZs selected and geographic area) is also important because the number of highway components (links, nodes, bridges, and tunnel) is also related to the study area. Import Wizard takes about 25 to 35 minutes to process 3217 Southern California TAZs, and about 10 minutes to process the Bay Area TAZs.

APPENDIX C
FHWA NETWORK DATA KEY FIELDS

C.1 The National Highway Planning Network (NHPN)

C.1.1 Node Attribute table (NAT)

RECID	A unique identifier for the node.

C.1.2 Arc Attribute Table (AAT)

S(STFIPS)NHPN	A unique identifier for the network link. "(STFIPS)" corresponds to the two digit state FIPS code. Each link identifier includes the state FIPS Code.
FCLASS	Identifies the functional class of each arc. Functional class designates roads as interstates, highways, arterials, or local rural roads
MILES	The length of the arc in miles.
FNODE	The unique ID of the "from node", or starting node of the network link. This is a link to the unique ID stored in the NAT table, and is used to create a relational join between the Link and Node tables.
TNODE	The unique ID of the "to node", or ending node of the network link. This is a link to the unique ID stored in the NAT table, and is used to create a relational join between the Link and Node tables.

C.1.3 Route Attribute Table (RAT)

LRS	A unique identifier for the interstate, highway, arterial, or local rural road.
LRSKEY	Standard route name for the LRS. For example, Interstate 10" has a value of "10".
BEGMPT	Value of the first mile marker in the route.
ENDMPT	Value of the last mile marker in the route.

C.1.4 Section Attribute Table (SAT)

ROUTELINK	Links to the LRS_ field
ARCLINK	Links to the S(STFIPS)NHPN_ unique identifier.

C.2 The Highway Performance Monitoring System (HPMS)

LRSKEY	Linear Referencing System Unique ID. This ID corresponds to the LRSKEY field in the NHPN RAT.
BEGIN_LRS	The first mile marker for a given HPMS event segment. May or may not correspond to a node in the NHPN NAT.
END_LRS	The last mile marker for a given HPMS event segment. May or may not correspond to a node in the NHPN NAT
RUR_URB	Indicates whether the route is in a rural, suburban or urbanized area.
THRU_LANES	Number of lanes in both directions combined.
F_SYSTEM	Functional class of road (Interstate interstates, highways, arterials, or local rural roads)

C.3 National Bridge Inventory (NBI)

Structure Number — The structure identifier recorded by the state transportation agency. This frequently serves as a unique identifier, but not for all states. Ideally, this identifier provides a method of linking to the State DOTs internal bridge databases.

State Name — A two character code that identifies the state (i.e. AL, AK, AR). Not a FIPS code.

Mile point — The linear referencing system (LRS) milepost marker is used to establish the location of the bridge on the base highway network. Uses the same LRS as the NHPN and HPMS.

Inventory route — LRS inventory route and numbers reported by the state. Typically corresponds to the HPMS and NHPN route numbers, but not always.

Inventory Subroute — LRS inventory subroute numbers reported by the state. Typically corresponds to the HPMS and NHPN route numbers, but not always. The subroute is an important component for dynamic segmentation.

Latitude/Longitude — Coordinates of the bridge in degrees. Datum and precision vary from state to state. Not used for bridge location within REDARS™.

Number of Spans — The number of bridge spans in the main section of the bridge

Number of Approach Spans — The number of spans before the first abutment.

Year Built — Year of construction. This field is not updated for retrofitting or reconstruction.

Lanes on the Structure — Lanes being carried by the structure, for the full length of the bridge, in both directions.

Length of Maximum Span — The length of the maximum span along the center of the bridge in meters.

Structure Length — Length of the road supported by the bridge structure in meters. Corresponds to the main section of the bridge as coded in the “number of spans” column.

Deck Width, Out-to-Out — The width of the bridge deck in meters.

Skew — The skew angle between the centerline of a bridge pier and a line normal to the roadway centerline. Measured in degrees.

APPENDIX D
REDARS™ DATA TABLE FIELD LIST

D.1 BRIDGE Table

Field Name	Description
GID	Unique identifier. [w] *
NBI Ref	NBI Identifer. [w]
Name	Like "Golden Gate". Populate to select bridge for probabilistic analysis. Typically blank. [u]
Link Id	Foreign key to the Link table identifying the link on which the bridge is located. [w]
Reverse Link Id	Foreign key to the Link table identifying the reverse-flow link on which the bridge is located. The bridge's damage state will affect this link as it does the [Link Id] link. [w]
Symbology	A value like "1", "2a", "2b". Used to determine the symbology of the drawn component. The lead number (like "2") is the number of co-located components. The letter (like "a") is the sequence (i.e. the slice number) for the co-located component. [w]
K3D	Used in the Rapid Pushover Method to modify the 'standard bridge' fragilities to account for 3-dimensional deck-arching membrane action. [w]
NBI X	Original X coordinate from the NBI database. [w]
NBI Y	Original Y coordinate from the NBI database. [w]
X	Display X coordinate (NAD83 longitude, dec. degrees) for the bridge. Seeded from NBI X and possibly improved through dynamic segmentation. [w]
Y	Display Y coordinate (NAD83 latitude, dec. degrees) for the bridge. Seeded from NBI Y and possibly improved through dynamic segmentation. [w]

* [w] Import Wizard populated field
[wd] Import Wizard Default
[u] User provided
[n] Transportation network model calculated
[c] SRA modules Calculated
[g] REDARS™ main module populated

Field Name	Description
Location Unverified	Yes if the NBI and LRS data sources disagree about the bridge's location. In this case, the user should verify the bridge's position and uncheck this value. [w,u]
Year Built	Year of construction of bridge. [w]
NBI Group	Three digit integer from NBI. E.g. 601. First digit indicates material (concrete, steel, etc). Last two digits indicate structure type. [w]
Mander Group	1 to 28. Derivative of NBI Group column number used for Mander-HAZUS99 model. [w]
PGD Group	1 to 8. Derivative of NBI Group column number used for PGD model. [w]
Total Len	Total Length of all spans (in meters). [w]
Num Main Spans	Number of main spans. [w]
Min Col Ht	Minimum column height (in meters). [w]
Num Lanes	Number of lanes. [w]
Max Span Len	Total length of maximum span of bridge (in meters). Was SPNMAX in REDARS™ beta documentation. [w]
Deck Wd	Bridge width (in meters). [w]
Avg Daily Traffic	Average Daily Traffic (cars per day). Not used by REDARS™ analysis. [w]
Skew Angle	Skew angle of the bridge between the centerline of pier and a line normal to the roadway centerline (in degrees). 0 = Unskewed. [w]
Num Approach Spans	Number of approach spans. [w]
Soil Code	Numerical interpretation (1..5) of 1997 NEHRP soils (A..E). [w]
Is Seismically Designed	From Calif and "Year Built". [w]
Is Column Jacketed	default = False [wd,u]
Can Liquefy	True if all or part of the component is on liquefiable soil. Default=No. [u]
Replacement Cost Override	Bridge replacement cost in dollars. When not null or zero, this value overrides default replacement cost calc. [u]
DS2 Repair Cost Override	Bridge repair cost in dollars for DS=2. When not null or zero, this value overrides default repair cost calc. [u]
DS3 Repair Cost Override	Bridge repair cost in dollars for DS=3. When not null or zero, this value overrides default repair cost calc. [u]
DS4 Repair Cost Override	Bridge repair cost in dollars for DS=4. When not null or zero, this value overrides default repair cost calc. [u]

Field Name	Description
AF Replacement Cost Override	Approach fill replacement cost in dollars. When not null or zero, this value overrides default replacement costs calc. [u]
AF DS2 Repair Cost Override	Approach fill repair cost in dollars for DS=2. When not null or zero, this value overrides default repair costs calc. [u]
AF DS3 Repair Cost Override	Approach fill repair cost in dollars for DS=3. When not null or zero, this value overrides default repair costs calc. [u]
AF DS4 Repair Cost Override	Approach fill repair cost in dollars for DS=4. When not null or zero, this value overrides default repair costs calc. [u]
GM Fragility Curve	Ground motion fragility curve name. Joins to Fragility Curve.Name. Blank or null indicates fragilitly curve, use the rapid pushover (Mander-HAZUS99 Bridge GM DS) model, others can be used for custom fragilities in future. [u]
PGD Fragility Curve	Permanent ground displacement fragility curve. Joins to Fragility Curve.Name. Blank or null indicates use of the HAZUS (1999) Bridge PGD DS model. Uses a vector sum of horizontal and vertical. [u]
PGA	Peak Ground Acceleration from sources like ShakeMap, SRCT, and ground motion modeling. Randomized by ground motion modeling during probabilistic processing. [u,c]
SA03	Spectral acceleration value for 0.3 seconds. Interpolated from PSA03 ShakeMap, SRCT, and ground motion modeling values. Randomized by ground motion modeling during probabilistic processing. [u,c]
SA10	Spectral acceleration value for 1.0 seconds. Interpolated from PSA10 ShakeMap, SRCT, and ground motion modeling values. Randomized by ground motion modeling during probabilistic processing. [u,c]
Num Approach Fills	0, 1, or 2. [wd,u]
AF A Surface Area	Square meters. Used to calculate AF replacement cost. Default is 30' x Deck Wd. [wd,u]
AF B Surface Area	Square meters. Used to calculate AF replacement cost. Default is 30' x Deck Wd. [wd,u]
AF A Thickness	T(AF). Meters. Thickness of approach fill at one bridge end. Default is minimum vertical underclearance + 1.52m. [wd,u]
AF B Thickness	T(AF). Meters. Thickness of approach fill at opposite bridge end. Default is minimum vertical underclearance + 1.52m. [wd,u]
AF A Proctor Density	RC. The measure of soil compressability at one bridge end. 0..1 default is 0.9. [wd,u]
AF B Proctor Density	RC. The measure of soil compressability at the opposite bridge end. 0..1 default is 0.9. [wd,u]

Field Name	Description
Liq Free Face Ratio	W = ratio of height of free face to distance from free face to the ith free face site. 0 for a site that is not free face. Used by Bardet et al. (%) [u]
Liq Ground Slope	S = ground slope parameter for ith ground slope site. 0 for a site that is free face. Used by Bardet et al. (%) [u]
Liq Cumulative Thickness	T15 = cumulative thickness of all liquefiable layers at the ith site (effective blowcounts < 15 and below water table). Used by Bardet et al. Meters. [u]
Liq Layer 1 Depth Top	DPTH in ft (of top of layer 1). Used by Tokimatsu-Seed. [u]
Liq Layer 1 Depth Bottom	DPTH in ft (of bottom of layer 1). Used by Tokimatsu-Seed. [u]
Liq Layer 1 Total Overburden Pressure	TOTOB in lb/sq-ft. Used by Tokimatsu-Seed. [u]
Liq Layer 1 Effective Overburden Pressure	EOTOB in lb/sq-ft. Used by Tokimatsu-Seed. [u]
Liq Layer 1 Blowcount	N160CS. Used by Tokimatsu-Seed. [u]
Liq Layer 2 Depth Top	DPTH in ft (of top of layer 2). Used by Tokimatsu-Seed. [u]
Liq Layer 2 Depth Bottom	DPTH in ft (of bottom of layer 2). Used by Tokimatsu-Seed. [u]
Liq Layer 2 Total Overburden Pressure	TOTOB in lb/sq-ft. Used by Tokimatsu-Seed. [u]
Liq Layer 2 Effective Overburden Pressure	EOTOB in lb/sq-ft. Used by Tokimatsu-Seed. [u]
Liq Layer 2 Blowcount	N160CS. Used by Tokimatsu-Seed. [u]
Liq PGD Horizontal	Liquefaction-based permanent ground displacement in the horizontal direction. Calculated by liquefaction model (typically Bardet et al). Randomized by model during probabilistic processing. Inches. >=0. [u,c]
Liq PGD Vertical	Liquefaction-based permanent ground displacement in the vertical direction. Calculated by liquefaction model (typically Tokimatsu-Seed). Randomized by model during probabilistic processing. Inches. >=0. [u,c]
SFR PGD	Surface fault rupture-based permanent ground displacement in any direction. Calculated by SFR PGD model (typically Youngs et al). Randomized by model during probabilistic processing. Inches. >=0. [u,c]
AF A PGD Vertical	Vertical settlement at first bridge end. Comes from AF calcs (typically Youd et al.). Inches. >=0. [u,c]
AF B PGD Vertical	Vertical settlement at opposite bridge end. Comes from AF calcs (typically Youd et al.). Inches. >=0. [u,c]

Field Name	Description
GM DS	Bridge's ground motion damage state. 1 = "none", 2 = "minor", 3 = "moderate", 4 = "major", 5 = "collapsed". [u,c]
PGD DS	Permanent ground displacement damage state 1..5. Based on the greater of (a) the vector sum of horizontal and vertical liquefaction PGDs (sqr(PGDh^2+PGDv^2)) or (b) SFR PGD. [u,c]
AF A PGD DS	Permanent ground displacement damage state 1..5. At one bridge end. (From vertical displacement only says Stu on 10/3/03). [u,c]
AF B PGD DS	Permanent ground displacement damage state 1..5. At opposite bridge end. (From vertical displacement only says Stu on 10/3/03). [u,c]
Day A Capacity	Bridge traffic carrying capacity A days after the event as a fraction of pre-EQ capacity. The range is 0 to 1. 0 is closed, 1 is open. Least of bridge and AF. Not editable per Stu. [c]
Day B Capacity	Bridge traffic carrying capacity B days after the event as a fraction of pre-EQ capacity. The range is 0 to 1. 0 is closed, 1 is open. Least of bridge and AF. Not editable per Stu. [c]
Day C Capacity	Bridge traffic carrying capacity C days after the event as a fraction of pre-EQ capacity. The range is 0 to 1. 0 is closed, 1 is open. Least of bridge and AF. Not editable per Stu. [c]
Day D Capacity	Bridge traffic carrying capacity D days after the event as a fraction of pre-EQ capacity. The range is 0 to 1. 0 is closed, 1 is open. Least of bridge and AF. Not editable per Stu. [c]

D.2 LINK Table

Field Name	Description
ANode Id	Foreign key into the Node table for the start of the link. [w]
Base Travel Time	Baseline travel time, Minutes. [wn]
Base Volume	Baseline Traffic volume, Passenger Car Unit [wn]
BNode Id	Foreign key into the Node table for the end of the link. [w]
Can Liquefy	True if all or part of the component is on liquefiable soil. Default=No. [u]
Capacity Per Lane	In Passenger Car Unit, Must be > 0. [w]
Day A Capacity	0..1. The minimum capacity of pavement, bridges, and tunnels on the link at day A. 0 is closed, 1 is open. Not editable per Stu. [c]
Day A Detour Lanes	Default 0. May be negative or positive. [wd,u]
Day A Travel Time	Minutes. [n]
Day A Volume	Link traffic volume in PCU per unit-hours (for all lanes on link) at day A. Unit-hours = 3 hours for LA. >=0 [n]
Day B Capacity	0..1. The minimum capacity of pavement, bridges, and tunnels on the link at day B. 0 is closed, 1 is open. Not editable per Stu. [c]
Day B Detour Lanes	Default 0. May be negative or positive. [wd,u]
Day B Travel Time	Minutes. [n]
Day B Volume	Link traffic volume in PCU per unit-hours (for all lanes on link) at day B. Unit-hours = 3 hours for LA. >=0 [n]
Day C Capacity	0..1. The minimum capacity of pavement, bridges, and tunnels on the link at day C. 0 is closed, 1 is open. Not editable per Stu. [c]
Day C Detour Lanes	Default 0. May be negative or positive. [wd,u]
Day C Travel Time	Minutes. [n]
Day C Volume	Link traffic volume in PCU per unit-hours (for all lanes on link) at day C. Unit-hours = 3 hours for LA. >=0 [n]
Day D Capacity	0..1. The minimum capacity of pavement, bridges, and tunnels on the link at day D. 0 is closed, 1 is open. Not editable per Stu. [c]

Field Name	Description
Day D Detour Lanes	Default 0. May be negative or positive. [wd,u]
Day D Travel Time	Minutes. [n]
Day D Volume	Link traffic volume in PCU per unit-hours (for all lanes on link) at day D. Unit-hours = 3 hours for LA. >=0 [n]
DS2 Repair Cost Override	Pavement repair cost in dollars for DS=2. When not null or zero, this value overrides default repair cost calc. [u]
DS3 Repair Cost Override	Pavement repair cost in dollars for DS=3. When not null or zero, this value overrides default repair cost calc. [u]
DS4 Repair Cost Override	Pavement repair cost in dollars for DS=4. When not null or zero, this value overrides default repair cost calc. [u]
Enc_Geometry	Binary graphic object. Populated Automatically by REDARS main module, or recreated by Admin > Rebuild BLOBS menu [g]
Free Flow Speed	Miles per hour - needs to be consistant with Link Len units. [w]
GID	Primary, unique identifier. [w]
Is Bridge Present	True if there are one or more bridges on the link. [w]
Link Len	Geodesy to populate if not >0, units = Miles. [w,g]
Link Type	Derived from NHPN. Values 0..10. 0=Outside-region link, 1=OD connector, 2=interstate, 3=freeway, 4= principal arterial, 5=minor arterial, 6=collector, 7=rural major arterial, 8=rural minor collector, 9=rural local, 10=ramp or junction. [w]
Liq Cumulative Thickness	T15 ; cumulative thickness of all liquefiable layers at the ith site (effective blowcounts < 15 and below water table). Used by Bardet et al. Meters. [u]
Liq Free Face Ratio	W ; ratio of height of free face to distance from free face to the ith free face site. 0 for a site that is not free face. Used by Bardet et al. (%) [u]
Liq Ground Slope	S ; ground slope parameter for ith ground slope site. 0 for a site that is free face. Used by Bardet et al. (%) [u]
Liq Layer 1 Blowcount	N160CS. Used by Tokimatsu-Seed. [u]
Liq Layer 1 Depth Bottom	DPTH in ft (of bottom of layer 1). Used by Tokimatsu-Seed. [u]
Liq Layer 1 Depth Top	DPTH in ft (of top of layer 1). Used by Tokimatsu-Seed. [u]

Field Name	Description
Liq Layer 1 Effective Overburden Pressure	EOTOB in lb/sq-ft. Used by Tokimatsu-Seed. [u]
Liq Layer 1 Total Overburden Pressure	TOTOB in lb/sq-ft. Used by Tokimatsu-Seed. [u]
Liq Layer 2 Blowcount	N160CS. Used by Tokimatsu-Seed. [u]
Liq Layer 2 Depth Bottom	DPTH in ft (of bottom of layer 2). Used by Tokimatsu-Seed. [u]
Liq Layer 2 Depth Top	DPTH in ft (of top of layer 2). Used by Tokimatsu-Seed. [u]
Liq Layer 2 Effective Overburden Pressure	EOTOB in lb/sq-ft. Used by Tokimatsu-Seed. [u]
Liq Layer 2 Total Overburden Pressure	TOTOB in lb/sq-ft. Used by Tokimatsu-Seed. [u]
Liq PGD Horizontal	Liquefaction-based permanent ground displacement in the horizontal direction. Calculated by liquefaction model (typically Bardet et al). Randomized by model during probabilistic processing. Inches. >=0. [u,c]
Liq PGD Vertical	Liquefaction-based permanent ground displacement in the vertical direction. Calculated by liquefaction model (typically Tokimatsu-Seed). Randomized by model during probabilistic processing. Inches. >=0. [u,c]
Name	Like "I5". Initially populated from NHPN. Typically blank. [w,u]
NHPN Ref	National Highway Planning Network identifier. [w]
Num Lanes	Lanes on the directional link Must be > 0. [w]
PGA	Peak Ground Acceleration from sources like ShakeMap, SRCT, and ground motion modeling. For pavement, refers to the point on the link that is closest to the current earthquake's fault. >= 0 [u,c]
PGD DS	Permanent ground displacement damage state 1..5. Based on the greater of (a) the vector sum of horizontal and vertical liquefaction PGDs (sqr(PGDh^2+PGDv^2)) or (b) SFR PGD. [u,c]
Pvmt Day A Capacity	0..1. Reduction in link's traffic carrying capacity due to pavement failure A days after the event as a fraction of pre-EQ capacity. 0 is closed, 1 is open (i.e. at pre-earthquake capacity). Not editable per Stu. [c]

Field Name	Description
Pvmt Day B Capacity	0..1. Reduction in link's traffic carrying capacity due to pavement failure B days after the event as a fraction of pre-EQ capacity. 0 is closed, 1 is open (i.e. at pre-earthquake capacity). Not editable per Stu. [c]
Pvmt Day C Capacity	0..1. Reduction in link's traffic carrying capacity due to pavement failure C days after the event as a fraction of pre-EQ capacity. 0 is closed, 1 is open (i.e. at pre-earthquake capacity). Not editable per Stu. [c]
Pvmt Day D Capacity	0..1. Reduction in link's traffic carrying capacity due to pavement failure D days after the event as a fraction of pre-EQ capacity. 0 is closed, 1 is open (i.e. at pre-earthquake capacity). Not editable per Stu. [c]
Replacement Cost Override	Pavement replacement cost in dollars. When not null or zero, this value overrides default replacement cost calc. [u]
Residual Capacity	0..1. Default 0.15 (15%). Set to link's percentage of pre-eq traffic capacity handled by neighboring, non-modeled roadways. Used by NA only when the link has been completely closed and has no detour lanes assigned for the given post-eq time. [wd,u]
SA03	Spectral acceleration value for 0.3 seconds. Interpolated from PSA03 ShakeMap, SRCT, and ground motion modeling values. For pavement, refers to the point on the link that is closest to the current earthquake's fault. >= 0 [u,c]
SA10	Spectral acceleration value for 1.0 seconds. Interpolated from PSA10 ShakeMap, SRCT, and ground motion modeling values. For pavement, refers to the point on the link that is closest to the current earthquake's fault. >= 0 [u,c]
SFR PGD	Surface fault rupture-based permanent ground displacement in any direction. Calculated by SFR PGD model (typically Youngs et al). Randomized by model during probabilistic processing. Inches. >=0. [u,c]
Soil Code	Numerical interpretation (1..5) of 1997 NEHRP soils (A..E). [w,u]

D.3 NODE Table

Field Name	Description
GID	Unique key - used for "from" and "to" nodes in link key - TAZ nodes must have lower Ids than roadway nodes. [w]
Is Zone Centroid	True indicates node is a TAZ centroid. False indicates the node is part of the road network. [w]
IsValid	True if the node is isolated from the road network. This column value is ignored when Is Zone Centroid is false. [w,n]
Name	Like "LAX" or "Long Beach Convention Center". This column value is ignored when Is Zone Centroid is false. [u]
NHPN Ref	National Highway Planning Network identifier. [w]
X	Longitude, NAD83, decimal degrees. [w]
Y	Latitude, NAD83, decimal degrees. [w]

D.4 SHAPEPOINTS Table

Field Name	Description
Feature Id	Id for the feature. Foreign key into the table named in Table Name. [w (for links)]
Seq	1, 2 , 3, etc. Each link will have at least two rows. [w (for links)]
Table Name	Table containing the feature (like "Link"). [w (for links)]
X	Longitude, NAD83, decimal degrees. [w (for links)]
Y	Latitude, NAD83, decimal degrees. [w (for links)]

D.5 TAZ Table

Field Name	Description
Base Access	Average travel time into this Zone from all other Zones before any event (in minutes). [w]
Base Attraction	Total trips to this Zone from all other Zones before any event (PCU). [w]
Base Egress	Average travel time from this Zone to all other Zones before any event (in minutes). [w]
Base Production	Total trips from this Zone to all other Zones before any event (PCU). [w]
Day A Access	Average travel time per trip per day into this Zone from all other Zones at day A (in minutes). [n]
Day A Attraction	Total trips per day to this Zone from all other Zones at day A (PCU). [n]
Day A Egress	Average travel time per trip per day from this Zone to all other Zones at day A (in minutes). [n]
Day A Production	Total trips per day from this Zone to all other Zones at day A (PCU). [n]
Day B Access	Average travel time per trip per day into this Zone from all other Zones at day B (in minutes). [n]
Day B Attraction	Total trips per day to this Zone from all other Zones at day B (PCU). [n]
Day B Egress	Average travel time per trip per day from this Zone to all other Zones at day B (in minutes). [n]
Day B Production	Total trips per day from this Zone to all other Zones at day B (PCU). [n]
Day C Access	Average travel time per trip per day into this Zone from all other Zones at day C (in minutes). [n]
Day C Attraction	Total trips per day to this Zone from all other Zones at day C (PCU). [n]
Day C Egress	Average travel time per trip per day from this Zone to all other Zones at day C (in minutes). [n]
Day C Production	Total trips per day from this Zone to all other Zones at day C (PCU). [n]
Day D Access	Average travel time per trip per day into this Zone from all other Zones at day D (in minutes). [n]
Day D Attraction	Total trips per day to this Zone from all other Zones at day D (PCU). [n]
Day D Egress	Average travel time per trip per day from this Zone to all other Zones at day D (in minutes). [n]
Day D Production	Total trips per day from this Zone to all other Zones at day D (PCU). [n]

Field Name	Description
Node Id	Foreign key into the Node table. [w]
Param A	Parameter used to determine how much travel is desired to or from this Zone. [w]
Param B	Parameter used to determine how much travel is desired to or from this Zone. [w]

APPENDIX E
DEFAULT VALUES FOR BRIDGE DATA

Field Name	Description
GID	Sequential starting from 1 to number of bridges
NBI Ref	NBI Item 8, Structure Number
Name	Blank
Link Id	The first [Link Id] of a directional link in Link table on which the bridge is located
Reverse Link Id	The last [Link Id] of a directional link in Link table on which the bridge is located
Symbology	One digit starting from 1 to N, where N is the number of co-locating bridges, followed by a character if the digit is greater than 1. The character starting from 'a' to N-th alphabet is the arbitrary determined sequuence of co-locating bridges.
NBI X	NBI Item 17, Longitude
NBI Y	NBI Item 16, Latitude
X	If NBI X is not null, it is used as initial value. Improved through dynamic segmentation
Y	If NBI Y is not null, it is used as initial value. Improved through dynamic segmentation
Location Unverified	True if the distance between (NBI X, NBI Y) and (X, Y) is more than 2miles. Otherwise True
Year Built	NBI Item 27, Year Built
NBI Group	NBI Item 43, Main Structure Type
Mander Group	If [Total Len] > 150 meters Then [Mander Group] = 6 Else If [Num Approach Spans] + [Num Main Spans] = 1 Then [Mander Group]] = 5 Else If (101≤ [NBI Group] ≤106) Or (301 ≤ [NBI Group] ≤ 310) Or (501 ≤ [NBI Group] ≤ 506) Then [Mander Group] = 1 Else If (205 ≤ [NBI Group] ≤ 206) Or (603 ≤ [NBI Group] ≤ 606) Then

Field Name	Description

	[Mander Group] = 2
	Else If (201 ≤ [NBI Group] ≤ 207) Or (601 ≤ [NBI Group] ≤ 607) Then
	[Mander Group] = 3
	Else If (402 ≤ [NBI Group] ≤ 410) Then
	[Mander Group] = 4
	Else
	[Mander Group] = 7
	End If
	
	If State = California Then
	If [Seismically Designed] Then
	[Mander Group] = [Mander Group] + 21
	Else
	[Mander Group] = [Mander Group] + 7
	End If
	Else
	If [Seismically Designed] Then
	[Mander Group] = [Mander Group] + 14
	End If
	End If

K3D	If ([Num Approach Spans] + [Num Main Spans]) = 1 Then
	[K3D] = 1.25
	Else If [Total Len] > 150 meters Then
	[K3D] = 1 + 0.25 / ([Span] - 1)
	Else If (101 ≤ [NBI Group] ≤ 108) Or (501 ≤ [NBI Group] ≤ 508) Then
	[K3D] = 1 + 0.25 / ([Span] - 1)
	Else If (201 ≤ [NBI Group] ≤ 208) Or (601 ≤ [NBI Group] ≤ 607)
	Or [NBI Group] = 111 Then
	If [Conventionally Designed] Then
	[K3D] = 1 + 0.33 / [Span]
	Else
	[K3D]= 1 + 0.33 / ([Span] – 1)
	End If
	Else If 301 ≤ [NBI Group] ≤ 310 Then
	If [Conventionally Designed] Then
	If [Total Len] < 20 Then ‘ 20 meters
	[K3D] = 1 + 0.2 / ([Span] - 1)
	Else
	[K3D] = 1 + 0.09 / ([Span] - 1)
	End If
	Else
	[K3D] = 1 + 0.25 / ([Span] - 1)
	End If
	Else If 402 ≤ [NBI Group] ≤ 410 Then
	If [Conventionally Designed] Then
	If [Total Len] < 20 Then ‘ 20 meters
	[K3D] = 1 + 0.1 / [Span]
	Else
	[K3D] = 1 + 0.05 / [Span]

Field Name	Description

	End If
	Else
	[K3D] = 1 + 0.33 / ([Span] - 1)
	End If
	Else
	[K3D] = 1
	End If

PGD Group	If ([Num Approach Spans] + [Num Main Spans]) = 1 Then
	[PGD Group] = 6
	Else If [Total Len] > 150 Then ‘ 150 meters
	[PGD Group] = 7
	Else If ([NBI Group] = 205, 206, 605, 606) Then
	[PGD Group] = 2
	Else If (101 ≤ [NBI Group] ≤ 106) Or (301 ≤ [NBI Group] ≤ 310)
	Or (501 ≤ [NBI Group] ≤ 506) Then
	[PGD Group] = 1
	Else If (201 ≤ [NBI Group] ≤ 206) Then
	[PGD Group] = 3
	Else If (601 ≤ [NBI Group] ≤ 607) Then
	[PGD Group] = 4
	Else If (402 ≤ [NBI Group] ≤ 410) Then
	[PGD Group] = 5
	Else
	[PGD Group] = 8
	End If

Total Len	NBI Item 49, Structure Length
Num Main Spans	NBI Item 45, Number of Spans in Main Unit
Min Col Ht	NBI Item 69, Minimum Vertical Under-clearance
Num Lanes	NBI Item 28, Lanes on and Under the Structure
Max Span Len	NBI Item 48, Length of Maximum Span
Deck Wd	NBI Item 52, Deck Width Out-to-Out
Avg Daily Traffic	NBI Item 29, Average Daily Traffic
Skew Angle	NBI Item 34, Skew
Num Approach Spans	NBI Item 46, Number of Approach Spans
Soil Code	Updated from NEHRP Soil map
Is Seismically Designed	If ([State] = California And [Year Built] >= 1975) Or ([Year Built] >= 1990) Then

Field Name	Description

	Is [Seismically Designed] = True
	Else
	Is [Seismically Designed] = False
	End if

Is Column Jacketed	False
Can Liquefy	False
Replacement Cost Override	0
DS2 Repair Cost Override	0
DS3 Repair Cost Override	0
DS4 Repair Cost Override	0
DS5 Repair Cost Override	0
AF Replacement Cost Override	0
AF DS2 Repair Cost Override	0
AF DS3 Repair Cost Override	0
AF DS4 Repair Cost Override	0
GM Fragility Curve	0
PGD Fragility Curve	0
PGA	0
SA03	0
SA10	0
Num Approach Fills	N = the first digit of [Symbology] If N =1 Then

Field Name	Description

	[Num Approach Fills] = 2
	Else
	    If the second character of [Symbology] = ‘a’ or N-th alphabet Then
	        [Num Approach Fills] = 1
	    Else
	        Num Approach Fills = 0
	End If

AF A Surface Area	If [Deck Width] > 0 Then
	    [Surface Area] = [Deck Width]
	Else
	    [Surface Area] = [Num Lanes] * 8
	End If

AF B Surface Area	[AF B Surface Area] = [AF A Surface Area]

AF A Thickness	If [Num Main Spans] = 1 And [Num Approach Spans] = 0 And
	    [Min Col Ht] = 0 Then
	    [AF A Thickness] = 3.66
	Else
	    [AF A Thickness] = 0
	End If

AF B Thickness	[AF B Thickness] = [AF A Thickness]
AF A Proctor Density	0
AF B Proctor Density	0
Liq Free Face Ratio	0
Liq Ground Slope	0
Liq Cumulative Thickness	0
Liq Layer 1 Depth Top	0
Liq Layer 1 Depth Bottom	0
Liq Layer 1 Total Overburden Pressure	0
Liq Layer 1 Effective Overburden Pressure	0
Liq Layer 1 Blowcount	0
Liq Layer 2 Depth Top	0

Field Name	Description
Liq Layer 2 Depth Bottom	0
Liq Layer 2 Total Overburden Pressure	0
Liq Layer 2 Effective Overburden Pressure	0
Liq Layer 2 Blowcount	0
Liq PGD Horizontal	0
Liq PGD Vertical	0
SFR PGD	0
AF A PGD Vertical	0
AF B PGD Vertical	0
GM DS	0
PGD DS	0
AF A PGD DS	0
AF B PGD DS	0
Day A Capacity	1
Day B Capacity	1
Day C Capacity	1
Day D Capacity	1

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