FGDC-STD-999.1-2000

National Spatial Data Infrastructure

NSDI FRAMEWORK TRANSPORTATION IDENTIFICATION STANDARD -- *Public Review Draft*

Ground Transportation Subcommittee
Federal Geographic Data Committee

December, 2000

Federal Geographic Data Committee

Department of Agriculture • Department of Commerce • Department of Defense
Department of Energy • Department of Housing and Urban Development
Department of the Interior • Department of Justice • Department of State
Department of Transportation • Environmental Protection Agency
Federal Emergency Management Agency • Library of Congress
National Aeronautics and Space Administration • National Archives and Records Administration
National Science Foundation • Tennessee Valley Authority

Federal Geographic Data Committee

Established by Office of Management and Budget Circular A-16, the Federal Geographic Data Committee (FGDC) promotes the coordinated development, use, sharing, and dissemination of geographic data.

The FGDC is composed of representatives from the Departments of Agriculture, Commerce, Defense, Energy, Housing and Urban Development, Interior, Justice, State, and Transportation; the Environmental Protection Agency; the Federal Emergency Management Agency; the Library of Congress; the National Aeronautics and Space Administration; the National Archives and Records Administration; the National Science Foundation; and the Tennessee Valley Authority. Additional Federal agencies and non-Federal agencies participate on FGDC subcommittees and working groups. The Department of the Interior chairs the committee.

FGDC subcommittees work on issues related to data categories coordinated under the circular. Subcommittees establish and implement standards for data content, quality, and transfer; encourage the exchange of information and the transfer of data; and organize the collection of geographic data to reduce duplication of effort. Working groups are established for issues that transcend data categories.

For more information about the committee, or to be added to the committee's newsletter mailing list, please contact:

Federal Geographic Data Committee Secretariat
c/o U.S. Geological Survey
590 National Center
Reston, Virginia 22092

Telephone: (703) 648-5514
Facsimile: (703) 648-5755
Internet (electronic mail): fgdc@www.fgdc.gov
World Wide Web: http://www.fgdc.gov

The following is the recommended bibliographic citation for this publication:
Federal Geographic Data Committee (Ground Transportation Subcommittee): NSDI Framework Transportation Identification Standard (Working Draft). Washington, D.C., 2000.

CONTENTS

Page

1 Introduction

1.1 Preface

1.1.1 Background

Many users of geospatial data within both the transportation and GIS communities have questions about the relationships among transportation features such as roads, their representation as geo-spatial objects in geographic information systems (GIS), and their representation in analytical networks. Much of this confusion results from the inconsistent use of terminology to describe transportation features and their representations. It is also perpetuated by current versions of GIS software, which fail to adequately address the differences between lines used for cartographic displays and those used for network analysis.

1.1.2 Need for Standards

One consequence of this confusion has been an inability to promulgate national standards for transportation spatial features to facilitate data sharing under the **National Spatial Data Infrastructure (NSDI)** initiative. A fundamental requirement of spatial data sharing is that both the supplier and the recipient of the data understand what the data represents in terms of real-world features. This is relatively straightforward for features having well defined boundaries such a building or airport. However, many transportation features are characterized by extensive linear networks, with no universally agreed upon standard for partitioning these networks into unique "segments." Each developer of a transportation network spatial database partitions the network to meet his or her specific application needs.

1.1.3 FGDC Action

The **Federal Geographic Data Committee (FGDC)** was established by the Office of Management and Budget (OMB) under Circular A-16 to promote the coordinated development, use, sharing, and dissemination of geographic data. The committee, which is composed of representatives from 17 departments and independent agencies, oversees and provides policy guidance for agency efforts to coordinate geographic data activities. The FGDC created the **Ground Transportation Subcommittee** in January 1992 to address data issues involving transportation features and networks. The objectives of the Subcommittee are to:

-- promote standards of accuracy and currency in ground transportation data which is financed in whole or in part by Federal funds;

-- exchange information on technological improvements for collecting ground transportation data;

-- encourage the Federal and non-Federal community to identify and adopt standards and specifications for ground transportation data; and

-- promote the sharing of ground transportation data among Federal and non-Federal organizations.

1.1.4 NSDI Framework Data

Transportation is one of the seven Framework layers identified in the National Spatial Data Infrastructure. NSDI framework data represents the "best" available geo-spatial data for an area. The data is collected or compiled to a known level of spatial accuracy and currency, documented in accordance with established metadata standards, and made available for dissemination at little or no cost and free of restrictions on use. Framework data is not necessarily uniform from one area to another; the quality of the data for a given area depends on the requirements of the participating data developers. The NSDI does not specify threshold standards for spatial accuracy, attribution, completeness of coverage, or currency for any of its framework themes. The resulting framework will be a "patchwork quilt" consisting of high quality geo-spatial data for some geographic areas, with lower quality or even missing data for other areas. As more data developers upgrade their geo-spatial data and participate in the NSDI, the overall quality of the data comprising the NSDI Framework and the completeness of nationwide coverage will improve. For further information see the FGDC publication "NSDI Framework Introduction and Guide," http://www.fgdc.gov/framework/frameworkintroguide/ .

1.1.5 The Transportation Framework Data Layer

The importance of geo-spatial data depicting transportation features – especially road networks – extends well beyond their cartographic value. Road networks provide the basis for several indirect location referencing systems, including street addresses and various linear referencing methods commonly used to locate features like bridges, signs, pavement conditions, and traffic incidents. Geo-spatial transportation segments can be connected to form topological networks, which can be used to more accurately measure over-the-road travel distances between geographic locations. Furthermore, when combined with the variety of network analysis tools that are available, topological networks can be used to find the shortest paths between two or more locations, to determine the most efficient route to cover all transportation segments (e.g., for planning of snow removal), or to estimate traffic volumes by assigning origin-to-destination flows to network segments.

Integration of the “best available” transportation databases into a national framework layer must provide for nationwide connectivity in order to support the network applications described above. This means that there can be no “gaps” (geographic areas where transportation data is totally absent). Further, the transportation data for each particular geographic area must be produced so that it can be connected topologically to transportation data for adjacent areas.

1.1.6 Federal, State and Local Transportation Data Resources

A nationwide NSDI framework road layer *could* be constructed from the national level databases developed by federal agencies: **Bureau of the Census** TIGER/Line files, **U.S. Geological Survey** Digital Line Graph (USGS/DLG) files, and the National Highway Planning Network (NHPN) developed by the **Federal Highway Administration** (FHWA). These databases serve most federal needs and many general public requirements for national level road data at the 1:100,000 scale, and provide network connectivity in those areas where more accurate transportation data does not exist. However, such a database would not offer the currency, completeness, and accuracy required by many other users.

Over half of the state Departments of Transportation (DOTs) have developed road databases at a scale of 1:24,000 or better. These databases are almost certainly of superior accuracy, completeness and currency than the national databases, and *could* take the place of federal road data as the framework database for their respective areas, providing they meet other

NSDI framework requirements (e.g., metadata documentation, no restrictions on use). Road data which is even more accurate and current exists for many smaller geographic units; e.g. counties or metropolitan areas. These databases *could* be utilized instead of either the federal or state transportation data as the framework database for their specific areas.

1.1.7 The Challenge

Creation of the NSDI framework transportation layer will require the participation of a large number of federal, state, and local transportation agencies, and their contribution of transportation databases developed for specific geographic areas and applications. The databases will be – or have been – developed at different scales, with different levels of positional accuracy, detail and completeness of coverage, and currency. These databases will have to be "stitched together" in order to provide the network connectivity required for many transportation applications. When new databases are added to the framework, or when specific attributes are updated or enhanced, users of framework data will need to be able to incorporate this new information into their applications in ways that are cost-effective.

The process of transferring information (including more accurate coordinates) from one geo-spatial database to another is known as "conflation." Successful conflation requires that the features in one geo-spatial database be matched to their counterparts in the other database. Once this match is achieved, geometric and/or attribute data can be exchanged from either of the two databases to the other. For example, coordinate data depicting the alignment of a transportation segment can be transferred from a transportation database digitized from 1:12,000 scale digital orthophotoquads (DOQs) to a database that had originally been digitized from 1:24,000 scale USGS topographic maps.

Typically the process of conflation uses a combination of coordinate matching and name matching. Depending on the similarity of the two databases, the percentage of successfully matched features can vary from over 90 percent to well under 50 percent. This range of variability is unacceptable for successful implementation of the NSDI framework, which will require ongoing additions of new framework databases and transactional updates to attributes in existing framework databases.

A more promising conflation method starts with the assignment of a stable and unique identifier to each geo-spatial feature. This identifier can then be used to match features across databases without having to rely on coordinate accuracy or the use of standard names. Unique feature identifiers work best when instances of features are well defined and spatially distinct.

The identification of a discreet feature instance is not always obvious for linear features such as roads and surface waters. Roads are segmented in an almost infinite number of ways, depending on the application needs of the database developer. Roads may be segmented at intersections for path building, or at changes in one or more attributes for use in facility management. Also, a transportation segment may terminate at a state, county, or municipal border, or other jurisdictional boundary.

Within the same geographical area multiple entities may create, update, and/or use different transportation databases. For example, a state DOT may create a transportation database that includes only state highways, and may segment its roads wherever one highway intersects another. A local transportation planning agency might create a database for the same area that includes all local roads; this agency could segment the state highways wherever they intersect any road. Finally, an E-911 agency could create yet a third transportation database for the area, segmenting all roads at each private driveway.

Most geographic information system (GIS) software packages currently do not enable the user to distinguish between an instance of a linear geo-spatial feature and how that feature is represented in a topological network. Each of the transportation databases mentioned above represents the same physical transportation network but divides it into different – often overlapping – segments in order to establish topological connections needed for the respective applications. Each segment becomes a distinct record in the geo-spatial database unique to that application. Finding a set of common transportation segments that carry topology and are useful in all existing and potential applications is impossible in most geographic areas.

The concept of a permanent transportation segment identifier is attractive, but the need to add new transportation segments to accommodate other applications or to reflect changes in infrastructure can create problems. Consider the case of a road segment (`Segment_A`) with an assigned permanent identifier, as illustrated in Figure 1. A new road (`Segment_B`) is built which intersects the old road segment part way along its length. In order to maintain network topology, the old road segment must be split and a node established where the new road intersects. The identifier for the old road segment is no longer valid. It must be retired and three new identifiers created: one for the new intersecting road (`Segment_B`) and one for each new segment (`Segments_AA` and `AB`) of the (now split) old road segment. Recording, disseminating, and applying these transactions could become prohibitively complex or time-consuming, both for the database developer and for users trying to incorporate the updated information into their own application database.

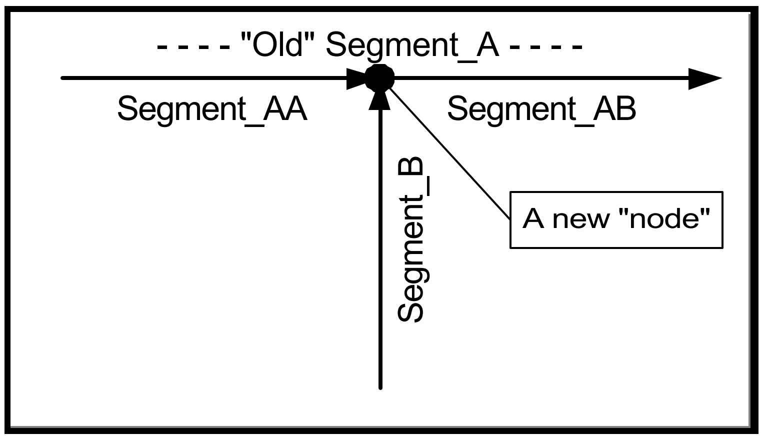

Figure 1 - Intersecting Road Segments

In summary, the growing needs of users make the argument for constructing an NSDI framework transportation data layer(s) a compelling one. Also, all users will benefit if the investments in high quality transportation information being made by many units of state and local government can be incorporated. The related technical requirements present a challenge in the development of standards, technology and procedures which will be needed in order to accomplish this task.

1.2 Conventions used in this Standard

The following conventions for forms of values for data elements are used in this Standard:

1.2.1 Calendar Dates

Values for day and month of year, and for years, shall follow the calendar date convention (general forms of YYYY for years; YYYYMM for month of a year (with month being expressed as an integer), and YYYYMMDD for a day of the year) specified in American National Standards Institute, 1986, Representation for calendar date and ordinal date for information interchange (ANSI X3.30-1985): New York, American National Standards Institute (adopted as Federal Information Processing Standard 4-1).

1.2.2 Latitude and Longitude

Values for latitude and longitude shall be expressed as decimal fractions of degrees. Whole degrees of latitude shall be represented by a two-digit decimal number ranging from 0 through 90. Positive numbers indicate North latitude; negative numbers indicate South latitude. Whole degrees of longitude shall be represented by a three-digit decimal number ranging from 0 through 180. Positive numbers indicate West longitude; negative numbers indicate East longitude. When a decimal fraction of a degree is specified, it shall be separated from the whole number of degrees by a decimal point. This form is specified in American National Standards Institute, 1986, Representations of Geographic Point Locations for Information Interchange (ANSI X3.61-1986): New York, American National Standards Institute.

1.2.3 Numeric Values

Values for distance and other measures are specified as a specific number of characters; this specification includes characters for plus (+) and minus (-) signs and decimal points (.) whenever appropriate. Many users will operate applications which store, compute, or analyze these attributes in a variety of “numeric” field formats, but they should be able to import and export these standardized data in the character field formats specified.

1.3 Justification

1.3.1 Objective

The objective of this content standard is to specify methods for identifying linear geo-spatial features that can be implemented within existing data structures without some of the topological problems cited above. Furthermore, the proposed standard should allow users to create customized topological networks from the reference segments without modifying the properties of the reference segments themselves. Successful achievement of this objective will facilitate transactional updates to framework transportation databases by allowing new transportation features to be added without changing existing transportation segments. The standard should define a transportation segment in such a way that it is independent of cartographic representation – irrespective of scale, attributes which can change over time, and network topology. Each defined transportation segment can then be assigned a unique identifier that does not need to be modified for different applications or for additions of new transportation features.

Establishment of stable transportation segment identifiers will facilitate the exchange of information between databases; e.g., improved geo-spatial coordinates, feature attributes like road names, or controls to various linear referencing methods like beginning and ending mile points, or low and high address values.

The **NSDI Framework Transportation Identification Standard** defines the collection of objects which serve as the basis for transferring information among different networks, higher level linear referencing systems, and cartographic representations of roads. The standard relates multiple cartographic and topological network data base representations to uniquely identified transportation segments in the real world, and provides the domain for transferring application attributes across linear referencing and cartographic systems. The model consists of a set of one-dimensional **Framework Transportation Segments (FTSeg)** that have zero-dimensional **Framework Transportation Reference Points (FTRP)** at their termini. FTRP and FTSeg are highly stable, unambiguously identified, and recoverable in the field.

The standard is not intended to be a geodetic or linear datum. It contains no specification for either coordinate or linear measurement accuracy. However, the standard does provide a structure for accommodating a linear datum by including coordinates and length measures as attributes, and by requiring accuracy statements whenever such measures are specified. This enables users to assess the suitability of the geometry or attributes from one or more transportation databases for their particular application(s).

1.3.2 Scope

The NSDI Framework Transportation Identification Standard is being proposed as an “FGDC data content standard.” It includes both standards for assigning and reporting identification codes as well as guidelines for data capture under the classification of a process standard.

Part II of this document provides a standard for identifying physical transportation segments that are temporally stable and independent of any cartographic representation, scale, level of detail, or network application. Any transportation databases considered to be compatible with the NSDI transportation framework layer must conform to this standard.

The data content standard includes a mandatory set of attributes for each Framework Transportation Segment (FTSeg), and a format for a unique identification code to be assigned to each identified segment. Each FTSeg begins and ends at a Framework Transportation Reference Point (FTRP); mandatory attributes and an identification code for each FTRP are also specified. Part II also specifies a process for assigning, modifying and recording FTRP and FTSeg identification codes, and proposes a national registry for their identification.

The standard articulated here can be extended in the future to cover other transportation features that could be represented as networks including railroads, commercial waterways, pipelines, and public transit guide ways. Other network layers will require different process standards for assigning and recording identification codes. These additional process standards are not included as part of this document.

Part III of this document is made up of technical appendices, including references, a glossary of relevant terms, examples, and further information. It includes guidelines for selecting and locating the reference points of appropriate transportation segments, as well as other implementation procedures. The user of this document need not follow the guidelines to be in conformance with the standard.

1.3.3 Applicability

This proposed standard will have widespread applicability for public-sector and commercial database developers and data users, because there are no national standards for identifying, segmenting, or representing transportation segments in digital geo-spatial databases. Each database developer segments transportation networks to satisfy his/her specific application needs; however, the segmentation may not be appropriate for other applications. Furthermore, there is no standard approach for documenting the relationship between a digitized transportation segment and the physical transportation feature that it represents. Consequently, the exchange of attribute information between two different transportation databases representing the same geographic area is difficult, time consuming and error prone.

The proposed national standard for identifying and documenting transportation segments will facilitate data exchange among different users by providing well defined, common reference segments that are tied to the physical transportation feature, rather than to any cartographic or network abstraction of that feature. It will allow users to create customized topological networks from the reference segments without modifying the properties of the reference segments themselves, and to make transactional updates to framework transportation databases.

1.3.4 Consistency with Other Relevant Standards & Policies

1.3.4.1 FGDC Standards

1.3.4.1.1 Spatial Data Transfer Standard (SDTS)

The purpose of the SDTS is to promote and facilitate the transfer of digital spatial data between dissimilar GIS software packages, while preserving information meaning and minimizing the need for information external to the transfer. Implementation of SDTS is of significant interest to users and producers of digital spatial data because of the potential for increased access to and sharing of spatial data, the reduction of information loss in data exchange, the elimination of the duplication of data acquisition, and the increase in the quality and integrity of spatial data. SDTS is neutral, modular, growth-oriented, extensible, and flexible -- all characteristics of an "open systems" standard.

The SDTS includes conceptual models and definitions for spatial objects; a partial glossary of geo-spatial features; and standardized files structures and encoding specifications. The SDTS accommodates all forms of spatial data representation including raster, vector and graphical objects. In its general form, it is too complex to be implemented within a single translation software program. Instead, more restrictive SDTS profiles are being developed to transfer a specific type of spatial data. To date, profiles have been developed for planar topological vector data, raster data, and high precision point data. For further information see http://mcmcweb.er.usgs.gov/sdts/.

1.3.4.1.2 SDTS Transportation Network Profile (TNP)

A draft profile was developed in 1995 for transferring non-planar vector data, characteristic of transportation networks. However, the profile was not submitted for formal adoption due to a number of unresolved issues. This standard is expected to address most of these issues and thereby enable resumption of the TNP development. For further information see: http://www.bts.gov/gis/reference/tnp_11.html.

1.3.4.1.3 Facility Identification Data Standard (proposed by the FGDC Facilities Working Group)

The proposed "FGDC Data Content Standard for Location and Identification of Facilities" is intended to develop a Facility Identification data standard that supports identification of place-based objects generally known as facilities. The draft standard incorporates identification of transportation objects which are defined as "Framework Transportation Segments." The proposed identifiers are defined and derived inconsistently in the two drafts; the Chair of the Ground Transportation Subcommittee has noted this in written comments. The Ground Transportation Subcommittee and the Facilities Working Group will work together to define a consistent identifier or to appropriately delineate the scope of each standard. For further information see http://www.fgdc.gov/standards/status/sub3_3.html .

1.3.4.1.4 Ground Transportation Data Content Standard (proposed by the FGDC Facilities Working Group)

The proposed "Data Content Standard" is intended to provide a common set of entity/attribute/domain definitions for transportation features. The Framework Transportation Identification Standard will provide the foundation on which transportation features in this content standard will be defined, and these two efforts will be closely coordinated. (See http://www.fgdc.gov/standards/status/textstatus.html)

1.3.4.1.5 Address Content Standard (proposed by the FGDC Cultural and Demographic Subcommittee)

The proposed "Address Content Standard" is intended to provide consistency in the maintenance and exchange of address data and enhance its usability.

This proposed standard will provide semantic definitions for components determined by the participants to be integral to the creation, maintenance, sharing, usability, and exchange of addresses and/or address lists. Within this scope, addresses are broadly defined as locators to places where a person or organization may reside or receive communications, but excluding electronic communications. An address list consists of one or more addresses. The "Address Content Standard" will additionally define an entity-relationship model for address data. The "Transportation Identification Standard" will establish criteria for defining and constructing transportation centerline networks to which address ranges and other linear referencing methods may be appended. The "Transportation Identification Standard" development is being coordinated with the address content standard to ensure they are compatible. (See http://www.fgdc.gov/standards/status/sub2_4.html .)

1.3.4.1.6 National Hydrography Dataset

The National Hydrography Dataset project aims to produce a well documented, maintainable and nationally consistent hydrography dataset. This database is also a non-planar topological network, and many of the same concepts will be used in the Transportation Identification Standard. However, the Transportation Identification Standard includes certain enhancements to handle the non-dendritic properties of transportation networks and to allow multiple data developers to contribute and enhance transportation data for the same geographic area. For further information see http://nhd.usgs.gov .

1.3.4.2 Other Organizations

1.3.4.2.1 Vector Product Format

VPF is a standardized format, based on a geo-relational data model, developed by the Defense Mapping Agency (now known as the National Imagery and Mapping Agency (NIMA)), for large geographic databases. VPF is designed to be compatible with a wide variety of applications and products, and allows application software to read data directly from various storage media without prior conversion to an intermediate form. VPF was primarily created as a storage and transfer format for cartographic data developed, maintained, and used by the military. It does not address the specific requirements of non-planar topological networks, nor does it address issues of data enhancement from multiple contributors. Databases constructed using the Transportation Identification Standard should be easily convertible to VPF. For further information see http://164.214.2.59/vpfproto/index.htm .

1.3.4.2.2 Other Models and Standards: GIS-T, Intelligent Transportation Systems, and GDF

The **GIS for Transportation** (GIS-T) research community has been investigating transportation data models for several years, and several candidate conceptual models have been proposed. The **Intelligent Transportation Systems** (ITS) movement has also addressed interoperability across data bases. For the most part, however, these candidate models are unfamiliar to many of the spatial database developers who are currently engaged in NSDI Framework activities.

This proposed standard is intended to use terminology and concepts which are entirely consistent with the GIS-T work, the ITS work, and other transportation conceptual models described elsewhere. At the same time the proposed standard is focused on objectives which are more limited than those advanced by either of these two efforts. These limitations are intended to make the proposed NSDI standard easier to understand and to implement across multiple database environments. Further information relating to GIS-T can be obtained at http://www4.nas.edu/trb/crp.nsf/All+Projects/NCHRP+20-27(2) . Further information relating to ITS can be obtained at http://itsdeployment.ed.ornl.gov/spatial/files/ITSDEF.htm .

Geographic Data Files format (GDF) is a European standard that is used to describe and transfer road networks and road related data. GDF provides rules of how to capture the data, and how the features, attributes and relations are defined. GDF has been developed in a European project called EDRM (European Digital Road Map). Its primary use will be for car navigation systems, but it is very usable for many other transport and traffic applications like Fleet Management, Dispatch Management, Traffic Analysis, Traffic Management, Automatic Vehicle Locations etc.

GDF version 3.0 has been released and issued to CEN (Central European Normalization) for the voting procedure. After the voting GDF will become the only CEN accepted standard for digital road networks; ISO standardization of GDF is expected in 2000. For further information see http://www.ertico.com/links/gdf/gdf.htm .

1.3.5 Standards Development Procedures

The FGDC initiated work on this proposed standard in December 1997 through a data developers' workshop held to discuss the topic. Workshop participants presented examples of their work on Framework projects, and articulated many common elements. For further information see http://www.fgdc.gov/framework/page04.html .

The first draft of this standard was prepared during the summer and early fall of 1998, for the review of a technical committee called together at the invitation of the Chair of the FGDC Ground Transportation Subcommittee. This is a third draft version, which incorporates comments collected during much of 1999, and is currently in Step 5 (Review Working Draft) of the FGDC Standards Reference Model.

1.3.6 Maintenance Authority

The current maintenance authority for the standard is the United States Department of Transportation (USDOT.) Questions concerning the standard should be addressed to: Mark Bradford, c/o USDOT/BTS K-40, Room #3430, 400 7th St. SW, Washington DC 20590. Copies of this publication are available from the FGDC Secretariat, in care of the U.S. Geological Survey, 590 National Center, Reston, Virginia 20192; telephone (703) 648-5514; facsimile (703) 648-5755; Internet (electronic mail) fgdc@www.fgdc.gov . The text also is available at the FGDC web site http://www.fgdc.gov/standards/ .

2 The Framework Transportation Identification Standard

2.1 Overview

A key piece in creating a national standard for geospatial data representing transportation networks is the development, implementation, and general acceptance of a transportation identification standard. The function of such a data standard is to enable database developers to transact updates and to exchange information by defining unique and relatively stable transportation reference points and segments that can be assigned permanent feature identifiers.

2.2 Relationships between the "Real World", Cartography, and Networks, and the Framework Transportation Identification Standard

A useful transportation identification standard must successfully address several issues without causing unreasonable extra burden to either database developers or users. First, the standard must be useful in representing the physical or real-world domain of transportation features. Second, the standard must be useful in fulfilling the wide variety of mapping requirements of users. Third, the standard must support a large number of different network applications; for example: *address geo-coding, network pathfinding, vehicle and incident location,* and *highway facility management*. Each of these applications typically segments the network in different ways.

2.2.1 Physical ("Real-World") Domain

Transportation features in the physical or real-world domain consist of tangible objects such as *roads, bridges, railroad tracks, and intersections*. At a minimum, representations of physical objects require information to enable someone to locate and recognize them in the real world. Location information may be purely descriptive (e.g. *"the intersection of the centerlines of 7^{th} & D Streets, SW in Washington, DC"*), or the description may be supplemented by measurements that can be repeated in the field (e.g., GPS coordinates).

This Standard supports the unambiguous identification of unique real-world features by requiring some descriptive information and some quantitative positional information about each feature, and by allowing its augmentation with other information when users make it available.

2.2.2 Cartographic Domain

Cartographic objects are used to represent real world features on a map. In vector-based GIS, real-world objects are typically displayed as *points* (or *symbols*), *lines,* or *polygons*. Transportation networks are displayed using points and strings of line segments. While there is no *a priori* requirement that cartographic points and strings must be topologically connected, most GIS software build topology to facilitate spatial and network computations. However, the topology created by the GIS may not be the same as the topology specified in the transportation network (e.g., a node may be placed where two links cross but don't intersect).

Planar coordinates define the relative locations and shapes of cartographic objects on a two-dimensional plane. These coordinates are typically transformations of real world geographic coordinates (e.g., given a specified geodetic datum and projection). However, the relative accuracy of each plotted point is subject to various errors (e.g., physical location measurements, digitizing accuracy, and distortions caused by planar projections of three-dimensional distances). Consequently, there are differences in both the location and distance measurements between the real world and a map.

This Standard does not attempt to address these cartographic differences; nor does it attempt to reconcile the differences that exist among multiple cartographic representations of the same real-world features. However it does propose a standard method for specifying real-world features, so that users of different cartographic representations can more easily exchange updates to both geometric and tabular information.

2.2.3 Network Domain

Network objects consist of *links* and *nodes,* which together form the *network*; these objects are inherently topological. Transportation networks provide information on the feasible paths between specified locations, and on decision points along those paths. Origins and destinations are assumed to be specific as to location, but the location of a decision point need not exist in the physical world. A network does not require cartographic coordinates; rather, only a set of choices need be identified at each decision point (e.g., the decision point to drive or take transit can be made at any time or place prior to the decision to use transit).

Once a network has been created, other transportation application layers can be built upon it, including *identified routes, linear referencing methods*, and *linearly referenced points* and *linear events.* All of these application layers can ultimately be mapped back to the transportation reference points and segments through the specific network links and nodes on which these application layers were built. Geometric shape is not a required part of network *links, routes,* or *linear events.* Any of these may be constructed without coordinates. All that is required to construct the network layer (links and nodes) is the topological connections of the segments. Construction of routes and linear referencing methods is accomplished through an ordered listing of the links (or parts of links) that comprise each route. *EXAMPLE: Emergency service authorities may wish to define a "Road-Name" Route to support vehicle dispatch. They can do so by defining the "official" road name as an attribute associated with all or a part of each link. The ordered listing of all the links associated with each "official" road name will define the "Road-Name" Route.*

This Standard does not attempt to define topological relationships within any one or more networks, but does provide to the users of multiple networks a stable identifier for real-world features.

2.3 Components of the Transportation Identification Standard[1]

2.3.1 **Framework Transportation Segment Reference Point (FTRP)** – *The specified location of a (required) endpoint of a Framework Transportation Segment (FTSeg), or an (optional) reference point offset along the length of the FTSeg, on a physical transportation system.*

2.3.1.1 The FTRP Table

An FTRP database record has a unique key consisting of fields 1, 2 and 3 (emboldened); values are required for all fields, except those designated "optional" or conditionally required. An FTRP record contains the following information[2]:

[1]The abbreviations "FTRP" and "FTSeg" are used in this document as singular or plural nouns. When used singularly they are modified by "an" rather than "a" as a matter of convention.

[2]The NSDI Framework Transportation Identification Standard is being proposed as an "FGDC data content standard." This proposal does not include standards for formatting or encoding the information described in this Table or in any other tables.

461	#	FTRP Table Field-Name	Description & Format/Domain
462	**1**	**Authority-ID**	Permanent and unique identifier of the organization which created this record. This ID may differ from the ID of the authority which created the original FTRP database entry or subsequent records. Format specified in Section 2.6
463	**2**	**FW-Transportation-Segment-Reference-Point-ID**	Permanent and unique identifier for the FTRP Format specified in Section 2.6
464	**3**	**Date**	Date of creation of the record Format YYYYMMDD
465	4	Location-Description	Unambiguous description of the FTRP that makes it field-recoverable Free text: 255 characters or less
466	5	FTRP-Feature-Type *(Optional)*	Format: Free text of ten characters or less; Domain declared by the authority
467	6	Latitude	Angular distance measured on a meridian north or south from the equator. (NAD83) Format: +/- DD.dddddd; 10 character Decimal degrees Range: +/-0 to 90.000000
468	7	Longitude	Angular distance between the plane of a meridian east or west from the plane of the prime meridian. (NAD83) Format: +/- DDD.dddddd; 11 character Decimal degrees Range: +/-0 to 180.000000

469	8	Horizontal-Accuracy-Measurement-Method	Three-character code which describes the derivation of the horizontal position, and which allows the user to assess the accuracy and precision of the FTRP latitude and longitude: **100** = Derived from stationary GPS measurement, with no differential correction ***1xx** = Stationary GPS measurement -differentially corrected to “xx” meters; e.g., **105** = differential correction to 5 meter accuracy **200** = Derived from mobile GPS measurement, without differential correction ***2xx** = Derived from mobile GPS measurement, differentially corrected to “xx” meters **300** = Derived from non-GPS survey methods - accuracy unknown ***3xx** = Derived from non-GPS survey methods - accuracy certified to “xx” meters **400** = Digitized from digital orthoimagery - Source scale unknown **4xx** = Digitized from digital orthoimagery - Source scale of image in 000's; e.g. 412 =1:12,000 scale source digital orthophotos. **5xx** = Digitized from paper map sources larger than 1:100,000 scale - Source scale in 000's e.g. 524 = 1:24,000 scale topographic maps **600** = Source scale 1:100,000 digital data - e.g., TIGER/Line or DLG **6xx** = Digitized from paper map sources smaller than 1:100,000 scale - Source scale in 100,000's e.g. 625 = 1:250,000 scale maps **900** = Other ** – “xx” should be “01" when accuracy is certified to 1 meter or less.*

470	9	Horizontal-Accuracy *(Optional and Recommended)*	Maximum estimated error in horizontal location Format: MMM.mm; 6 characters, indicating “plus or minus” a number of meters
471	10	Elevation *(Optional and Recommended)*	Elevation above/below sea level Format: +/- MMM.mm; 7 character decimal meters, indicating “plus or minus” a number of meters
472	11	Vertical-Accuracy-Measurement-Method *(Required if Elevation is not “blank")*	Three-character code which describes the derivation of the elevation, and which allows the user to assess the accuracy and precision of the FTRP elevation: **100** = Derived from stationary GPS measurement, with no differential correction ***1xx** = Stationary GPS measurement -differentially corrected to “xx” meters; e.g., **105** = differential correction to 5 meter accuracy **200** = Derived from mobile GPS measurement, without differential correction ***2xx** = Derived from mobile GPS measurement, differentially corrected to “xx” meters **300** = Derived from non-GPS survey methods, accuracy unknown ***3xx** = Derived from non-GPS survey methods, accuracy certified to “xx” meters **800** = Derived from a Digital Elevation Model **900** = Other ** – “xx” should be “01" when accuracy is certified to 1 meter or less.*
473	12	Vertical-Accuracy *(Optional and Recommended)*	Maximum estimated error in vertical location Format: MMM.mm; 6 characters, indicating “plus or minus” a number of meters
474	13	Status	**P** = Proposed; **A** = Active; **R** = Retired

2.3.1.2 Description of FTRP Table Elements

Fields emboldened above are "key" fields – **Authority, FTRP-ID,** and **Date**; taken together, they make up a unique key for each record in the FTRP Table. They are required so that a record which describes a specific FTRP can be improved over time. Multiple authorities and data users will recognize, access, use, and archive FTRP records that represent a "real world" location, as identified by a particular authority at a particular point in time.

The required textual **Location-Description** must be sufficient to allow all users to unambiguously identify that FTRP in the field. However changes in applications and technology will allow the multiple authorities to refine over time the specifics of the Location-Description, coordinates, and accuracy Description. The use of a multi-part key provides relative permanence to the FTRP-ID, while allowing the creation of additional database records which can reflect these refinements. As a result, users will be able to embed FTRP within their own data structures, and acquire refined information about them over time (as it is made available by multiple authorities). At the same time they will not have to expend resources on updating internal references to this primary key.

The optional **FTRP-Feature-Type** allows the authority to provide information about the type of point feature designated as the FTRP. Each authority which chooses to use this field must reference the domain of valid attribute values in the NSDI Framework Authority Index (See

Section 2.8). The Authority-Information field of this record should contain a brief reference to the authority's use of the FTRP-Feature-Type, and should direct the user to the source of metadata about this attribute.

The **Latitude**, **Longitude,** and **Horizontal-Accuracy- Measurement-Method** of each FTRP must be provided. **Horizontal-Accuracy** is optional, but should be provided when the Authority believes accuracy to be +/- 1 meter (or better). When the **Elevation** is not blank, a valid **Vertical-Accuracy-Measurement-Method** code is also required. **Vertical-Accuracy** is optional, but should be provided when the Authority believes accuracy to be +/- 1 meter (or better). The measurement method codes are intended to allow data users to assess the accuracy and precision of the FTRP position without requiring authorities to provide a quantitative error estimate.

A required **Status** code allows authorities to design and share/compare "proposed" FTRP with other interested authorities before coming to agreement on their designation. Also retention of records coded as "retired" enables users to update their databases after FTRP have been retired because of physical re-alignments or reconciliation of duplicate records.

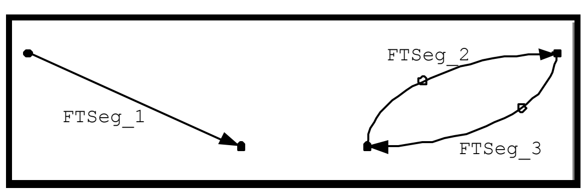

Figure 2 – Unique pathways connecting two FTRP

2.3.2 Framework Transportation Segment (FTSeg) – *A specified*

directed path between two Framework Transportation Segment Reference Points along a physical transportation system that identifies a unique segment of that system.

FTSeg have no explicit geometry other than the locations of associated reference points (FTRP). Most FTSeg terminate at two FTRP. However, cul-de-sac loops may consist of FTSeg which originate and terminate at the same FTRP, and FTSeg may have other FTRP offset along their length. FTSeg should be depicted either by straight lines connecting two FTRP or by curved lines (if two or more FTSeg terminate at the same two FTRP.)[3]

2.3.2.1 Requirements for FTSeg

2.3.2.1.1 FTSeg must represent a component of the transportation network, with unambiguous beginning and end points (FTRP) that can be initially located and subsequently recovered in the field.

2.3.2.1.2 FTSeg must be independent of any particular cartographic display or analytical network. The nodes of a particular analytical network may be useful in defining the FTRP which begin and end at an FTSeg, but other points may serve as well.

[3]Guidelines for cartographic representation of FTRP and FTSeg are provided in Section 1.1 of Informative Appendix C.

2.3.2.1.3 An FTSeg may not cross the boundary of a State, territory or equivalent jurisdiction; therefore the maximum length of any FTSeg is the span of the jurisdiction in which it lies.

2.3.2.1.4 FTSeg must be stable over time. New links are routinely added, and existing links are routinely split in many transportation networks. New links may represent a newly constructed road, or they may represent a set of features (e.g., driveways) needed to support a particular application. In either case, existing FTSeg should not be changed in order to handle these additional links. In some rare instances it may be necessary and permissible to modify an existing FTSeg. The specific update procedures needed to handle such situations are detailed in Part 3 of this document.

2.3.2.2 The FTSeg Table

An FTSeg database record has a unique key consisting of fields 1, 2 and 3 (emboldened); all fields are required, unless otherwise indicated. An FTSeg record contains the following information:

#	FTSeg Table Field-Name	Description & Format/Domain

541	**1**	**Authority-ID**	Permanent and unique identifier of the organization which created the record. This ID may differ from the ID of the authority which created the original FTSeg database entry or subsequent records. Format specified in Section 2.6
542	**2**	**FW-Transportation-Segment-ID**	Permanent and unique identifier for the FTSeg Format specified in Section 2.6
543	**3**	**Date**	Date of creation of the record Form YYYYMMDD
544	4	From-End-Point	Unique identifier of the FTRP at which this FTSeg begins Format specified in Section 2.6
545	5	To-End-Point	Unique identifier of the FTRP at which this FTSeg ends Format specified in Section 2.6
546	6	Path-Description	Unambiguous description of the path of this FTSeg, which is unique with respect to any other FTSeg which connects the same two End-points. Free text: 255 characters or less
547	7	Intermediate-Point *(Required when Applicable)*	Identifier of the FTRP located at an intermediate point on the FTSeg for the purpose of distinguishing this FTSeg from (one or more) other FTSeg which share the same end points. Format specified in Section 2.6
548	8	FTSeg-Feature-Type *(Optional)*	Format: Free text of ten characters or less; Domain declared by the authority
549	9	State	Two-character code indicating the State, territory or equivalent entity within which the transportation segment begins and ends Codes are specified in FIPS 5-2

10	Length *(Optional and Recommended)*	Measured length of the segment Format: MMMMMM.mm; 9 character decimal meters
11	Length-Accuracy-Measurement-Method *(Required if Length is not "blank")*	Three-character code which describes the derivation of the Length measurement, and which allows the user to assess the accuracy and precision of the FTSeg length: **100** = Survey measurement **210** = Measured by a distance measurement device; e.g., "fifth wheel" **220** = Measured by an automobile odometer or analogous device **310** = Computed from a digital vector database scaled at larger than 1:12000 **320** = Computed from a digital vector database scaled at from 1:12000 to 1:100,000 **330** = Computed from a digital vector database scaled at smaller than 100,000 **900** = Other
12	Status	**P** = Proposed; **A** = Active; **R** = Retired

2.3.2.3 Description of FTSeg Table Element

Fields emboldened above are "key" fields – **Authority, FTRP-ID,** and **Date**; taken together, they make up a unique key for each record in the FTSeg Table. These fields are required in order that FTSeg records can be improved by multiple authorities over time, archived, and accessed by different users, just as FTRP records can be. The **From-End-Point** and **To-End-**

Point values are required in order to unambiguously delineate each FTSeg. (Refer to description **Intermediate-Point**, below.)

An FTSeg record must include an **Intermediate-Point** consisting of a single FTRP-ID whenever the FTSeg in question has the same From-End-Point and To-End-Point as one or more other FTSeg. The additional FTRP identified in this field should represent an intermediate point along the FTSeg, judiciously selected in order to assure that the multiple FTSeg which terminate at the same FTRP are unambiguously differentiated. Pairs of FTSeg for which the To-End-Point and From-End-Point are reversed will occur routinely; they must be assigned different unique FTSeg identifiers, but need not have Intermediate-Points.

A textual **Path-Description** that is sufficiently complete as to allow other users to unambiguously identify the course of the FTSeg in the field is also required.

The optional **FTSeg-Feature-Type** allows the authority to provide information about the type of linear feature designated as the FTSeg. Each authority which chooses to use this field must reference the domain of valid attribute values in the NSDI Framework Authority Index (See Section 2.8). The Authority-Information field of this record should contain a brief reference to the authority's use of the FTSeg-Feature-Type, and should direct the user to the source of metadata about this attribute.

A required **State** code allows authorities and users to more easily identify records of possible interest. Because FTSeg may not cross state boundaries, in most cases the code should indicate the State, territory or equivalent entity within which the transportation segment begins and ends. If the FTSeg lies precisely along a boundary line between two States, territories or equivalent entities, these entities should derive a shared business rule for coding the FTSeg.

Length and **Length-Accuracy-Measurement-Method** are optional. The accuracy description codes are intended to allow data users to assess the precision of the FTSeg length without requiring authorities to provide a quantitative error estimate.

A required **Status** code allows authorities to design and share/compare “proposed” FTSeg

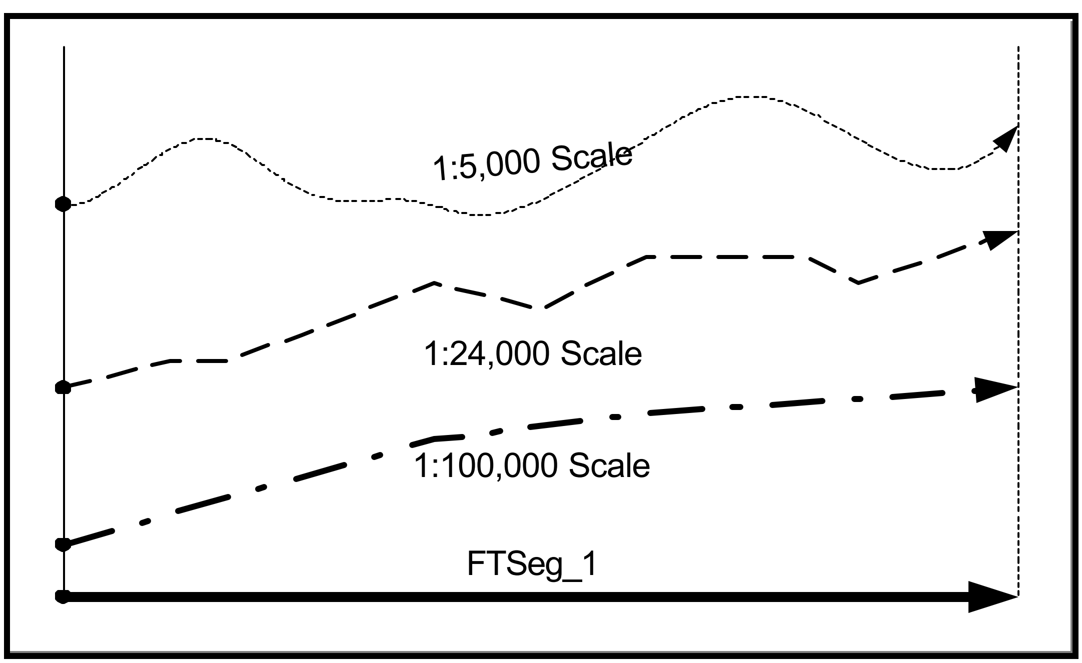

Figure 3 - Representation of an FTSeg and different scales

with other interested authorities before coming to agreement on their designation. Also retention of records coded as “retired” enables users to update their databases after FTSeg have been retired because of physical re-alignments or reconciliation of duplicate records.

While FTSeg have no explicit geometry themselves, they may be represented by a variety of cartographic line segments depicting their shape and location on the earth. The line segments may be more or less complex, reflecting different scales of resolution, map projections, or structural detail.

2.4 Connectivity of Framework Transportation Segments

FTSeg may be used to construct topological networks, but do not represent a topological network by themselves. FTRP are required to establish connections among two or more FTSeg, either at their termini and/or at some offset along their length. FTRP can optionally be placed along FTSeg in locations at which no connectivity occurs. The structure in which these relationships are established is described below.

2.4.1 The Connectivity Table

All topological relationships between entities in the data standard are described in the Connectivity Table. At least one record must exist for each FTSeg. At least one record must exist for each FTRP, even if it occurs at the terminus of an FTSeg or at some other location at which no connectivity exists; e.g., a bridge or a railroad crossing. More than one record will exist for each FTRP at which connectivity occurs. The Connectivity Table supports a “one-to-many” relationship between FTRP and the number of connections made at each, so is in the form of an unordered list:

#	Connectivity Table Field Name	Description & Format/Domain
1	Authority-ID	Permanent identifier of the organization which created this record. This ID may differ from the ID of the authority which created the original FTRP database entry or subsequent records. Format specified in Section 2.6
2	FW-Transportation-Segment-Reference-Point-ID	Permanent and unique identifier for the FTRP Format specified in Section 2.6
3	Date	Date of creation of this record Format YYYYMMDD
4	FTSeg-ID	Unique identifier of an FTSeg along which this FTRP falls. Format specified in Section 2.6
5	FTSeg-Offset-%	Percentage offset from the FTSeg From-End-Point at which this FTRP falls A positive decimal number greater than or equal to “0" and less than or equal to “100.0000". Format: 000.0000; 8 characters

6	Offset-%-Accuracy-Description	Three-character code which describes the derivation of the FTSeg-Offset-% measurement, and which allows the user to assess the accuracy and precision of the offset along the FTSeg: **100** = Survey measurement **210** = Measured by a distance measurement device; e.g., "fifth wheel" **220** = Measured by an automobile odometer or analogous device **310** = Computed from a digital vector database scaled at larger than 1:12000 **320** = Computed from a digital vector database scaled at from 1:12000 to 1:100,000 **330** = Computed from a digital vector database scaled at smaller than 100,000 **900** = Other
7	Status	**P** = Proposed; **A** = Active; **R** = Retired

2.4.2 Description of Connectivity Table Elements

FTRP-ID, Authority, and **Date** are required so that each record indicates what authority established the placement of an FTRP along an FTSeg, and when.

An **FTSeg-ID** indicates the segment along which the FTRP lies. The **FTSeg-Offset-%** indicates the FTRP's placement along the FTSeg, and the **Offset-%-Accuracy-Description** codes are intended to allow data users to assess the precision of the FTSeg-Offset-% without requiring authorities to provide a quantitative error estimate.

A required **Status** code allows authorities to design and share/compare “proposed” FTRP with other interested authorities before coming to agreement on their designation. Also retention of records coded as “retired” enables users to update their databases after FTRP have been retired because of physical re-alignments or reconciliation of duplicate records.

2.4.3 Categories of Connectivity[4]

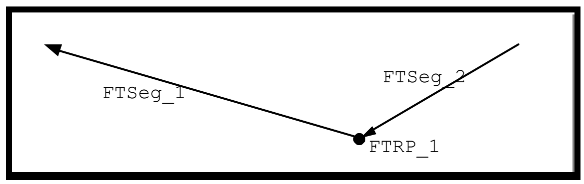

Figure 4 – Terminal connectivity of two FTSeg at FTRP_1

2.4.3.1 Two or more FTSeg are said to be *terminally* connected if they share a common FTRP at their termini. The terminal connectivity illustrated in Figure 4 is implemented in the Connectivity Table in two records for `FTRP_1`; one indicates that `FTRP_1` is offset 0% of the length of `FTSeg_1`. The second record indicates that `FTRP_1` is offset 100% of the length of `FTSeg_2`. The FTSeg-Offset-% in such records will always by “0%” or “100%.” The Table would contain one record for any additional FTSeg which was terminally connected at `FTRP_1`.

[4]Previous drafts of the Standard defined two connectivity types; this version introduces a third connectivity type. The definition of *explicit connectivity* is the same as in previous drafts. The definition of *implicit connectivity* has changed from that used in previous drafts, and the definition used formerly applies in this draft to *terminal connectivity*.

2.4.3.2 Segments are said to be *explicitly* connected whenever:

2.4.3.2.1 there are two or more records in the Connectivity Table which describe the same FTRP, and

2.4.3.2.2 at least one of the records indicates that the FTRP falls at a termini of an FTSeg, and

2.4.3.2.3 at least one other record indicates that the FTRP lies on an FTSeg at a point other than a terminus.

In Figure 5, `P3` is an end point of `FTSeg_2` and `P4` is an end point of `FTSeg_3` and `FTSeg_4`. All of these segments are connected *explicitly* to `FTSeg_1`, which is the entire line segment terminating at `P1` and `P2`. The values entered in the important fields of the Connectivity Table are as follows:

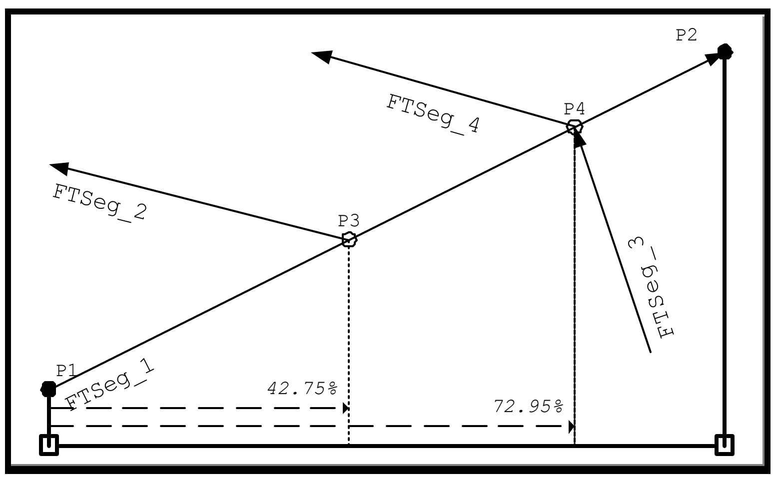

Figure 5 - `FTSeg_2, FTSeg_3`, and `FTSeg_4` are connected explicitly to `FTSeg_1`

Field #2- FTRP-ID	Fields #1, #3, #6, #7	Field #4- FTSeg-ID	Field #5- FTSeg-Offset-%
P3	Other Data	FTSeg_2	0.00%
P3	"	FTSeg_1	42.75%
P4	"	FTSeg_3	100.00%
P4	"	FTSeg_4	0.00%
P4	"	FTSeg_1	72.95%

2.4.3.3 Two or more FTSeg are said to be *implicitly* connected when there are two or more records in the Connectivity Table which describe the same FTRP, and all of these records indicate that the FTRP lies on the (multiple) FTSeg at a point other than a terminus of the FTSeg. The implicit connectivity illustrated in Figure 5 is implemented in the Connectivity Table in two records for `FTRP_1`, each indicating that it is offset a specific percentage of the length of `FTSeg_1` and `FTSeg_2`. The Table would contain one record for any additional FTSeg which passed through or which terminated at `FTRP_1`.

2.4.4 Conditions lacking Connectivity

2.4.4.1 An FTRP which does not connect multiple FTSeg may be offset along

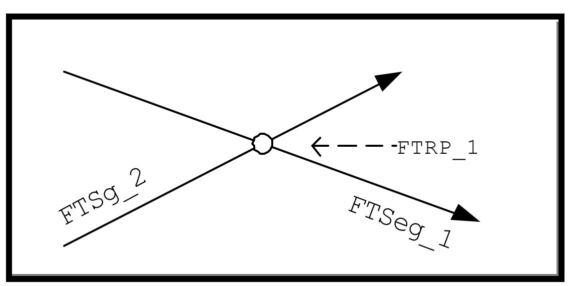

Figure 6 - Implicit connectivity of FTSeg_1 and FTSeg_2

the length of an FTSeg in order to establish the distinction among two or more segments which terminate at the same two endpoints. Such an FTRP is recorded as the Intermediate-Point of the FTSeg record to establish uniqueness, and should be recorded in the Connectivity Table.

2.4.4.2 An unconnected FTRP may be offset along the length of an FTSeg to mark its intersection with an important but unconnected linear feature (jurisdiction boundary, railroad or water bridge), and should be recorded in the Connectivity Table.

2.4.4.3 The topological properties of FTSeg consist exclusively of the connectivity derived from a shared FTRP. Therefore FTSeg_1 and FTSeg_2 may cross without the need for an FTRP at the crossover, as in Figure 7. There is no connectivity between the transportation segments illustrated in this figure; no topological connection exists for FTSeg_1 and FTSeg_2 unless an FTRP is defined in order to provide for a topological connection.

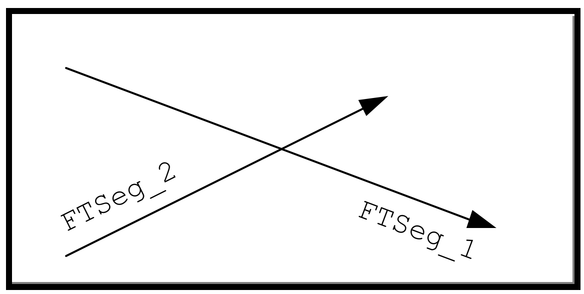

Figure 7 - Intersecting but unconnected FTSeg

2.4.4.4 Two unconnected FTRP may share the same horizontal coordinates, though not the same elevation. In such circumstances there is no implication either that the two FTRP are identical, or that the two sets of FTSeg are connected. Figure 8 shows that `FTSeg_1` and `FTSeg_2` are connected terminally at `FTRP1`, and that `FTSeg_3` and `FTSeg_4` are connected terminally at `FTRP2`. `FTRP1` and `FTRP2` share the same (X-Y) coordinates but have different elevations, so there is no connectivity between the two sets of FTSeg.

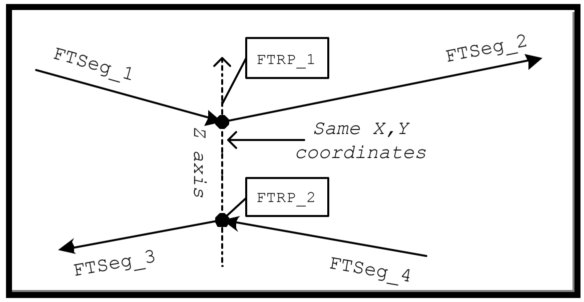

Figure 8 - Unconnected sets of FTSeg

Using terminal, implicit, and explicit connectivity encoded in the Connectivity Table, selected subsets of FTSeg may be combined to create custom networks. The only requirement for the derivation of such networks is that any FTSeg included in the network must connect with another FTSeg that is also part of the network.

2.5 Relating Attributes of Transportation Segments to FTRP and FTSeg

Organizations that wish to share information about different transportation databases will have an interest in identifying those "real world" feature attributes (e.g. functional class, name or route number, and street address ranges) of value within their applications. The identification of such attributes, definition of their domains or formats is not a part of this Standard. This and other information about these attributes will be defined by national standards and practices, or by the users of the data for a particular geography.

Often the values of defined attributes of linear features will not relate to 100% of the length of a particular FTSeg. These attributes -- in addition to attributes pertaining to an FTRP or a complete FTSeg – can be shared by means of an Attribute Table that relates the particular attribute values to one or more FTRP or FTSeg. The Attribute Table supports a “many-to-many” relationship between FTRP and FTSeg objects, and the attributes associated with each, so is in the form of an unordered list:

#	Attribute Table Field-Name	Description & Format/Domain
1	Authority-ID	Permanent and unique identifier of the authority which generates or distributes the attribute. Format specified in Section 2.8
2	FW-Transportation-Segment-ID-or-Reference-Point-ID	Permanent and unique identifier for the FTSeg or FTRP with which an attribute is associated Format specified in Section 2.6
3	Date	Date of creation of the attribute record Format YYYYMMDD

4	Start-Offset	For FTRP attributes: "000.0000" For FTSeg attributes: Percentage offset from the FTSeg From-End-Point at which this attribute value commences A positive decimal number greater than or equal to "0" and less than or equal to "100.0000" with format: +000.0000
5	End-Offset	For FTRP attributes: "000.0000" For FTSeg attributes: Percentage offset from the FTSeg From-End-Point at which this attribute value ends A positive decimal number greater than or equal to "0" and less than or equal to "100.0000" with format: +000.0000
6	Attribute-Name	Free text: 64 characters or less
7	Attribute-Value	Attribute value

Values are required for all fields. Descriptions of **Authority-ID, FTSeg-or-FTRP-ID, Date,** and **Offset**s can be found in the discussion of the FTSeg Table earlier in section 2.3.2.2. **Attribute-Name** and **Attribute-Value** are fields which should contain the name applied by the Authority to a specific attribute, as well as the value of that attribute. Attribute values conveyed in table records apply to the FTRP or FTSeg (or portion thereof) identified in the particular record. Information about different named attributes (e.g., "Route-#" and "Road-Name") must be conveyed in separate records pertaining to each FTRP or FTSeg (or portion thereof). Metadata about each named attribute – including the description, format and domain – should accompany the Attribute Table, and should conform to the FGDC Content Standard for Digital Geospatial Metadata (version 2.0).

2.6 Unique Identifiers of FTRP and FTSeg

Each FTRP and FTSeg has a unique and permanent identification code of fixed length in the following format:

AAAAA.O.XXXXXXXXX

2.6.1 Authority-ID

AAAAA – Each FTRP and FTSeg identifier includes the unique identifier of an Framework Transportation Data Authority. This code identifies the organization which generated the first database entry, or "originating" record describing the FTRP or FTSeg. An Authority-ID also occurs in a separate data base field in each FTRP and FTSeg record. This field records the identity of an authority which improves database records about FTRP or FTSeg subsequent to the creation of the unique FTRP or FTSeg identifiers. (Specifications for creating identifiers for each authority are the topic of a following section.).

2.6.2 Object Type

O – Each FTRP identifier includes a “P” and each FTSeg includes an “S.”

2.6.3 Identity-Code

XXXXXXXXX is a zero-filled, right-justified, alpha-numeric identifier of nine characters in length for each FTRP or FTSeg. Authorities can use different methods for designating unique values for the Identity Code; assignment of sequential integers, or use of segment codes already in use are acceptable methods. Such codes, once assigned, are part of the permanent identifier of each FTRP and FTSeg, and do not change if the pre-existing codes change in a particular user database or application.

2.7 Relating Equivalent Representations of FTRP and FTSeg

2.7.1 Equivalent FTRP and FTSeg

At points of connectivity between differing representations of the traveled way(s) all FTSeg must be capable of connecting to other FTSeg. And wherever authorities maintain databases describing different representations of equivalent features FTRP and FTSeg must be related so they can support exchange of attributes across these databases.

2.7.1.1 Many authorities will maintain databases in which two or more traveled ways separated by a physical barrier are represented by two or more sets of line segments, which can be represented as separate segments.

2.7.1.2 Other data authorities may maintain databases in which parallel traveled ways separated by a physical barrier are represented by a single set of line segments; e.g. a small-scale representation of an Interstate highway.

2.7.1.3 Still other authorities may maintain databases in which the same roadway is represented with "complex" features such as lanes, access roads, and entrance/exit ramps. "Complex" FTRP or FTSeg represent multiple discrete physical points or segments included within the same undivided travelway, over any of which vehicles can pass while remaining within that traveled way.

2.7.2 The FTSeg and FTRP Equivalency Table

Equivalence among multiple representations of FTRP and FTSeg can be sustained by the creation and maintenance of Equivalency Table data records that establish analogous relationships between two or more FTRP, or between one FTSeg and another FTSeg (or portion thereof.) One FTRP (or FTSeg) may have 0 or 1 or more FTRP (or FTSeg) which are equivalent, but which make up a different representation. Since one FTSeg also may be equivalent to a fraction of another FTSeg, the Table supports “many-to-many” relationships, and is in the form of an unordered list:

#	Equivalency Table Field-Name	Description & Format/Domain
1	Reference-FTRP-ID or Reference-FTSeg-ID	Permanent and unique identifier for the FTRP or FTSeg Format specified in Section 2.6
2	Equivalent_FTRP_ID or Equivalent_FTSeg_ID	Permanent and unique identifier for the FTRP or FTSeg which is equivalent Format specified in Section 2.6
3	Date	Date of creation of the record Format YYYYMMDD
4	Start-Offset *(required if the entity named in Fields 1 & 2 is an FTSeg)*	For FTSeg records only: Percentage offset from the From-End-Point of the FTSeg identified in the Reference-FTSeg-ID at which equivalency commences A positive decimal number greater than or equal to “0" and less than or equal to “100.0000" with format: +000.0000
5	End-Offset *(required if the entity named in Fields 1 & 2 is an FTSeg)*	For FTSeg records only : Percentage offset from the From-End-Point of the FTSeg identified in the Reference-FTSeg-ID at which this equivalency ends A positive decimal number greater than or equal to “0" and less than or equal to “100.0000" with format: +000.0000
6	Status	**P** = Proposed; **A** = Active; **R** = Retired

The **Reference-FTRP-ID** or **Reference-FTSeg-ID** and **Equivalent_FTRP_ID** or **Equivalent_FTSeg_ID** are the IDs of entities which have been created in the FTSeg Table or the FTRP Table, and which are equivalent (wholly or in part). The **Start-Offset** and **End-Offset** are percentage numbers used to identify the portion of two different FTSeg which are equivalent (wholly or in part). Authorities must indicate equivalency by making entries in this Table whenever they create:

2.7.2.1 a new representation of a point or segment which is equivalent to one or more other representations of the same point or segment identified by already-existing FTRP or FTSeg,); or

2.7.2.2 a representation of a (new) FTSeg that is equivalent to a fraction of another FTSeg representation.

2.7.3 Relating Equivalent FTRP and FTSeg

Each FTRP and FTSeg which represents a portion of a transportation network is assigned a unique Identity Code which is a permanent nine-character identifier. Each authority creates or uses an FTRP-ID or FTSeg-ID to identify segments and points in one (or more) specific database(s), and makes entries in the Equivalency Table when these segments and points represent the same physical features represented in other databases using other FTRP-IDs or FTSeg-IDs.

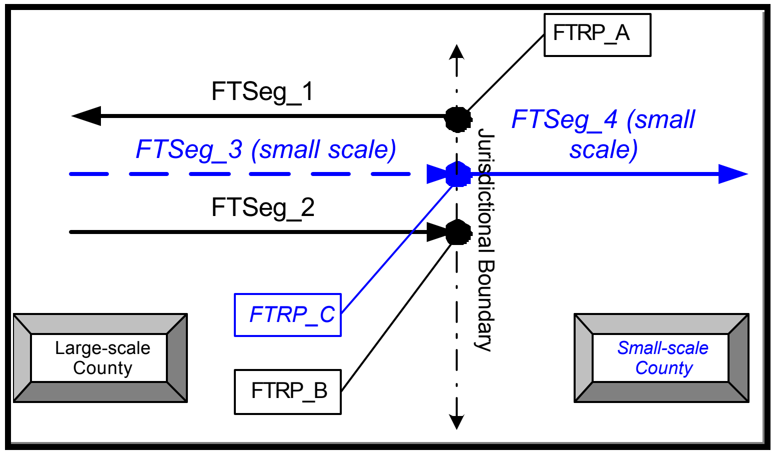

Figure 9 - Equivalency between "Single line" and "Dual line" representations of a Divided Roadway

In Figure 9, an authority has created a more-detailed representation of the divided highway to the left of the boundary; segments are identified as `FTSeg_1` and `FTSeg_2`. For another less-detailed representation of the same segments an authority has used FTSeg-ID numbers `FTSeg_3`, and has connected it to `FTSeg_4`. The authority should make entries in the Equivalency Table to indicate that `FTSeg_1`, `FTSeg_2`, and `FTSeg_3` are all representations of the same feature(s). (Similar entries should be made to indicate that the three FTRP are equivalent.) Use of the Equivalency Table supports establishment of equivalency between any number of representations of equivalent points (FTRP), and any number of representations of equivalent segments or partial segments (FTSeg) on a "one to many" or "many to one" basis. The entries which should be made in the important fields of the Equivalency Table in order to represent the equivalent entities illustrated in Figure 9 are as follows:

Field #1-Reference-ID	**Field #2 - Equiva-lent-ID**	**Field #4-Start-Offset**	**Field #5-End--Offset**

FTSeg_1	FTSeg_3	0.00%	100.00%
FTSeg_2	FTSeg_3	100.00%	0.00%
FTRP_A	FTRP_C	0.00%	0.00%
FTRP_B	FTRP_C	0.00%	0.00%

2.8 Framework Transportation Data Authorities

An NSDI Framework Transportation Data Authority may perform some or all of the functions necessary to build and operate the NSDI Framework. These functions are: *Data Development, Maintenance, and Integration, Data Access, Data Management, Coordination, Executive Guidance, Resource Management*, and *Monitoring and Response*. For further information, see the "NSDI Framework Introduction and Guide," FGDC, 1997, Chapter 4.

2.8.1 Definition of an Authority

Any organization which takes responsibility for proposing, designating, or working in partnership with other organizations to define FTRP and FTSeg is -- for the purposes of this standard -- operating as an "authority." Organizations which act as authorities:

2.8.1.1 create or update transportation databases (or plan to do so), and

2.8.1.2 share those databases or related attribute sets with others (or plan to do so), and

2.8.1.3 conform database development and maintenance activities to this standard.

2.8.2 Unique Identifiers for Authorities

Each authority is identified by a permanent, unique, fixed-length code of five characters in the form of **AAAAA**. Organizations which perform authority functions in one state or any part of one state will assume a unique identifier, the first two characters of which consist of the state or territory code specified in FIPS 5-2. The following three characters consist of a unique code for each authority located within the state. The code should be made up of three numeric characters. *EXAMPLE: The Vermont Agency of Transportation could assume an Authority-ID of "50001," the Vermont Enhanced-911 Board could assume the Authority-ID of "50002," with other state-specific state, regional and local agencies assuming other identifiers.*

Federal agencies, organizations which produce data for multiple states, and non-domestic authorities can all be accommodated by using the code of “00" in the first two characters. The remaining three characters consist of a code unique to each authority, as described in the previous section. Multi-state authorities which have multiple database maintenance operations or separate geographic units can assume separate Authority-IDs. *EXAMPLE: Some federal agencies which are FGDC members perform data development and maintenance in facilities in multiple regions of the US. Such regional data maintenance facilities may choose to become authorities, and each should use a unique code beginning with "00."*

2.8.3 Descriptive Attributes for each Authority

Information about each authority is maintained in an NSDI Framework Authority Index; (See Part 3 - Implementation Procedures). The information content relating to each authority is based on the "Contact-Information" content specified within the FGDC "Content Standard for Digital Geospatial Metadata." It includes the following information:

#	Authority Field-Name	Description & Format/Domain
1	**Authority-ID**	Permanent and unique identifier of the organization. Five character numeric code: see Section 2.8.1 and 2.8.2
2	Date	Date of creation of the record Format YYYYMMDD
3	Authority-Name	Name of the organization acting as an authority Free text: 255 characters or less
4	Contact-Person-Primary	Name of a contact person Free text: 255 characters or less

867	5	Contact-Voice-Telephone	Voice telephone number of Contact-Person-Primary Free text: 20 characters
868	6	Contact-Facsimile-Telephone *(optional)*	Fax telephone number of Contact-Person-Primary Free text: 20 characters
869	7	Contact-Electronic-Mail - Address *(optional)*	E-mail address of Contact-Person-Primary Free text: 64 characters or less
870	8	Contact-URL *(optional)*	Universal Resource Locator for Internet access to the Authority Free text: 64 characters or less
871	9	Contact-Instructions	Instructions for contacting the Authority Free text: 255 characters or less
872	10	Authority-Address	Mail delivery address of the Authority Free text: 255 characters or less
873	11	Authority-City	Mail delivery city of the Authority Free text: 255 characters or less
874	12	Authority-State-or-Province	Mail delivery state (US) or province (non-US) of the Authority Free text: 64 characters or less
875	13	Authority-Postal-Code	Mail delivery ZIP (US) or postal code of the Authority Free text: 20 characters or less
876	14	Authority-Country	Mail delivery Country of the Authority Free text: 64 characters or less

877	15	Authority-Index-Access-Information	Information informing potential users of the Authority’s data how to obtain access to or a copy of the index containing the relevant FTRP and FTSeg information. Link(s) to the standardized metadata describing the database(s) should be included. Free text: 255 characters or less
878	16	Authority-Information *(optional)*	Additional information about the geographic area, types of transportation activities, or data maintenance operations in which the Authority is engaged Free text: 255 characters or less
879	17	Status	**P** = Proposed; **A** = Active; **R** = Retired

Appendix A – Terminology

(Informative)

This appendix contains terms used throughout this document, with reference to broader technical glossaries developed by other organizations.

Definitions for the terms and concepts presented in this section have been extracted from a variety of sources. Where appropriate, language has been retained from existing definitions, including from the Spatial Data Transfer Standard (SDTS), by the FGDC Ground Transportation Subcommittee, the NCHRP Report 359, and concept and workshop papers recently authored by Butler, Dueker, Fletcher, Vonderohe, et al. When utilized, specific references to these sources appear in parentheses following the definitions.

Arc. A locus of points that forms a curve that is defined by a mathematical expression (SDTS).

Chain. A directed non-branching sequence of nonintersecting line segments and (or) arcs bounded by nodes, not necessarily distinct, at each end (SDTS).

Framework Transportation Reference Point (FTRP). The specified location of a endpoint of a Framework Transportation Segment (FTSeg), or a reference point offset along the length of the FTSeg, on a physical transportation system.

Framework Transportation Segment (FTSeg). A specified directed path between two Framework Transportation Segment Reference Points along a physical transportation system that identifies a unique segment of that physical system.

Line. A generic term for a linear object. Lines can be defined variously as "line segment," "string," "arc," or "chain." Lines have shape and position.

Line segment. A direct line between two points (SDTS).

Linear datum. The collection of objects which serve as the basis for locating the linear referencing system in the real world. The datum relates the data base representation to the real world and provides the domain for transformations among linear referencing systems and among geographic representations. The datum consists of a connected set of anchor sections that have anchor points at their junctions and termini (Fletcher). A linear datum is not based upon a network with GIS geometry, but instead is properly considered to be an abstract representation of objects (lines, nodes) that describes how the objects are related.

Linear Referencing Method (LRM). A mechanism for finding and stating the location of an unknown point along a network by referencing it to a known point (Vonderohe). Common methods include milepost, link-node, route-segment-offset, and address.

Linear Referencing System (LRS). The procedures that relate all location referencing methods to each other, including office and field techniques for storing, maintaining, and retrieving location information (O'Neill).

Link. A topological connection between two ordered nodes (Vonderohe, SDTS). Links do not necessarily have shape or position.

Link-Node. A location referencing method based upon a unique numbering system describing links (or arcs) and nodes; it does not inherently contain measurement data.

Location. The name given to a specific point on a highway for which an identification of its linear position with respect to a known point is desired. (TRB, 1974)

Locational Referencing Method (Highway). The technique used to identify a specific point (location) or segment of a highway, either in the field or in the office. (TRB, 1974)

Locational Referencing System (Highway). The total set of procedures for determining and retaining a record of specific points along a highway. The system includes the location reference method(s), together with the procedures for storing, maintaining, and retrieving location information about the points and segments on the highways. (TRB, 1974)

Milepost/Milepoint/Reference Post. A commonly used location referencing method. Location of features is specified as a measured distance or offset from a known point such as an intersection. In the field, reference posts may be used as the primary known point.

Network. A graph without two-dimensional objects or chains. An aggregation of nodes and links representing a topological object (SDTS, Vonderohe). A network implies that there is a graphic connectivity, or topology, among elements.

Node. A zero-dimensional object that is a topological junction of two or more links, or an end point of a link or chain (Vonderohe, SDTS).

Point. A zero-dimensional object that specifies geometric location. A pair (e.g., “x,y”) or triplet (e.g., “x,y,z”) of coordinates specifies the location (SDTS).

String. A connected non-branching sequence of line segments specified as the ordered sequence of points between those line segments (SDTS).

Topology. A branch of mathematics concerned with those properties of geometry that are independent of a distance metric and are unchanged by any continuous deformation. Topology, as used in cartography, concerns those characteristics of geometric objects that do not depend on measurement in a coordinate system. (Chrisman)

Traversal. An ordered and directed, but not necessarily connected, set of whole links (Vonderohe).

Appendix B – Bibliographic References

(Informative)

1. Butler, J.A. and Dueker, K.J., "A Proposed Method of Transportation Feature Identification," Center for Urban Studies -- School of Urban and Public Affairs (Portland State University), Portland OR, 1998. http://www.upa.pdx.edu/CUS/

2. Chrisman, N., Exploring Geographic Information Systems, John Wiley & Sons, NY, 1997.

3. Dueker, K.J. and Butler, J.A., "GIS-T Enterprise Data Model with Suggested Implementation Choices," Center for Urban Studies -- School of Urban and Public Affairs (Portland State University), Portland OR, 1997. Published in the URISA Journal, vol. 10, num. 1, Spring 1998, pp. 12-36. http://www.upa.pdx.edu/CUS/

4. Fletcher, D., Espinoza, J., Mackoy, R.D., Gordon, S., Spear, B., Vonderohe, A., "The Case for a Unified Linear Reference System," published in the URISA Journal, vol. 10, num. 1, Spring 1998, pp. 7-11. http://www.urisa.org/abstracts/linearre.htm

5. North Carolina Department of Transportation, "Linear Referencing Systems: Review and Recommendations for GIS and Database Management Systems," Raleigh (NC), 1997.[5]

[5] A "proposed" strategy; not fully endorsed or implemented by NCDOT at this time.

6. O'Neill, W., and Harper, E., "Resource Guide on the Implementation of Linear Referencing Systems in Geographic Information Systems," Bureau of Transportation Statistics (U.S. Department of Transportation), Washington, DC, 1998.

7. Rabkin, M. and Maccalous, S., "Transportation Spatial Data Dictionary," Ground Transportation Subcommittee (Federal Geographic Data Committee), Washington, DC, 1997. http://www.bts.gov/gis/fgdc/pubs/tsdd.html

8. "Highway Location Reference Methods," (NCHRP Synthesis of Highway Practice 21,) Transportation Research Board, Washington, DC, 1974.

9. Vonderohe, A., Chou, C., Sun, F., Adams, T., "A Generic Data Model for Linear Referencing Systems," Research Results Digest #218 of the Transportation Research Board (National Research Council), Washington, DC, 1997. See http://www4.nas.edu/trb/crp.nsf/All+Projects/NCHRP+20-27(2) and http://www.bts.gov/gis/reference/report.html .

10. "Representations of Geographic Point Locations for Information Interchange (ANSI X3.61-1986)," American National Standards Institute, New York, 1986.

11. "United States National Map Accuracy Standards," Bureau of the Budget, Washington, DC, 1947. http://rockyweb.cr.usgs.gov/nmpstds/nmas.html .

12. "Codes for the Identification of the States, the District of Columbia and the Outlying Areas of the United States, and Associated Areas," Federal Information Processing Standards (FIPS) Publications 5-2.. http://www.itl.nist.gov/fipspubs/fip5-2.htm

13. "Representation of Calendar Date for Information Interchange (ANSI X3.30-1997),": Federal Information Processing Standards (FIPS) Publications 6-1, 1998. http://www.nist.gov/y2k/fip4-2.htm

14. "Content Standard for Digital GeoSpatial Metadata" (V2.0, FGDC-STD-001-1998), Federal Geographic Data Committee, Washington, DC, 1998. http://www.fgdc.gov/metadata/contstan.html

15. "Development of a National Digital GeoSpatial Data Framework," , Federal Geographic Data Committee, Washington, DC, 1995. See http://www.fgdc.gov/framework/framdev.html for the full report, or http://www.fgdc.gov/publications/documents/framework/frameover.html for a summary

16. "NSDI Framework Introduction and Guide," Federal Geographic Data Committee, Washington, DC, 1997. http://www.fgdc.gov/framework/frameworkintroguide/

17. "Data Content Standard for Location and Identification of Facilities (Working Draft 2.0)," Federal Geographic Data Committee, Washington, DC, 1997. http://www.fgdc.gov/standards/status/sub3_3.html

18. "Address Content Standard (proposed)," Federal Geographic Data Committee, Washington, DC, 1997. http://www.fgdc.gov/standards/status/sub2_4.html

Appendix C – Implementation Procedures

(Informative)

This section includes guidelines for placement of Framework Road Segments (FTSeg) and Framework Road Segment Reference Points (FTRP). It also describes recommended procedures for implementing this standard, conventions for cartographic display of FTRP and FTSeg, and conformance testing.

1 Implementation Procedures

The NSDI Framework Transportation Identification Standard imposes only one constraint with respect to how a physical road is partitioned into FTSeg: segments must not span state borders. This section therefore provides a set of guidelines for placing FTRP and creating FTSeg that are expected to meet the needs of a great many – but not all – of those organizations that wish to participate in sharing road information. These guidelines are intended to be compatible with the practices of organizations that support network applications and require connectivity of the links and nodes which correspond to the FTSeg and FTRP defined in this standard.

The procedures recommended in these guidelines are consistent with the level of detail found in maps at scales ranging from 1:12,000 to 1:24,000. Many transportation databases are being created at these scales by digitizing from USGS quadrangles or from standard Digital Orthophoto Quarter Quadrangles (DOQQs). This section offers procedures and rules of good practice intended for use at this scale: other users developing databases at smaller or larger scales may need to consider departures from these procedures. These procedures are specifically not applicable to users whose applications are based on CAD-scale engineering databases that graphically depict roadway widths, curbs, right-of-ways, etc.

FTSeg should be created to represent those segments of roads about which attributes (including cartographic shape) are to be shared among organizations. Segmentation of roads into links which are specific to particular network applications (e.g., driveway-to-driveway road segments for E-911 dispatch, shopping center parking lots for transit buses, or back alleys for trash collection) do not require FTSeg unless they have associated with them information useful to other users or applications.

Road data authorities should coordinate the development of a road data base with all relevant stakeholders, particularly with respect to which roads should be included in a local implementation. The decision of which roads to include should reflect a reasonable compromise between an economical number of FTRP and FTSeg, and common network application needs of the stakeholders. *Example: A local E-911 agency may wish to incorporate intersections of local roads with private driveways. However, such a data structure would proliferate the number of FTSeg in the road database. Unless other cooperating road data authorities agree that this structure is useful, they should place FTRP only at intersections of public roads; the E-911 agency can create a supplemental road database using explicit connectivity to join driveways to local roads.*

1.1 Cartographic Representation of FTRP and FTSeg

1.1.1 Display of County and State Density

The state to which each FTSeg record pertains is encoded within the unique identifier, as is the state in which an Authority operates (with some exceptions.) This information, plus the coordinates of FTRP, can be used to display general location and density of FTRP and FTSeg records.

1.1.2 Display of FTRP and FTSeg

1.1.2.1 FTSeg should be depicted either by straight lines connecting two FTRP or by curved lines (if two or more FTSeg terminate at the same two FTRP.) Each FTSeg should be displayed as a line terminating in a single "arrow-head" at the "To-FTRP" terminus. Various line symbols and widths may be used. More realistic cartographic representation of FTSeg requires that they be linked to table(s) of attributes which include the coordinates of shape points.

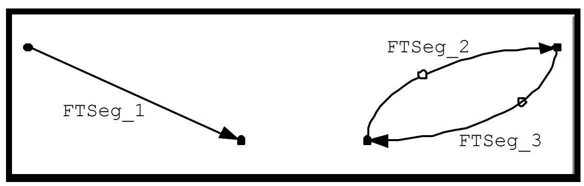

Figure 10 – Cartographic representation of FTSeg

1.1.2.2 Coordinate values (horizontal) and related accuracy statement fields are required within each FTRP record. Availability of this information will allow the cartographic display of point locations along with information about the known accuracy of each. FTRP should be symbolized as one of three representations of circles.

1.1.2.2.1 FTRP which terminate one or more FTSeg, and through which no FTSeg pass without terminating, should be represented by a filled circle. Such FTRP indicate terminal connectivity.

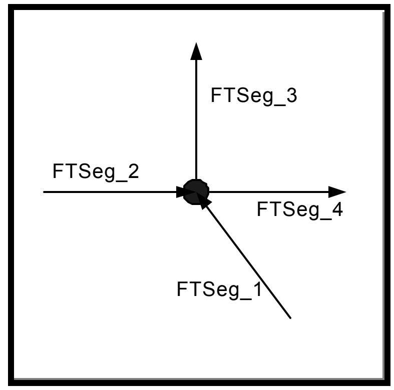

Figure 11 - Cartographic representation of terminal connectivity at an FTRP

1.1.2.2.2 FTRP which do not lie at the terminus of any FTSeg should be represented by an open circle; the lines representing FTSeg which pass through the FTRP should not be visible within the unfilled (opaque) center of the circle. Such FTRP might not indicate any FTSeg connectivity; e.g., they are used to indicate a unique Intermediate Point on an FTSeg. Alternatively, such FTRP might indicate implicit connectivity; e.g., two FTSeg cross at -- but do not terminate at -- an FTRP.

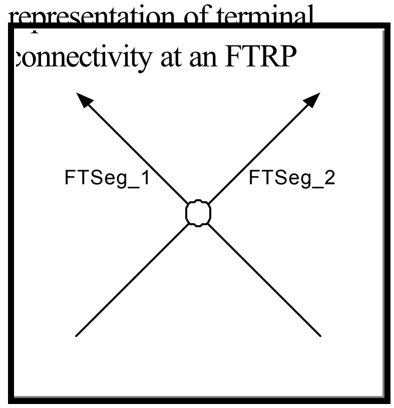

Figure 12 - Cartographic representation of no connectivity at an FTRP

1.1.2.2.3 FTRP which terminate one or more FTSeg, and through which one or more FTSeg pass without terminating, should be represented by an unfilled circle; the lines representing FTSeg which pass

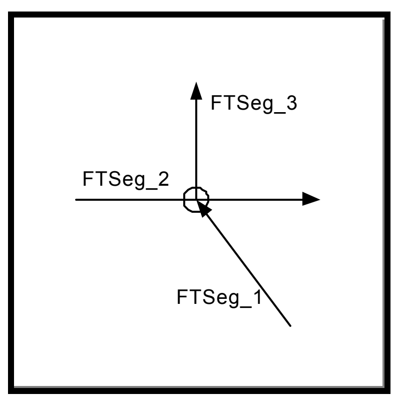

Figure 13 - Cartographic representation of mixed connectivity at an FTRP

through or terminate at the FTRP should be visible within the unfilled (transparent) center of the circle.

1.1.3 Relationship to Other Cartographic Elements

FTRP and FTSeg identifiers will be encoded as attributes associated with lines and intersections within geographic information systems, and associated with links and nodes in network representations. Cartographic representations which utilize FTRP and FTSeg should be carefully symbolized, labeled and/or annotated so that users do not impute to the FTRP and FTSeg position or precision which is not warranted, or confuse them with links and nodes. FTSeg have no shape points or inherent geometry, and need not have a measured length. Users will associate them with arcs and chains contained within their datasets, and display them as such. Such display of FTSeg will be necessary during the process of their initial definition and subsequent updates, and will be helpful to many users.

1.2 Establishing Framework Road Segment Reference Points (FTRP)

1.2.1 At Jurisdictional Boundaries

FTRP should be placed wherever a road crosses a jurisdictional boundary between two road data authorities. The road data authorities on either side of the jurisdictional boundary should coordinate the identification and placement of the FTRP so that one common FTRP is used to identify the crossing point. *Example: Two neighboring states should coordinate identification of FTRP at their common boundary with each other and with contiguous counties and/or other jurisdictions (where pertinent) who share the same boundary line(s).*

1.2.1.1 State and International Borders

FTRP must be placed wherever a road crosses a state border, regardless of whether or not there is a designated road data authority in the adjoining state or country. Such FTRP should terminate FTSeg representing any road which intersects the border.

1.2.1.2 County Boundaries

Authorities should consider placing an FTRP wherever a road crosses the boundary between two counties within a state. Even in those cases where the delineation of a county boundary is not easily located in the field, placement of an FTRP could facilitate coordination with authorities and road data users on either side of the boundary.

1.2.2 Simple Road Intersections

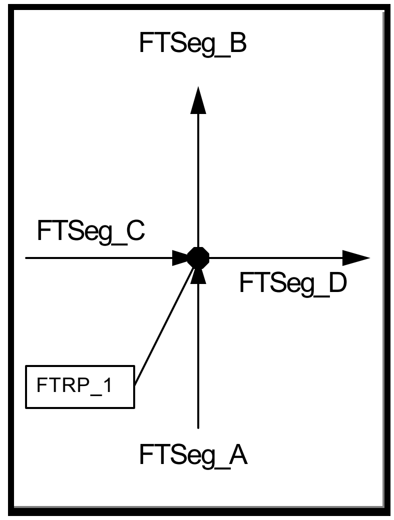

Figure 14 - Simple Road Intersection

An FTRP should be placed wherever two roads of similar functional class or importance cross one another at grade. Roads segments which share a common FTRP are connected terminally or explicitly; therefore no additional information is required in order to establish connectivity in any application network built from the road data. Road data authorities should identify those roads for which they want to ensure connectivity in all network applications and place FTRP at each intersection. *Example: A state DOT may wish initially to construct a statewide road base map, consisting only of state highways, U.S. routes and Interstate highways. FTRP would be placed only at the intersections of these roads. Intersections with county and local roads could be accommodated at some future time through explicit connectivity to FTSeg on the statewide road base map.*

A single FTRP can be created to represent the intersection of two or more roads; it can be used to terminate all segments of intersecting roads (illustrated in Figure 14 as terminal connectivity of segments FTSeg_A, B, C, and D.)

In addition, a single FTRP can be created to represent an intersection of two or more roads where not all segments of intersecting roads terminate (illustrated in Figure 15 as explicit connectivity of segments FTSeg_E, F, and G.) A cartographic convention used in this figure places an arrow-head at FTRP_2, where the FTRP breaks the "east-west" road into two segments[6]. FTSeg_G passes through the same point unbroken, as is indicated by the lack of an arrow-head at FTRP_2. FTRP_2 provides terminal connectivity between the two segments for which it serves as a terminus. If it also serves to connect one or more terminated segments to an unbroken segment, then the FTRP data record also provides for explicit connectivity to the unbroken other segment – illustrated as FTSeg_G.

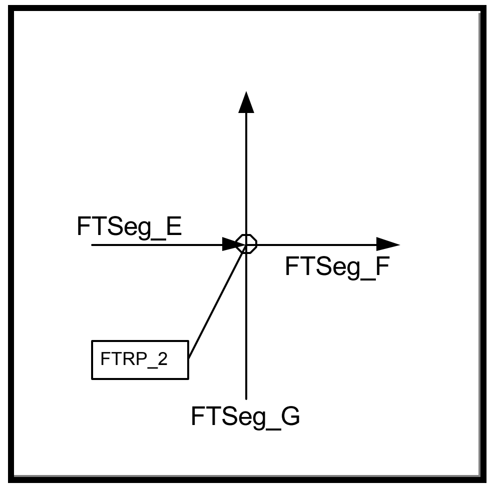

Figure 15 Simple Road Intersection

1.2.3 Offset Intersections

Occasionally, one road may intersect another at two distinct intersections offset by a short distance. In order to avoid creating a very short FTSeg, road data authorities should use an FTRP to represent explicit connectivity at only one of the intersections. Depending on the level

[6]See Implementation Procedures – Section 1.1 for recommenced cartographic conventions.

of spatial resolution represented in the road database, the second (offset) intersection may be joined using explicit connectivity, or the offset distance may be ignored and treated as a conventional at-grade intersection.

1.2.4 Overpasses and Underpasses

FTRP may be placed at grade-separated crossings such as overpasses or underpasses in order to meet several needs. First, if placed at such a crossing the FTRP could represent the terminal connectivity of two segments which terminate on the upper grade or the lower grade. Similarly, if segments terminate on both roads, two separate FTRP should be used to represent connectivity at the upper and lower termini. Finally, an FTRP can be placed at such an intersection and not serve as a terminal point of any segment; i.e., it could serve only as an "intermediate-point" of one of the segments. In summary, placement of an FTRP at such a location requires users to provide additional information in any network applications, so that users do not make unsupported assumptions about implicit connectivity.

1.2.5 Grade-Separated Interchanges

Grade-separated interchanges consist of one or more overpasses, and entrance and exit ramps to connect the otherwise non-intersecting main roads. In general, an FTRP does not need to be placed at the location of the overpassing roads if network connectivity can be established using the ramps. However, road data authorities may wish to place FTRP at interchanges in order to create manageable length road segments. *Example: On limited-access highways a state DOT may choose to establish FTSeg that go from interchange to interchange.*

If an FTRP is placed at a grade-separated interchange, it should only connect one of the two crossing roads, not both. In other words, the FTRP should serve as the end point for only two FTSeg, either the over passing road or the under passing road, but not both. If the transportation data authority chooses to segment both roads at the interchange, two unique FTRP should be created, one connecting the over passing road, and one connecting the under passing road. These FTRP may either be assigned the same X-Y coordinate values, or may be offset from one another.

1.2.5.1 Entrance and Exit Ramps

An FTRP should not terminate a segment of a road at every gore point (i.e., intersection) where the road is joined by entrance or exit ramps. To do so would divide the road into a large number of very short FTSeg in the vicinity of the interchange. Entrance and exit ramps are better handled using explicit connectivity to join the end point of the ramp to the main road at some specified offset distance along a segment of the road.

1.3 Establishing Framework transportation Segments (FTSeg)

A single FTSeg represents an unambiguously defined path along a physical transportation network between two FTRP. In most instances, FTRP can and should be selected in such a way that there is only one path between them along a transportation network In cases where two or more uninterrupted paths exist between the same two FTRP, the fields for Intermediate-Point and Path-Description in the FTSeg record must be used to differentiate among the paths. Transportation data authorities with overlapping responsibilities for a geographic area should coordinate the identification of FTSeg. *Example: A state DOT and a county road authority are both responsible for building a road framework data base for the county. The technical staff for each agency should agree on which agency has responsibility for identifying FTSeg of which roads (e.g., the state DOT authority designates FTSeg for all Federal and state sign routes, while the county authority designates FTSeg for all county routes and local roads).*

1.3.1 Segment Length

The appropriate FTSeg length represents a tradeoff between maintaining information on a large number of short segments, and potential errors introduced by measurements over a long linear segment. This standard prohibits segments which span boundary lines of states, territories, or equivalent jurisdictions. Transportation data authorities within a particular geography will need to assess whether more restrictive guidelines regarding FTSeg length are needed to support common applications among various transportation database users within that geography.

1.3.1.1 Roads that Cross Jurisdictional Boundaries

Roads that cross state and county jurisdictional lines should be represented by FTSeg that terminate at the boundaries. Consequently, no FTSeg should be longer than the driving distance across a state; in all but the most rural areas, authorities should consider terminating FTSeg at county boundaries.

1.3.1.2 Roads that Coincide with Jurisdictional Boundaries

Roads which run along a jurisdictional boundary should be represented by FTSeg whose length does not exceed the line dividing the jurisdictions. When a road runs along a jurisdictional boundary for a portion of the boundary length, an FTSeg should be terminated where it leaves the boundary line, and a new FTSeg should be initiated – except in locations where local authorities determine that the departure from the boundary line is insignificant. Part III-D of this standard provides an example.

1.3.2 Road Types

The decision to represent a particular road by a single FTSeg or two (or more) parallel FTSeg should be based on scale, accuracy, cartographic and network application requirements. In general, network applications are facilitated where FTSeg and FTRP can be directly replaced by network links and nodes. These guidelines are aimed at minimizing additional work beyond establishing explicit connections for FTSeg to create a flowable transportation network.

1.3.2.1 Roads with no Access Restrictions or Medians

One-way and two-way roads with no significant access restrictions or physical median separating directional roadways should be represented by a single FTSeg. Most local streets, connectors, and minor arterials fall into this category.

1.3.2.2 Roads with Center Medians but no Access Restrictions

Some major urban and rural arterials have a center median which divides the travel lanes in each direction (e.g., Commonwealth Avenue in Boston). However, intersecting streets can access either direction of travel lanes via short transportation segments crossing the median at each intersection. These roads may be represented either by a single FTSeg which ignores the center median, or by two parallel FTSeg depicting directional roadways on either side of the median. If parallel FTSeg are used, intersecting FTSeg should be terminated at only one of the two parallel FTSeg, not both.

1.3.2.3 Limited-Access Divided Highways

Most Interstate Highways and major, high speed expressways can only be entered or exited via specifically designated ramps. These roads almost always have some median strip or other physical barrier that prohibits vehicles from reversing direction without first exiting the highway at a designated ramp. These roads should always be represented by two FTSeg regardless of the actual physical separation between the lanes (e.g., even roads which are separated by a concrete “Jersey Barrier” should represented by two FTSeg if each direction is served by its own entrance and exit ramps.)

1.3.2.4 Physically Separated, Limited-Access Parallel Lanes

Some high volume roads, particularly in urban areas, may designate certain lanes for high occupancy vehicles (HOV) or auto-only, and physically separate these lanes from the main travel lanes (e.g., I-395 in northern Virginia, or the New Jersey Turnpike outside New York City). If these physically separated lanes are served by their own entrance and exit ramps, they should be represented by their own FTSeg. Furthermore, if the priority lanes are also separated directionally, each direction should be represented by its own FTSeg. *Example: The northern end of the New Jersey Turnpike includes physically separated auto-only lanes, running parallel to the main traffic lanes in both directions. Both the main lanes and the auto-only lanes have their own entrance and exit ramps. This facility should be* *represented by four parallel FTSeg – one for each direction of the main lanes and one for each direction of the auto-only lanes.*

1.3.2.5 Entrance and Exit Ramps

Entrance and exit ramps are one-way or two-way roads that provide general vehicle access to limited-access highways. Each entrance or exit ramp should be represented by an FTSeg. FTRP which terminate entrance or exit ramps should use explicit connectivity to join with the main road which the ramp accesses.

1.3.2.6 Frontage Roads

A frontage or access road is a one- or two way, unlimited-access surface street that parallels but is physically separated from a more limited-access major arterial. Its main purpose is to provide access to establishments along the major arterial corridor while preventing access traffic from disrupting the flow of through traffic on the major arterial. Access from the frontage road to the major arterial is typically limited to intersections of cross-streets and/or specifically designated “gaps” in the median or physical barrier. Frontage roads should be represented by their own FTSeg. Entrance “gaps” between the frontage road and the main arterial should be treated similar to an entrance or exit ramp.

1.3.2.7 “Stacked” Highways

A stacked highway occurs when one road or directional roadway is built above another roadway. Although the two roads are separated vertically, when displayed on a two-dimensional surface (e.g., map or computer monitor) they appear as a single line. Each road or directional roadway should always be represented by its own FTSeg, regardless of how they might be displayed.

1.3.3 Complex Intersections

The preceding guidelines provide rules for placing FTRP and using FTSeg to represent various types of transportation features in a generally consistent way and without creating short, difficult to locate FTSeg. The following examples illustrate some typical combinations of roads and intersections and how they might be represented using FTRP, FTSeg, and explicit connectivity relationships.

1.3.3.1 Full Interchange, Two Limited-Access Divided Highways

The classic "cloverleaf" interchange and its assorted variations of ramps provides network connections between two crossing, limited-access divided highways such that there exists a

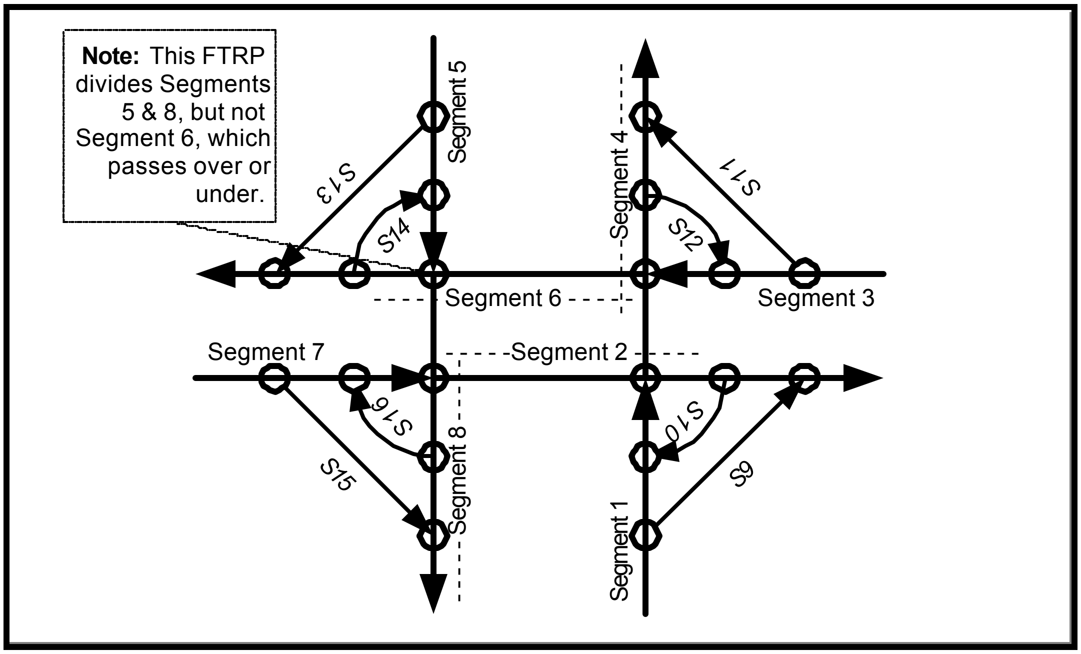

Figure 16 Full Interchange, Two Limited-Access Divided Highways

valid network connection from any directional roadway to any other roadway. Each directional roadway should be split only once within the interchange. This can be done by splitting each incoming directional roadway where it first crosses (either as an overpass or underpass) a directional roadway of the other highway. Only the incoming FTSeg is split; the FTRP does not split the crossing directional roadway at this point; the "Note" in Figure 16 highlights this. The resulting configuration consists of four FTRP, one at each of the four corners of the intersecting directional roadways. However, each of these FTRP connects only two of the four apparently intersecting lines. Ramps are added to the interchange using explicit connectivity to join each endpoint of the ramp to one of the directional roadways of the crossing highways. The resulting interchange consists of eight FTSeg for the main highways (each of the four directional roadways is split into two FTSeg), and up to eight FTSeg for the interchange ramps.

1.3.3.2 "Diamond" Interchange

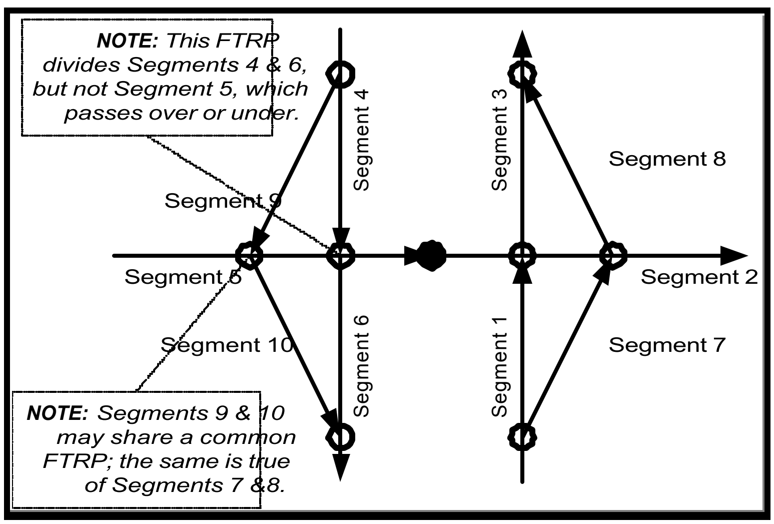

Figure 17 - "Diamond" Interchange

The classic "diamond" interchange provides a network connection between a limited-access divided highway and a two-way surface roadway. On the divided highway, each directional roadway should be split where it crosses (either as an overpass or underpass) the two-way street. As with the full cloverleaf interchange, the FTRP on the directional roadway does not split the crossing two-way street. The two-way street should be split either by a second FTRP assigned the same X-Y coordinate values as one of the two FTRP of the directional roadways, or by an FTRP located "between" the two directional roadways, as illustrated above. Ramps are added to the interchange using explicit connectivity to join one endpoint of the ramp to one of the directional roadways of the divided highway and the other endpoint to a location on the two-way roadway. The resulting interchange consists of six FTSeg for the crossing roads, and four FTSeg for the interchange ramps.

1.3.3.3 Intersection: Two-Way Surface Street with a Center Median Surface Street

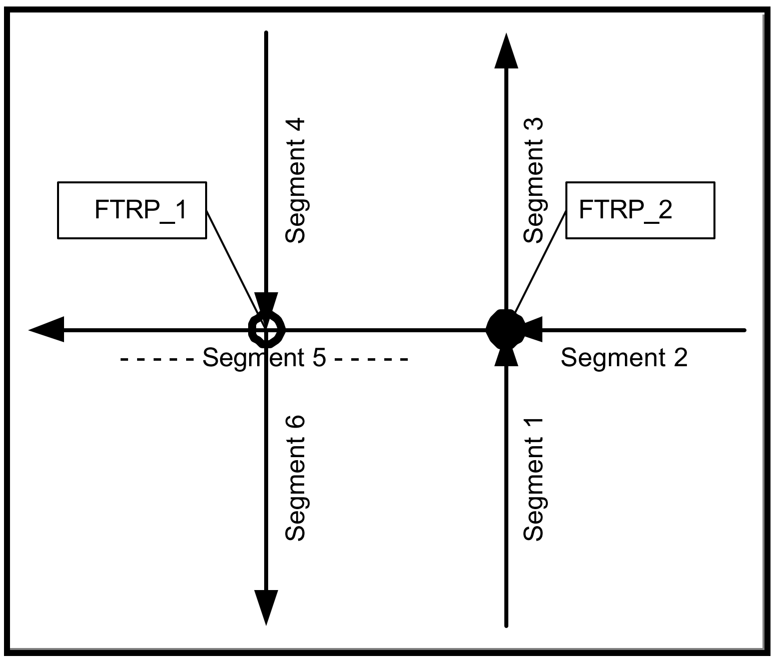

Figure 18 - Intersection: Two-Way Surface Street with a Center Median Surface Street

This intersection looks similar to the “diamond” interchange, except that there are no overpassing roads: the two-way crossing street actually intersects each directional roadway. In order to avoid creating a very short FTSeg representing the road surface crossing the median area, a single FTRP should be placed at one of the two intersections that splits both the crossing two-way roadway and one of the two directional roadways. This is labeled as “FTRP-2" in Figure 18. The other directional roadway should be split with an FTRP

-- labeled as “FTRP-1" -- that indicates explicit connectivity to the FTSeg that represents the crossing two-way road. The resulting intersection consists of six FTSeg and two FTRP.

1.3.3.4 Traffic Circle

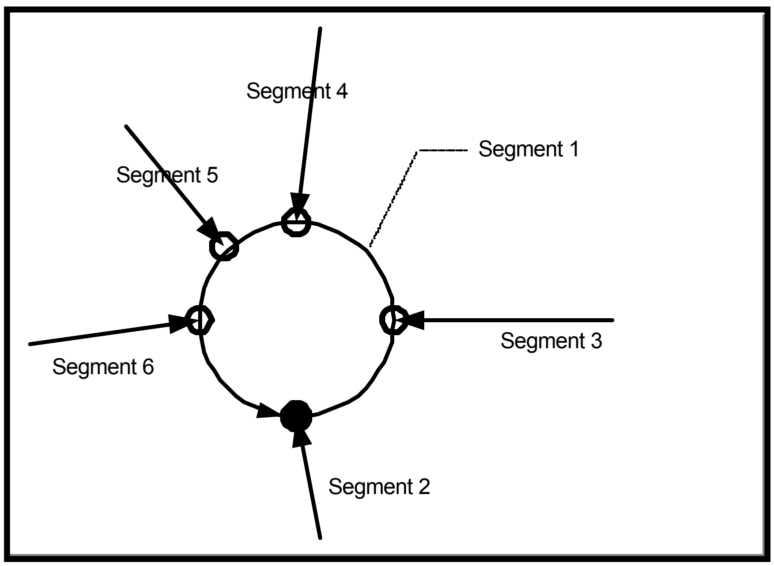

Figure 19 - Traffic Circle

A traffic circle consists of a circular loop road that is intersected by several other roads which radiate outward from the circle. The traffic circle should be represented either as a single FTSeg that begins and ends at the same FTRP (illustrated in Figure 19), or by two FTSeg that each represent some portion of the circle. The FTRP marking the intersection of each radiating road should be connected to the traffic circle FTSeg using explicit connectivity to avoid creating short FTSeg between each radiating road. The path description for the FTSeg representing the traffic circle should include a direction (either clockwise or counterclockwise) to indicate the order in which the radiating roads intersect. One of the radiating roads may share the same FTRP as the traffic circle FTSeg.

1.4 Creating New or Updated FTSeg and FTRP

Multiple FTRP and FTSeg records can exist for any point or segment, because their multi-part key includes “Authority-ID” and “Date”. *“Creating”* FTRP and FTSeg refers to generating a record keyed with a new and unique FTRP-ID or FTSeg-ID. *“Updating”* FTRP and FTSeg refers to creating a new database record for a previously-identified FTSeg or FTRP. Each “update” record will utilize an already-defined FTRP-ID or FTSeg-ID, and use a new and unique combination of “Authority-ID” and “Date” information.

In the normal course of events authorities will update records to reflect improvements in description or measurement for the same point or segment – even if there is no change in the “real world” features represented by the FTRP or FTSeg. Older database records are retained in the index along with the database records which reflect “updates” to non-key information fields.

1.4.1 Road reconstruction

New FTRP and/or FTSeg records must be created when FTRP are relocated and FTSeg are re-defined during the (re-)construction of roads or changes in intersection alignment. This requires retirement of old FTRP and associated FTSeg, and creation of updated FTRP and FTSeg, as described below. The unique identifier for FTRP and/or FTSeg records which are retired as a result of (re)construction may be encoded within other records to which the retired objects are topologically connected. Affected records may occur in FTRP and FTSeg tables, as well as the Connectivity and Equivalency tables. Therefore the references in these other records must be updated with the identities of the objects which have replaced the retired objects, or the records must be retired.

1.4.2 Re-measuring

FTRP and/or FTSeg records should be updated when more accurate measurement of coordinates/lengths are obtained. This entails creating new records with a unique key made up of the FTSeg-ID and/or FTRP-ID, the Authority-ID, and the Date, updating the information in other fields (as appropriate), and carrying forward information from fields which are not updated.

1.5 Retiring FTSeg and FTRP

1.5.1 Road reconstruction

As stated above, new FTRP and FTSeg should be created during the construction or reconstruction of roads; e.g., addition of ramps, or changes in intersection alignment. Those

FTRP and FTSeg used exclusively to designate the (old) feature which has been reconstructed should be retired by changing the "Status" of all records which identify the (old) feature from "A" (active) to "R" (retired).

1.5.2 FTRP Duplication

Instances can occur in which two authorities create unique FTRP IDs which identify the same "real world" feature.

1.5.2.1 Before identifying new FTRP each authority should evaluate existing FTRP records maintained in the distributed index, and should coordinate with other authorities concerned about the same or contiguous geography, in order to prevent such duplication. Analysis of the"AAAAA" substrings and the coordinates of existing FTRP identifiers will in most cases allow an authority to avoid duplication.

1.5.2.2 When authorities verify that duplicate FTRP-IDs exist for the same feature, they should retain the unique ID which has the earliest date of assignment. All FTRP and FTSeg records which contain a duplicate ID should be retired by changing their "Status" to "R" (retired). Any useful information which is contained within these (retired) records should be copied into active records that contain the ID which has been retained, and that are identified uniquely as to "Authority-ID" and "Date".

Example: Two neighboring jurisdictions use and update two different road base maps, and have not coordinated activities in the past. They independently identify FTRP that describe identical "real world" features at their shared border. They should review coordinate and description data in order to select and analyze possible duplicates, whether at the level of a sub-county border, a county border, or a state border. They should retain the oldest of each set of duplicate records as "active," update these with any useful information from records which are to be retired, and change the status of newer duplicate records to "retired."

1.6 The Distributed Index of Transportation Authorities, FTSeg, and FTRP

1.6.1 Transportation Authorities

Part II of this standard describes the role of NSDI Framework Transportation Authorities and the coding of a unique identifier and attributes for each. Designation as an authority is voluntary and self-initiated by any organization which performs the role(s) described.

1.6.1.1 Initial Assignment and Maintenance

The initial assignment and maintenance of each unique authority identifier will be performed by the FGDC or one of its participating agency. These functions will be implemented within a WWW-based software application providing for data entry and validation, assignment of an ID and password, and search and download functions.

1.6.1.2 Access

Provision of access to the indexed database of authorities and the public dissemination of information about each authority will be the ongoing responsibility of the FGDC or a participating agency. Access and information about authorities will be available through the WWW and in printed form.

1.6.2 Points and Segments

Part II of this standard describes the specification of Framework Road Segments and Framework Reference Points, and the coding of unique identifiers, the record structure, and attributes for each. This section describes the procedures by which records describing each point and segment are established, maintained, and made accessible to the public.

1.6.2.1 Initial Assignment (Creation) and Maintenance of FTSeg and FTRP Records (voluntary & distributed)

The FGDC or one of its participating agencies will implement a WWW-based software application providing for data entry and validation, assignment of an ID and password, and search and download functions. This database application will operate in a fashion very similar to the FGDC Metadata Clearinghouse application.

The index will operate on a central server(s), and the same application will be provided to Authorities who wish to provide their own indices of FTSeg and FTRP. The data will be maintained on this decentralized network of servers – each authority need not operate the application; multiple Authorities can cooperate in hosting the application. Search, display and download functions will be publicly accessible. Each Authority will have the secure ability to make add-update transactions for records containing its unique Authority-ID. Any Authority will have the ability to create uniquely-keyed “update” records relating to an FTRP or FTSeg which has been defined previously.

1.6.2.2 Access

Provision of access to the indexed database of FTSeg and FTRP, and the public dissemination of information about the data will be the ongoing responsibility of the FGDC or a participating agency, and of participating Authorities. Access and information about FTSeg and FTRP will be available through the WWW and in printed form.

1.7 Defining FTSeg and FTRP within a Geographic Area

The implementation of this standard requires development of consensus among a limited number of authorities who create and update transportation data within a specified geographic area. Those participating will have a thorough knowledge of NSDI Framework principles and roles, and will likely be performing several of the identified functions of Framework management. The tasks that they will have to accomplish in order to implement this standard are summarized below.

1.7.1 Geographic Extent

Implementation of the standard should be attempted within an explicitly bounded geographic area consisting of one state, or a sub-state area. The extent of this area must be determined by all organizations which may wish to share data within the area, or to become cooperating authorities. Often the choice made will be closely linked with the following task.

1.7.2 Cooperating Authorities

All organizations which develop or maintain road centerline databases should be informed of efforts to implement the standard, and should be invited to participate. Agencies of the U.S. Departments of Interior, Transportation, Commerce, and others may want to participate, depending upon the geographic area. It is likely that successful completion of this and related tasks depends upon the willingness of one organization to assume a leadership role in gaining the cooperation of others. Each participating organization should recognize that the incentive to incur the workload of implementation consists of future enhancements in its ability to share data which supports key business functions, and consequent reductions in the costs of sharing data.

Those organizations that agree to implement the standard should make their commitment explicit, and should determine that the institutional relationships required for data sharing with others are or can be put in place. Other organizations which operate applications that require or would benefit from improved sharing of transportation data – but which do not actually develop or maintain data – should also be informed. No commitment is required from these other organizations.

1.7.3 Contiguous Jurisdictions

Major state-level or sub-state data producers in contiguous jurisdictions should be identified and informed of efforts. The current status of data sharing operations at relevant jurisdictional lines should be assessed. When practical, organizations which might serve as authorities should be identified, and their cooperation in identifying FTRP at boundaries should be sought.

1.7.4 Inventory of Databases and Applications

Once the questions of "Who?" and "Where?" have been addressed, participants should inventory all transportation database development and maintenance operations which will be affected by the implementation of the standard. Participants should also inventory the applications which depend upon the transportation data, and the value of the improved data sharing which is likely to result from use of the standard. Particular attention should be given to the networks which have been developed, their commonalities and differences. The common requirements of applications will lead authorities to determine whether or not county and/or local and/or private roads should be included in an initial implementation.

1.7.5 Base Data for Initial Assignment

Participants will have to examine available data assets to determine the extent to which nationally or locally available sets of names, points and lines, or links and nodes may provide a "starting point" for implementation. *Example: In a large rural area, locally-enhanced TIGER line file data and a "starter set" of points such as the ITS Datum Prototype Version 1.1 CD may provide the basis for determining the local scope of an initial implementation of* *the standard. In a more urbanized area where road names are well-known, used, and stable, a larger-scale local database which includes network nodes and links based on unique road names may be a better point for initial creation of FTSeg and FTRP records.*

1.7.6 Prototype Implementation

Within a limited section of the geographic area cooperating authorities should do a prototype implementation, utilizing this standard and other locally-developed guidelines for achieving FTRP densities and FTSeg spans that best meet their needs. All data records should be accorded the STATUS of “Proposed.” All cooperating authorities should then attempt to embed the FTRP and FTSeg identifying information within their own data structures, determine any difficulties, and agree on refinements in the implementation. Following implementation of the prototype, cooperating authorities should determine the sequence and timing of operations to implement the standard within the geographic area selected. Authorities should populate identifying records in the Index of Authorities, and cooperators should identify the Index of FTRP and FTSeg which will be the registry for their information.

1.8 Establishing Object Identity and Connectivity

Each Framework transportation data developer will have to know some characteristics of multiple transportation databases which may be under development or maintenance within the developer's geographic extent, and those which may exist at the boundaries of that extent. The data developer will very likely want to implement this standard in such a way as to assure that other users will be able to relate and connect their databases. *Example: In a particular jurisdiction two authorities may have separate representations of the same transportation features; differences in scale and applications could mean that some roads are represented by parallel FTSeg for one authority, and by single FTSeg for the other. Each developer will need to make additional application-based decisions about the logical relationship between the single-line and dual-line representations of the same physical transportation segments and the relationship of attributes associated with each, in order to share each others' information. The developers will have to decide whether they can implement the standard by agreeing on a single set of FTRP and FTSeg identifiers, or by agreeing to relate two sets through extensive use of equivalency table records, or a combination of both strategies.*

1.8.1 Implementation Sequence (Overview)

Data developers can establish object identity relationships and connectivity by making the following analysis of their Framework transportation environment:

1.8.1.1 Inventory Transportation Data Organizations and Databases – What organizations maintain transportation data within the geographic extent in question? At its boundaries?

What transportation databases exist within this area? At its boundaries? At what scale, with what spatial accuracy, and with what attribution?

1.8.1.2 Assess Current and Projected Conformance with this Standard – Are these organizations registered Framework Transportation authorities? Do they plan to become authorities?

Do registered FTSeg and FTRP exist within this area? Do registered FTRP exist at its boundaries?

1.8.1.3 Utilize Existing FTSeg and FTRP as much as Practical – Have other Authorities identified FTSeg which represent the same transportation features in your database?

Can you utilize existing FTRP to define new FTSeg, updating FTRP records when helpful, and identifying new FTRP only when necessary?

1.8.2 Implementation Sequence (Detail)

1.8.2.1 Inventory Transportation Data Organizations and Databases

Designation of FTSeg and FTRP should not be undertaken without an understanding of the specific business benefits which will accrue. Most often these are benefits which arise from sharing data with other database developers within the specific geography, and/or from establishing connectivity with transportation databases covering contiguous jurisdictions.

Identification of all organizations which are or may become authorities within and contiguous to the specific geography is necessary to the building of a "business case" for implementing the Standard. The technologies used, business missions, and policy environments of all such organizations should be well-understood, as they impact the ability of organizations to participate in the NSDI Framework. Likewise, all transportation databases which might be pertinent to sharing or connectivity should be inventoried as to scale, accuracy and attribution, in order to better understand the potential costs and benefits of sharing data or connecting to them.

1.8.2.2 Assess Current and Projected Conformance with this Standard

Identification of any transportation databases which are candidates for inclusion in the NSDI Framework should lead to more detailed analysis. A data developer who will implement this Standard should:

1.8.2.2.1 Identify other registered Framework transportation authorities operating within or contiguous to the specific geography;

1.8.2.2.2 Develop thorough FGDC-standardized metadata for Framework transportation databases, and acquire metadata for other candidate databases maintained by other authorities;

1.8.2.2.3 Determine applicability of other relevant standards to the databases, and assess compliance with those standards;

1.8.2.2.4 Determine whether registered FTRP exist within this area, or at its boundaries, and whether FTSeg have already been identified within this area.

1.8.2.3 Utilize Existing FTSeg and FTRP as much as Practical

A data developer should seek to utilize the unique identifiers of all FTRP and FTSeg which describe the same physical transportation features as are represented in the candidate database. A data developer who will implement this Standard should:

1.8.2.3.1 Identify all registered FTRP and FTSeg which exist within and at the boundary of the specific geography

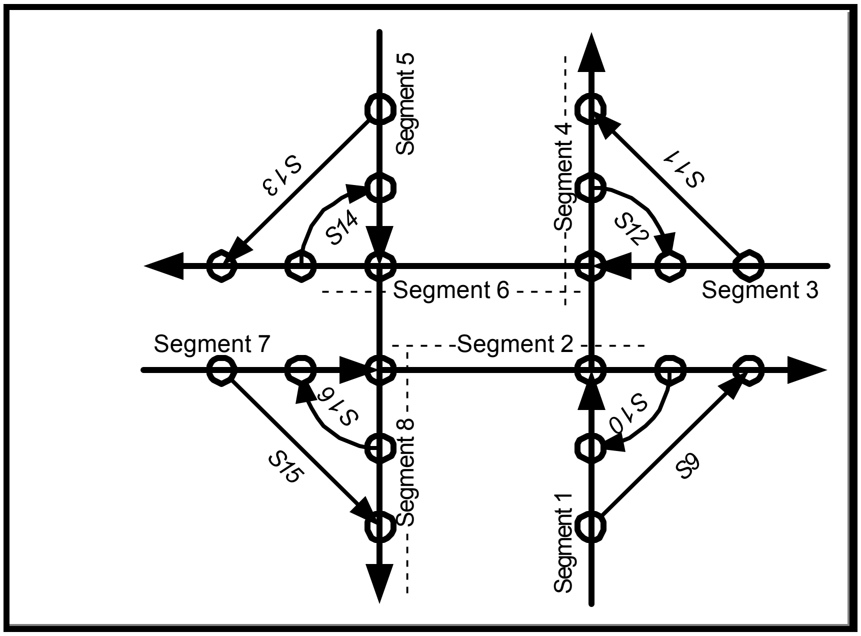

Figure 20 - Utilizing existing FTRP and FTSeg

1.8.2.3.2 Acquire a copy of the database(s) in which FTSeg identifiers are assigned to the spatial data, and encode the same FTSeg on the appropriate segments in the candidate database. *Example: Figure 20 might illustrate FTSeg identified by two different authorities. A developer of a "larger scale" database might implement this Standard in an area where a developer of"intermediate scale" data had already identified Segments 1-8. The first developer should utilize these FTSeg identifiers, updating FTRP records as necessary, and should add new ones only for Segments 9-16.*

1.8.2.3.3 Create new FTRP records only when necessary. FTRP are required as termination points for each FTSeg, required to establish the uniqueness of multiple paths between a pair of FTRP, and may be used at other locations. Creation of new records should follow procedures stated in the following section.

1.9 Conformance Testing

FTSeg and FTRP consist of information which can be structured into tables of information, and then exchanged with others who find the information useful, or combined into larger tables of like information. FTRP and FTSeg may relate to spatial features, objects, or spatial data records contained within individual geographic information systems. Conformance tests are specified in order to assure that the information associated with each FTRP and FTSeg -- and with related attributes -- meets stated content requirements, and that the format of each record is compatible with that used by others who create or update FTSeg and FTRP records.

1.9.1 FTRP and FTSeg Geometry

FTRP and FTSeg are intended to be developed and exchanged without implied geometry; this standard does not include specifications relating to geometry.

1.9.2 Record Content

1.9.2.1 The content of each of the following fields in the FTRP and FTSeg records shall fall within the specified range or domain, as described in Part II of this standard.

1.9.2.1.1 The content of the substrings of unique FTRP and FTSeg identifiers referred to as “AAAAA” and the content of the field “Authority-ID” within FTRP and FTSeg records shall be verifiable when compared against the unique identifiers maintained in the NSDI Framework Authority Index.

1.9.2.1.2 The content of the substrings of unique FTRP and FTSeg identifiers referred to as “O” shall fall within the domain of defined objects: “S” (Segment) or “P” (Point.)

1.9.2.1.3 The content of the substrings of unique FTRP and FTSeg identifiers referred to as “XXXXXXXXX” shall consist of nine alphanumeric characters.

1.9.2.1.4 The content of all date fields shall be valid dates greater that “19990101"

1.9.2.1.5 In records detailing related attributes and equivalency the value of the “End-Offset” shall be greater than the value of the “Start-Offset.”

1.9.2.2 The content of other required fields in each FTRP, FTSeg, and related attribute record shall be within specified domains. When not “blank,” the content of each optional field shall be within specified domains. The content of each conditional field shall be within specified domains when the stated condition is "true."

1.9.3 Consistency of FTRP and FTSeg Records

The unique identifiers FTRP named as the From-End-Point and To-End-Point within an FTSeg record must exist within the distributed registry of FTRP, and the unique identifier of the FTSeg-ID required in some FTRP records must exist within the distributed registry of FTSeg.

1.9.4 FTRP and FTSeg Topology

All topological relationships among FTRP and FTSeg are explicitly declared within the Connectivity Table defined in Section 2.4.1 of this standard.

1.9.4.1 At least one record in the Connectivity Table shall contain the unique identifier of each FTSeg and each FTRP.

1.9.4.2 At least two records in the Connectivity Table shall contain the unique identifier of each FTRP at which any connectivity occurs.

1.9.5 Record Format

Data described in this Standard should be exchanged in a common (ASCII) format which can be generated and interpreted by commercial-off-the-shelf (COTS) software.

1.9.5.1 The first line of characters contained in the file should consist of “FTRP” or “FTSeg” or “Attribute” or “Equivalency” or “Authority” , followed by a <Carriage Return / Line Feed> to indicate the type of content in the file.

1.9.5.2 Each record contained in the file should commence on a new line, may be of variable length, and should conclude with <Carriage Return / Line Feed>.

1.9.5.3 Each field should be part of the record -- even if blank (null), and should be of the specified format and length, with the exception of free text fields, which should not exceed the specified length. Each field should be separated from the field preceding and following by a <Tab> character.

1.9.6 Validation

The FGDC will provide computer software which can read and interpret files of information formatted as specified. The software will include a facility for performing all checks on record content specified in this standard, and for providing the user with reports detailing features of particular records which do not meet specifications for content.

Appendix D – Examples

(Informative)

The following are intended to serve as examples of how users of this standard might implement and maintain information about FTRP and FTSeg.

1 Improvements in FTRP over time

Within a particular geographic area additional FTRP can be identified over time, and existing FTRP can be improved by the creation of newer records containing upgraded Locational_description, Accuracy_statement or coordinate values. The addition or improvement of existing FTRP is not a matter of improving density or accuracy of points, as most often understood in establishment of geodetic control. Nor need the sequence or densification of FTRP over time correspond to a "top-down" hierarchy in the development of Framework transportation data.

Most typically FTRP extracted from Federal-level databases will be less dense and less accurate, because of the scale and the transportation features of interest to Federal users of data. FTRP derived from local-level databases will very likely contain more complete locational_descriptions and accurate coordinates and – where such databases exist – may be developed sooner than (or instead of) FTRP derived from at the Federal level.

Figure 21 is intended to illustrate how an FTRP which serves as the end points for `FTSeg_98` and `FTSeg_96` could be improved over time:

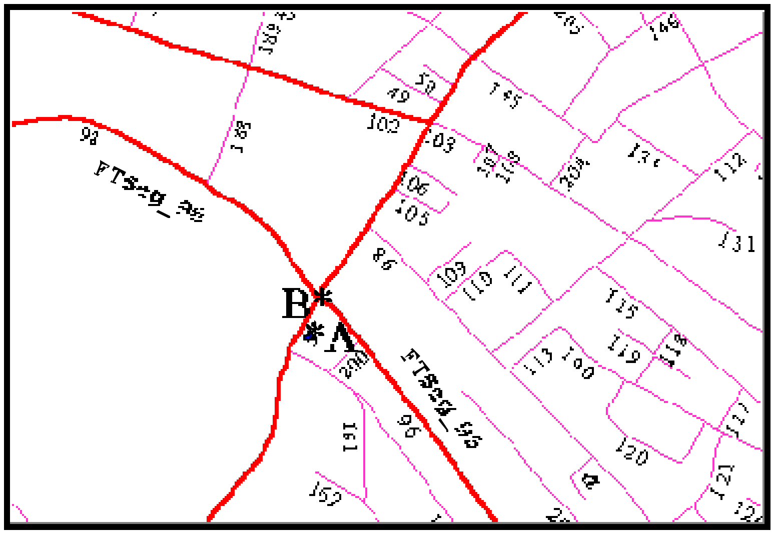

Figure 21 – Improvements in FTRP over time

ID	Auth.	Date	Description & Accuracy Statement	LAT.	LONG.
A	US-DOT	1996-0101	Intersection of Vermont Route 12 and US Route 2 in Montpelier (VT); position extracted from ITS Datum Prototype,V1.1; estimated accuracy = +/-80 ft	44.25738	-72.5783
B	City	1998-0101	Intersection of road center lines of Vermont Route 12 and US Route 2 in Montpelier (VT); position based on 1:5000 digital Ortho photograph; estimated accuracy = +/- 11 ft.	44.25739	-72.5782

2 Economical Placement of FTRP

Figure 22 shows the designation of an FTRP (`P3`) at the intersection of a state highway and a county road. Both physical roads are represented as FTSeg which terminate at this intersection. Additional FTRP should not be introduced to mark the intersection with a driveway or with a local road which is not assigned an FTSeg.

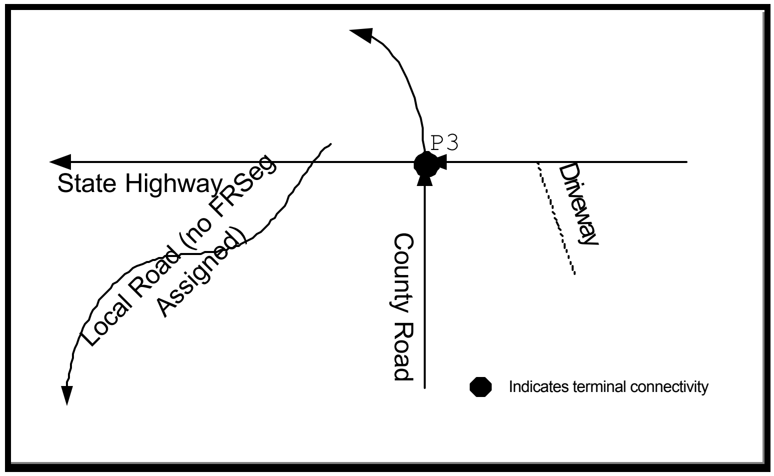

Figure 22 Economical placement of FTRP with regard to intersections

3 Transportation Segments and Sub-state Jurisdictional Boundary Lines

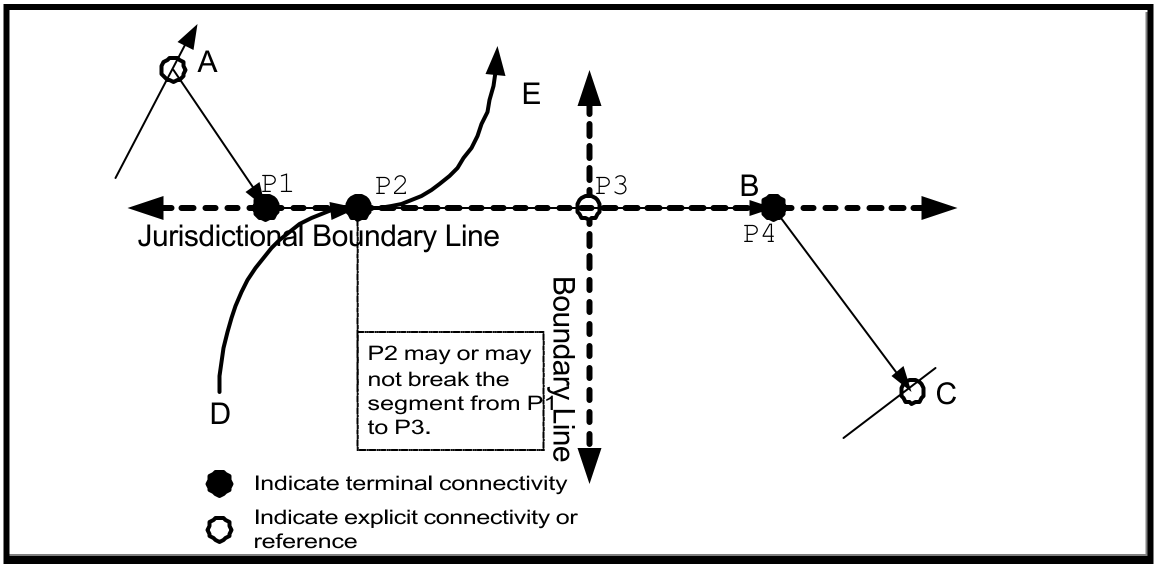

Figure 23 - Roads on or crossing Boundaries

Figure 23 illustrates the identification of FTRP at various points in and around the intersection of roads with a sub-state boundary. A road runs from point "A" to point "C", running along several township or county boundaries, passing through the shared corner of four jurisdictions, and taking a short departure from the boundary around point "B". In this example the transportation segments terminate at points "A" and "C," and these FTRP explicitly connect these segments to other segments not illustrated. Further, FTRP "P1" and "P4" would be used to terminally connect segments at the points where the road leaves the county boundary. "P3" would be a reference FTRP which identifies the point where the road crosses a boundary line which separates one pair of jurisdictions from a different pair of jurisdictions. Additional FTRP would be identified around point “B” only if transportation authorities determine that it is made up of significant segments.

Additionally, an FTRP could (optionally) be defined at“P2" – the point where road “D-E” intersects the jurisdictional boundary. Point “P2" could terminally connect segments of road “D-E,” but need not break the FTSeg between P1 and P4. P2 would break this segment only if transportation authorities determined that creation of two FTSeg between P1 and P4 would be helpful for data sharing.

4 Road (Re)Construction

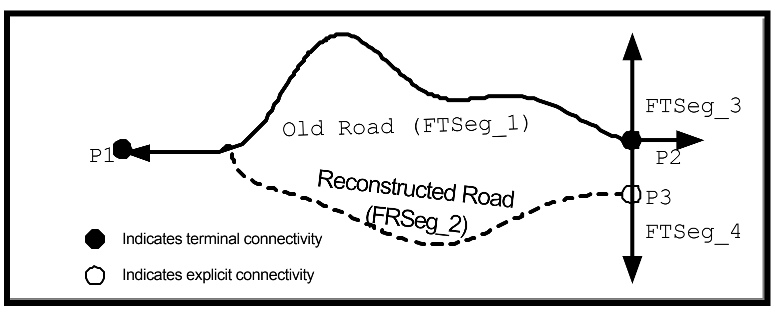

Figure 24 - Road Reconstruction

The “Old Road” `FTSeg_1` ran from point “P1" to the intersection at reference point “P2,” where it implicitly connected with `FTSeg_3` and `FTSeg_4`. It has been replaced by a reconstructed `FTSeg_2`, which terminates at the new “P3.” P2 and P3 may be at nearby locations; but P2 must be retained as a terminus of `FTSeg_3` and `FTSeg_4`, as well as the unnamed segment which runs to the right edge of

Figure 24. P3 must be created in order to reflect the creation of `FTSeg_2`, and is explicitly connected to `FTSeg_4` at some offset along its length. The following records need to be created, updated and retired:

	Segment / Point ID	Action	Description
Action 1	FTSeg_1	Retire	Old road is discontinued
Action 2	FTSeg_2	Create	New road is constructed
Action 3	P2	Update	Modify description to reflect retirement of FTSeg_1
Action 4	P3	Create	Create new record reflecting reconstructed reference point of FTSeg_2

5 Integration of Multiple FTRP and FTSeg at a Complex Intersection

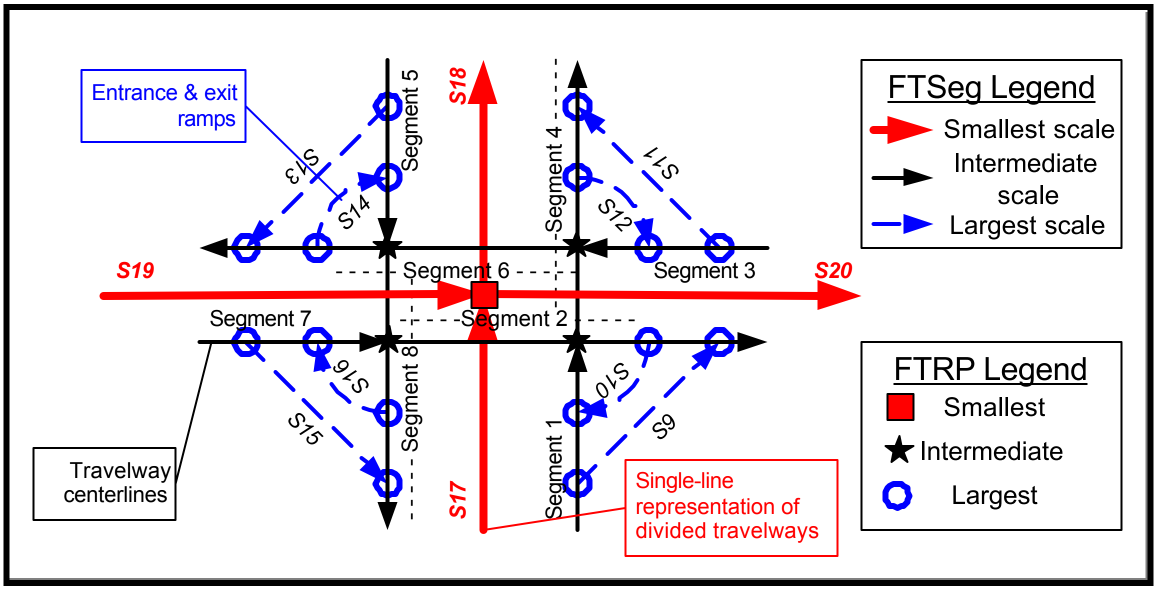

Figure 25 - Integration of Multiple FTRP and FTSeg at a Complex Intersection

Figure 25 illustrates the FTSeg and FTRP which might be used to represent a complex intersection of divided roadways. Red objects (heavy lines) illustrate how the intersection might be represented in a small-scale spatial database (e.g. those based on TIGER files). Black objects (normal lines) illustrate how the same intersection might be represented in a spatial database for which 1:24,000 topographic maps provided the source materials. Blue objects (dashed lines) illustrate the FTSeg and FTRP which would be necessary to represent segments for each exit and entrance ramp in a large-scale spatial database (e.g., those developed from source materials scaled at 1:12,000 or larger). Users of the red, blue, and black objects must be able to relate information contained in one database to the segments and points represented in the other database(s). Use of shared objects and maintenance of the Connectivity Table are the keys to this integration.

6 Creation of a new FTRP

New FTRP should be identified and created only when an existing FTRP cannot be utilized because the **Location-Description** and **Horizontal-Accuracy-Description** code do not indicate that the desired point is located appropriately, or with the degree of accuracy desired by the data developer. *Example: An existing FTRP is described as being located "at the intersection of centerlines" of an elevated crossing, and coded as being based on 1:100,000 scale source maps. A developer of a local E-911 transportation database requires greater precision, so creation of a new record is needed.*

6.1 Existing FTRP: Unhelpful (estimated) Accuracy

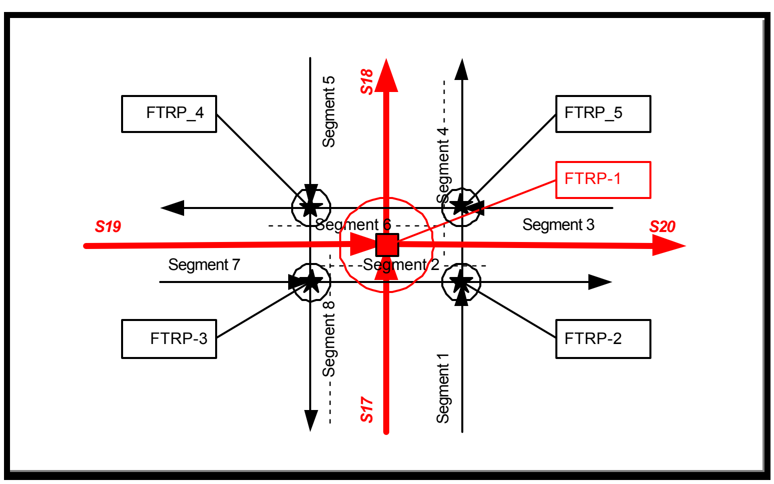

Figure 26 - Illustration of a pre-existing FTRP insufficiently accurate for "intermediate scale" reference

Figure 26 illustrates a situation in which a developer of "intermediate scale" transportation data identifies the pre-existing FTRP_1. This FTRP has a **Horizontal-Accuracy-Description** code which leads the developer to estimate its location as anywhere within the red circle around FTRP_1.

The developer must create new FTRP_2 through FTRP_5 in order to terminate Segments 1 through 8, and to allow accurate depiction of connectivity along these segments. The black circles around each of these FTRP indicate the locational accuracy which the data developer is able to assign to these points.

The developer should also create four entries in the FTRP Equivalency Table to document the logical identity between FTRP_2 through FTRP_5, and FTRP_1. (See following Section.)

New FTRP are created, and require entries in the FTRP Equivalency Table in order to support connectivity with the larger-scale data set.

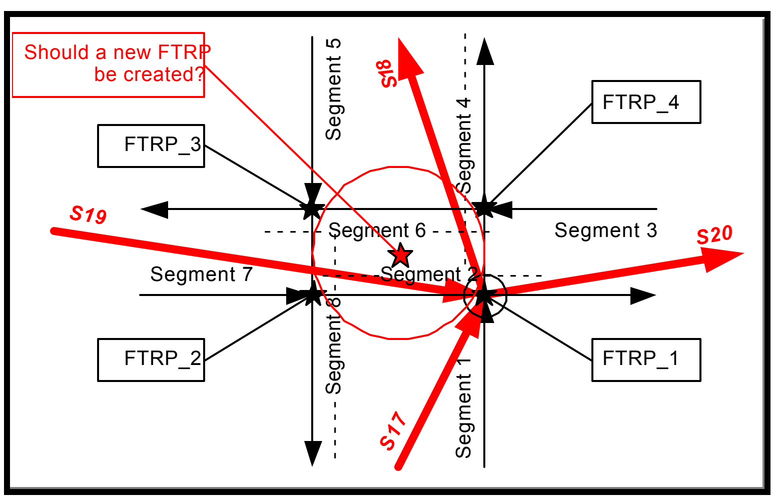

Figure 27 - Illustration of a pre-existing FTRP useful for "small scale" reference

6.2 Existing FTRP: Useful (estimated) Accuracy

The sequence of events is reversed in the Figure 27.

That is, the developer of "small scale" data discovers the pre-existence of FTRP_1 through FTRP_4 useful for "medium scale" database representation. The "small scale" developer believes each of these FTRP to be positioned with an accuracy represented by the circle around FTRP_1. This is a point whose accuracy description meets the less-exacting locational accuracy requirements inherent in the "small scale" database.

Therefore, rather than creating a new FTRP (represented by the red star at the center of the intersection) the data developer utilizes the existing FTRP_1. **An existing FTRP is utilized, and no new entries in the FTRP Identity Table are required.**