3. **Appendices**

A. Terminology

B. References

C. Implementation Guidelines

D. Examples

E. Open Issues

Appendix A

Terminology

(Informative)

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 Vonderohe, Dueker, and Fletcher et al. When utilized, specific references to these sources appear in parentheses following the definitions.

Anchor point. A zero-dimensional location that can be uniquely identified in the real-world in such a way that its position can be determined and recovered in the field. Anchor points serve as a geodetic control mechanism to facilitate construction of a linear datum model and/or route network (Vonderohe).

Anchor section. A continuous, directed, non-branching linear feature, connecting two anchor points, whose real-world length (in distance metrics) can be determined in the field. Anchor sections are specified as having a "from" anchor point and a "to" anchor point and a "distance" attribute (Vonderohe).

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 one endpoint of a Framework Transportation Segment 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 one-dimensional object. Lines can be defined variously as "line segment," "string," "arc," or "chain." Lines have shape and position (SDTS).

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 addresses.

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)

Location Reference 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)

Location Reference 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 location. A pair or triplet of coordinates specifies location.

Reference Object. A physical object which is not readily movable (e.g. curb intersection, bridge end, traffic signal pole, survey marker) that can easily be found in the field and represented as a point on a map.

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

Topology. Spatial relationships and connectivity among graphic GIS features, such as points, lines, and polygons. These relationships allow display and analysis of "intelligent" data in GIS. Many topological structures incorporate begin and end relationships, direction, and right/left identification.

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

Traversal Reference Point. A zero-dimensional location along a traversal that is used to reference events along the traversal (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. 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/

3. 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

4. North Carolina Department of Transportation, "Linear Referencing Systems: Review and Recommendations for GIS and Database Management Systems," Raleigh (NC), 1997.[1] http://www.doh.dot.state.nc.us/planning/gis/gis/newlinref/default.html

5. 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.

[1] A “proposed” strategy; not fully endorsed or implemented by NCDOT at this time.

6. 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

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

8. 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://www2.nas.edu/trbcrp/685a.html and http://www.bts.gov/gis/reference/report.html .

9. "Counties and Equivalent Entities of the United States, its Possessions, and Associated Areas," Federal Information Processing Standards (FIPS) Publications 6-4, August 1990. http://www.itl.nist.gov/div897/pubs/fip6-4.htm

10. "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

11. "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

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

13. “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

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

1 IMPLEMENTATION PROCEDURES

1.1 Establishing Framework Road Segment Reference Points (FTRP) . . . . Part III-C Pg. 3
1.1.1 At Jurisdictional Boundaries . . . . Part III-C Pg. 3
1.1.2 Simple Road Intersections . . . . Part III-C Pg. 4
1.1.4 Overpasses and Underpasses . . . . Part III-C Pg. 6
1.1.5 Grade-Separated Interchanges . . . . Part III-C Pg. 6
1.2 Establishing Framework transportation Segments (FTSeg) . . . Part III-C Pg. 7
1.2.1 Segment Length . . . . Part III-C Pg. 9
1.2.2 Road Types . . . . Part III-C Pg. 10
1.2.3 Complex Intersections . . . . Part III-C Pg. 13
1.3 Creating New or Updated FTSeg and FTRP . . . . Part III-C Pg. 17
1.3.1 Reconstruction . . . . Part III-C Pg. 18
1.3.2 Re-measuring . . . . Part III-C Pg. 19
1.4 Retiring FTSeg and FTRP . . . . Part III-C Pg. 19
1.4.1 Road (re)construction . . . . Part III-C Pg. 19
1.4.2 FTRP Duplication . . . . Part III-C Pg. 19
1.5 The Distributed Index of Transportation Authorities, FTSeg, and FTRP . . . . Part III-C Pg. 21
1.5.1 Transportation Authorities . . . . Part III-C Pg. 21
1.5.2 Points and Segments . . . . Part III-C Pg. 22
1.6 Defining FTSeg and FTRP within a Geographic Area . . . . . . Part III-C Pg. 23
1.6.1 Geographic Extent . . . . Part III-C Pg. 24
1.6.2 Cooperating Authorities . . . . Part III-C Pg. 24
1.6.3 Contiguous Jurisdictions . . . . Part III-C Pg. 25
1.6.4 Inventory of Databases and Applications . . . . Part III-C Pg. 25
1.6.5 Base Data for Initial Assignment . . . . Part III-C Pg. 26

1.6.6 Prototype Implementation . . . . Part III-C Pg. 26
1.7 Establishing Object Identity and Connectivity . . . . Part III-C Pg. 27
1.7.1 Implementation Sequence (Overview) . . . . Part III-C Pg. 27
1.7.2 Implementation Sequence (Detail) . . . . Part III-C Pg. 29
1.8 Cartographic Representation of FTRP and FTSeg . . . . Part III-C Pg. 31
1.8.1 Display of County and State Density . . . . Part III-C Pg. 31
1.8.2 Display of FTRP and FTSeg . . . . Part III-C Pg. 32
1.8.3 Relationship to Other Cartographic Elements . . . . . Part III-C Pg. 33
1.9 Conformance Testing . . . . Part III-C Pg. 34
1.9.1 Record Content . . . . Part III-C Pg. 34
1.9.2 Consistency of FTRP and FTSeg Records . . . . Part III-C Pg. 36
1.9.3 Record Format . . . . Part III-C Pg. 37
1.9.4 Validation . . . . Part III-C Pg. 38

1 IMPLEMENTATION PROCEDURES

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.

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 Establishing Framework Road Segment Reference Points (FTRP)

Each FTRP must be categorized as either “Physical” or “Logical;” FTRP that are “physical” represent a point on or at the end of a FTSeg over which a vehicle can pass while remaining within the traveled way. FTRP that are “logical” are most often those used in small-scale representations of more complex physical features. Examples of “logical” points include single-point representations of complex intersections. The FTRP placement guidelines below apply to points which are either physical or logical.

1.1.1 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).*

1.1.1.1 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.

1.1.1.2 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.

1.1.2 Simple Road Intersections

A 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 implicitly connected and therefore do not require additional information 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 roads; it can be used to terminate segments on one or both intersecting roads (illustrated in Figure 1 as segments "A-B" and "C-D" .) A cartographic convention used in this figure places an arrow-head at FTRP_1, where the FTRP breaks "C-D' into two segments[1]. Segment "A-B" passes through the same point unbroken, as is indicated by the lack of an arrow-head, which would represent the terminus of two segments. FTRP_1 provides implicit connectivity between the two segments for which it serves as a terminus -- in this Figure the two segments going from "C" to "D." If it serves to segment just one of the two crossing paths (as illustrated in Figure 1) then the FTRP data record also provides for explicit connectivity to the unbroken other path – in this Figure the single segment going from "A" to "B."

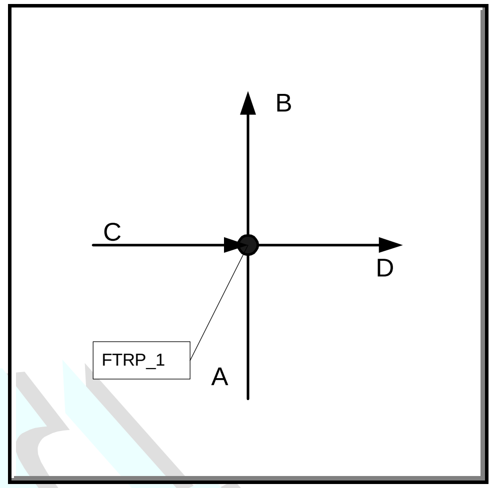


Figure 1 Simple Road Intersection

1.1.3 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 implicit connectivity at only one of the intersections. Depending on

[1]See Implementation Procedures – Section 1.8 for recommenced cartographic conventions.

the level 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.

1.1.4 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 implicit 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 a 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.

1.1.5 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, a 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.

1.1.5.1 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.

1.2 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.

Each FTSeg must be categorized as either “Physical” or “Logical;” segments that are “logical” are most often those used in small-scale representations of more complex physical features. An FTSeg which is “physical” represents an transportation segment over which a vehicle can pass while remaining within the traveled way. An FTSeg should be designated as physical ONLY if it begins and ends at a physical FTRP. Examples of “logical” segments include single-line representations of divided highways. The FTSeg placement guidelines below apply to points which are either physical or logical.

Each “real world” transportation segment should be described by one, and only one, “physical” FTSeg and by no more than one FTSeg identifier categorized as “logical.” Transportation data authorities with overlapping responsibilities for a geographic area should coordinate the identification of FTSeg and establishment of equivalency between “physical” and “logical” 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).*

1.2.1 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 state boundaries. 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.

1.2.1.1 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.

1.2.1.2 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, a 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.

1.2.2 Road Types

The decision to represent a particular road by a single logical FTSeg or two or more parallel physical 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.

1.2.2.1 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.

1.2.2.2 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. (See Figure 4.)

1.2.2.3 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.) (See Figures 2 & 3.)

1.2.2.4 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.*

1.2.2.5 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 a FTSeg. FTRP which terminate entrance or exit ramps should use explicit connectivity to join with the main road which the ramp accesses.

1.2.2.6 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.

1.2.2.7 “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.

1.2.3 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.

1.2.3.1 Full Interchange, Two Limited-Access Divided Highways

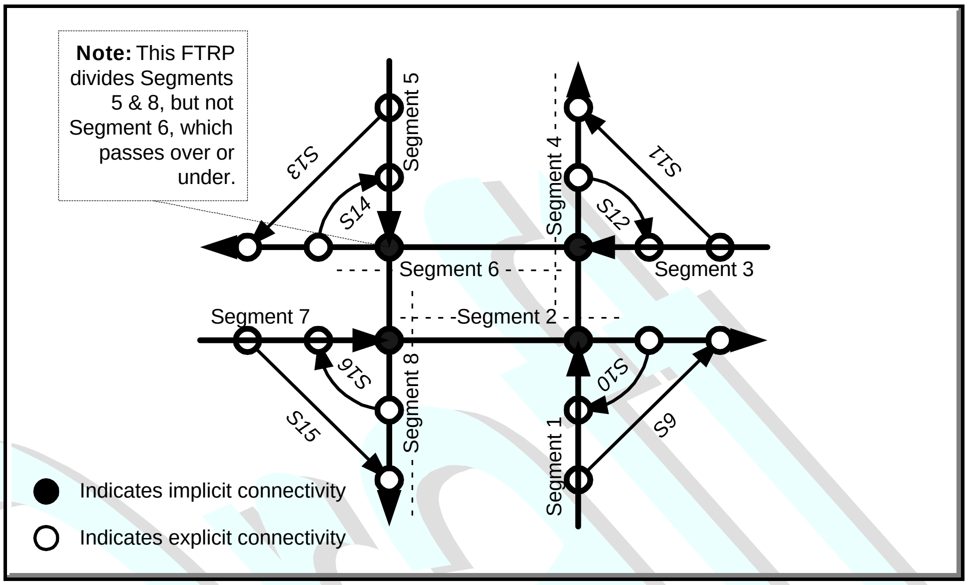


Figure 2 Full Interchange, Two Limited-Access Divided Highways

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 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 2 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.

1.2.3.2 "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 a FTRP located "between" the two directional roadways, as illustrated above. Ramps are added to the interchange using explicit connectivity to join one

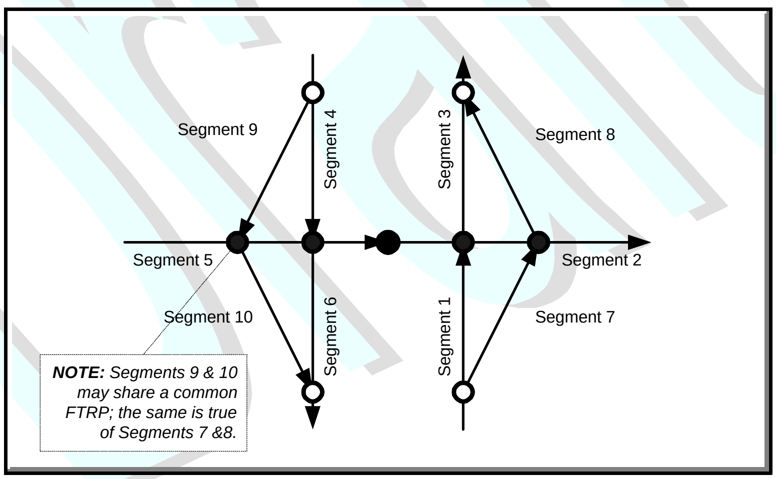


Figure 3 "Diamond" Interchange

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.

1.2.3.3 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 the Figure above. The other directional roadway should be split with a 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.

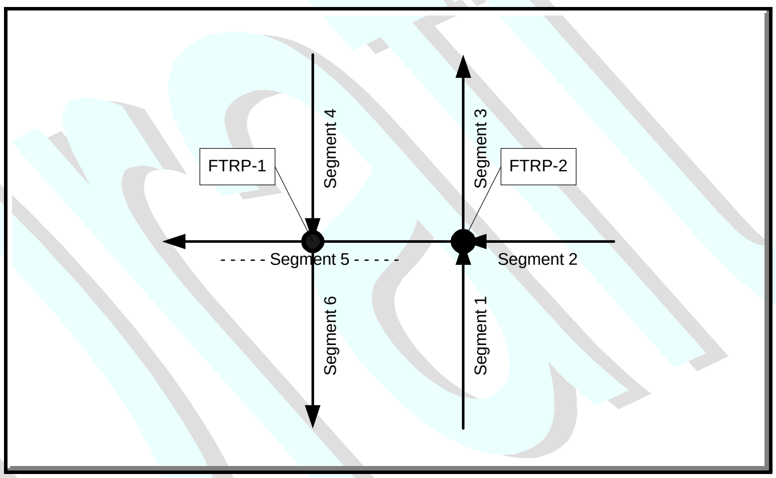


Figure 4 Intersection: Two-Way Surface Street with a Center Median Surface Street

1.2.3.4 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 5), 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.

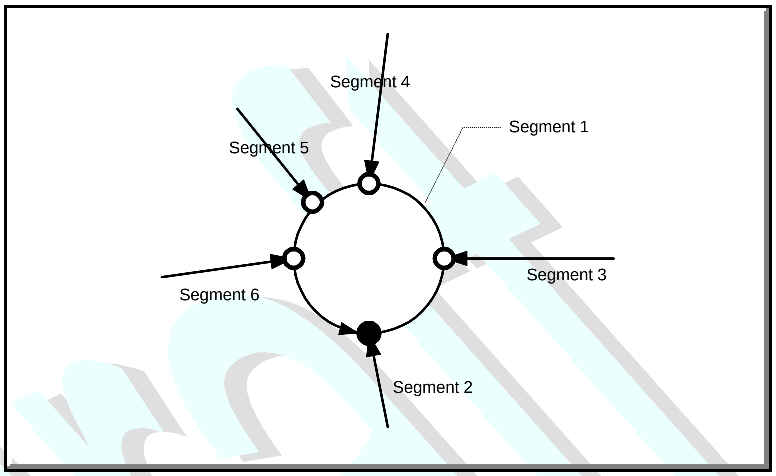


Figure 5 Traffic Circle

1.3 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 new record keyed with a new and unique identifier. “*Updating*” FTRP and FTSeg refers to creating a new database record(s) with an already-defined identifier, new and unique “Authority-ID” and/or “Date” information, and new or updated information in other fields.

In the normal course of events authorities will update records (using the same FTRP-ID or FTSeg-ID, with a different “Date”, and possibly a different “Authority-ID”.) These will 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.

1.3.1 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 FTRP and/or FTSeg records to which the retired objects are implicitly or explicitly connected. Therefore the references in these other records must be updated with the identities of the objects which have replaced the retired objects.

1.3.2 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.

1.4 Retiring FTSeg and FTRP

1.4.1 Road (re)construction

As stated above, new FTRP and FTSeg should be created during the (re-)construction of roads — 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).

1.4.2 FTRP Duplication

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

1.4.2.1 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.

1.4.2.2 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. Other records which describe the same feature but use a redundant ID should be retired by changing the “Status” of all records containing the FTRP-ID of the redundant entity as “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 at their shared borders. 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 any redundant records as* *"active," update these with any useful information from records which are to be retired, and change the status of newer records to "retired."*

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

1.5.1 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.

1.5.1.1 Initial Assignment and Maintenance

The initial assignment and maintenance of each unique authority identifier will be performed by the FGDC or a 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.

1.5.1.2 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.

1.5.2 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.

1.5.2.1 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-modify transactions for records containing the unique Authority ID.

1.5.2.2 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.

1.6 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.

1.6.1 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.

1.6.2 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.

1.6.3 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.

1.6.4 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.

1.6.5 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.*

1.6.6 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.

1.7 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 may not be able to implement this standard in such a way as to assure that all users will be able to relate and connect their databases for all purposes. *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.*

1.7.1 Implementation Sequence (Overview)

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

1.7.1.1 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?

1.7.1.2 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?

1.7.1.3 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?

1.7.2 Implementation Sequence (Detail)

1.7.2.1 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.

1.7.2.2 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:

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

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

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

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

1.7.2.3 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:

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

1.7.2.3.2 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 2 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.*

1.7.2.3.3 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.

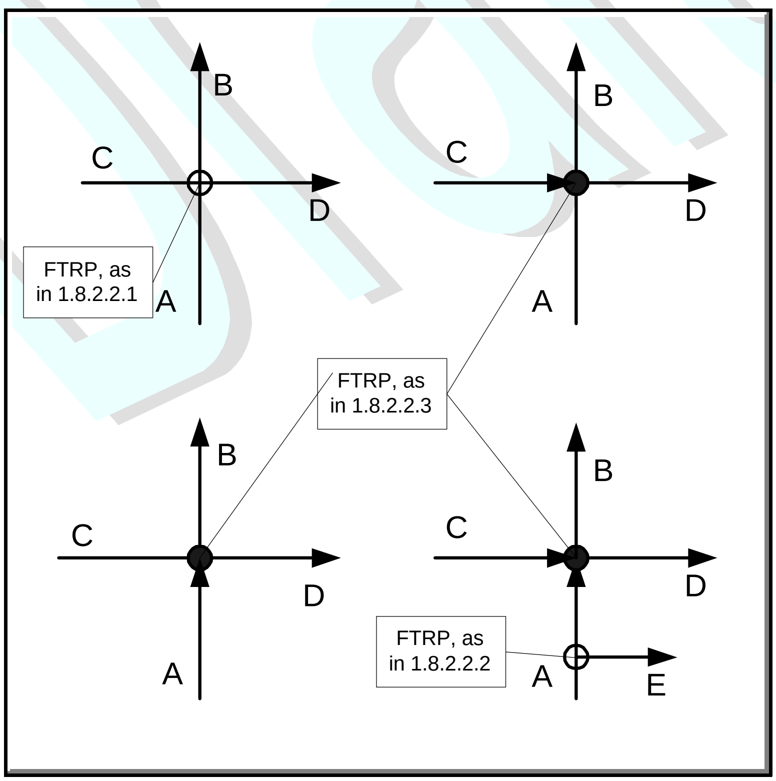
1.8 Cartographic Representation of FTRP and FTSeg

1.8.1 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.

1.8.2 Display of FTRP and FTSeg

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. Cartographic representation of a FTSeg requires that it be linked to table(s) of attributes which include the coordinates of shape points. The following display conventions are recommended, and are illustrated in Figure 6:



1.8.2.1 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.

1.8.2.2 FTRP should be symbolized as circles.

1.8.2.2.1 FTRP which do not lie at the terminus of any FTSeg should be represented by an open circle.

1.8.2.2.2 FTRP which lie at the terminus of one FTSeg and represent explicit connectivity should be represented by an open circle.

1.8.2.2.3 FTRP which lie at the terminus of two or more FTSeg should be represented by a circle which is completely filled.

1.8.3 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.

1.9 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. But FTRP and FTSeg are intended to be developed and exchanged without implied or linked topology or geometry. Consequently this standard does not include specifications relating to geometry or topology. 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 Record Content

1.9.1.1 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.

1.9.1.1.1 The content of the substring of unique FTSeg identifiers referred to as "FF" shall conform to this standard.

1.9.1.1.2 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.

1.9.1.1.3 The content of the substrings of unique FTRP and FTSeg identifiers referred to as "XXXXXXXX" shall consist of eight numeric characters (0-9).

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

1.9.1.1.5 In records detailing related attributes the value of the "End-Offset" shall be greater than the value of the "Start-Offset."

1.9.1.2 The content of other required fields in each FTRP, FTSeg, and related attribute record shall be within specified domains.

1.9.1.3 The content of each conditional field in FTRP and FTSeg records shall be within specified domains when the stated condition is "true."

1.9.1.4 The content of each optional field in FTRP and FTSeg records, when present, shall be within specified domains.

1.9.2 Consistency of FTRP and FTSeg Records

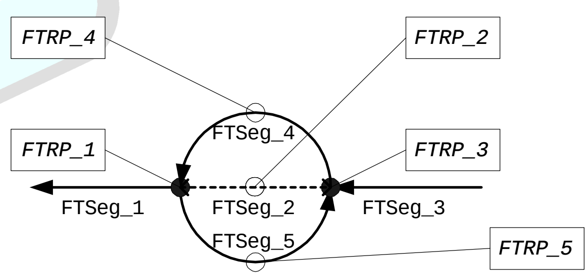
1.9.2.1 The unique identifiers FTRP named as the From-End-Point and To-End-Point within an FTSeg record must exist within the distributed registry of FTRP, and the unique identifier of the FTSeg-ID required in some FTRP records must exist within the distributed registry of FTSeg.

1.9.2.2 FTSeg and FTRP Category Consistency

1.9.2.2.1 For any FTSeg record, if the **Category** is “P”(Physical), the FTRP **Category** for the (required) From-End-Point and To-End-Point and the (optional) Intermediate-Point must also be “P”(Physical).

1.9.2.2.2 If the FTRP **Category** is “L”(Logical), the FTSeg **Category** of every FTSeg for which the unique FTRP is identified as a From-End-Point or a To-End-Point or an Intermediate-Point must also be “L”(Logical).

Four FTSeg and four FTRP in Figure 7 are assigned **Category** = “P” (Physical) because (by definition) they



An undivided road splits into two traveled ways for a short length. Segments 1,3,4 and 5 are PHYSICAL, while FTSeg_2 is a LOGICAL "single-line" representation of the divided traveled way.

Figure 7 - “Physical” and “Logical” FTSeg

fall in the traveled way. Only FTSeg_2 and FTRP_2 are categorized as “L” (logical) because (by definition) they do not fall in the traveled way.

IF:	THEN:
FTSeg-Category = “P”	FTRP-Category must equal “P” for the From-End-Point and To-End-Point and Intermediate-Point
FTSeg-Category = “L”	FTRP-Category may equal “P” or “L” for the From-End-Point or To-End-Point, but must equal “L” for the Intermediate-Point
FTRP-Category = “L”	FTSeg-Category must equal “L” for all FTSeg in which the FTRP is recorded as the From-End-Point or To-End-Point or Intermediate-Point
FTRP-Category = “P”	FTSeg-Category may equal “P” or “L” for any FTSeg in which the FTRP is recorded as the From-End-Point or To-End-Point, but must equal “P” for any FTSeg in which the FTRP is recorded as the Intermediate-Point

1.9.3 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.

1.9.3.1 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.

1.9.3.2 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>.

1.9.3.3 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.

1.9.4 Validation

The FGDC shall provide computer software which can read and interpret files of information formatted as specified. The software shall 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 . . . . Part III-D Pg. 3

2 **Economical Placement of FTRP** . . . . Part III-D Pg. 4

3 Transportation Segments and Sub-state Jurisdictional Boundary Lines . . . . Part III-D Pg. 5

4 Road (Re)Construction . . . . Part III-D Pg. 6

5 Integration of Physical and Logical FTRP and FTSeg at a Complex Intersection . . . . Part III-D Pg. 7

6 Creation of a new FTRP . . . . Part III-D Pg. 9

6.1 Existing FTRP: Same Category: Unhelpful (estimated) Accuracy . . . . Part III-D Pg. 9

6.2 Existing FTRP: Same Category: Useful (estimated) Accuracy Part III-D Pg. 10

6.3 Existing FTRP: Different Category: Unhelpful (estimated) Accuracy . . . . Part III-D Pg. 11

6.4 Existing FTRP: Different Category: Useful (estimated) Accuracy . . . . Part III-D Pg. 12

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.

The figure at right is intended to illustrate how a FTRP which serves as the end points for FTSeg_98 and FTSeg_96 could be improved over time:

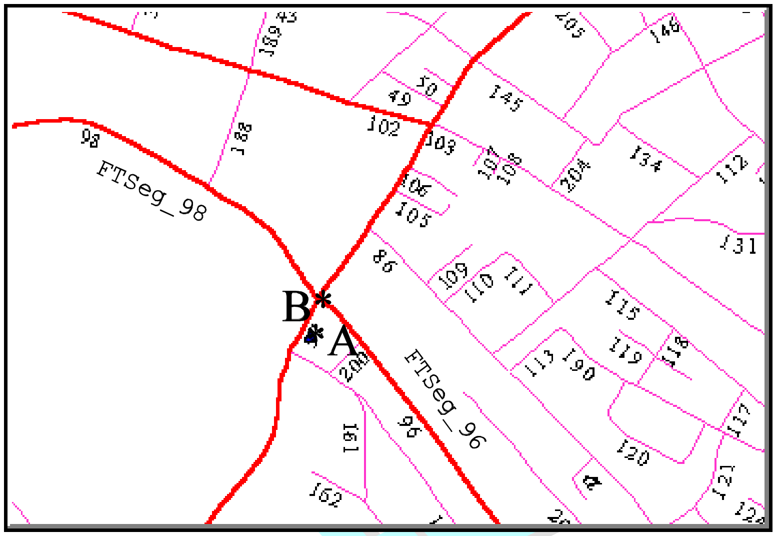


Figure 1 – Improvements in FTRP over time

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

The figure at right shows the designation of an FTRP (P3) at the intersection of a state highway and a county

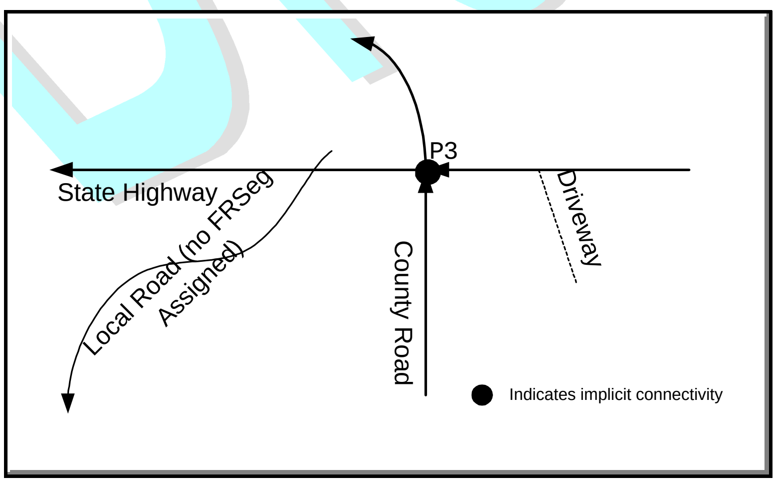


Figure 2 Economical placement of FTRP with regard to intersections

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.

3 Transportation Segments and Sub-state Jurisdictional Boundary Lines

The following figure 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 implicitly connect these segments to other segments not illustrated. Further, FTRP “P1" and “P4" would be used to implicitly connect segments at the points where the road leaves the county boundary. “P3" would be a FTRP which terminates segments at the point where

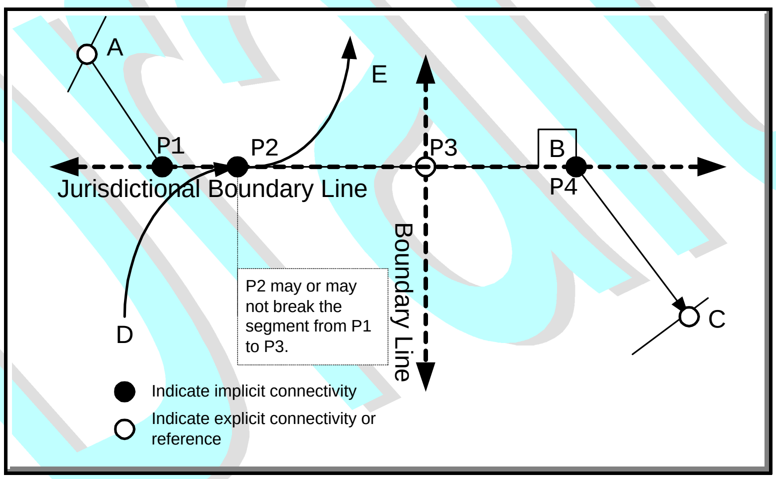


Figure 3 Roads on or crossing County Boundaries

the road crosses from a boundary line which separates two jurisdictions to a boundary line which separates 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, a FTRP could (optionally) be defined at"P2" – the point where road "D-E" intersects the jurisdictional boundary. Point "P2" would implicitly connect segments of road "D-E" but need not break the FTSeg between P1 and P3. P2 would break this segment only if transportation authorities determined that creation of two FTSeg between P1 and P3 would be helpful for data sharing.

4 Road (Re)Construction

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

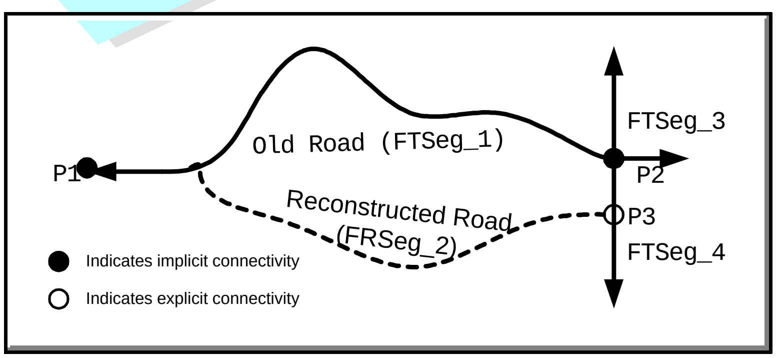


Figure 4 Road Reconstruction

terminus of FTSeg_3 and FTSeg_4, as well as the unnamed segment which runs to the right edge of the figure. 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 Physical and Logical FTRP and FTSeg at a Complex Intersection

The figure below illustrates the FTSeg and FTRP which might be used to represent a complex intersection of divided roadways. Red objects (heavy lines) illustrate how the

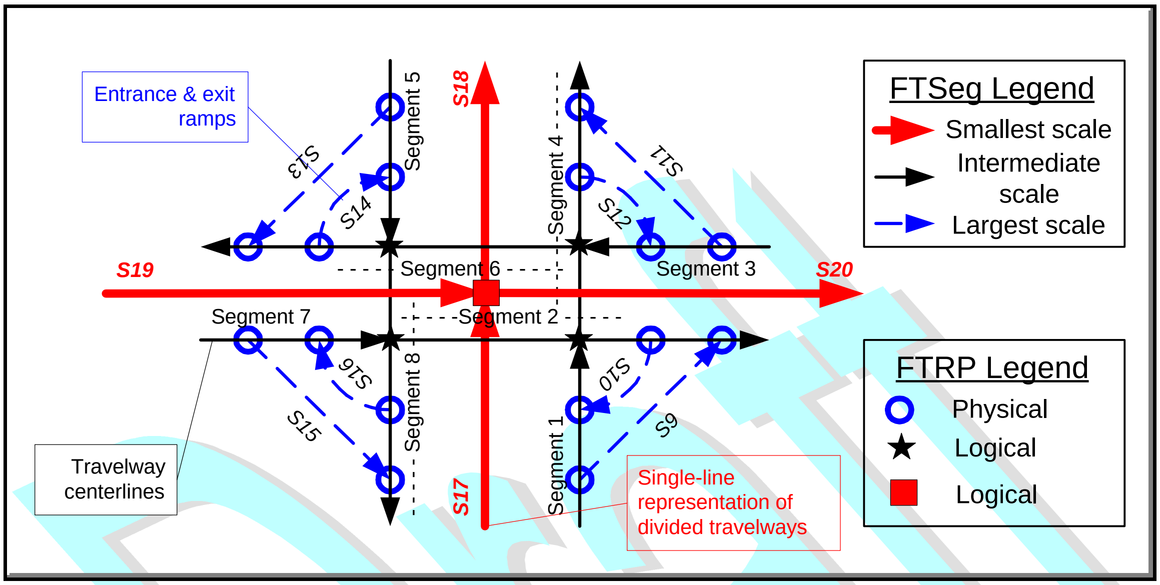


Figure 5 - A Complex Intersection

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).

6 Creation of a new FTRP

New FTRP should be identified and created only when an existing FTRP cannot be utilized because it is not of the correct **Category**, or 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 "logical" 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 for a "physical" FTRP, so creation of a new record is needed.

6.1 Existing FTRP: Same Category: Unhelpful (estimated) Accuracy

The figure below illustrates a situation in which a developer of "intermediate scale" transportation data identifies the pre-existing "logical" FTRP shown as LP-1. This FTRP has a **Horizontal-Accuracy-Description** code which leads the developer to estimate its location as

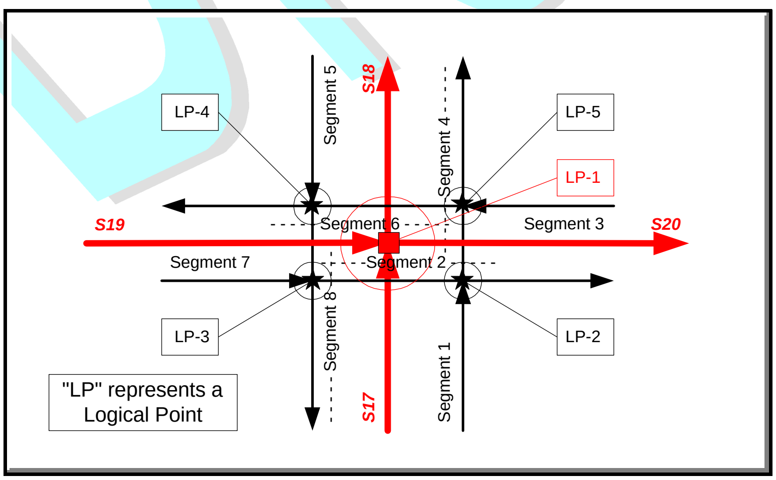


Figure 6 - Illustration of a pre-existing "Logical" FTRP insufficiently accurate for "intermediate scale" reference

anywhere within the red circle around LP-1.

The developer must create new LP-2 through LP-5 in order to terminate FRSeg-1 through FRSeg-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 Identity Table to document the logical identity between LP-2 through LP-5, and LP-1. (See following Section.) **A new FTRP is created, and requires entries in the FTRP Identity Table.**

6.2 Existing FTRP: Same Category: Useful (estimated) Accuracy

The sequence of events is reversed in the figure below. That is, the developer of "small scale" data discovers the pre-existence of FTRP (LP-1 through LP-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 LP-1. This is a point whose accuracy description

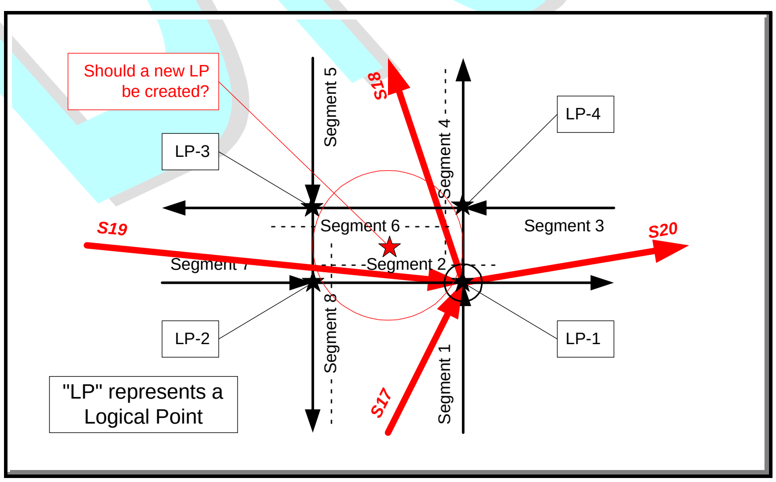


Figure 7 - Illustration of a pre-existing "Logical" FTRP useful for "small scale" reference

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 LP-1. **An existing FTRP is utilized, and no new entries in the FTRP Identity Table are required.**

The previous examples are illustrated with “logical” FTRP, but the same reasoning should be applied if existing “physical” FTRP can be considered for utilization in creating new FTSeg.

6.3 Existing FTRP: Different Category: Unhelpful (estimated) Accuracy

The developer of “small scale” data (represented by segments S17 through S20) discovers the pre-existence of FTRP (PP-1 through PP-4) developed by local government to terminate “large scale” segments

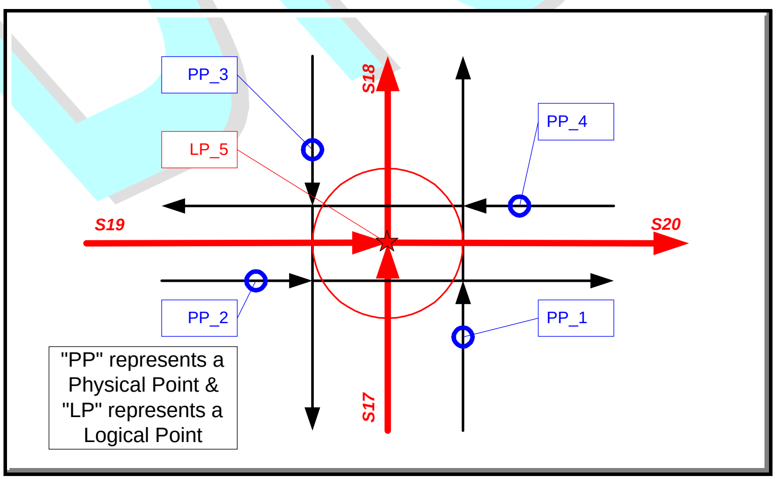


Figure 8 - Illustration of pre-existing “Physical” FTRP not useful for “large scale” reference

representing entrance and exit ramps. The developer needs a "logical" FTRP to terminate segments S17 through S20, and it can be located with relatively unexacting accuracy represented by the circle around LP-1. However the existing "physical" FTRP have been located with high accuracy, and fall outside of the tolerance allowed by the developer.

The developer must create new LP-5 in order to terminate S17 through S20, and to allow accurate depiction of connectivity along these segments. The developer should also create four entries in the FTRP Identity Table to document the logical identity between PP-1 through PP-4, and LP-1.

6.4 Existing FTRP: Different Category: Useful (estimated) Accuracy

The developer of "medium scale" data finds pre-existing "physical" FTRP developed by local government to terminate "large scale" segments representing entrance and exit ramps. The "medium scale" developer wishes to use FTRP with an estimated accuracy represented by the circle around LP-1. The

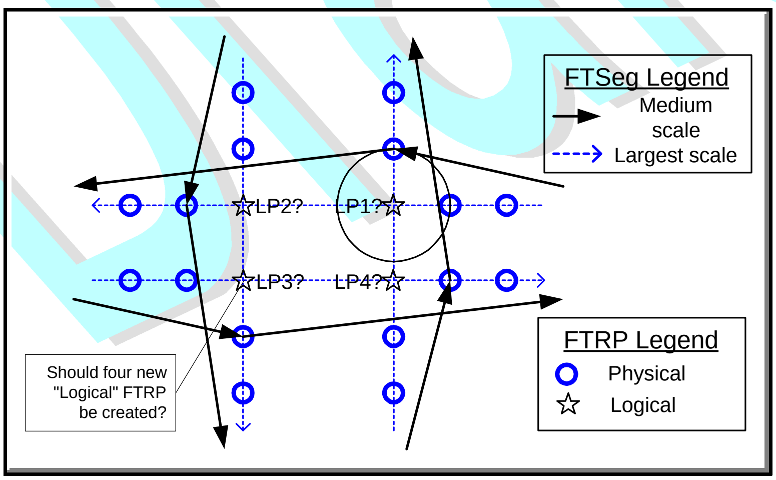


Figure 9 - Illustration of a pre-existing "Physical" FTRP useful for "intermediate scale" reference

"physical" FTRP fall within this range. Therefore, rather than creating a new FTRP (represented by the stars at the four intersections) the data developer utilizes four of the existing "physical" FTRP. **Existing FTRP are utilized, and no new entries in the FTRP Identity Table are required.**

Appendix E

Open Issues

(Informative)

The following are intended for the discussion of the Technical Review Committee. Each issue is stated as a question (to which, of course, more than one answer can be offered.) It is followed by a brief discussion of the answer(s) reflected in this draft, and of related issues.

1 The draft standard includes limited topology. Specifically: 1) Connectivity at shared FTRP is stipulated as "implicit connectivity," and 2) connectivity at other junctions is created through entries in the FTRP record ("explicit connectivity.") What would be sacrificed if the standard did not contain any topology at all? Would simplicity and understandability result? This issue has been addressed by several thoughtful comments (Olmstead and Deuker) on ROAD-L.

2 Should the "Feature_type" be embedded in the unique ID of each FTSeg and/or FTRP? Several commenters have taken the position that it is just an attribute of any feature, and that such "intelligence" should not be built into the identifier?

3 Should the sequential/random portion of the FTRP and FTSeg unique identifiers be limited to numeric characters, as is currently proposed? Are there data processing efficiencies or other benefits which can be envisioned as a result of this limitation? On the other hand, many users will have "legacy" alpha-numeric ID schemes for segments and points, and they'll want to use these to "initialize" IDs. Do the potential benefits of limiting the IDs to be numeric characters warrant the disadvantaging of users with pre-existing alpha-numeric ID schemes?

4 Is explicit allocation of identifier number ranges for the sequential/random portion of the external identifier <u>necessary</u> to the orderly assignment of these identifiers by

multiple transportation authorities? Or is it at least in some way desirable (See Butler posting to ROAD-L)?

5 One authority might create "logical" FTRP and FTSeg to identify his/her single-line representation of a divided highway. Another authority might create different "physical" FTRP and FTSeg to identify his/her dual-line representation of the same divided highway. Does the authority which acted later in time have the obligation to make entries to an identify table in order to support data sharing and to help assure that future users are aware of both sets of database records? If not, does anyone have such an obligation? If not, what solution will support data sharing?

6 Authorities who define FTRP and FTSeg for complex intersections will face choices of whether to represent connectivity through MORE "physical" features (representing each physical segment of connectivity) or LESS "logical" features. Should the Standard or the Implementation Guidelines include a recommendation on how to make these choices, based on scale, or on any other criteria?

7 Al Butler named a "compound feature" which he called a "traversal segment," which is defined as being made up of some number – not necessarily an integer – of FTSeg greater than "0," but not equal to "1." He pointed out that most attributes of interest to users will be associated with a "traversal segment" rather than with an FTSeg. However, for purposes of data exchange, the attribute values will be associated with

one or more instances of an FTSeg (either complete or partial.) Should this point receive greater emphasis in the standard?

8 There was consideration of creating a "Logical-only" flag for FTSeg which begin and end at logical FTRP. Because FTSeg can be coded "physical" only when both terminal FTRP are coded "physical," such a flag would separate the "Logical-only" FTSeg from those which begin or end at a "physical" FTRP. Would the use of such a flag offer benefits that would outweigh the cost of accurately maintaining another FTSeg attribute?