Geographic Information Framework –
Data Content Standards
For Transportation Networks: Base Standard

American National Standard
for Information Technology

Geographic Information Framework
Data Content Standards
For Transportation Networks: Base Transportation Standard

(Part XXX)

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Foreword

The primary purpose of the standard is to support the exchange of transportation data related to five modes of transportation (road, air, rail, transit, and waterways) within the Geospatial One Stop. This standard also seeks to establish a common baseline for the content of Transportation databases for public agencies and private enterprises. It seeks to decrease the costs of acquiring and exchanging Transportation data for local, tribal, state, and federal users and creators of Transportation data. Benefits of adopting the standard also include the long-term improvement of the geospatial Transportation data, improved integration of safety and enforcement data, and streamlined maintenance procedures.

This is the first edition of this standard. However, this standard was preceded in development by a number of other standards, including the National Spatial Data Infrastructure (NSDI) Framework Transportation Identification Standard of December 2000. The Transportation Identification Standard served as one of the starting points for this standard.

This standard has been developed to fulfill one of the objectives of the NSDI, i.e., to create common geospatial data for seven critical data themes. These core themes are considered Framework data, reflecting their critical importance as geographic infrastructure. The Geospatial One Stop initiative is an e-government initiative of the federal government designed to expedite development of the seven Framework layers. This standard has been developed in response to the Geospatial One Stop initiative to realize the goals and objectives of the NSDI. Geospatial One Stop is an implementation of the NSDI.

Suggestions for improvements of this standard will be welcome. They should be sent to

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This standard was processed and approved for submittal to ANSI by the Accredited Standards Committee – INCITS/L1. Committee approval of this Standard does not necessarily imply that all committee members voted for its approval.

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American National Standard for Information Technology
Geographic Information Framework
Data Content Standards
(ANSI X.X.X2003)

1 Scope of this Standard

This standard defines the components of transportation systems for five modes that compose the Transportation theme of the NSDI. The primary purpose of the standard is to support the exchange of Transportation data related to transportation systems. It is the intent of the standard to set a common baseline that will ensure the widest utility of Transportation data for the user and producer communities through enhanced data sharing and the reduction of redundant data production.

At a high level, the Transportation System described in the standard is made up of Transportation Features, which can have geographic locations and characteristics. These Transportation Features can be interconnected in various ways and across several modes to represent Transportation Networks for path finding/routing applications. While the design team has considered the need for path finding applications, the level of data required by such applications is beyond the scope of many organizations. Specifically, many state and local government agencies do not have adequate data for routing purposes, and they do not have the budget to create and maintain this data. It is expected that the content in the standard should support the development of specialized networks for routing applications, but this level of information is not a requirement of the data standard.

The standard can be implemented using a variety of software packages and is designed to accommodate data encoded without geometry as well as to support the exchange of data encoded in a variety of geographic information systems. The standard accommodates assets associated with the transportation system that are typically used for navigation, safety, and measurement.

The standard applies to National Spatial Data Infrastructure (NSDI) Framework Transportation data produced or disseminated by or for the federal government. According to Executive Order 12906, Coordinating Geographic Data Acquisition and Access: the National Spatial Data Infrastructure [1], federal agencies collecting or producing geospatial data, either directly or indirectly (e.g., through grants, partnerships, or contracts with other entities), shall ensure, prior to obligating funds for such activities, that data will be shared in a manner that meets all relevant standards adopted through the Federal Geographic Data Committee (FGDC) process.

This standard is the base transportation standard that integrates the five modes of Transportation systems: roads, rail, transit, air, and water.

1.1 Issues

The following is a brief discussion of issues that are of particular importance to this standard. Some of these have not been completely incorporated into the standard for various reasons. They are introduced here to allow the reader to fully appreciate the challenges faced by those who developed this standard.

1.1.1 Linear Referencing Systems and Transportation Data

Linear Referencing Systems (LRS) are, in the strictest sense, not a central part of the standard, and also are complex enough to warrant separate treatment. This standard references the linear referencing scheme adopted by TC211 for ISO standard 19133 [2], Tracking and Navigation and is included here as informative Annex A. LRS are used in this standard to support the exchange of asset information, such as sign locations and project boundaries. In this model, these types of information are considered **Feature Events.** As described in the standard, Feature Events can have their own geometry, such as may be created through GPS data, and they also have an LRS location that describes their location along or near a transportation feature.

Another key use of LRS in this model allows the exchange of attribute information that describes road features, such as number of lanes and speed limits. In this standard, these attributes are called **Events** and can have either a point or line representation through the application of an LRS-specified location on road geometry using dynamic segmentation. This use of LRS may not be familiar to many readers of this document, but it has important implications for feature segmentation and attribution for data exchange.

1.1.2 Unique Identifiers

One key issue is the generation of **identifiers** for data elements. This has implications for data sharing and the source management of framework data sets. This issue has been elevated beyond the Transportation MATs for further review. This standard does not currently define a mechanism for the generation of unique identifiers, but the requirement for unique, permanent identification is recognized. Some solutions for permanent identifiers are proposed and discussed in Annex B.

1.1.3 Feature Equivalence

Equivalence of features is another consideration, and is discussed in Annex C. Within a dataset or package that is being exchanged, some ability to convey that one segment of road or rail or route is equivalent to another has been made available. Further action to support equivalencies will be based on needs defined during the prototype and review stages of the standard’s development.

1.1.4 Temporal Data

Another key issue is the **temporal representation** of dynamic features. At this point, only the need to exchange "current" data is seen as a requirement. This means that only the current view of the source database is required. Another way to say this is that on July 1, 2003 one can get the data as it exists in the database on that date is a requirement of the standard, but obtaining earlier versions of the data, such as may describe the transportation system on, say, July 1, 2002, as part of the same dataset is not directly supported. Metadata should be used to document the source data currency, author, and associated information about the datasets. Temporal support, therefore, is assumed to not be a requirement since multiple data sets with their separate time stamps may be available from a single source. Information about features in different stages of the planning and construction lifecycle can be shared (such as proposed roads), but there is no mechanism to exchange deleted data except through a data source's voluntary program of producing and sharing "snapshots" of the data set. To facilitate change detection over time, an attribute for the last updated date is present for all class types in the standard.

1.1.5 Metadata

The use of feature-level **metadata** is another issue in the development of this standard. While the use of feature-level metadata has not been ruled out, the focus of this work so far has been on minimal data source and data quality information expressed as attributes, such as through the use of Source, Positional Accuracy, and Last Update attributes. There were concerns about software support for feature-level metadata and the ability to require metadata elements to be populated on features. Conceptually, feature-level metadata is acceptable, but the cost of maintaining this on an individual feature basis has been debated. In this standard, metadata applies to all features in an exchange dataset unless metadata is specifically defined for a feature class or group of individual features. At this point, the identification of a data source or authority that created the data set is just a simple text field that needs further definition. However, the list of data creators and a scheme for identifying those authors is not just a transportation issue, and a common technique should be adopted across all Framework themes.

1.1.6 Multiple geometric representations

This version of the standard does not support the sharing multiple representations of the same Transportation Feature within a single data set. While some discussion of **multiple geometries** has occurred, these geometries typically have different data sources and update attributes associated with them. Future support for multiple geometries has been discussed and will be explored as a future addition to this standard.

1.1.7 UML representations

Lastly, a linkage between this standard and appropriate ISO standards for representing spatial features using the **Unified Modeling Language (UML)** has been developed. (For a brief explanation of UML diagrams, see Annex D.) These upper-level classes are not necessarily unique to Transportation. A specific profile of those standards has been assembled as the base classes for this model, primarily to take advantage of existing geometry, topology, and metadata standards. Additional work by ISO TC211 and TC204 to harmonize Geographic Data File (GDF) [3] and LRS standards is in progress in parallel with the development of this standard.

There were a number of other technical issues identified during the course of developing the standard that are of interest to other Framework data themes. Some of these issues, and their relevance for this standard, are discussed in the informative annexes. Decisions have been made for the purpose of this version of the standard, but further investigation and feedback may lead to the modification of the standard, or move the resolution of these issues into a common Framework Base Standard document.

2 Normative References

The following standards contain provisions, which through reference in this text constitute provisions of this American National Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this American National Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

[1] Executive Order 12906, Federal Register, Vol. 59, No. 71, April 13, 1994

[2] ISO 19133, *Geographic Information—Location Based Services Tracking and Navigation.*

[3] ISO/TR 14825 *GDF, Geographic Data Files,* Version 4.0

[4] ISO 19109, *Geographic Information—Rules for Application Schema.*

[5] ISO 19110, *Geographic Information—Feature Cataloging Methodology*.

[6] ISO 19115, *Geographic Information—Metadata*.

[7] ISO 19107, *Geographic Information—Spatial Schema*.

[8] ISO 19103, *Geographic information - Conceptual schema language*

3 Definitions

Definitions applicable to this standard are listed here. Other definitions, specific to a particular transportation mode, are listed within the modal standard.

Distance Expression – Measure, in a position expression, the linear distance measured along a linear element.

Entity- Something that has separate and distinct existence and objective or conceptual reality. This is a UML modeling concept illustrated as a box without a name.

Event- A manner in which the value for an attribute and its location of applicability can be defined along a road feature, either at a single point (point event) or for a linear interval along the road feature (linear event), without requiring that the road feature be segmented wherever the value of the attribute changes.

Event Model- That part of the transportation model that defines a manner in which to model attributes that may have values that change along the length of a segment or path.

Feature Event- A special type of feature which can be located by linear referencing along a transportation segment or transportation path in addition to behaving as a feature by virtue of its having its own attributes, including its own (optional) geometry, independent of the geometry of any transportation segment or transportation path it is linearly reference along, e.g. a bridge might be represented as a Feature Event so that it can have attributes such as type, length, and year of construction and its own spatial representation, either as a point, line, or polygon (in future versions of the standard, it may have all three) as well as being linearly reference along a transportation segment or transportation path.

Geometry-The shape and geolocation of a feature

Linear Element-The underlying curvilinear element along which a linear referenced measure is taken.
Linear Event- An event that is represented as a line string. The representation of the linear event may be specified using the applicable portion of a linear feature or as a line within an areal feature. Alternatively, a linear event may be represented by a range of addresses that have been assigned along the length of a linear feature. A linear event carries an attribute that specifies the permanent identifier of the feature to which it is associated.

Linear Feature- A feature that is represented as a line string or sequence of line strings.

Linear Location-A location that is specified as a distance along a one-dimensional feature, such as a roadway, specified with a single coordinate, whose coordinate axis is the linear feature itself.

Linear Reference Model- That part of the road model which defines the manner of describing locations along linear entities (e.g., RoadSegs and RoadPaths) used to specify the extent of applicability of values of attributes along segments or paths or the linear referenced locations of feature events and the "along" type of road points.

Linear Referencing- The description of a location using a one-dimensional measurement along a linear element based upon the rules and units of some Linear Referencing Method.

Linear Referencing Method-Any of a number of schemas used to measure a location along or beside a linear feature as a distance from a known location measured along (and optionally laterally offset from) the linear feature.

Linear Referencing System- The linear referencing method (LRM) and the associated rules and protocols governing the application of the LRM

Point Event- An event that is represented as a point position. The representation of the point event may be specified as a point adjacent to, or coincident with a linear feature, or within an areal feature. A point event carries an attribute that specifies the permanent identifier of the feature to which it is associated.

Position Expression- Used to describe a position using linear referencing and comprised of a measured value (distance expression), the curvilinear element being measured (linear element), and the method of measurement (LRM).

Referent- In the distance expression of a position expression, a known location from which a relative measurement can be made, e.g., a milepost or reference post along a highway.

Transportation Network-The set of transportation features participating in a set of topological relationships that define an uninterrupted path through the transportation system.

Transportation System- The physical and non-physical components representing all modes of travel that allow the movement of goods and people between locations.

4 Symbols (and abbreviations)

Symbols and associated abbreviations applicable to this standard are listed below. Other symbols and abbreviations applicable to a particular transportation mode are listed in the modal standard.

AIR – Three letter mnemonic designating the Air subtheme of the Transportation theme

GOS-Geospatial One Stop

LRM - Linear Referencing Method

LRS – Linear Referencing System
Three letter abbreviations for the modes…

ROD – Three letter mnemonic designating the Road subtheme of the Transportation theme

RRX – Three letter mnemonic designating the Rail subtheme of the Transportation theme

TRN – Three letter mnemonic designating the Transportation theme

TST – Three letter mnemonic designating the Transit subtheme of the Transportation theme

WTY – Three letter mnemonic designating the Inland Waterway subtheme of the Transportation theme

5 The GOS Feature Meta Model

5.1 Semantics

A feature is an abstraction of a real world phenomenon that is of interest to the application. Instances of features that share common characteristics are organized in classes. Classes are object realizations of the Metaclasses defined in the ISO Rules for Application Schemas Standard [4], and instances of the types described in the ISO Feature Catalogs Standard [5] Road Segments and Intersections are examples of Feature Types.

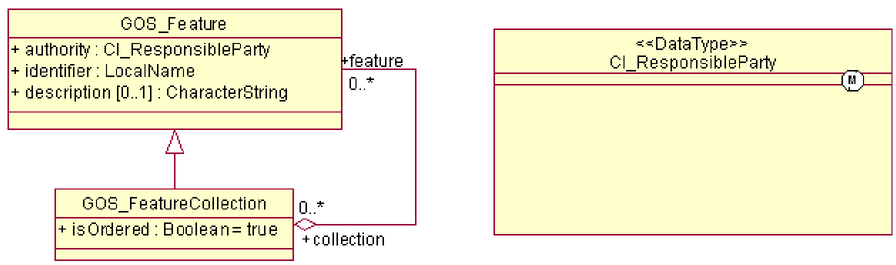

Figure 1–The GOS Metafeature Model

Figure 1 shows GOS_Feature, which is an object realization of the metaclasses defined in the ISO feature model. Features have identifiers, "LocalName" that are unique within the namespace of the feature collection or the database in which they exist. GOS_Feature has a mandatory attribute called "source".

The source attribute has type CI_ResponsibleParty that is defined in ISO 19115 [6]. It provides standardized method for citing a resource as well as information about the source agency or party responsible (CI_ResponsibleParty) for a resource. The CI_ResponsibleParty data type contains the identity of person(s), and/or position, and/or organization(s) associated with the resource.

GOS_FeatureCollection is a collection of features. Feature collection is an aggregate of zero or more features. Feature collections are also features and therefore can have their own attributes and feature names. Feature collections can be, but not in all cases, defined as ordered lists.

6. Transportation Feature Model

6.1 Semantics

Many transportation features have certain characteristics in common, such as linear geometries, a connective nature, and a system for indexing these real world features. In this version of the standard, road, rail, and transit modes share a common model for segmentation shown in Figure 1a. TRN_Feature is simply an extension of GOS_Feature that includes any and all transportation features. TRN_Feature has three feature subclasses TRN_Path, TRN_segment, and TRN_Point. These three feature subclasses have analogues in the road, rail, and transit modes of transportation.

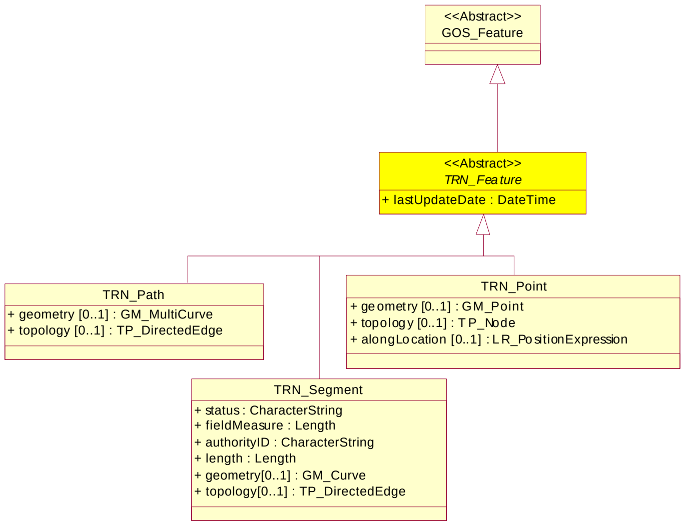

Figure 2–The Abstract Transportation Model

Figure 3 shows the abstract transportation model. TRN_segment and TRN_Point are subclasses derived from TRN_Feature. TRN_Path can be regarded as either a collection of TRN_segment or a subclass of TRN_Feature. Figure 3 also shows the relationship of TRN_Event to TRN_segment and TRN_Path. Events, as will be shown later, is a concept that handles characteristics of the transportation system. Two types of events are recognized: TRN_AttributeEvent and TRN_FeatureEvent. TRN_AttributeEvent handles characteristics that have no physical representation in the transportation system. Examples of such characteristics include speed limits, or rail condition. TRN_FeatureEvent handles physical features associated with the transportation system, such as signage, or signals. These features could also be considered as part of a non-transportation application, which is reflected in Figure 3 by the relationship of TRN_FeatureEvent to the generic GOS_Feature class as well as to TRN_Event.

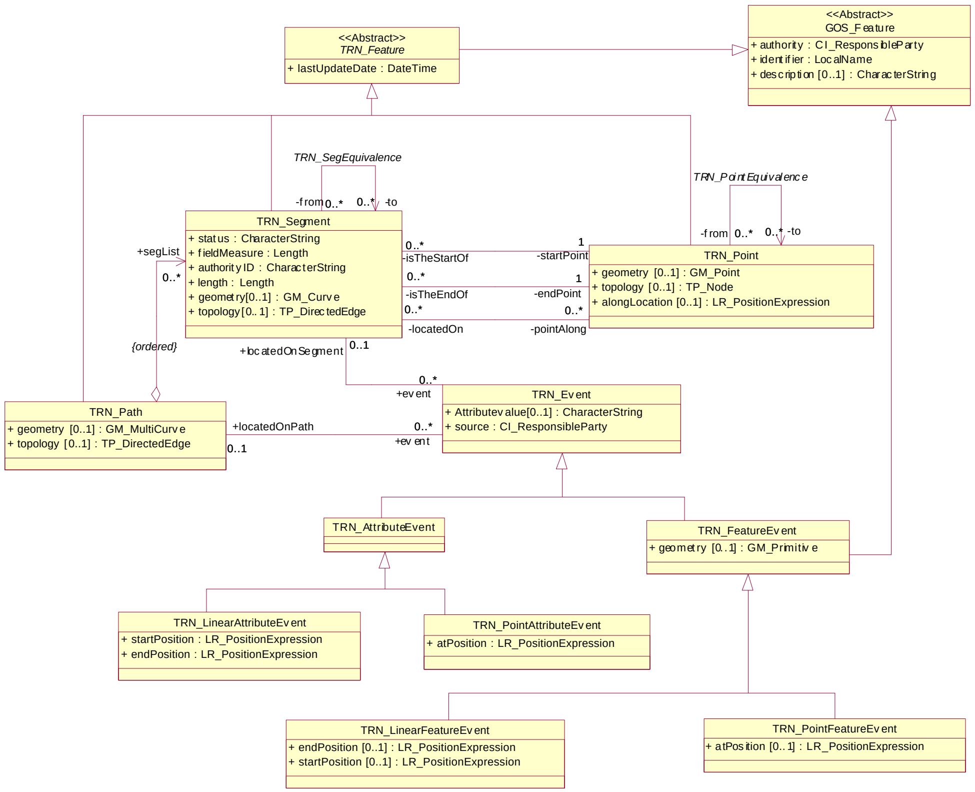

Figure 3–The Base Transportation Model

7 Transportation Segmentation Model

7.1 Semantics

Many transportation features have certain characteristics in common, such as linear geometries, a connective nature, and a system for indexing these real world features. In this version of the standard, road, rail, and transit modes share a common model for segmentation shown in Figure 2. TRN_Feature is simply an extension of GOS_Feature that includes any and all transportation features. TRN_Feature has three feature subclasses TRN_Path, TRN_Seg, and TRN_Point. These three feature subclasses have analogues in the road, rail, and transit modes of transportation.

7.2 TRN_segment

7.2.1 Semantics

TRN_segment represents a linear section of a physical transportation system designed for, or the result of, human or vehicular movement. As shown in Figure 2, TRN_segment extends TRN_Feature. Within this standard, TRN_segment may be defined in a variety of ways for depending on mode and business application. It is left to the data creator to decide how to segment their transportation features in a manner that supports their organizational functions. A single TRN_segment can represent an entire segment between two points, or, a separate TRN_segment can be defined for each direction of travel. Defining how and where segments are defined is dictated by the need of the application.

TRN_segment can have geometry of type GM_Curve as defined in ISO 19107 [7]. TRN_segment can also have a topology of type TP_DirectedEdge as defined in ISO 19107. According to ISO 19107, GM_Curve extends GM_OrientableCurve and therefore, has direction. The direction of a TRN_segment is determined by the “from” and “to” TRN_Points. TP_DirectedEdge has been introduced to facilitate the representation of feature topology through its combinatorial structures independent of its geometry. This has practical application within the road, rail, and transit standards as providers of those data may choose to represent only the geometry of a TRN_segment, which implies a direction inherited from GM_OrientableCurve. Other data providers may choose not to supply feature geometry for and only provide the orientation of the TRN_segment using its topology attribute. Users should consult each modal standard for more specific information.

The relationship between TRN_segment and TRN_Point in Figure 3 shows that each TRN_segment must have a StartPoint and EndPoint. In addition to TRN_segment start and end points, Figure 3 also shows that TRN_Point may occur anywhere along TRN_segment.

7.3 TRN_Point

7.3.1 Semantics

TRN_Point is a point along the transportation system that has some special significance either for starting or ending a segment or for representing a significant position along the transportation system such as the start or center of a tunnel or other transportation feature.

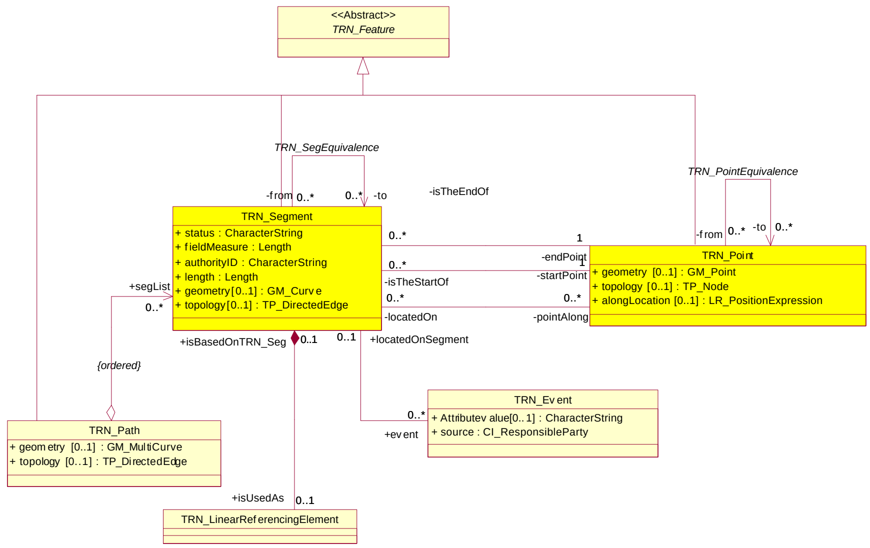

Figure 4–The relationship between TRN_segment and TRN_Point

The case where it is the specified location of an endpoint of a TRN_segment is illustrated in Figure 5, where two TRN_Points, A and B, bound a TRN_segment. A TRN_Point can also be located along a TRN_segment as in TRN_Point C or offset from a TRN_segment as in TRN_Point D. Examples of these locations might be the center of an intersection or the start of a bridge abutment. No requirements are specified on how or where to place TRN_Points, except as indicated above for TRN_segment termini and that it be done consistently throughout the data set.

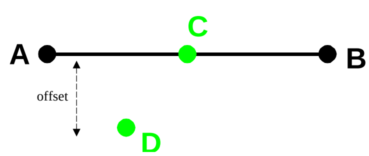

Figure 5–TRN_Points bounding a TRN_segment (A, B) or independent (C, D) of TRN_segment

TRN_Point is a subtype of TRN_Feature. TRN_Points can therefore have a geometry and topology attribute and may have one or more attributes that are associated with the location where the point occurs. Geometry is restricted to be of type GM_Point and topology to be of type TP_Node. Both GM_Point and TP_Node are defined in ISO 19107.

7.4 TRN_Path

7.4.1 Semantics

A TRN_segment is used to represent a physical transportation feature and attributes about that feature. TRN_Path, as applied in the rail, road, and transit modal standards, can represent how the transportation features are organized such as administrative routes like US 50, the 'A' Train. Because it is a path along the physical transportation feature, the TRN_Path is merely a collection of one or more, whole or partial, TRN_segment.

Figure 6 shows how TRN_Path extends TRN_Feature. It is an instance of the feature collection meta-model shown in Figure 2. This means that members of the feature collection can consist of all or parts of segments, and may or may not be contiguous. The geometry of TRN_Path can be explicitly defined by a GM_MultiCurve, or implicitly defined by the sum of the geometries defined for its component TRN_Segment. It is also possible to use both geometry approaches. For example, the TRN_Segment geometries may be a more precise representation of the transportation feature, whereas the TRN_Path geometry may be a more generalized representation. Refer to each modal standard for more information.

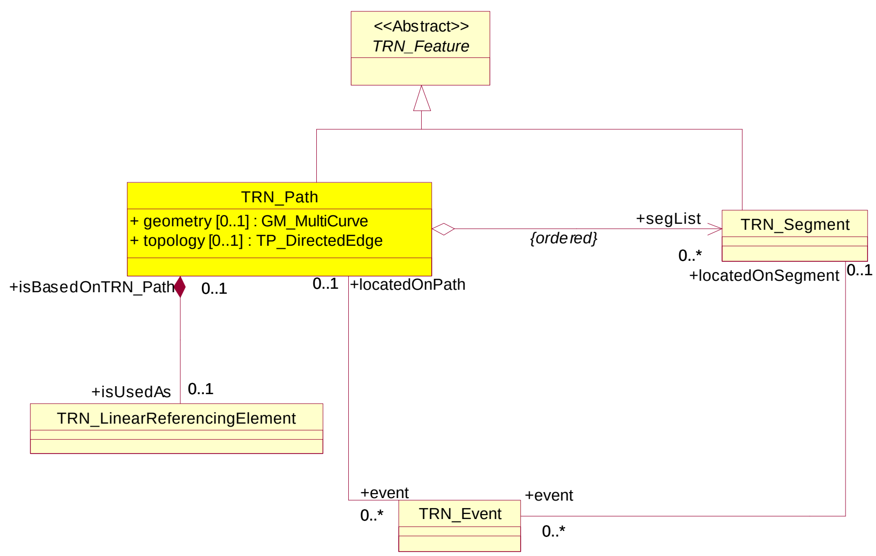

Figure 6–The TRN_Path Model

7.5 The Transportation Event Model

7.5.1 Semantics

An event is a concept that handles characteristics of the Transportation components. Events may alter the attributes of the associated Transportation feature. An event occurs within a defined time period at a defined location. Figure 7 shows that events are divided into two broad classes: attribute events and feature events. Both are extensions of feature types TRN_Segment and TRN_Path. Attribute events are those types of characteristics that have different values at different stretches along a TRN_Segment. Feature events are events associated with real world physical features that are associated with or appurtenances to the transportation system.

The location of events is determined using a Linear Reference System (LRS), discussed in detail in Annex A. PointFeature events have well-defined types described in the Code List. LinearFeature events add geometric properties to events independent of the segments to which they apply. For example, a construction area or rail yard can be encoded as a feature event with geometry GM_Polygon.

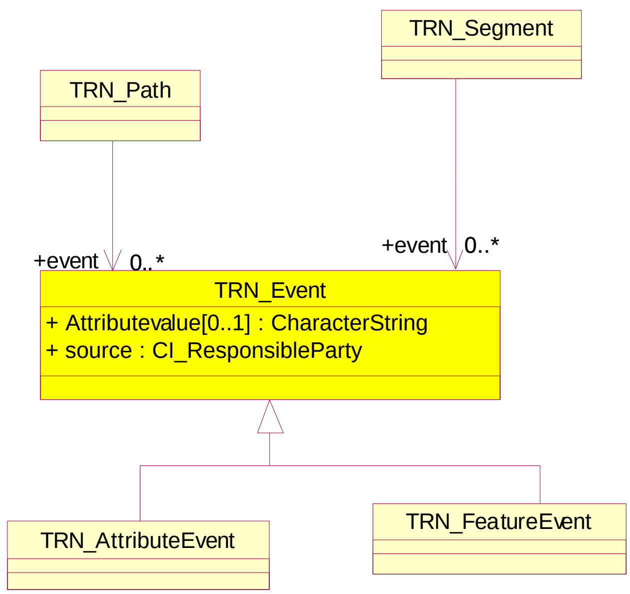

Figure 7–Context diagram: the event model

Figure 8 shows that TRN_AttributeEvent and TRN_FeatureEvent can be further divided into subclasses. TRN_PointAttributeEvent and TRN_LinearAttributeEvent are subclasses of TRN_AttributeEvent. TRN_PointAttributeEvent is expressed as a linear reference expression (LRX). Positional values for TRN_PointAttributeEvent are given in TRN_PointEventList. The location of a TRN_LinearAttributeEvent is given by a pair of linear reference expressions corresponding to the start and end positions of the event. Domain values for TRN_LinearAttributeEvent are given in TRN_LinearEventList.

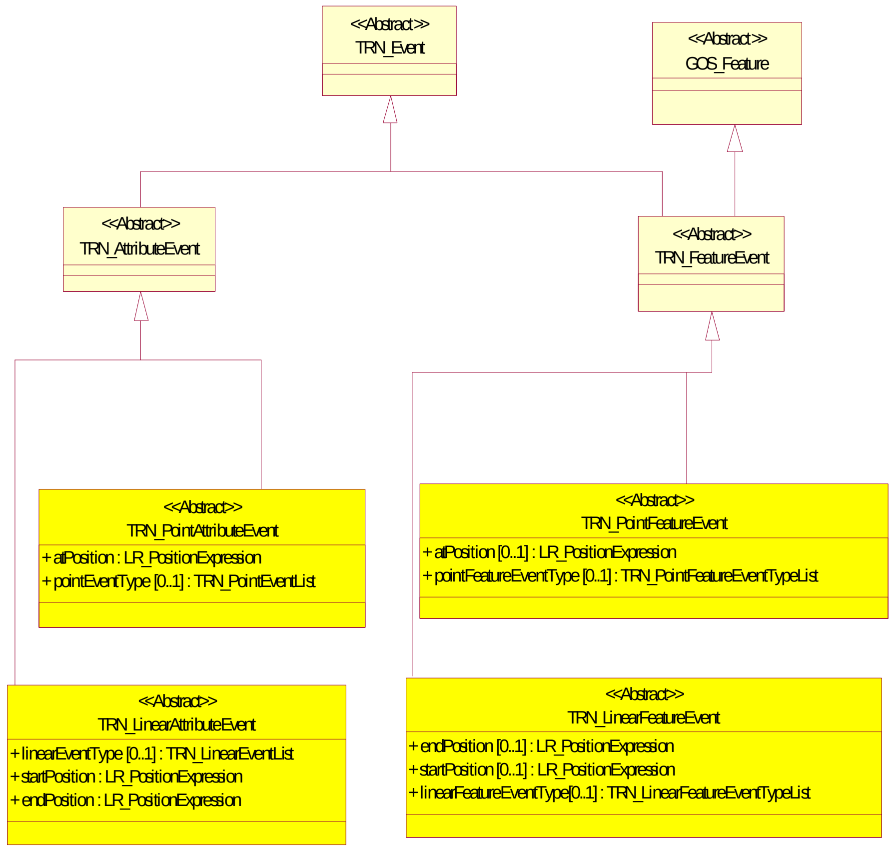

Figure 8–The Transportation Event Model

7.6 TRN_LinearAttributeEvent

7.6.1 Semantics

TRN_LinearAttributeEvents are events that have linear characteristics. However, linear attribute events are not a special class of GOS_Features, as they typically have a short temporal horizon and/or have no geometry. Linear attribute events are located along TRN_Segments that already have geometry. An example of a linear event is a traffic jam or a speed limit. An example list of LinearAttributeEvents is provided in Table 1.

7.7 TRN_PointAttributeEvent

7.7.1 Semantics

Point attribute events are events that have point characteristics. However, PointAttributeEvents are not features because, like LinearAttributeEvents, they have a short temporal duration and /or have no geometry. Point events are located along TRN_segments that already have geometry. Examples of point events include an accident, a spill, or other ephemeral event. A list of PointAttributeEvent is provided in Table 2.

7.8 TRN_LinearFeatureEvent

7.8.1 Semantics

TRN_LinearFeatureEvent is the class of linear feature events. These events are real world features that can be associated with a TRN_Segment or TRN_Path through the linear referencing method. In practical application, these events find expression in the modal standards, typically as guardrails, pavement types, walls, or other such linear features. Table 3 is the code list giving the range of possible values for TRN_LinearFeatureEvent. The start and end positions of a TRN_LinearFeatureEvent are given by a pair of linear reference expressions (LRX). Its geometry is inherited from TRN_FeatureEvent, which determines whether it is a TRN_LinearFeatureEvent or TRN_PointFeatureEvent.

7.9 TRN_Point Feature Event

7.9.1 Semantics

TRN_PointFeatureEvent is the class of point feature events and can be associated with a TRN_Segment or TRN_Path through the linear referencing method. Point feature events have a geometry, inherited from TRN_FeatureEvent, and in practical application represent features such as transportation signage or signals. The position of the TRN_PointFeatureEvent is given by a linear reference expression (LRX).

7.10 Attributes for events

Listed below in table 1 are linear event objects and their associated attributes. Similarly, table 2 lists point event objects and their associated attributes. The ‘definition’ column gives a brief definition of the term. The ‘M’ and ‘O’ in the ‘Obligation/Condition’ column stand for ‘Mandatory’ and ‘Optional’. The ‘Maximum Occurrence’ column indicates whether there are one or more occurrences. ‘Data type’ shows how the object is encoded. The ‘Domain’ column shows the object type.

Table 1 – Linear Attribute Events

	Name / Role name	Definition	Obligation / Condition	Maximum occurrence	Data type	Domain
1.	LinearAttributeEvent	event between two points	Use obligation from referencing object	Use maximum occurrence from referencing object	Class	
2.	startMeasure	Measure indicating the start of the event	M	1	Class	DistanceExpression
3.	startOffset	Measure indicating the start of the offset	O	1	Class	OffsetExpression
4.	endMeasure	Measure indicating the end of the event	M	1	Class	DistanceExpression
5.	endOffset	Measure indicating the end of the offset	O	1	Class	OffsetExpression
6.	linearReferenceMethod	linear reference method used to define the measures	M	1	Class	LinearReferenceMethod
7.	linearEventType	type of linear event	M	1	Class	LinearEventList <<Codelist>>

Table 2 – Point Attribute Events

	Name / Role name	Definition	Obligation / Condition	Maximum occurrence	Data type	Domain
8.	PointAttributeEvent	event at a single location	Use obligation from referencing object	Use maximum occurrence from referencing object	Specialized Class (Event)	
9.	atMeasure	Measure at which the event is located	M	1	Class	DistanceExpression
10.	AtOffset	offset at which the event is located	O	1	Class	OffsetExpression
11.	linearReferenceMethod	linear reference method used to define the measures	M	1	Class	LinearReferenceMethod
12.	pointEventType	type of point even	M	1	Class	PointEventList
13.	*Role Name:* associatedWith	point where the event is located	M	1	Association	TRN_Point

8 Code Lists

Listed below in table 3 is the code list for measurement methods used for Linear Referencing.

Table 3 – Measurement Methods

	Name	Domain code	Definition
1.	MethodType		type of measurement method
2.	absolute	001	location is measured along the linear element starting at the beginning of the linear element
3.	relative	002	location is measured along the linear element starting at the location of a predefined referent
4.	interpolative	003	location along the linear element is determined by applying linear interpolation of the specified measure against the total length of the linear element
5.	projected	004	location along the linear element is determined by projecting the specified spatial location onto the linear element

Annex A Linear Reference System

This standard relies on the linear referencing standard, ISO 19133 [5] and is included here as a reference to supplement and clarify the concepts introduced in this document.

Package: Linear Reference Systems

Semantics

The package “Linear Reference Systems” supplies classes and types to the definition of linear reference systems. Linear reference systems are in wide use in transportation. They allow for the specification of positions along curvilinear features by using measured distances from known positions, usually represented by physical markers along the right-of-way of the transportation feature.

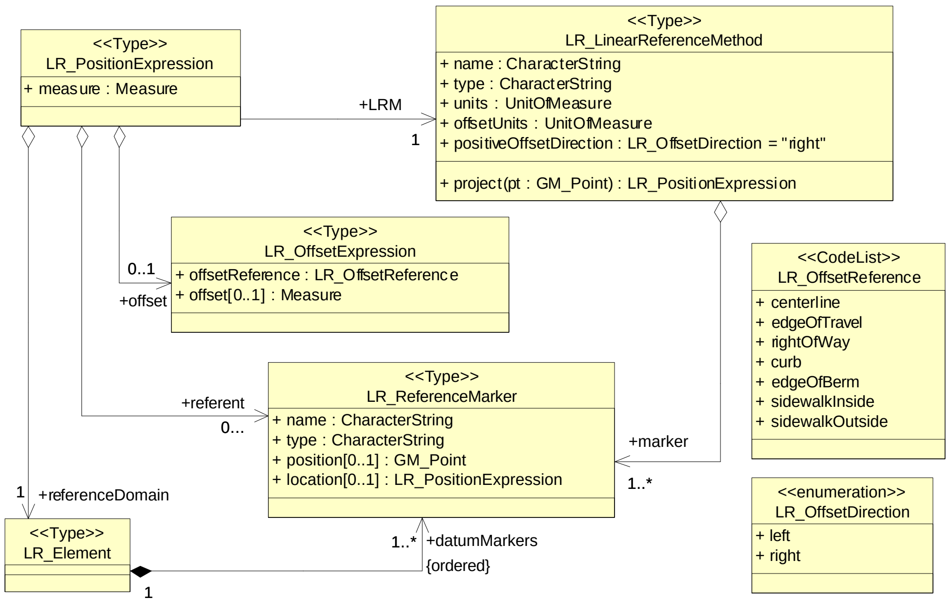

Figure 9 — LRS classes

LR_PositionExpression

Semantics

The class “LR_PositionExpression” is used to describe position given by a measure value, a curvilinear element being measured, and the method of measurement.

Attribute: measure : Measure

The attribute “measure” gives measure (usually a distance) of this position expression.

```
LR_PositionExpression :: measure : Measure
```

Role: LRM : LR_LinearReferenceMethod

The role “LRM” gives the linear reference method used for this position expression.

```
LR_PositionExpression :: LRM : LR_LinearReferenceMethod
```

Role: referent [0..1] : LR_ReferenceMarker

The optional association role “referent” gives the marker or known position from which the measure is taken for the linear reference method used for this position expression. If the referent is absent, the measurement is made from the start of the LR_element.

```
LR_PositionExpression :: referent [0..1]: LR_ReferenceMarker
```

Role: referenceDomain : LR_Element

The role “referenceDomain” gives the linear object upon which the measure is taken for the linear reference method used for this position expression.

```
LR_PositionExpression :: referenceDomain : LR_Element
```

Role: offset[0..1] : LR_OffsetExpression

The optional association role “offset” gives perpendicular distance offset of this position expression. If the offset is absent, then the position is on the LR_element..

```
LR_PositionExpression :: offset[0..1] : LR_OffsetExpression
```

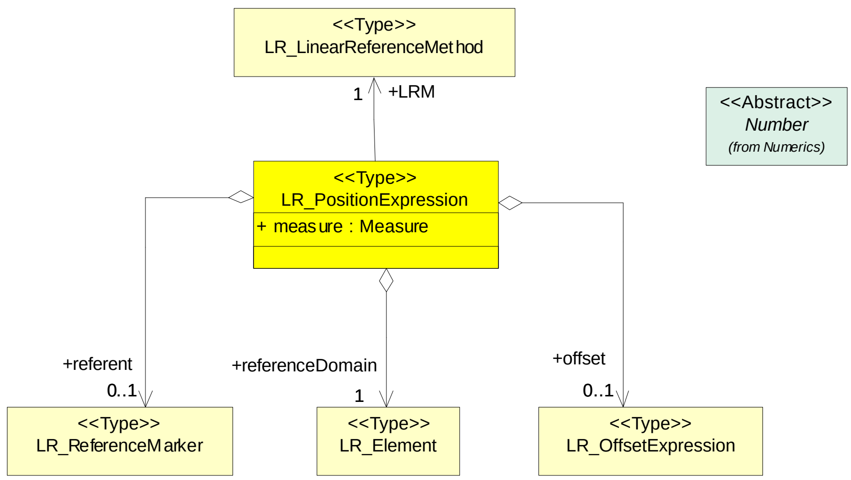

Figure 10 — Context Diagram: LR_PositionExpression

LR_LinearReferenceMethod

Semantics

The type “LR_LinearReferenceMethod” describes the manner in which measurements are made along (and optionally laterally offset from) a curvilinear element.

Attribute: name : CharacterString

The attribute: “name” gives the name of this linear reference method.

```
LR_LinearReferenceMethod :: name : CharacterString
```

Attribute: type : CharacterString

The attribute: “type” gives the type of this linear reference method.

```
LR_LinearReferenceMethod :: type : CharacterString
```

Attribute: units : UnitOfMeasure

The attribute: “units” gives the units of measure used for this linear reference method for measures along the base elements.

```
LR_LinearReferenceMethod :: units : UnitOfMeasure
```

Attribute: offsetUnits : UnitOfMeasure

The attribute: “offsetUnits” gives the units of measure used for this linear reference method for measures perpendicular to the base elements.

```
LR_LinearReferenceMethod :: offsetUnits : UnitOfMeasure
```

Attribute: positiveOffsetDirection : LR_OffsetDirection = "right"

The attribute: “positiveOffsetDirection” gives the direction used as positive for this linear reference method for measures perpendicular to the base elements. The default value is right for positive, left for negative.

```
LR_LinearReferenceMethod ::
      positiveOffsetDirection : LR_OffsetDirection = "right”
```

Role: marker[1..*] : LR_ReferenceMarker

The association role “marker” aggregates all reference markers used by the linear reference methods. Normally, this will be grouped by linear element.

```
LR_LinearReferenceMethod :: marker[1..*] : LR_ReferenceMarker
```

Role: referenceElement[1..*] : LR_Element

The role: “referenceElement” aggregates all the linear elements along which this method is supported.

```
LR_LinearReferenceMethod :: referenceElement[1..*] : LR_Element
```

Operation: project

The operation “project” will find the measure of the point on a base element closest to the given point, and then express the point as position expression for the linear reference method. If the point is precisely on one of the linear elements, then the offset will be zero there is no offset expression.

```
LR_LinearReferenceMethod ::
      project(GM_Point pt) : LR_PositionExpression
```

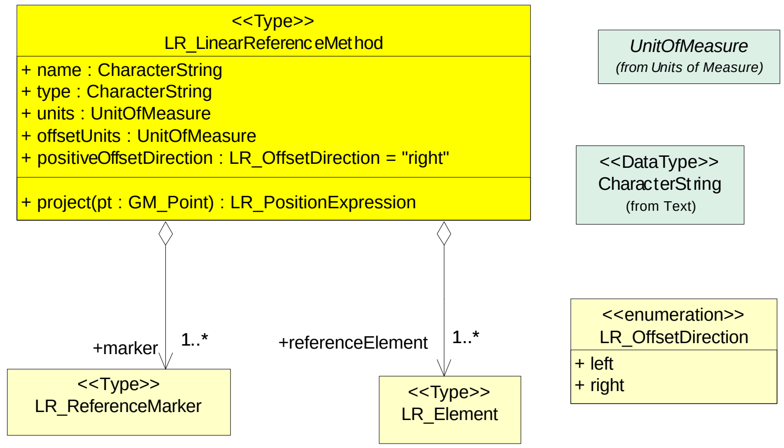

Figure 11 — Context Diagram: LR_LinearReferenceMethod

LR_OffsetDirection

The enumeration “LR_OffsetDirection” gives the two options for offset measure. The values are left and right. This offset direction is as viewed from above the linear element facing in the direction of increasing measure.

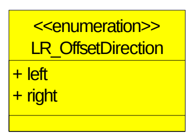

Figure 12 — Context Diagram: LR_OffsetDirection

LR_ReferenceMarker

Semantics

The type “LR_ReferenceMarker” is used to describe reference markers used in linear reference systems. At least one of the attributes “position” or “location” must be given. If both are given they must refer to the same physical location.

Attribute: name : CharacterString

The attribute “name” is the identifier used for this marker.

```
LR_ReferenceMarker :: name : CharacterString
```

Attribute: type : CharacterString

The attribute “type” is the type of this marker.

```
LR_ReferenceMarker :: type : CharacterString
```

Attribute: position[0..1] : GM_Point

The optional attribute “position” is the position of this for this marker, given in some coordinate system. If this attribute is not given, then the “location” must be given.

```
LR_ReferenceMarker :: position[0..1] : GM_Point
```

Attribute: location[0..1] : LR_PositionExpression

The optional attribute “location” is the location of this marker given as a linear reference measure along and from the start of the underlying linear element.

```
LR_ReferenceMarker :: location[0..1] : LR_PositionExpression
```

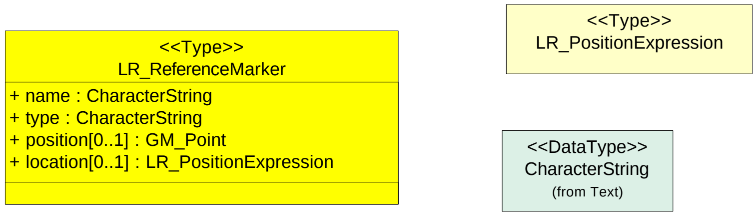

Figure 13 — Context Diagram: LR_ReferenceMarker

LR_OffsetReference

The code list “LR_OffsetReference” enumerates the offset reference types used for this linear reference method. The initial value domain included:

"centerline"	the center of the paved area
"edgeOfTravel"	the outside edge of all travel lanes
"rightOfWay"	the edge of the legal right of way
"curb"	the curb (the roadway must be curbed for this to be used)
”edgeOfBerm"	the outside edge of all paved surface, usually used in place of “curb’ when no curb is present
”sidewalkInside"	sidewalk edge closest to travel lanes
”sidewalkOutside”	sidewalk edge furthest from travel lanes

LR_Feature

The type “LR_Feature” is a behavioral description of features used as base elements in a linear reference method. This is the most common approach used for LRS’s.

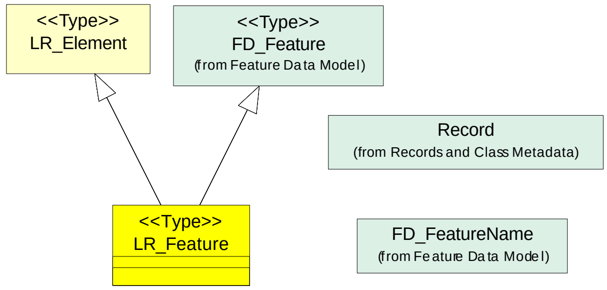

Figure 14 — Context Diagram: LR_Feature

LR_Element

Semantics

The type “LR_Element” describes the underlying curvilinear elements upon which the measures in the linear reference system are taken.

Role: datumMarkers[1..*] : LR_ReferenceMarker

The ordered association role “datumMarkers” aggregates the markers along this element. The ordering of the markers is consistent with the order in which the markers would be found in traversing the LR_Element from beginning to end (i.e. in increasing order of distance from the “zero marker” the beginning of the element).

```
LR_Element :: datumMarkers[1..*] : LR_ReferenceMarker
```

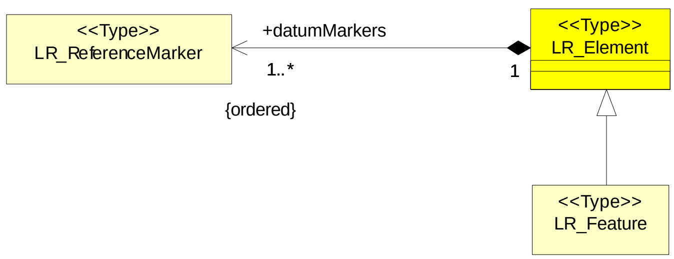

Figure 15 — Context Diagram: LR_Element

LR_OffsetExpression

Semantics

The type “LR_OffsetExpression” is used to describe the offset for a position described using a linear reference method.

Attribute: offsetReference : LR_OffsetReference

The attribute “offsetReference” indicates the base line for the offset measure.

```
LR_OffsetExpression :: offsetReference : LR_OffsetReference
```

Attribute: offset[0..1] : Number

The optional attribute “offset” is the measure of the offset of the position expression. A missing value is to be interpreted as being located at the offset reference.

```
LR_OffsetExpression :: offset[0..1] : Measure
```

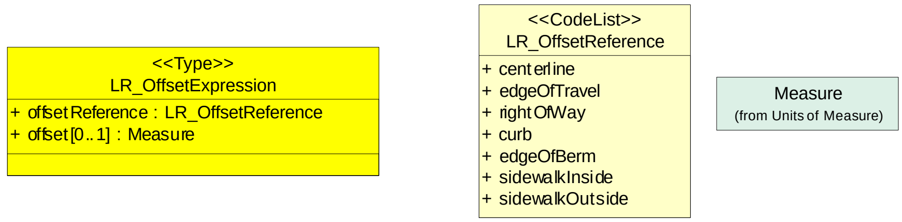

Figure 16 — Context Diagram: LR_OffsetExpression

Annex B Identification

Numerous data exchanges will not include geometric representations. A single data source, or multiple data sources may supply several representations of the same feature. In either case, an identifier is necessary so that users may distinguish which feature is described by the spatial and non-spatial representations in the data set. The real world identifier must be persistent and unique for all data sources. The identifier for the feature geometry must also be unique and persistent for each representation, even those within a single source.

Identification is an important issue for the development of the National Spatial Data Infrastructure (NSDI). The requirement is that a permanent, unique identifier must be assigned to road features so that relationships can be made between those elements and associated data. This document discusses some of the options and tradeoffs for different approaches to identification.

First, to clarify what Identification means: tax parcels usually have a unique identification scheme assigned by the county property assessment system. In a county those identifiers can be used as a "key" to search through multiple databases and find information about tax bills, payment history, and property tax maps. Similarly, unique identifiers can be assigned to sections of a highway and record information about pavement condition, accident locations, and road signage using a location description along with the identifier. These IDs are numeric or alphanumeric values that are typically stored as a column in a database table.

Traditionally, most organizations have defined their own identification system with little regard to uniqueness or consistent ID generation across multiple organizations. In regard to the NSDI, unique identification becomes critical to reliably connecting data to geographic locations.

Semi-Meaningful Unique Identifiers

There are several approaches that have been considered for creating these identifiers. Often, organizations want to define a semi-meaningful ID. One example could be

AA.BBBB.CCCCCCCCCC

Where AA is a two character Federal Information Processing Standards (FIPS) Code for a state, BBBB is a state or federal designated organization number, and CCCCCCCCCC is a 10 character unique id within one organization's database.

Pro:

1. End users like this approach because they can understand something about the source of the data through the ID.
2. Organizations can define their own ID scheme and mechanism for generating the unique values.

Con:

1. It works well for organizations that work within one state but does not work for federal government agencies and private companies. This leads to an extended FIPS coding scheme.
2. There has to be a system established for assigning organization IDs (the BBBB). Neither the federal or state organizations have established a system to date.
3. It is an optimistic approach to creating Identifiers that does not guarantee that two agencies might use the same organization code (BBBB) and IDs, which could result in duplicate IDs in a national system.

Globally Unique, Meaningless Identifiers

Another approach that can be used is to find a way to create globally unique identifiers. One technique is to use GUIDs, a computing industry standard technique that uses a combination of a computers unique hardware Ethernet address plus a unique system-generated ID. The result looks like:

{7A566981-C114-11D2-8A28-006097AFF44E}

Pro:

1. Easy for programmers and data publishers to define.
2. Guaranteed to be unique.
3. Information engineers and database designers favor this approach.
4. End user needs for data source and quality information can be carried in other attributes.
5. Easy to add this ID to existing datasets.

Con:

1. End users often don't like this approach because the key is meaningless.

Identifier Web Service

Another technique for generating IDs is to create a national ID server that simply serves up unique Identifiers for NSDI. In the past this was not technically feasible, but with the advent of the Internet and Web Services, this would be a relatively simple service from a technical standpoint. In the simplest form, this could just be a meaningless ID generator like a GUID or some other structure. There is also the potential to create a semi-meaningful ID based on requestor information and authentication.

Pro:

1. Flexibility to guarantee unique IDs in either meaningful or meaningless IDs.

Con:

1. Requires a reliable connection to the ID Web Service at all times.
2. Performance over the Internet unknown.
3. Requires development and maintenance of the ID service.

Annex C Equivalencies

The central issue for the Road Standard is how to equate segments from disparate databases that represent the same real world features. In other words, different databases will have different positional accuracies and different linear referencing methods (LRM) to represent the same piece of road and end users may have a variety of compelling business needs to distinguish each representation but also know that each is a representation of the same section of road. **Equivalency** is the term given to the process of equating road segments from disparate databases.

Assume that there are three segmentation schemes developed for a real road, as depicted in figure 14. All data sets include only ROD_Segs. The basic difference between the two local ROD_Seg data sets is the use of different intersections to base the segmentation; i.e., to form ROD_Seg termini.

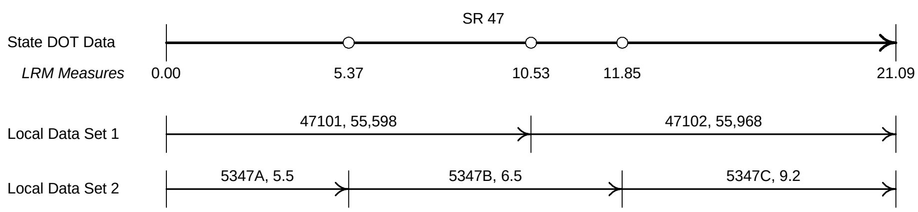

Figure 17–Sample data sets representing the same segment of road.

For simplicity, the only mandatory attributes of a ROD_Seg are its identifier and length. The State DOT data set includes linear referencing method (LRM) measures for the intersections (point events) and ROD_Seg termini. To make it more interesting (and realistic), different resolutions for LRM measures are shown on the three data sets. Here are all the numbers:

1. The State DOT data set states that the road is 21.09 miles long and includes three intersection point events along its extent at distances of 5.37, 10.53, and 11.85 miles from the LRM origin.
2. Local Data Set 1 states that the road is 111,566 feet long and consists of two ROD_Seg features, one has the feature ID of 47101 and is 55,598 feet long, and the other has a feature ID of 47102 and a length of 55,968 feet.
3. Local Data Set 2 states that the road is 21.2 miles long and consists of three segments, 5347A at 5.5 miles in length, 5347B at 6.5 miles in length, and 5347C at 9.2 miles in length.

An end user may need to construct **equivalencies** between the each of the two local ROD_Seg data sets and the State DOT data set. The State DOT ROD_Seg is the reference feature and the local ROD_Segs are the equivalent features. This means the local ROD_Segs will be restated as the equivalent pieces of the State DOT ROD_Seg.

Local Data Set 1:

- ROD_Seg 47101 starts at 0.000% and ends at 49.834% (55,598/111,566);
- ROD_Seg 47102 starts at 49.834% and ends at 100.000%.

Local Data Set 2:

- ROD_Seg 5347A starts at 0.000% and ends at 25.943% (5.5/21.2);
- ROD_Seg 5347B starts at 25.94% and ends at 56.604% ((5.5+6.5)/21.2);
- ROD_Seg 5347C starts at 56.604% and ends at 100.000%.

Note two important points. First, this is exactly the same straight-line interpolation as used by dynamic segmentation. Second, the differences in LRM units and values between the data sets are inconsequential as the distances are computed in the separate LRM values and are consistent within each linear referencing system.

Annex D UML notations

The material in this annex is drawn from ISO/TS 19103 [8] and ISO 19115: Geographic information - Conceptual schema language.
The diagrams that appear in this Standard are presented using the Unified Modeling Language (UML) static structure diagram with the ISO Interface Definition Language (IDL) basic type definitions and the UML Object Constraint Language (OCL) as the conceptual schema language. The UML notations used in this standard are described in Figures 9 and 10.

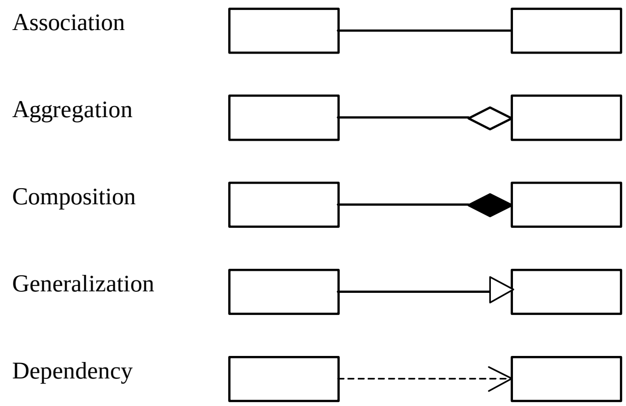

Figure 18–UML notation

UML model relationships

Associations

An association is used to describe a relationship between two or more classes. UML defines three different types of relationships, called association, aggregation and composition. The three types have different semantics. An ordinary association shall be used to represent a general relationship between two classes. The aggregation and composition associations shall be used to create part-whole relationships between two classes. The direction of an association must be specified. If the direction is not specified, it is assumed to be a two-way association. If one-way associations are intended, the direction of the association can be marked by an arrow at the end of the line.

An aggregation association is a relationship between two classes in which one of the classes plays the role of container and the other plays the role of the contained. A composition association is a strong aggregation. In a composition association, if a container object is deleted, then all of its contained objects are deleted as well. The composition association shall be used when the objects representing the parts of a container object cannot exist without the container object.

Generalization

A generalization is a relationship between a superclass and the subclasses that may be substituted for it. The super-class is the generalized class, while the subclasses are specified classes.

Instantiation / Dependency

A dependency relationship shows that the client class depends on the supplier class/interface to provide certain services, such as:

— Client class accesses a value (constant or variable) defined in the supplier class/interface;

— Operations of the client class invoke operations of the supplier class/interface;

— Operations of the client class have signatures whose return class or arguments are instances of the supplier class/interface.

An instantiated relationship represents the act of substituting actual values for the parameters of a parameterized class or parameterized class utility to create a specialized version of the more general item.

Roles

If an association is navigable in a particular direction, the model shall supply a “role name” that is appropriate for the role of the target object in relation to the source object. Thus in a two-way association, two role names will be supplied.

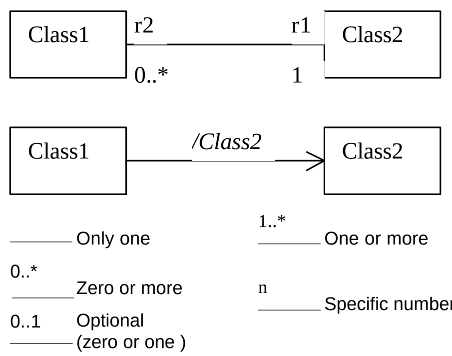

Figure 19–UML roles

Figure 10 represents how role names and cardinalities are expressed in UML diagrams. The role name “r1”’ is Class1’s relationship to Class2. The role name “r2” is Class2’s relationship to Class1. The cardinalities show that “zero or many” Class1s are related to “exactly one” Class2.

Figure 2 also shows how derived classes will be expressed. The diagram indicates that Class1 is a derived class of Class2. Any attributes and aggregates of Class1 are also derived from Class2.

UML model stereotypes

A UML stereotype is an extension mechanism for existing UML concepts. It is a model element that is used to classify (or mark) other UML elements so that they in some respect behave as if they were instances of new virtual or pseudo metamodel classes whose form is based on existing base metamodel classes. Stereotypes augment the classification mechanisms on the basis of the built-in UML metamodel class hierarchy. Below are brief descriptions of the stereotypes used in this Standard:

a) <<DataType>> descriptor of a set of values that lack identity (independent existence and the possibility of side effects). Data types include primitive predefined types and user-definable types. A DataType is thus a class with few or no operations whose primary purpose is to hold the abstract state of another class.
b) <<CodeList>> used to describe a more open enumeration. <<CodeList>> is a flexible enumeration. Code lists are useful for expressing a long list of potential values. If the elements of the list are completely known, an enumeration should be used; if the only likely values of the elements are known, a code list should be used.
c) <<Abstract>> class (or other classifier) that cannot be directly instantiated. UML notation for this to show the name in italics.
d) <<Package>> cluster of logically related components, containing sub-packages.
e) <<Leaf>> package that contains definitions, without any sub-packages.

Annex E Other Applicable Standards

This standard was preceded in development by many other standards that were consulted in the development of this standard. These standards are not listed in Section 2, nor directly referenced in the body of the standard. They include the following:

FGDC-STD-002.5, *Spatial Data Transfer Standard (SDTS), Part 5: Raster Profile and Extensions.*

FGDC-STD-002.6, *Spatial Data Transfer Standard (SDTS), Part 6: Point Profile.*

FGDC-STD-002.7-2000, *SDTS Part 7: Computer-Aided Design and Drafting (CADD) Profile.*

FGDC-STD-007.1-1998, *Geospatial Positioning Accuracy Standard, Part 1, Reporting Methodology.*

FGDC-STD-007.3-1998, *Geospatial Positioning Accuracy Standard, Part 3, National Standard for Spatial Data Accuracy.*

FGDC-STD-007.4-2002, *Geospatial Positioning Accuracy Standard, Part 4: Architecture, Engineering Construction, and Facilities Management.*

FGDC-STD-001-1998, *Content Standard for Digital Geospatial Metadata (version 2.0).*

INCITS 353:2001, *Spatial Data Standard for Facilities, Infrastructure, and Environment.*

ISO 19111, *Geographic Information—Spatial Referencing by Coordinates*.

ISO 19123, *Geographic Information—Schema for Coverage Geometry and Functions.*

U.S. CADD/GIS Technology Center, *Spatial Data Standards for Facilities, Infrastructure and the Environment*, V2.2