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Geographic information — Linear referencing

Information géographique — Référencement linéaire

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO 19148 was prepared by Technical Committee ISO/TC 211, *Geographic information/Geomatics*.

Introduction

This International Standard is a description of the data and operations required to support linear referencing. This includes Linear Referencing Systems, linearly located events and linear segments.

Linear Referencing Systems enable the specification of positions along linear objects. The approach is based upon the Generalized Model for Linear Referencing[3] first standardized within ISO 19133:2005, 6.6. This International Standard extends that which was included in ISO 19133, both in functionality and explanation.

ISO 19109 supports features representing discrete objects with attributes having values which apply to the entire feature. ISO 19123 allows the attribute value to vary, depending upon the location within a feature, but does not support the assignment of attribute values to a single point or length along a linear feature. Linearly located events provide the mechanism for specifying attribution of linear objects when the attribute value varies along the length of a linear feature. A Linear Referencing System is used to specify where along the linear object each attribute value applies. The same mechanism can be used to specify where along a linear object another object is located, such as guardrail or a traffic accident.

It is common practice to segment a linear object having linearly located events, based upon one or more of its attributes. The resultant linear segments are attributed with just the attributes used in the segmentation process, insuring that the linear segments are homogeneous in value for these segmenting attributes.

This International Standard differs from ISO 19133:2005, 6.6 in the following areas.

a) All occurrences of Linear Reference Method and Linear Reference System have been changed to Linear Referencing Method and Linear Referencing System, respectively.

b) LR_Element has been renamed LR_LinearElement and further defined as being a feature or geometry or topology. These shall support the newly introduced interface ILinearElement, meaning that it is possible to measure (linearly) along them.

c) The newly introduced ILinearElement interface includes operations for returning the default Linear Referencing Method of the linear element and any of its length or weight attribute values. It also includes operations for translating between Linear Referencing Methods and/or linear elements.

d) The types of Linear Referencing Methods have been formalized as a CodeList. Names of common Linear Referencing Methods have been added as an informative annex.

e) An additional attribute, constraint[0..*], has been added to Linear Referencing Method to specify the constraints imposed by the method, such as “only allows reference marker referents”. This is an alternative to subtyping the methods that would force a too-structured approach, inconsistent with the Generalized Model, and would be indeterminate due to the wide variety of Linear Referencing Methods currently in use.

f) The Linear Referencing Method “project” operation has been renamed “lrPosition” and moved to the ISpatial interface and a second, opposite, operation “point” has been added. Only LR_Curves realize this interface since their spatial representation is requisite for the two operations, along with the ILinearElement interface.

g) The LR_PositionExpression measure attribute has been extracted out into a Distance Expression along with the optional referent and offset roles consistent with the original theoretical model. This allows for specifying only an LR_DistanceExpression when the LR_LinearElement and LR_LinearReferencingMethod are already known.

h) Reference Marker has been generalized to LR_Referent to enable support for other referent types such as intersections, boundaries and landmarks. This type has been formalized as a CodeList.

i) A second, optional (towards) Referent has been added in a new (optional) package, Linear Referencing Towards Referent (LRTR), for those Linear Referencing Methods which allow this to disambiguate measurement direction.

j) Lateral Offsets have been moved to a new (optional) package, Linear Referencing Offset (LRO). Horizontal, vertical, and combined horizontal and vertical offsets are now supported. Offset referent has been generalized to allow for feature instances as well as character strings.

k) Vector Offsets have been adopted from ISO 19141. They exist in a new (optional) package, Linear Referencing Offset Vector (LROV). An optional offset vector Coordinate Reference System (CRS) can be provided if it is different from the CRS of the linear element.

l) The theoretical model on which the original standard was built is explained in Annex B.

m) More descriptive text is added throughout this International Standard to explain the concepts being presented.

n) Minor changes to some class, attribute and role names have been made.

o) A new (optional) package, Linearly Located Event (LE) has been added which uses linearly referenced positions to specify where along a linear feature a particular attribute value or other feature instance applies.

p) A new (optional) package, Linear Segmentation (LS) has been added to support the generation of homogeneous attributed linear segments from linear features with length-varying attribution.

q) Absolute Linear Referencing Method with non-zero linear element start is now accommodated.

r) lateralOffsetReferentType and verticalOffsetReferentType have been changed from CodeLists to Character Strings.

Geographic information — Linear referencing

1 Scope

This International Standard specifies a conceptual schema for locations relative to a one-dimensional object as measurement along (and optionally offset from) that object. It defines a description of the data and operations required to use and support linear referencing.

This International Standard is applicable to transportation, utilities, location-based services and other applications which define locations relative to linear objects.

2 Conformance

2.1 Conformance overview

Clause 6 of this International Standard uses the Unified Modelling Language (UML) to present conceptual schemas for describing the constructs required for Linear Referencing. These schemas define conceptual classes that shall be used in application schemas, profiles and implementation specifications. This International Standard concerns only externally visible interfaces and places no restriction on the underlying implementations other than what is required to satisfy the interface specifications in the actual situation, such as

— interfaces to software services using techniques such as SOAP;

— interfaces to databases using techniques such as SQL;

— data interchange using encoding as defined in ISO 19118.

Few applications require the full range of capabilities described by this conceptual schema. Clause 6, therefore, defines a set of conformance classes that support applications whose requirements range from the minimum necessary to define data structures to full object implementation. This flexibility is controlled by a set of UML types that can be implemented in a variety of manners. Implementations that define full object functionality shall implement all operations defined by the types of the chosen conformance class, as is common for UML designed object implementations. It is not necessary for implementations that choose to depend on external “free functions” for some or all operations, or forgo them altogether, to support all operations, but they shall always support a data type sufficient to record the state of each of the chosen UML types as defined by its member variables. It is acceptable to use common names for concepts that are the same but have technically different implementations. The UML model in this International Standard defines abstract types, application schemas define conceptual classes, various software systems define implementation classes or data structures, and the XML from the encoding standard (ISO 19118) defines entity tags. All of these reference the same information content. There is no difficulty in allowing the use of the same name to represent the same information content even though at a deeper level there are significant technical differences in the digital entities being implemented. This “allows” types defined in the UML model to be used directly in application schemas.

2.2 Conformance classes

2.2.1 General

Conformance to this International Standard shall consist of either data type conformance or both data type and operation conformance.

2.2.2 Data type conformance

Data type conformance includes the usage of data types in application schemas or profiles that instantiate types in this International Standard. In this context, “instantiate” means that there is a correspondence between the types in the appropriate part of this International Standard, and the data types of the application schema or profile in such a way that each standard type can be considered as a supertype of the application schema data type. This means that an application schema or profile data type corresponding to a standard type contains sufficient data to recreate that standard type's information content.

Table 1 assigns conformance tests to each of the packages in Clause 6. Each row in the table represents one conformance class. A specification claiming data type conformance to a package in the first column of the table shall satisfy the requirements specified by the tests given in the remaining columns to the right.

Table 1 — Data type conformance tests

Package	Conformance test					
	A.1.1	A.1.2	A.1.3	A.1.4	A.1.5	A.1.6
Linear Referencing System	X	—	—	—	—	—
Linear Referencing Towards Referent	X	X	—	—	—	—
Linear Referencing Offset	X	—	X	—	—	—
Linear Referencing Offset Vector	X	—	X	X	—	—
Linearly Located Event	X	—	—	—	X	—
Linear Segmentation	X	—	—	—	X	X

2.2.3 Operation conformance

Operation conformance includes both the consistent use of operation interfaces and data type conformance for the parameters, and return values used by those operations. Operation conformance also includes get and set operations for attributes.

Table 2 assigns conformance tests to each of the packages in Clause 6. Each row in the table represents one conformance class. A specification claiming operation conformance to a package in the first column of the table shall satisfy the requirements specified by the tests given in the remaining columns to the right.

Table 2 — Operation conformance tests

Package	Conformance test					
	A.1.1 A.2.1	A.1.2 A.2.2	A.1.3 A.2.3	A.1.4 A.2.4	A.1.5 A.2.5	A.1.6 A.2.6
Linear Referencing System	X	—	—	—	—	—
Linear Referencing Towards Referent	X	X	—	—	—	—
Linear Referencing Offset	X	—	X	—	—	—
Linear Referencing Offset Vector	X	—	X	X	—	—
Linearly Located Event	X	—	—	—	X	—
Linear Segmentation	X	—	—	—	X	X

3 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/TS 19103, *Geographic information — Conceptual schema language*

ISO 19107, *Geographic information — Spatial schema*

ISO 19108, *Geographic information — Temporal schema*

ISO 19111, *Geographic information — Spatial referencing by coordinates*

4 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

4.1
attribute event
value of an attribute of a **feature** (4.4) that may apply to only part of the feature

NOTE 1 An attribute event includes the **linearly referenced location** (4.16) where the attribute value applies along the **attributed feature** (4.2).

NOTE 2 An attribute event may be qualified by the **instant** (4.8) in which, or **period** (4.20) during which, the attribute value applied.

4.2
attributed feature
feature (4.4) along which an **attribute event** (4.1) applies

4.3
direct position
position (4.21) described by a single set of coordinates within a coordinate reference system

[ISO 19107:2003, 4.26]

4.4
feature
abstraction of real world phenomena

[ISO 19101:2002, 4.11]

4.5
feature event
information about the occurrence of a **located feature** (4.17) along a **locating feature** (4.18)

NOTE 1 A feature event includes the **linearly referenced location** (4.16) of the located feature along the locating feature.

NOTE 2 A feature event may be qualified by the **instant** (4.8) in which, or **period** (4.20) during which, the feature event occurred.

4.6
geometric primitive
geometric object representing a single, connected, homogeneous element of space

[ISO 19107:2003, 4.48]

4.7
height
h, H
distance of a point from a chosen reference surface measured upward along a line perpendicular to that surface

[ISO 19111:2007, 4.29]

NOTE The surface is normally used to model the surface of the Earth.

4.8
instant
0-dimensional **geometric primitive** (4.6) representing **position** (4.21) in time

[ISO 19108:2002, 4.1.17]

NOTE The geometry of time is discussed in ISO 19108:2002, 5.2.

4.9
linear element
1-dimensional object that serves as the axis along which **linear referencing** (4.10) is performed

NOTE Also known as curvilinear element.

EXAMPLES **Feature** (4.4), such as “road”; curve geometry; directed edge topological primitive.

4.10
linear referencing
specification of a **location** (4.19) relative to a **linear element** (4.9) as a measurement along (and optionally offset from) that element

NOTE An alternative to specifying a location as a two- or three- dimensional **spatial position** (4.22).

4.11
Linear Referencing Method
manner in which measurements are made along (and optionally offset from) a **linear element** (4.9)

4.12
Linear Referencing System
set of **Linear Referencing Methods** (4.11) and the policies, records and procedures for implementing them[1]

4.13
linear segment
part of a linear **feature** (4.4) that is distinguished from the remainder of that feature by a subset of attributes, each having a single value for the entire part

NOTE 1 A linear segment is a one-dimensional object without explicit geometry.

NOTE 2 The implicit geometry of the linear segment can be derived from the geometry of the parent feature.

4.14
linearly located
located using a **Linear Referencing System** (4.12)

4.15
linearly located event
occurrence along a **feature** (4.4) of an attribute value or another feature

NOTE 1 The event **location** (4.19) is specified using **linearly referenced locations** (4.16).

NOTE 2 A linearly located event may be qualified by the **instant** (4.8) in which, or **period** (4.20) during which, the linearly located event occurred.

NOTE 3 ISO 19108 limits events to a single instant in time and does not include the specification of a location.

4.16
linearly referenced location
location whose **position** (4.21) is specified using **linear referencing** (4.10)

4.17
located feature
feature (4.4) that is **linearly located** (4.14) along an associated (locating) feature

EXAMPLE A feature "bridge" may be a located feature along the feature "railway" [a **locating feature** (4.18)].

4.18
locating feature
feature (4.4) that is used to identify the **location** (4.19) of **linearly located** (4.14) features

EXAMPLE A feature "road" may be the locating feature for a feature "pedestrian crossing" [a **located feature** (4.17)].

4.19
location
identifiable geographic place

[ISO 19112 :2003, 4.4]

NOTE A location is represented by one of a set of data types that describe a **position** (4.21), along with metadata about that data, including coordinates (from a coordinate reference system), a measure [from a **Linear Referencing System** (4.12)], or an address (from an address system). [ISO 19133].

4.20
period
one-dimensional **geometric primitive** (4.6) representing extent in time

[ISO 19108:2002, 4.1.27]

NOTE A period is bounded by two different **temporal positions** (4.23).

4.21
position
data type that describes a point or geometry potentially occupied by an object or person

[ISO 19133:2005, 4.18]

NOTE A **direct position** (4.3) is a semantic subtype of position. Direct positions as described can define only a point and, therefore, not all positions can be represented by a direct position. That is consistent with the "is type of" relation. An ISO 19107 geometry is also a position, just not a direct position.

4.22
spatial position
direct position (4.3) that is referenced to a 2- or 3-dimensional coordinate reference system

NOTE An alternative to specifying a **location** (4.19) as a **linearly referenced location** (4.16).

4.23
temporal position
location (4.19) relative to a **temporal reference system** (4.24)

[ISO 19108:2002, 4.1.34]

4.24
temporal reference system
reference system against which time is measured

[ISO 19108:2002, 4.1.35]

4.25
valid time
time when a fact is true in the abstracted reality

[ISO 19108:2002, 4.1.39]

5 Abbreviated terms

CRS Coordinate Reference System

LRM Linear Referencing Method

LRS Linear Referencing System

SOAP Single Object Access Protocol

SQL Structured Query Language

UML Unified Modelling Language

XSP Cross-Sectional Positioning

NOTE The UML notation described in ISO/TS 19103 is used in this International Standard.

6 Linear referencing

6.1 Introduction

6.1.1 Linear referencing concepts

6.1.1.1 General

Linear Referencing Systems are in wide use in transportation but are also appropriate in other areas such as utilities. They allow for the specification of positions along linear elements by using measured distances along (and optionally offset from) the element. This is in contrast to using spatial positions that use two- or three-dimensional coordinates, consistent with a particular Coordinate Reference System (CRS).

Linearly referenced locations are significant for several reasons. First, a significant amount of information is currently held in huge databases from legacy systems that pre-date Geographic Information Systems (GIS). Many useful applications can and have been built on these data with no understanding of where on the earth's surface the data are located. Knowing where they are located relative to a linear element such as a roadway route or pipeline is sufficient to support these applications and can be used as a means of integrating data from multiple, disparate sources.

In some situations, having a linearly referenced location along a known linear element is more advantageous than knowing its spatial position. Consider a crash in need of emergency assistance. Knowing the linear element (Northbound I-95) and the approximate linear location is superior to having a potentially more precise spatial GPS location that is not of significant accuracy to determine whether it is northbound or southbound I-95, especially if an impassable barrier separates the two carriageways.

The linearly referenced location as specified in this International Standard as a position expression, therefore, has many uses. It can be used to tie information about a linear facility to a specific location along that facility. It can also be used to find a position on the face of the earth by specifying how far along the position is (and optionally offset from) on a particular linear element.

This International Standard proposes a consistent specification for describing linearly referenced locations that also enables translation between different referencing methods and/or linear elements. It also specifies how these position expressions can be used to specify how information that pertains to only a part of a linear element can be specified as linearly located events.

A Linear Referencing System is a set of Linear Referencing Methods (LRM) and the policies, records and procedures for implementing them. There are numerous, seemingly disparate, Linear Referencing Methods in use today. There is no single, best method, as each has advantages in certain situations. It is, therefore, unreasonable to propose a single standard Linear Referencing Method. The Generalized Model for Linear Referencing[3] has been developed which instead categorizes Linear Referencing Methods into a basic set of common concepts. The additional advantage of this approach is that it also enables a singular method for translating linearly referenced locations into locations specified by another method or along an alternative linear element. This translation method is both closed and transitive, insuring round-tripping and translation chaining.

The Generalized Model standardizes the content of a linearly referenced location as containing three components: that which is being measured (linear element), the method of measurement (Linear Referencing Method) and the measured value (distance expression).

6.1.1.2 Linear element

Linear element is the general term which encompasses anything that can be measured using linear referencing. This includes ISO 191*nn* features, linear geometries and linear topologies.

Features do not have to be linear. A road feature, for example, may have multiple spatial representations to support multiple applications. These can be high-precision linear curves to support civil engineering design, low-resolution straight linestrings to support GIS applications, or areas to support pavement management applications. The only requirement is that it be possible to measure along the feature in a linear, one-dimensional, sense.

Features may represent fundamental entities, like a road element between two intersections, or more complex entities, such as a highway route spanning an entire state or country. Depending on the application schema, the feature can represent the entire road (width-wise) or only one of its carriageways. Therefore, this International Standard uses the word “roadway” intentionally to mean either the full road or a single carriageway.

Linear element features may have no geometry at all. Many existing systems store information about roads by defining roadway characteristics along the roadway, without specifying where the road is physically located. This does preclude the ability to translate spatial positions into linearly referenced locations along the feature. However, it is possible to translate linearly referenced locations to other linear elements or to other Linear Referencing Methods. Using linear referencing instead of its geometry to define roadway characteristics directly against the feature enables the definition of multiple geometries for the feature without having to repeat the roadway characteristics for each spatial representation. It also allows for the definition of roadway characteristics when no geometry exists.

The linear geometry type of linear element includes instances of geometric curves, as these can be measured along and their geometric location is known. It is, therefore, possible to project a spatial position onto the linear geometry and represent its location as a linearly referenced location along the geometry. It is also possible to translate a linearly referenced location along the geometry into two- or three-dimensional space.

Geometric curves are typically represented as attributes of features. Once a spatial position has been projected onto the curve, it is then possible to translate this location into a linearly referenced location on the feature itself.

The linear topology type of linear element includes instances of directed edges. Edges usually do not have a length attribute but do have one or more weights associated with the cost of traversing the edge. Measuring along an edge, therefore, entails *pro rata* distribution based upon the weight value(s). Only a limited number of Linear Referencing Method types can be used for measuring edges.

Linear elements can have attributes. If specified for the linear element, the value of these attributes applies to the entire linear element. Attribute events enable attribute values to apply to part of the linear element (see 6.1.1.5).

6.1.1.3 Linear Referencing Method

How a linear element is measured is specified by the Linear Referencing Method. Example Linear Referencing Methods are included in Annex C. The Linear Referencing Method specifies whether the measurement is absolute, relative, or interpolative. Absolute measurements, such as milepoint, hecto-metre and kilometre-point, are made from the start of the linear element. Relative measurements, such as a milepost, kilopost or reference post, are made from some known location along the linear element, called a referent. Interpolative measurements, such as percentage or normalized, use linear interpolation along the entire length of the linear element.

The Linear Referencing Method specifies if an additional, offset measurement can be made perpendicular to the linear element to specify a location that does not lie directly on the linear element. The offset measurement can be made from the linear element itself or relative from an offset referent, for example, 5 m from the reference line of a road or 5 ft from the back of the curb, respectively.

The Linear Referencing Method specifies the units of measure for measuring along the linear element. This results in the fundamental difference between a milepoint versus a kilometre-point Linear Referencing Method; the first measures in miles, the second in kilometres. If a Linear Referencing Method allows offsets, the Linear Referencing Method also specifies the units of measure for offset measurements.

Because of the wide variety of Linear Referencing Methods currently in use, it is possible to enumerate particular constraints about the method, for example, to allow only reference marker type of referents for a Reference Post Linear Referencing Method. Constraints for commonly used Linear Referencing Methods are suggested in Annex C.

6.1.1.4 Distance Expression

6.1.1.4.1 Distance Along

The measured value which defines the location along the linear element in accordance with the Linear Referencing Method is specified with a distance expression. In its simplest form, this is the "distance along" the linear element for an absolute Linear Referencing Method. It specifies how far along the linear element to measure from the start of the linear element in the direction towards the end of the linear element. The resultant "along" location A is on the linear element, as shown in Figure 1. For example, a distance expression with a "distance along" of 4,0 for a kilometre-point Linear Referencing Method along Route 1 specifies a location on Route 1 that is measured 4,0 kilometres along the route from its start.

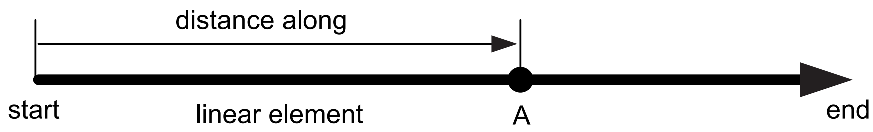

Figure 1 — Linearly referenced along location A with an absolute Linear Referencing Method

It is often the case that the measure at the start of the linear element is not equal to zero for a particular absolute type of Linear Referencing Method. For example, in Figure 2, the linear element start has a kilometre-point value of 0,5 km. An "absolute zero" point is, therefore, introduced to specify where an absolute Linear Referencing Method shall begin measuring distance along values.

In Figure 2, absolute zero occurs 0,5 km prior to the start of the linear element for the specified absolute Linear Referencing Method. A position expression having this Linear Referencing Method of kilometre-point and a distance expression with a distance along value of 4,0 km specifies a location that is measured 4,0 km along the linear element from absolute zero. The result is an along location A that is 3,5 km from the start of the linear element.

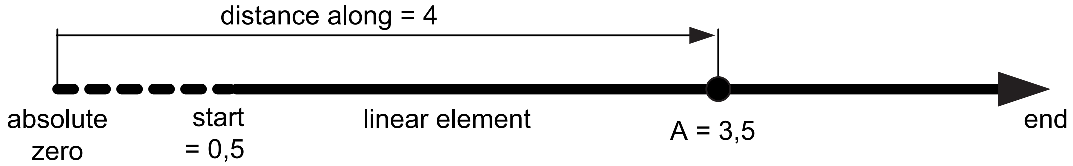

Figure 2 — Absolute Linear Referencing Method with non-zero linear element start

For an interpolative Linear Referencing Method, the distance expression is comprised of a single measure value. Here this value is used with linear interpolation to determine the location along the linear element based on the length (or weight) of the linear element as shown in Figure 3. A distance expression with a measured value of 60 for a percentage Linear Referencing Method along Route 1, which has a length of 50 km, specifies an along location A on Route 1 which is 30 km along the route from its start.

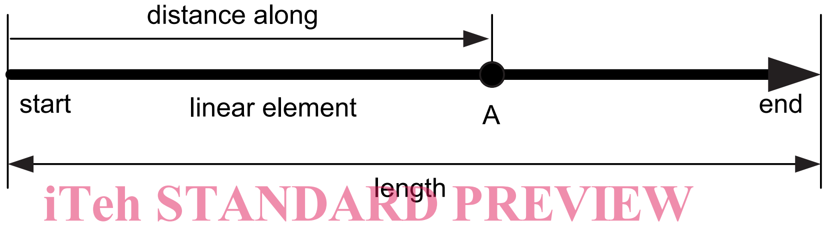

Figure 3 — Linearly referenced along location A with an interpolative Linear Referencing Method

6.1.1.4.2 Referents

For relative Linear Referencing Methods, the “distance along” is measured along the linear element from a known location on the linear element, called a “from referent”, as shown in Figure 4. For example, a distance expression with a “distance along” of 0,5 for a kilometre-post Linear Referencing Method along Route 1 specifies an along location A on Route 1 that is 0,5 km along the route from the specified kilometre-post located at referent location R. If the kilometre-post is located 4,0 km from the start of Route 1, then the resultant location is 4,5 km from the start of the route.

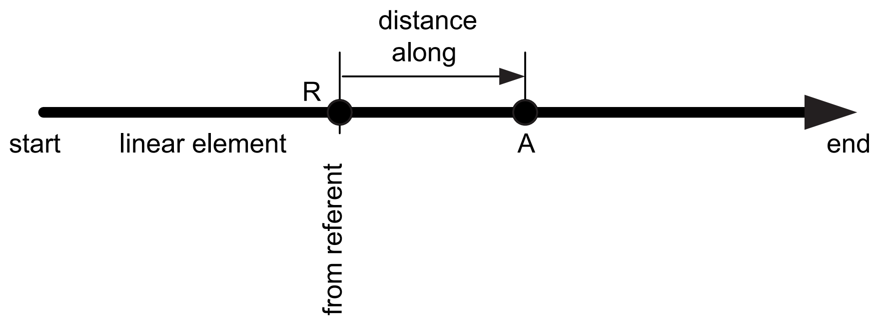

Figure 4 — Linearly referenced along location A with a relative Linear Referencing Method

Referent types vary between Linear Referencing Methods. These include, for example, intersections, administrative and maintenance boundaries, landmarks and physical reference markers.

If the Linear Referencing Method is of type Linear Referencing Method With Towards Referent, a “towards referent” can be added to a distance expression to disambiguate the direction in which the measurement is