NCHRP 20-27 to ISO 19148: 18 Years of Progress in Linear Referencing

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• **1995**: “Results of a Workshop on a Generic Data Model for Linear Referencing Systems”, NCHRP 20-27, Alan Vonderohe, Chih-Lin Chou, Forest Sun, Teresa Adams, GIS-T ‘95, Sparks, Nevada

• **2012**: *ISO IS 19148:2012, Geographic Information – Linear referencing*, International Organization for Standardization, Geneva, Switzerland
What problem are we trying to solve?
Integration by Location

US Transportation Research Board (TRB)\(^1\):

“data integration across different application areas is an urgent, long-standing need of DOTs”

“the concept of location … can serve as an integrative concept across a wide variety of data, both geographic and of other kinds”

\(^1\)NCHRP Report 359, 1993
**BRIDGE**
bridge:
  id: value
type: value
location

**USER DEFINED SEGMENT**
segment:
  attribute-1: value
  attribute-2: value
location

**PROJECT**
  project:
  name: value
cost: value
location

**ROADWAY CHARACTERISTICS**
  1-pavement: value, location
  2-lanes: value, location
  3-shoulder: value, location
  ...
  100-speed: value location

**DESIGN**
  design speed: value, location
  sight distance: value, location

**TRAFFIC**
  AADT: time, value, location

**CRASH**
  crash:
  conditions: value
  fatalities: value
location

**LOCATION**
Locations

132+00  (1.00, 1.00, 5280.00)

4 km  ©  + 1.8 miles

(39.580613, -105.157732)

‘A’ 89+20  2 + .50 miles

(10.251, 20.507)

2.5 miles  50 %  + .400

55
Premise

There is no single “best” location referencing method.

– each database / application has unique requirements which need not be compromised.

– integration can still be achieved.
Linear Referencing

Measuring along a line
… or any linear element
How we measure:
  Linear Referencing Method (LRM)
Why linear referencing?

- Lots of data is currently stored that way
- Requires less storage (single coordinate)
- Reduce redundancy (represent geometry once)
- Computationally simpler (intersect)
- More accurate in some situations
  - divided or grade-separated highways
  - railroad lateral clearances
Multiple Graphic Reps
NCHRP LRS Data Model Conceptual Overview

Event 1/1/1 → Event 1/1/2 → Event 1/1/N → LRM 1/1 → Network 1 → Datum

Event 1/1/1 → Event 1/1/2 → Event 1/1/N → LRM 1/2 → Network 1 → Datum

Event 1/1/1 → Event 1/1/2 → Event 1/1/N → LRM 1/N → Network 1 → Datum

Event N/N/1 → Event N/N/2 → Event N/N/N → LRM N/1 → Network N → Datum

Event N/N/1 → Event N/N/2 → Event N/N/N → LRM N/2 → Network N → Datum

Event N/N/1 → Event N/N/2 → Event N/N/N → LRM N/N → Network N → Datum

Source A → Datum

Source B → Datum

Source N → Datum
NCHRP 20-27

• Seminal effort on standardizing LR

• Strengths
  – introduced the notion of a linear datum
  – separated out \([0..\ast]\) cartographic representation similar to geospatial GFM
  – topology also “separate”
  – supported point and linear “events”
Events

LRMs

Networks

Datum

Cartographic Representations

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location ---> TRP

traversal ---> link

node ---> anchor section

line ---> anchor section
NCHRP 20-27

• Improvement Opportunities
  – simplify the model
  – optionalize the topology level
  – normalize events
  – eliminate extraneous nodes
  – consistently map between levels
  – allow multiple datums
Generalized Model for Linear Referencing

• Developed in 1998: need for simplified, COTS solution
• Introduced at GIS-T ‘99, San Diego
• Published for peer review in US and International, Civil and GIS Journals:
  - Journal of Computing in Civil Engineering, Jan ‘01
  - GeoInformatica, Mar ’02
• Commercial Product Release (Bentley ProjectWise) 2009
Standards Adopting the Generalized Model

- ISO (TC211) IS 19133:2005 Clause 6.6; TRR 2005
- AASHTO TransXML, NCHRP 20-64, 2006
- FGDC STD-014-2008 Geographic Information Framework Data Standard
- ISO (TC204) IS 14825:2011, Graphic Data Files (GDF)
- ISO (TC211) IS 19148:2012 Linear referencing
- OGC Abstract Specification Topic 19
- OGC GML 3.3 (+ ISO 19136-2 pending)
Generalized Model

- Event 1/1/1
- Event 1/1/2
- Event 1/1/N
- Event N/N/1
- Event N/N/2
- Event N/N/N

- LRM 1/1
- LRM 1/2
- LRM 1/N
- LRM N/1
- LRM N/2
- LRM N/N

- Network 1
- Network 2
- Network N

- Datum

- Source A
- Source B
- Source N

linear elements

traversal
link
anchor section
line
Generalized Model

Event 1/1  Event 1/2  Event 1/N  
LRM 1  

Event N/1  Event N/2  Event N/N  
LRM N  

τ_{1-N}  

route  
street  
alignment  
link  
anchor section  
line  

route  
street  
alignment  
link  
line
Generalized Model: Characteristics

• Formalizes “linearly referenced location”, “linear element” (LE), “linear referencing method” (LRM), “distance expression”
• De-couples LE from LRM
• Focuses on LE similarities
• Enables event locations on any LE
• Generalizes the translation process
• Expandable for new LE and LRM types
• Supports existing IT investment in legacy data, systems, expertise and LRM selection
• Minimizes change and risk
Linear Reference Methods:

- Absolute
  - MilePoint
  - KilometerPoint
  - Stationing*
- Relative
  - MilePost
  - ReferencePost
  - County MilePoint
  - CrossStreet
- Interpolative
  - Percentage
  - Normalized
  - Address
- Local Interpolative
  - M values

“a way to identify a specific location with respect to a known point”
Distance Expressions

50 %
4 km
2.5 miles
‘A’ 89+20
55
132+00
2 + .50 miles
2 + .400
© + 1.8 miles
Linearly Referenced Locations

(HOW: LRM, WHAT: LinearElement, Measure)

(MilePoint, Route: C-470, 2.5 )
(KilometerPoint, Route: C-470, 4 )
(Percentage, Link: Link 1034, 50 )
(Mile Post, Route: US-40, 2 + .50 )
(Reference Post, Route: I-95, 2 + .400 )
(County MilePoint, Route: I-95, ©+1.8 )
(Station, Alignment: Project 42, 132+00 )
(Address, Street: Smith Rd., 55 )
Translations

• Between LRMss and/or Linear Elements
  – single algorithm (linear interpolation)
  – determinate, closed
  – commutative, transitive

• Between Linear and Spatial (GIS)
  – point
  – IrPosition
Offsets
Also in 19148

- Linearly Located Events
  - Attribute vs. Feature
  - At (Point) vs. From / To (Linear)
  - Instant vs. Period
- Segmentation
- Linear SRS
Summary

• NCHRP 20-27 was a seminal contribution to standardizing linear referencing
• ISO IS 19148 is the new standard
• Based on Generalized Model
  – sound theoretical basis
  – widespread standards acceptance
• Can retain the “best” method for each database / application and still be able to integrate data
• For additional information: paul.scarponcini@live.com