North Carolina
Department of Transportation
Geographic Information Systems (GIS) Unit

LINEAR REFERENCING SYSTEM (LRS) PROJECT DEFINITION
Version 1.0

REVISION HISTORY

Date	Document Manager	Revision Purpose
6/13/06	John Farley	Update document and schedule to reflect plan for v1.1 and v1.2. Updated Diagram 4

LRS Task Force
June 13, 2006
http://www.ncdot.org/it/gis

Introduction

At its core, a Linear Referencing System (LRS) is a geospatial concept that is defined as follows:

> *"A method for storing geographic data by using a relative position along an already existing linear feature; the ability to uniquely identify positions along lines without explicit x,y coordinates. Location is given in terms of a known linear feature and a position, or measure, along it. Linear referencing is an intuitive way to associate multiple sets of attributes to portions of linear features."*
>
> -- *ESRI*

Within the North Carolina Department of Transportation, the development of an enterprise LRS was begun and subsequently fell prey to shifting goals and purposes. One key result of these shifting goals and purposes was to have the effort and even the term "LRS" take on different meanings for different people and groups. To address these and other issues, this Project Definition document was developed.

The purpose of the Project Definition document is to clearly define the "LRS Project" in terms of deliverable data products, establish a repeatable business process, and finally to manage these products.

LRS Goals and Objectives

The LRS Task Force has identified the following objectives of the LRS Project:

1. *Integrate the following Core Linear Referencing Methods (LRMs)*
   - Route and Mile Post
   - Generation1 (G1) FTSeg's and Offsets
   - Coordinate Route
   - Intersection and Offset

2. *Support Transformations*
   The LRS must support transformations between referencing methods with a minimal loss of accuracy.

3. *Maintain the Linear Datum*
   Conceptually, the underlying network itself. The Linear Datum is also sometimes referred to as the base reference network.

4. *Data Extent*
   The LRS Project currently includes only NCDOT state maintained roads. It does not currently include non-NCDOT state maintained roads.

5. *Maintain Timely Data*
   Changes to the NCDOT state maintained road network will be added to the LRS within two weeks of official notification to the GIS Unit (See **Schedule Section** below).

6. *Provide Ad hoc and Predefined Data Processing*
   Allow user access to the LRS by facilitating the use of decision support systems, and allowing ad-hoc reporting (map and tabular). Users should also be able to use pre-defined access and reporting tools.

7. *Be a Scalable System*
   The LRS must be extendable in future to intermodal transportation systems.

8. *Ensure Changes to the System Will Not Affect Existing Event References*
   Route changes, road additions, road relocations, renamed roads, or road abandonments will not affect prior events or activities that were spatially referenced to the Generation 1 FTSegs (see below).

9. *Provide a Choice of Linear Referencing Methods (LRM)*
   The LRS PROJECT should not mandate, but only recommend, which of the core LRMs should be used by customers for data collection

LRS Design Constraints

The LRS Task Force identified the following constraints on the LRS design. These constraints directly influence how the system should be defined, developed, and implemented.

1. The LRS PROJECT will be developed using NCDOT's standard technology product lines from Oracle and ESRI.

2. The LRS PROJECT will use existing NCDOT base map data, although perhaps not in their current structure.

3. Initially, the LRS PROJECT will include only the existing NCDOT state maintained roads. Additional roads will be included in future releases. This effort does not include data collection.

4. The LRS must have one linear datum that supports all stated networks and LRMs.

The LRS Task Force also feels that the legacy data and existing business processes should place no constraints on the LRS design. That is, the LRS design can alter these systems. This is necessary because of the NCDOT's need to accommodate timely, accurate, and updateable information.

Conceptual Design NCDOT LRS

The core of the NCDOT Linear Referencing System is the Linear Datum, which is comprised of Framework Transportation Reference Points (FTRP), Framework Transportation Segments (FTSeg), and their relationships. This in turn provides the fundamental referencing space for the transformation among various linear referencing methods, network models, and cartographic representations (See Diagram 1).

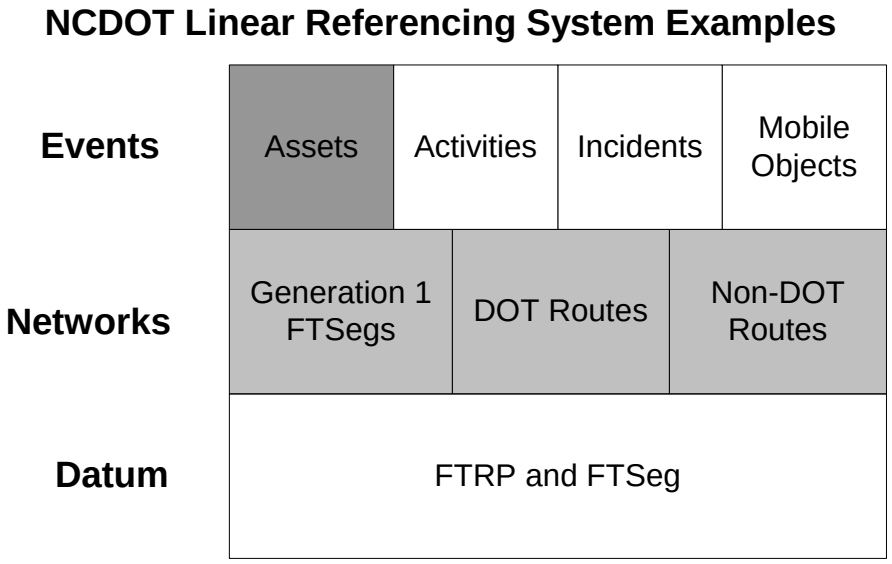


Diagram 1

The Linear Datum is created by projecting the state-maintained roads (the physical transportation network) onto the planar surface of the Earth as defined by the North American Datum of 1983 (NAD83) state plane coordinate system for North Carolina. Road termini, county boundary points, state boundary points, and the intersections of roadways are represented by the FTRP. The FTRPs define the beginning and end points of the FTSeg's. Unique identification numbers are assigned to each FTRP (P#) and FTSeg (F#) (See Diagram 2).

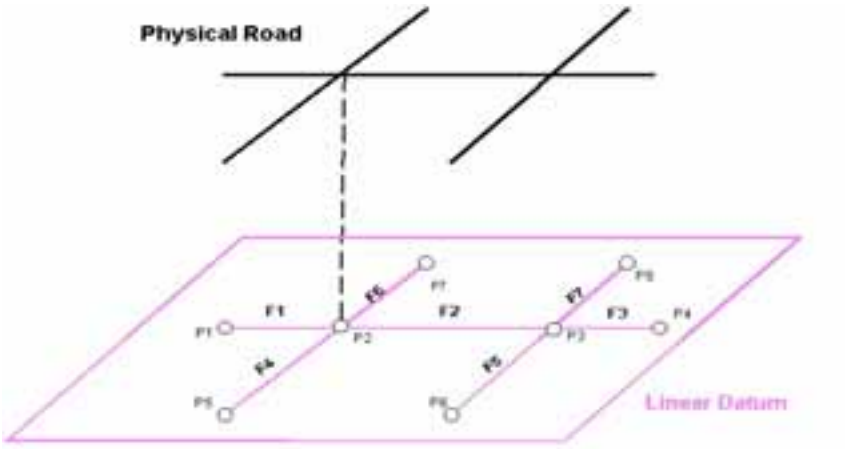
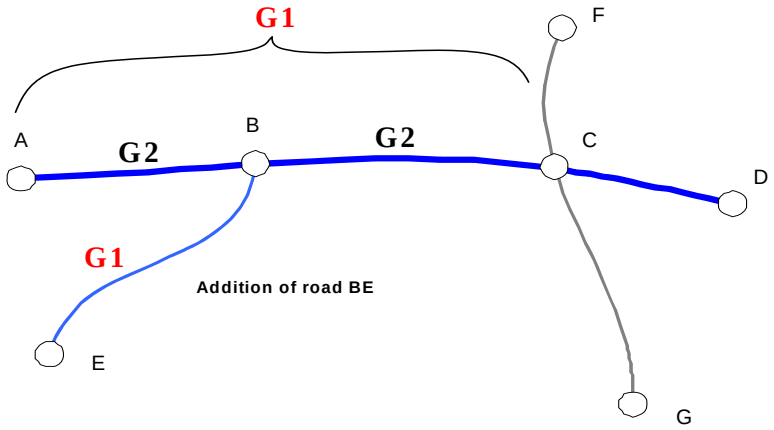


Diagram 2

The Linear Datum is managed through the NCDOT LRS MXD. Each segment of the state maintained road network is assigned a Generation 1 (G1) FTSeg when newly digitized. GIS operations, such as dynamic segmentation and network analysis, are supported and can be applied to the NCDOT LRS and related business data.

While several referencing methods are supported, the primary linear referencing method of NCDOT LRS is the distance/offset referencing method relative to the G1 FTSeg's. Because G1 FTSeg's don't change they uniquely represent the whole physical highway transportation system.

Once added to the Linear Datum, a G1 FTSeg will always remain in the LRS as originally defined. As illustrated in the diagram below, addition of a new system road BE, which intersects the existing road ABCD, does not split G1 FTSeg AC. Instead, a new G1 FTSeg BE and two new (Generation 2) FTSeg's (AB and BC) are added to the Linear Datum. The original AC G1 FTSeg remains unchanged. Point B is a FTRP as defined by the intersection of roadways (See Diagram 3).



Generation 1 (G1) FTSegs and maintenance of the Linear Datum

Diagram 3

Maintaining G1 FTSeg's creates a unique and stable system that a) reduces the overhead of data processing, b) provides for the historical tracking of events, and c) allows the easy integration of data using other supported linear referencing methods. As a result, other GIS operations, such as dynamic segmentation and network analysis, are easily supported and can be applied to the NCDOT LRS and related business data. Therefore, it is highly recommended that point or linear events are stored against the G1 FTSeg.

Deliverables

The output from the LRS Project encompasses many different deliverables in three general categories. The first category deals with documentation pertaining to the project and its deployment. The second category deals with required applications developed to produce and maintain the various dataset deliverables. Finally, the third category deals with the various datasets themselves. These datasets are generated in order to provide LRS functionality to NCDOT. Below are the specific deliverables as well as their descriptions:

Category 1: Documentation

Data Integration Guide for LRS Deployment
This document is intended to assist customers in preparing their current datasets for use with the NCDOT LRS v.1. This will include use cases and specific examples of LRM implementations.

Category 2: Applications

LRS Access and Reporting System (LARS)
This is a web browser based multi-tier database management application. This application maintains a non-spatial tabular road network with symbolic topology and geometry in an Oracle environment.

LRS Database Management API
The LRS Database Management API is a Simple Object Access Protocol (SOAP) web services application programming interface (API) for managing LRS tabular database core components.

NCDOT LRS MXD
This is an ArcGIS based toolset for maintaining the line work and attributes of the NCDOT Road Linework by County geodatabases (see below).

Category 3: Data

NCDOT Road Linework by County (Personal Geodatabases)
This dataset represents the base layers used to build all other products. The critical spatial LRS road information for each county within the State of North Carolina will exist in its own personal geodatabase. These personal geodatabases will be maintained through the LRS MXD.

NCDOT Road Linework (Personal Geodatabase)
This dataset represents the combined information from the NCDOT Road Linework by County geodatabases to form a single State-wide dataset. In addition, the link-node attributes are added to this dataset.

Road Route and Mile Post Personal Geodatabase
The dataset is created from the NCDOT Road Linework geodatabase and the Road Inventory LRS v.7 Oracle database. It is a subset representing the NCDOT State maintained road system with route, milepost, and link-node attributes.

Road Characteristics Personal Geodatabase
The dataset is created from the NCDOT Road Linework geodatabase and the Road Inventory LRS v.7 Oracle database. It is a subset representing the NCDOT State maintained road system identified with road characteristics (conditions or attributes).

Road Intersections Personal Geodatabase
The dataset is created from the NCDOT Road Linework geodatabase and the Road Inventory LRS v.7 Oracle database. It is a subset representing and identifying (through attributes) the intersections of the NCDOT State maintained road system.

LRS Cartographic Features DGN
This dataset is created from the NCDOT Road Linework by County geodatabases and contains digital line, point (cell), and polygon layers; stored in Microstation format. Data represents all CAD elements required for Microstation cartographic production.

Road Inventory (RI) LRS Database - Road Inventory Module
The RI LRS Database Road Inventory module is a collection of relational database tables for the storage and management of the data items that were stored in the Universe Mainframe File.

Road Inventory (RI) LRS Database - Core Components
The RI LRS Database core components are a collection of relational database tables for the storage and management of the linear datum and posted routes.

Link-Node Database
The Link-Node database is a collection of relational database tables for the support of the link-node reference method. These tables continue to support applications that require the link-node reference method.

Business Process

The business process to implement and maintain the LRS and its products requires some fundamental changes to the GIS Unit. These changes include reorganizing staff and developing tools to allow for the entry of changes to the LRS to occur in one place by one operator. These changes also necessitate more centralization of datasets across the GIS Unit.

Diagram 4 illustrates the proposed business process and supporting organizational structure for implementing and maintaining the NCDOT LRS.

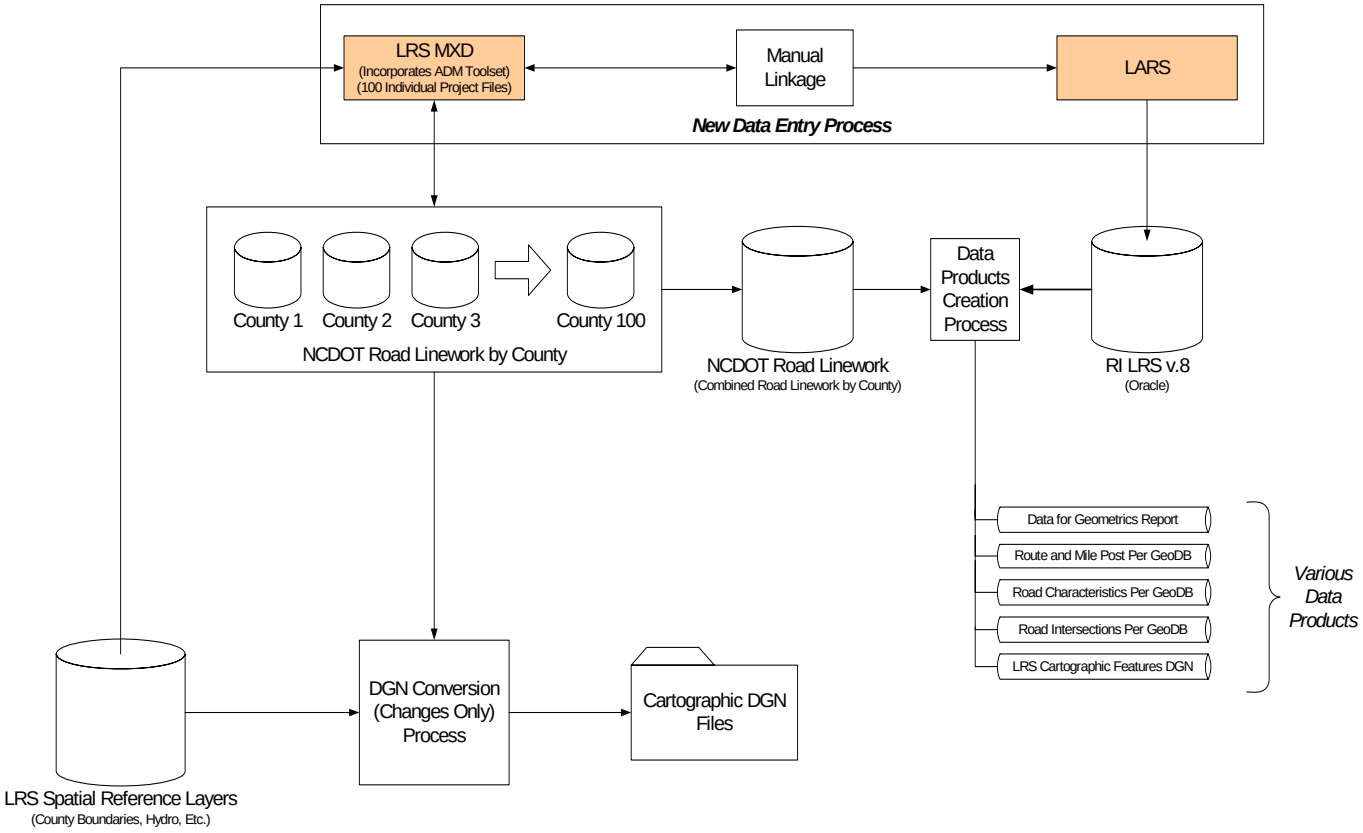


Diagram 4

Schedule

The LRS Project as reconstituted under the LRS Task Force kicked off on August 15, 2005. Since that time the GIS Unit has completed the following tasks:

- NCDOT LRS v1 Project Definition
- GIS Unit Reorganization
- DGN Conversion Process and Testing
- Link-Node Responsibility Development and Test
- RI LRS v7 Database

Version	Date	Implemented
1.0	August 2006	LRS Process, LRS MXD, LRS Core Module, RI Database v8.0
1.1	November 2006	Road Inventory Attribute Module
1.2	February 2006	Begin two week turn-around for new information received

Future Enhancements

Once Version 1.x of the NCDOT LRS has been released, the following items will be evaluated for inclusion in Version 2.

- Full integration with the LRS process and ArcSDE, to include a geodatabase based data model
- Non-DOT Roads as part of core dataset
- Unified LRS Edit/Management Tool

References

NSDI Framework Transportation Identification Standard. Public Review Draft, FGDC-STD-999.1-2000

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Linear Referencing in ArcGIS, ESRI, 2005

A Conceptual Design for the Iowa DOT Linear Referencing System, Iowa DOT, 2000

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