Managing Transportation Data with Oracle

Introducing LRSx™
Linear Referencing System Extensions for the Oracle Database

TRANSDECISIONS

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Introduction

Much of the data collected and analyzed for transportation systems is spatially enabled. However, unlike traditional spatial information which is located using two or three dimensional coordinates, most of the transportation data is located using a system of linear location references that require specialized software to manage, analyze, and map. Linear Referencing Systems (LRSs) have specifically been developed to manage and maintain spatial phenomena that reside within the context of a transportation system. Such data is referenced with respect to known locations on the transportation facilities such as a bridge on a highway, a street intersection, or a milepost along a river, and are independent of the coordinate or projection system in which the transportation facilities are located.

This document provides and overview of linear referencing, and describes some of the key features of the Linear Referencing System Extensions (LRSx™) for Oracle® Spatial. It explains how the existing Oracle data model is extended to enable the efficient and effective management of transportation data.

Who Uses Linear Data?

Linear locations are stored, referenced, and analyzed in a large number of organizations and agencies across a wide variety of industries. Some of the more traditional users of linear referencing are:

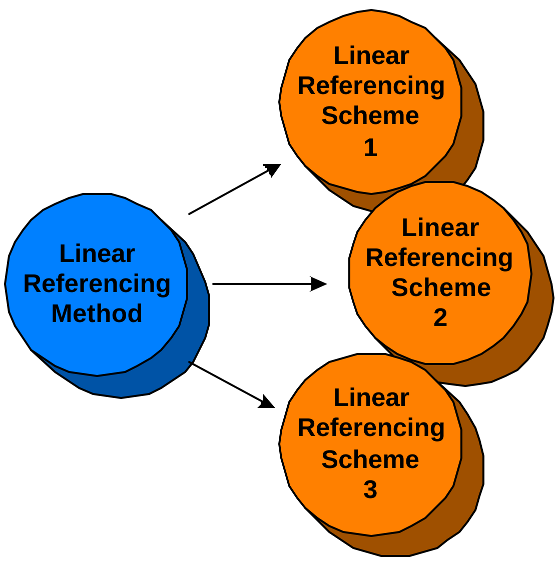
- Highway management organizations
- Rail management agencies
- Gas and oil pipeline industries
- Utility industries
- Police and emergency management organizations
- Military planning organizations

More recent adopters of linear referencing include:

- Transit agencies
- Fleet management industries
- Automatic Vehicle Location (AVL) systems
- Intelligent Highway Systems

The LRSx for Oracle Spatial enable users in these different business sectors to enhance their analytical and storage capability for transportation data, and to provide a framework from which transportation applications can be developed quickly and inexpensively.

A linear referencing method can support many implementations.



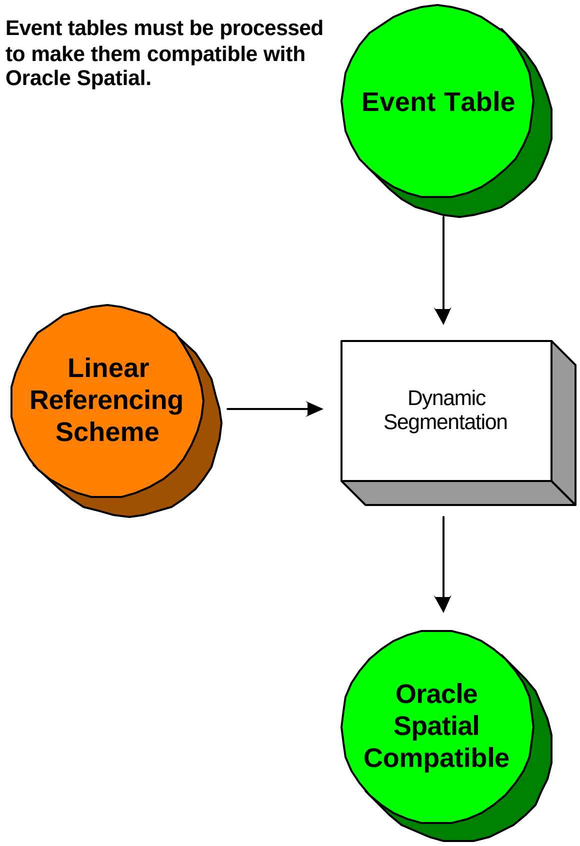
The Linear Referencing Extensions are designed for the following groups of users:

- Traditional transportation database users to enhance their capability for data management, reporting, and analysis within their existing Oracle databases.
- Application developers who need to store and maintain linear referencing system data structures in a GIS-independent format for their customers.

Linear Referencing Overview

Linear Referencing Methods (LRMs) are abstract models that describe the structure and organization of the components comprising the transportation system. A *Linear Referencing Scheme* is an application-dependent implementation of an LRM, and describes the data keys, metrics, and other attributes that enable data to be collected, stored, retrieved, and compared in a database. A *Linear Referencing System* is a combination of an LRM and its implementation as a Linear Referencing Scheme, together with the constraints and implementation details that make it a viable component in an enterprise-wide data modeling system.

It is important to distinguish between the method and its implementation, as many transportation agencies have LRMs in common but cannot share data because the schemes are not compatible. Within many large transportation agencies there may be multiple schemes in use by different departments, which prohibits the sharing of data across the organization.



Events are phenomena that are located in linear space, and their spatial components are described in the context of a Linear Referencing Scheme. Events are stored and managed in *Event Tables* in the database. Each record in an event table contains a location reference component, and a set of attributes that describe and classify the event–the business component. An event may be any type of information that is collected on the transportation system. For example, accident locations, infrastructure improvement projects, bridges, valve locations, and intersections are all examples of phenomena that occur discontinuously over the transportation system. Other types of data such as the number of lanes, diameter of a pipe, pavement quality, right of way, ownership, and flow volume are all examples of attributes that are continuous and describe the characteristics of the transportation system itself.

Event data cannot be displayed or analyzed using traditional mapping and GIS methods because they require special software that is able to convert the linear reference to a standard geometric feature. The process of converting the linear reference to a cartographic reference is called *Dynamic Segmentation*. Once an event has been dynamically segmented, it can be used in spatial analyses to generate maps and reports, as it is compatible with Oracle Spatial data formats.

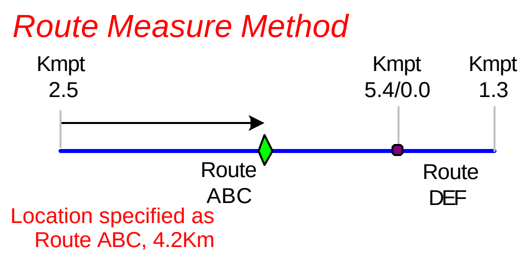
Linear Referencing Methods

There are three LRMs commonly used by transportation agencies: Route Measure, Marker-Offset, and Link-Node. Other names for these methods are in use within particular transportation industries such as Route-Milepoint, Reference Post, and Track-Segment. But essentially, they are equivalent to one of the three systems described below.

Hybrids and derivations of these three basic methods are widely implemented within transportation agencies throughout the world. Each version is implemented via the definition of a linear referencing scheme that is adopted by the transportation agency. In many cases, more than one linear referencing scheme might be in use by a single agency.

Route Measure Methods

Route Measure methods, and their derivations, are possibly the most common linear referencing methods in use. The LRS consists of a set of linear features that have been categorized into one or more logical routes for administrative purposes. Each route is designated by a unique set of attributes called *Route Keys*. Routes are continuous and have linear measures accruing over their length, from an identified origin to a destination. The start and end measures denote both a cardinal direction for the route and a measured extent. Locations over the route are interpolated from the logical start of the route feature in the cardinal direction.

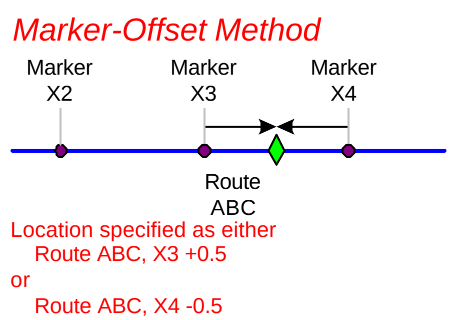


Phenomena are located in linear space by using a combination of route identifiers and offsets over the route. Examples are Route ABC, Kmpt 3.2, and Route XYZ between Kmpts 3.0 and 4.0.

Marker Offset Methods

Marker Offset methods associate named locations in linear space with known locations in the real world. Each marker is uniquely identified within a logical route and has an associated measure. Physical markers, sometimes called reference posts, are often positioned along the transportation features at regular intervals to make data collection in the field simpler and more accurate.

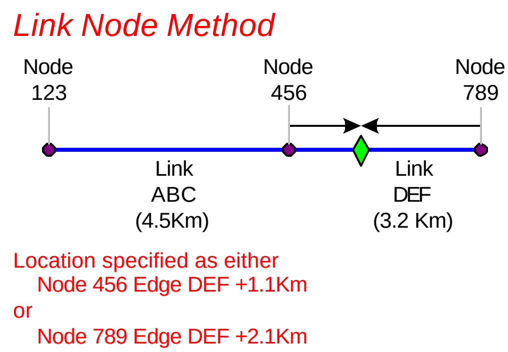
Locations in linear space are interpolated as +ve or –ve distances from the marker. Examples are Marker X3 +0.5Km and between Marker X3 –0.25Km and Marker X4 +0.5km.



Link-Node Methods

Link Node methods are similar to Marker Offset methods, as locations are derived from a known location. In this method, however, nodes are located at known real-world locations such as street intersections, administrative or jurisdictional boundaries, or other similar features, and are uniquely identified. Links are logical connections with measured length between the nodes and are uniquely identified.

Locations in linear space are derived by interpolating a measured offset over an edge from a node. Examples are Node 456, Link Def, Offset 1.1Km. and between Node 123, Link ABC, Offset 0.5km and Node 789, Link DEF, Offset 1.5Km.



Events

The linear reference component of an event is specific to a particular linear referencing scheme, and at a minimum must contain attributes that allow the phenomenon to be located on the transportation system using a particular scheme. In this manner, an event that is collected using one linear referencing scheme may not be locatable using another, even though they reference the same transportation system. Users of the transportation system's data are usually concerned with storing and analyzing discrete events such as traffic accidents. Managers of the transportation systems are often more concerned with describing and monitoring the systems, and are concerned with collecting both discrete and continuous types of data.

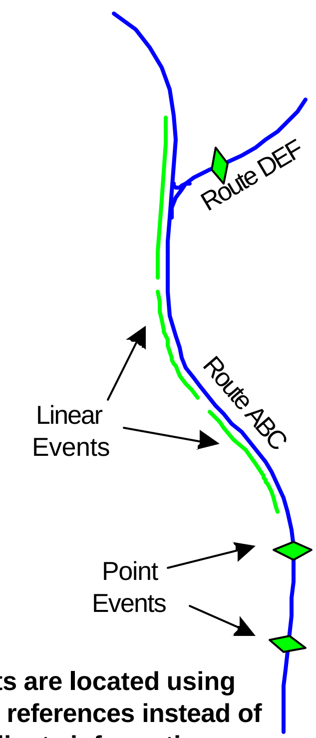
There are several organizations of events that can be managed and analyzed by the LRS Extensions.

Point Events

Point events are discrete, and are defined at a single point in linear space. Point events can be associated with any of the Linear Referencing methods supported by the LRSx.

Examples of point events are:

- A video inventory taken at 25m intervals along a highway.
- The location of an incident on the transportation system.
- The location of a signal next to a rail line.
- The location of a pumping station on a pipeline.



Events are located using linear references instead of coordinate information.

Linear Events

Phenomena associated with the transportation system that have a definite measurable extent can be modeled as linear events. Linear events start at a defined point in linear space, and terminate at some other point.

Examples of linear events include:

- A section of highway that has just been paved.
- The extent of a tunnel on a rail track.
- The portion of a pipeline that is a certain width.
- The section of a rail line that has a traffic density of 20 million metric tons or more.

Duration Events

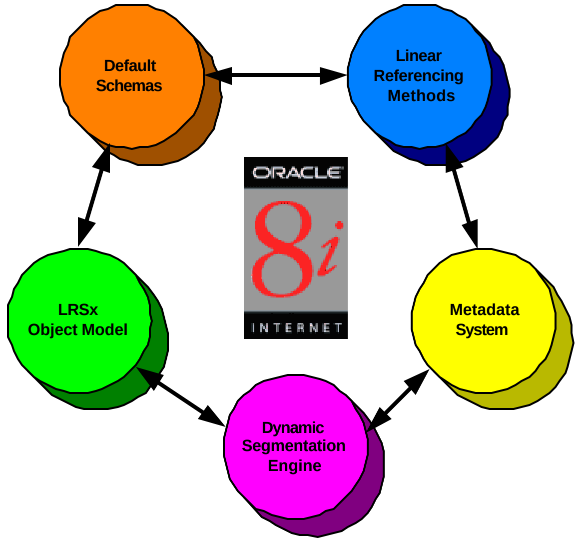
Duration events are similar to linear events but contain a starting location for the event and a measured duration. The end point for the event is derived from the combination of the start measure and the extent of the duration.

LRS Extensions

The Linear Referencing System Extensions provide an integrated set of functions and procedures that provide for the organization, retrieval, and validation of data that is linearly referenced. The extensions enhance the capability of Oracle Spatial with the ability to store, manage, query, and report transportation-related data within the database. These extensions enable the user to develop applications that combine spatial and transportation-related data together in a single extensible database system, and take full advantage of the security, recovery, reliability, scalability, and performance features offered by the Oracle database.

100% Java Solution

The LRSx are written entirely in Java, and feature a completely open, layered architecture that is seamlessly integrated into the Oracle database server.



The following components comprise the LRSx for Oracle Spatial:

- Support for three standard linear referencing methods.
- Default linear referencing schemes that provide the storage, syntax, and semantics of the Linear Referencing system. The schemes are extensible to enable the user to customize the organization of the database to suit the requirements of the application.
- A metadata system that describes the linear referencing systems, and the configuration of dependent event tables.
- A dynamic segmentation engine to process event tables.
- An open programmable Java API.

The LRS Extensions also provide:

- Procedures and functions to perform update, query, and maintenance on the LRS and event tables.
- Administrative utilities.

As these extensions enhance the native capability of Oracle Spatial, it is necessary to have the correct version of Oracle Spatial licensed and installed before the extensions will work. The current version requires Oracle version 8.1.5 or greater.

Metadata

The LRSx provide a metadata system that can be extended by the user to accommodate the development of user-specific applications.

Metadata for LRSs

Information about each LRS such as the type of linear referencing method, the distance measures, and key fields, are collated in the metadata tables. Once configured, the LRS metadata can hide the complexity of the linear referencing system mechanisms from the user or application developer. An added advantage of the metadata system is that a single set of transportation features can support multiple linear referencing methods.

Metadata for Events

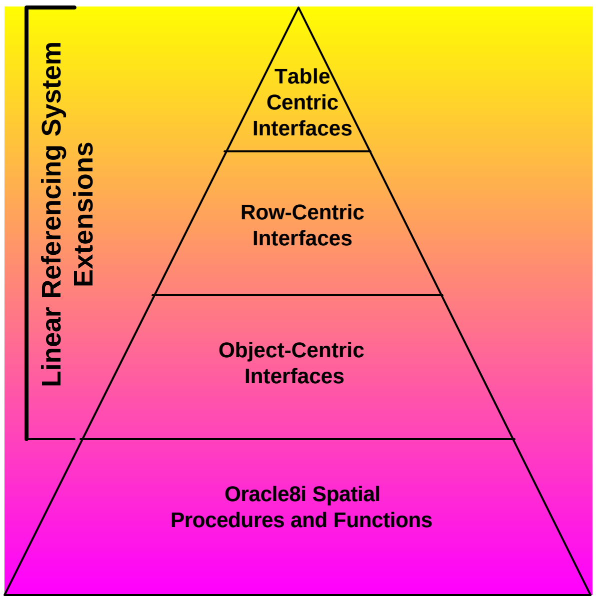
Event tables can be managed within the LRSx's metadata to simplify the management of event data. Column names and other dependencies of the events can be automatically managed when the table is added to the metadata system. Event tables are dependent on an LRS, so when the LRS is modified the event records need to be re-evaluated. The LRSx can automate the update of the event tables and re-generate the geometry for any events that need to be updated.

Tiered Application Architecture

The LRSx have been developed with the requirements of the typical LRS user in mind. There are three tiers of software architecture that can be recognized depending on the needs of the user.

Highest Tier

The highest level of access to the system is through a set of procedures that bulk process pre-configured data that is stored in event tables. These table-centric interfaces rely on pre-configured metadata to provide the details pertinent to the LRM and are designed for offline-batch processing.



Middle Tier

The middle tier provides a programmable set of functions and procedures through which the user can control the flow of the dynamic segmentation process, and build custom applications. These interfaces are row-centric and operate row-by-row on tables specified by the user.

Lowest Tier

The lowest tier of the architecture provides the building blocks through which the middle and highest tiers are supported. Access to low-level functions allows the user to build custom applications using triggers, stored procedures, and other Oracle development paradigms, to operate at an object level within in the system.

Analyzing Data

The spatial component of event data can be collected in a variety of ways. An incident occurring on a highway, for example, might be reported using a GPS point, a distance from an intersection along a street, at an offset from a marker, or even as occurring outside a street address or any combination. Consider the case where an incident management agency receives two separate reports of an incident occurring on the transportation system. One report might provide a GPS point, while the other report provides a route and offset location. The incident management agency must be able to resolve these two reports, determine if there are indeed two accidents or simply two reports of the same accident, and respond accordingly.

The LRS Extensions provide ways to locate events, and convert from one form of reference to another. For example, a user could create a geometric point from a linear reference or convert a point, such as a GPS point, to a linear reference. This ability to convert between referencing systems allows data from the field to be quickly analyzed and compared by the database. In the example above, the incident management agency could quickly determine how many accidents there are and invoke the appropriate response.

Application Development

Users can define, manage, and manipulate transportation data through standard Oracle methods. SQL, JSQL, and Java stored procedures are all available to the application developer to build new applications. Using the standard Oracle development environment reduces development costs of transportation-specific applications, as there are no new languages to learn and maintain. Moreover, the tiered architecture allows developers to select the level of programming necessary to best support their application requirements. Simple applications, such as web-based analyses, can use the high-level batch processing functions. As the requirements get more complex, the developer can use functions and procedures lower down the function hierarchy to gain access to row-specific or even object-specific tools.

System Requirements

Database

- Oracle version 8.1.5 or greater.
- Oracle Spatial

Supported Platforms

- Windows NT®
- Sun Solaris™