A Physical Design Summary for the State of Iowa Department of Transportation's Linear Referencing System

PHYSICAL DESIGN SUMMARY DOCUMENT

July 2000

Prepared by

GeoAnalytics™
1716 Fordem Avenue
Madison, WI 53704
Phone: 608-241-7100
Facsimile: 608-241-7116
E-mail: office@geoanalytics.com
URL: http://www.geoanalytics.com

TRANSDECISIONS
11835 W. Olympic Blvd.
Suite 700E
Los Angeles CA 90064
Phone: (865) 988-8345
Facsimile: (865) 988-8744
E-mail: JulianRay@TransDecisions.com

With

Oracle Corporation
222 West Las Colinas Blvd.
Consulting
Suite 1000
Irving, TX 75039
Phone: (972) 409-3907
Facsimile: (972) 409-3041
E-Mail: jlwinter@us.oracle.com

Iowa Department of Transportation
800 Lincoln Way
Ames, IA 50010
Phone: 515-233-7770
Facsimile: (515) 239-1828
E-mail: wschuma@max.state.ia.us

Table of Contents

Table of Figures

Index of Tables

Physical Design for the Iowa DOT Linear Referencing System Technical Summary Document

1. Executive Summary

1.1. Background

In April 1999, the Iowa Department of Transportation (DOT) began a project to develop a Linear Referencing System (LRS) for the Department. A linear reference system's primary purpose is to allow the DOT to integrate disparate data by using linear reference method (LRM) locations as the common link. These LRMs locate transportation objects (signs, pavement) and events (crashes, traffic collection section) relative to a position along a transportation feature (e.g. a roadway). Referencing items by milepost is an example of a DOT LRM. The DOT has identified six key LRMs used in the Department.

The purpose of the Iowa DOT LRS Development Project is to improve how the DOT manages and applies its LRMs by developing a linear reference system to integrate these methods and their associated business data. Specifically, there are five project objectives:

1. The LRS will provide improved data integration and access.
2. The LRS will provide improved accuracy of the features referenced to the road network.
3. The LRS will provide a way to linearly locate roadway data along all public roads in the State.
4. The LRS will help minimize redundancy in DOT database systems.
5. The LRS will help minimize data maintenance that is needed due to changes in the transportation network.

Iowa DOT contracted with GeoAnalytics, Inc. to provide counsel and facilitate Department decisions related to improved linear reference management. In addition, GeoAnalytics will provide technical support services for the testing and validation of LRS design decisions. The Project Team assigned to this project is composed of both GeoAnalytics and Iowa DOT staff members. A Project Steering Committee, composed of representatives from all DOT Divisions, guides the Project Team.

1.2. Approach

This project has been broken into several tasks. Recently, the Project Team successfully completed the Physical Design task. Both a Conceptual Design and Logical Design preceded this Physical Design. The Conceptual Design defined the overall structure of the LRS. The Conceptual Design also illustrated how the LRS interacts with existing DOT applications and set the scope for the Logical Design. The Logical Design captured Iowa DOT's detailed requirements for maintaining and using the LRS. The Logical Design detailed LRS data, process, organizational, and technology requirements.

The Physical Design captures how Iowa DOT will successfully meet the LRS requirements using Iowa DOT's technological and organizational environments. Subsequent to the Physical Design, the Project Team will perform a pilot task that will construct certain components of the LRS and test them against pre-determined benchmarks.

1.3. Physical Design Results

The major goals of the Physical Design are as follows:

- Provide a physical system that is as close to the logical design as possible and one that implements the spirit of the NCHRP 20-27(2) – *A Generic Data Model for Linear Referencing Systems.*
- Provide a run-time system that is highly scalable and can support Iowa DOT's existing and future needs.
- Provide a system that is maintainable and extensible to accommodate changing requirements over time.
- Use industry standard development environments and techniques.

These goals have been met in the Physical Design. Some of the key components of the Physical Design are described below.

1.3.1. System Architecture

The completed Physical Design includes specifications for both LRS operational and LRS decision support requirements. The specifications for operational requirements describe how Iowa DOT will maintain the LRS. The specifications are grouped into eight separate but inter-related subsystems that manage the LRS. These management subsystems are the Linear Datum, Route (transportation networks, routes), LRS Milepoint LRM, Segmental LRM, Stationing LRM, Reference Post LRM (previously called milepost), Literal Description LRM, and Coordinate Route LRM.

The specifications for the decision support requirements document how Iowa DOT will use the LRS to access, integrate, and analyze business data (pavement condition, crash, inventory, etc). The LRS decision support specifications add capabilities to the existing Iowa DOT GeoData Warehouse (GDW).

This LRS subsystem design and the GDW integration design reflect the NCHRP 20-27(2) LRS model. The LRS is also designed so LRS interfaces, business logic, and data are separate but interrelated. This design allows the system to be highly scalable and accommodate changing needs over time.

The Physical Design applies existing Iowa DOT technology standards and strategies. These technologies reflect validated trends in transportation information technology development. The LRS operational data and GDW data will reside primarily in Oracle database technologies. Core LRS functionality used for maintenance and decision support will be developed in the Java programming language.

The core LRS functionality can be accessed by applications (called clients) via Oracle-based interfaces. These client applications can be Standard Query Language (SQL) applications, custom applications, and web-enabled applications. The applications under design in this project are used for LRS maintenance and GDW processing. These applications will primarily use Intergraph (GeoMedia product line) and Oracle (SQL / Plus) products. LRS data collection technologies will be evaluated in the pilot phase of this project.

1.3.2. Organizational Findings

The Physical Design also recommends which DOT offices would have LRS management responsibilities. Some responsibility assignments are new or have recommended changes because the LRS offers new capabilities. Some assignments would require additional staffing. However, the magnitude and duration of these needs will not be known until later in this project. Most assignments would require Divisions to invest in the technologies described above, and receive LRS and technology training.

All divisions, except the Operations and Finance Division and the Director's Staff, have some direct involvement in LRS management. Brief descriptions of these assignments for each division are provided below.

- **Planning and Programming Division**: The Office of Transportation Data would be assigned the majority of LRS data collection and maintenance tasks. Many of the data and workflow requirements are very similar to current Office responsibilities. These tasks include the development of new data, and therefore require an increased level of effort. Some modification to current workflows would be required. Additional staffing would be necessary.

- **Highway Division**: The following offices would be impacted by LRS management assignments: District Offices, Office of Maintenance, Office of Construction, Office of Design, Office of Traffic Engineering and Safety, Office of Bridges and Structures.

  The primary assignments impact the Offices of Design and Maintenance. The Office of Design would assume management responsibility for the Stationing Subsystem. Staffing needs are uncertain at this time. The Office of Maintenance would assume management responsibility for the Reference Post Subsystem. This assignment would include moving tasks, and potentially related staffing, from the Information Technology Division to the Office of Maintenance. The Reference Post Subsystem would require a database redesign.

  The District Offices would require more rigorous process definition for locating station and reference markers in the field, and would require creating improvement project data for the Stationing Subsystem. The Offices of Construction and Traffic Engineering and Safety would require improvements to design and field procedures. The Office of Bridge and Structures would require improvements in how bridges are located.

- **Modal Division**: The Office of Rail Transportation would require improvements in how railroad crossings are located.

- **Motor Vehicle Division**: The Office of Driver Services would assist the Office of Transportation Data in maintaining LRS routes. This involvement is expected to improve Driver Services' crash locating tasks.

- **Research Management Division**: The Division would initially manage the implementation of the Coordinate Route Subsystem.

- **Information Technology Division**: The GIS Team would manage the overall LRS, and assume LRS-related management tasks for the GeoData Warehouse. PMIS Support would transfer their Reference Post management tasks to the Highway Division. The Division would provide Oracle Database Administration and LRS maintenance services to the LRS subsystem managers under the direction of the GIS Team.

A tactical LRS management team, called the LRS Operational Work Team, would manage improvements to the LRS over time. The Team is composed of LRS subsystem managers, and therefore the following Divisions would be on the Team: Planning and Programming, Highway, Research Management, and Information Technology. In addition, all Divisions would provide a manager as a member to the LRS Board of Directors. The LRS Board of Directors would provide DOT LRS task prioritization and direction to the LRS Operational Work Team. The managers assigned to the LRS Board of Directors must be knowledgeable of LRS benefits and must promote LRS development through their division.

1.3.3. Project Objectives

The above Physical Design results remain focused on the five project objectives mentioned in the Background section of this Executive Summary. The following characterizes these results:

1. *The LRS will provide improved data integration and access.* The Physical Design captures how disparate business data will be integrated (e.g., pavement type, crashes, ADT) regardless of which supported LRM is used (e.g., Reference Post, Literal Description). The Physical Design also documents how users will be able to access and analyze this business data in an ad hoc or pre-defined fashion via Iowa DOT's GeoData Warehouse. When these design specifications are implemented, the LRS is expected to decrease data integration efforts and increase end user data analysis capabilities.

2. *The LRS will provide improved accuracy of the features referenced to the road network.* The Physical Design includes specifications to provide a linear datum and LRMs that can support the accuracy needs of Iowa DOT LRS users. The LRS will also be able to report the quality of its accuracy. When these specifications are implemented the LRS will allow the staff maintaining the business data to improve its locational accuracy.

3. *The LRS will provide a way to linearly locate roadway data along all public roads in the State.* The Physical Design captures the specifications for two LRMs that can be used across all public roads in the state. The Literal Description LRM is a verbal description of a linear location. It requires no additional field signing and is simple enough to be used by the general public. The Coordinate Route LRM supports the use of advanced field-locating technologies such as Global Positioning Systems (GPS) and map interface systems. These technologies are

currently used in the Motor Vehicle Division for locating crashes. When these LRMs are implemented, the LRS is expected to provide more accurate location data and allow for reduced data collection efforts.

4. *The LRS will help minimize redundancy in DOT database systems.* The Physical Design includes integration specification, so business data does not need to be redundantly collected or stored in Iowa DOT database systems. When these specifications are implemented, the LRS is expected to reduce Iowa DOT data update efforts, as well as reduce the ambiguities of accessing and applying official Iowa DOT data.

5. *The LRS will help minimize data maintenance that is needed due to changes in the transportation network.* The Physical Design includes integration specifications so the staff maintaining the business data need only update their specific business data. The Design also includes location transformation specifications, allowing the staff maintaining the data to automatically compute new location descriptions for business data if a roadway alignment or a signed route changes. When these specifications are implemented, the LRS is expected to reduce Iowa DOT data update efforts.

1.4. Conclusion

The Project Team has successfully completed the Physical Design task of the Iowa DOT LRS Development Project. The results of the Physical Design are a detailed account of data, process, technology, and organizational specifications of the LRS. These specifications reflect LRS operational (maintenance) needs and how the LRS must support DOT data integration, analysis and decision-making.

The Physical Design contains recommendations on DOT assignments to LRS Management. All Divisions, except the Operations and Finance Division and Director's Staff Divsion would have a role in LRS Management. Some assignments would be new because the LRS offers new capabilities. Some of these new responsibilities will require additional staffing, but the magnitude and duration of such staffing won't be determined until the later phases of this project.

The Physical Design is used to construct the LRS in Iowa DOT's technology and organizational environment. The next project task is a pilot, in which selected LRS components will be built and tested against pre-determined benchmarks. The pilot results will then be used to provide an initial implementation plan for the LRS. This plan will include implementation costs and benefits.

2. Overview

The Physical Design is the last of three design tasks in the Iowa DOT Linear Reference System (LRS) Development Project. The purpose of this document is to provide an overview of the completed Physical Design specifications for the LRS. These specifications document how the LRS requirements will be met in Iowa DOT's targeted technology and organizational environments. This document attempts to describe these specifications so those with only a basic understanding of information technology can appreciate the design.

The completed Physical Design includes both operational and decision support specifications for the LRS. Operational specifications describe how Iowa DOT will maintain the LRS. The operational specifications are grouped into eight interoperable subsystems that manage the LRS. These management subsystems are the Linear Datum, Route (transportation networks, routes), LRS Milepoint LRM, Segmental LRM, Stationing LRM, Reference Post LRM (previously called milepost), Literal Description LRM, and Coordinate Route LRM.

The decision support specifications document how Iowa DOT will access, integrate, and analyze business data using the LRS. The LRS decision support specifications add capabilities to the already existing GeoData Warehouse (GDW). The GDW is a decision support environment based on GIS at Iowa DOT.

The major goals of the Physical Design are as follows:

- Provide a physical system that is as close to the logical design as possible and one that implements the spirit of the NCHRP 2027(2) model by maintaining the physical separation of the logical layers of the system.
- To provide a run-time system that is highly scalable and can support Iowa DOTs existing and future needs.
- Provide a system that is maintainable and extensible to accommodate changing requirements over time.
- Use industry standard development environments and techniques.

These goals have been met in the physical design.

Section 3 of this document describes the LRS technology architecture required to support the LRS. The technology architecture addresses both LRS maintenance and LRS decision support (GeoData Warehouse). This section includes an overview of the three-tier application framework, interoperability approach, the operational architecture, and an estimated level of effort to develop the system.

Section 4 provides an overview of the GeoData Warehouse (GDW) specifications. This section briefly describes three key GDW user tools: LRS Reference Calculator, Linear Transform, and Linear Overlay. This section also provides an overview on GDW metadata handling and staging LRS data to the GDW.

Business Logic is described in Section 5. Business logic is the heart of the system and is used by both the LRS maintenance and GDW architectures of the LRS. This section provides an overview of linear transformation, data staging, linear overlay, and dynamic segmentation handling.

The next section, Section 6, provides an overview of the LRS maintenance specifications. This section provides a general description of maintenance functions and the technology used to support these functions. The section also provides an overview of the how events propagate changes through the LRS.

The last section, Section 7, describes how the LRS Subsystems and their related components are assigned to DOT organizational units. This section assigns both Subsystem management and specific workflows within these subsystems. The section indicates who was chosen, describes general impacts to current workflows, and describes what technology and skills are needed. Appendix 8 provides details on these assignments.

Finally, two other appendices are included with this document. Appendix 9 describes specific issues relevant to the Physical Design that were identified during design review sessions with Iowa DOT management and staff. Included with each issue is how or when the issue will be resolved. Appendix 10 provides a glossary of key terms used in this document.

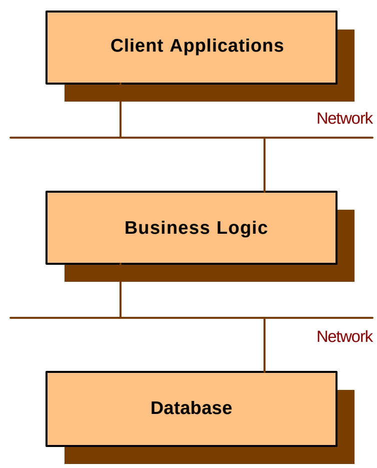
A Physical Design Technical Document also exists, and is written for information technology specialists and business staff with information technology competencies. It provides the detailed specifications of the LRS technology architecture, organizational architecture, and workflow specifications by LRS subsystem. Detailed data specifications can be found in the Physical Database Model Technical Reference Document. For insight into physical design results please see the Decisions Behind the Physical Design Technical Reference Document.

3. TECHNOLOGY SPECIFICATIONS

3.1. Application Framework Overview

The Physical Design defines an implementation of the LRS as a multi-tier distributed system. Multi-tier distributed systems centralize data and business logic associated with solving a problem onto database and middle-tier servers and allow clients to interact with the data and business logic over the network. Figure 1 illustrates the overall application framework for the LRS. This design provides for a highly scalable and maintainable computing environment and allows a variety of heterogeneous client systems to utilize the components of the LRS over a network connection.

Figure 1 - 3-Tier Application Framework



The system is designed as a distributed three-tier system composed of clients, business logic, and data stores, all of which are logically connected via a network. The business logic, also called the middle tier, contains services and facilities that implement the linear transformation, linear overlay, and staging operations that are part of the LRS application.

3.1.1. Client Tier

The Client tier is the user interface used to communicate with the business logic and database tiers. The types of client applications that can interact with the LRS implemented as a multi-tier system are as follows:

- GIS (GeoMedia) clients
- Database reporting tools (Crystal Reports, Oracle Forms, Microsoft Access, etc.)
- Web-based applications (HTML) Clients
- Command line database interfaces (Oracle's SQLPlus)
- Other network-enabled business systems (Bridge or Pavement Management)

3.1.2. Business Logic Tier

The Business Logic tier is composed of a set of Java classes and stored procedures that implement the major functions of the LRS. These functions include code that performs linear transformations, linear overlay, dynamic segmentation, and functions that stage data from the LRS maintenance environment to the GDW.

3.1.3. Database Tier

The Database tier is where the data for the LRS resides. There are basically two types of LRS data. The first is LRS data that is stored in a format as it is maintained. Access to this data is typically restricted to only those who edit the LRS data. The second type is data formatted for use. This data will reside in the GDW. GDW data is derived from LRS and business data and is read-only (cannot edit this data).

3.2. Interoperability

Interoperable systems have negotiated process interfaces, but do not require the systems to be internally specified in any specific way. In other words, interoperable systems can do whatever and however they want internally, but what and how the systems communicate with other systems must be standardized (share data, present errors, etc.). Interoperability is considered a requirement of the LRS based on conclusions from the Conceptual Design. There are two notions of interoperability that pertain to the use and maintenance of the LRS. Within the LRS itself, the subsystems are interoperable; and within the Iowa DOT enterprise, applications can interoperate with the LRS.

3.2.1. LRS Subsystem Interoperability

The individual LRS management subsystems interoperate to form the LRS. Each management subsystem can be independently managed and maintained as a set of asynchronous processes. This idea is illustrated in Figure 2.

Changes generated in one of the subsystems can affect other subsystems. These changes are managed as events that can be trapped and used by other subsystems. As these subsystems all exist within the LRS schema, database triggers and referential integrity constraints can be used to provide the firing mechanisms for the events. For example, when an anchor section is retired, all the links and related routes using that anchor section must be notified and some action must occur in the LRS schema to retire the associated links and adjust the route.

3.2.2. LRS Application Interoperability

Eventually the LRS will become the focus of several client systems that require the transformation, overlay, and staging services of the LRS. These systems can be developed to interoperate with the LRS business logic tier through the network. This concept is illustrated in Figure 3.

External applications interoperate by passing LRMs over the network. The GeoMedia custom commands detailed in this document are the first interoperable components that will be developed to run against the business logic.

Figure 2 - LRS Subsystem Interoperability

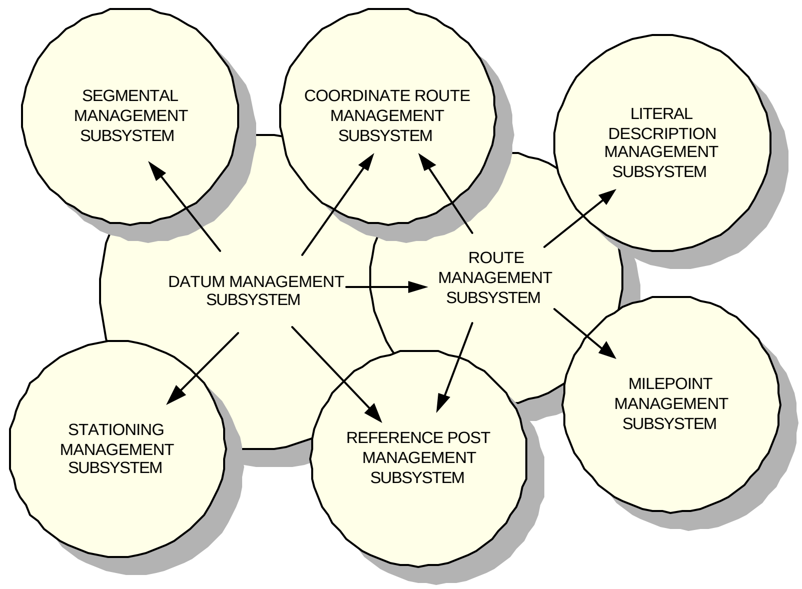
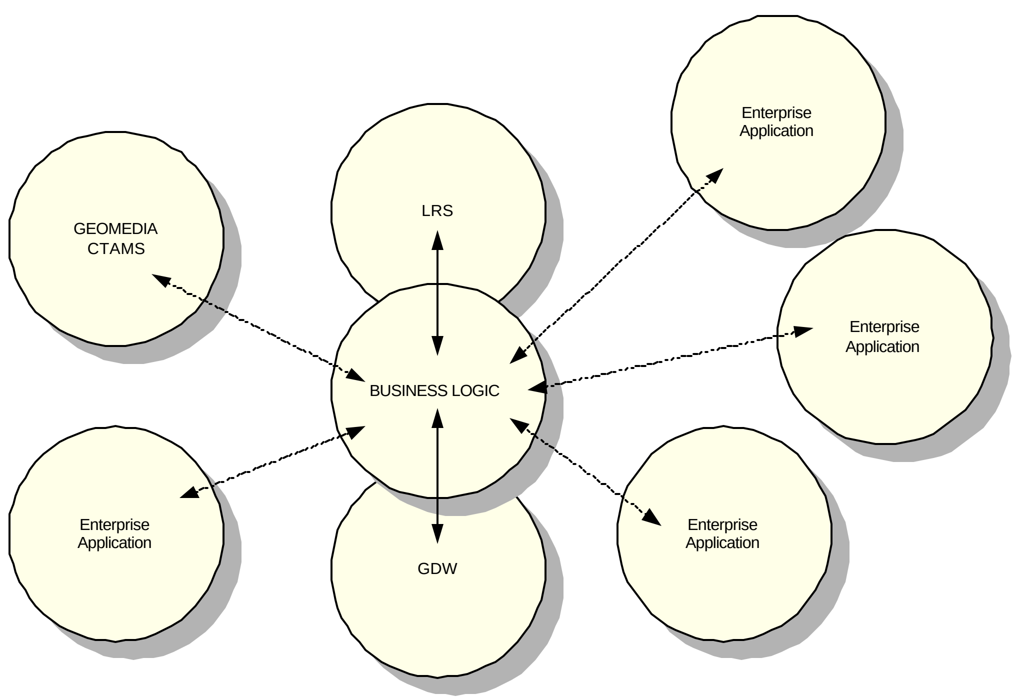


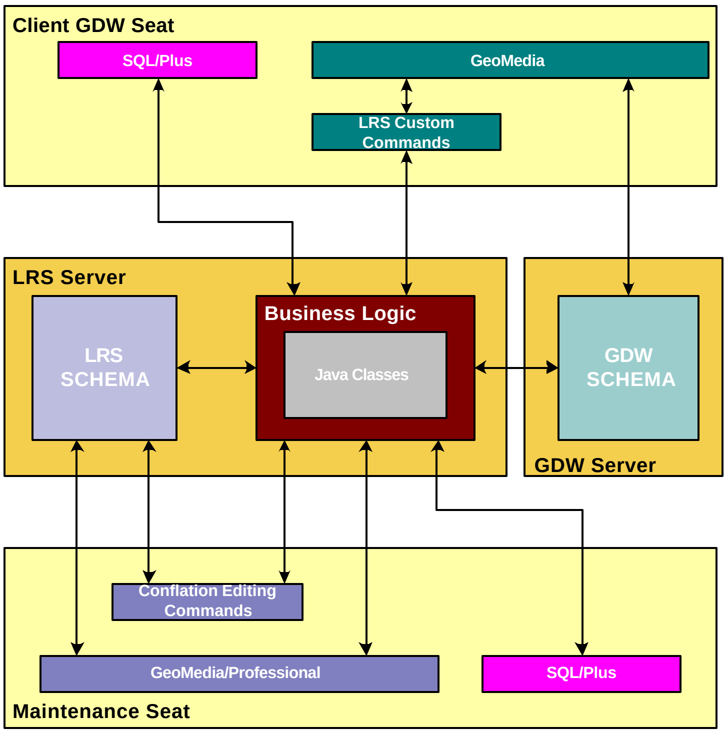
Figure 3 - LRS Application Interoperability



3.3. System Architecture

The operational architecture of the system describes how each of the application tiers will be specifically implemented at Iowa DOT. This architecture includes the types of technologies applied and describes how these technologies will be packaged. The operational architecture is illustrated in Figure 4. Notice there are two types of clients, and that the business logic and database tiers have been combined.

Figure 4 - Design for the LRS Application Architecture



3.3.1. LRS User Clients

The clients have access, through GeoMedia, to the data that has been staged in the GDW in read-only mode. Via the custom commands, they also have the ability to execute stored procedures that perform linear transform and overlay operations. Additionally, access to both the staged data and stored procedures is provided by other non-GIS database interfaces such as SQL/Plus.

The GeoMedia clients will be able to integrate data from other parts of the GDW such as Arc/Info, MGE, and GeoMedia staged data.

Note that GeoMedia is only required for clients that need to create maps or use the GeoMedia LRS Custom Commands. SQL/Plus is installed as part of the Oracle client installation and can be used as an alternate interface for running stored procedures and generating reports.

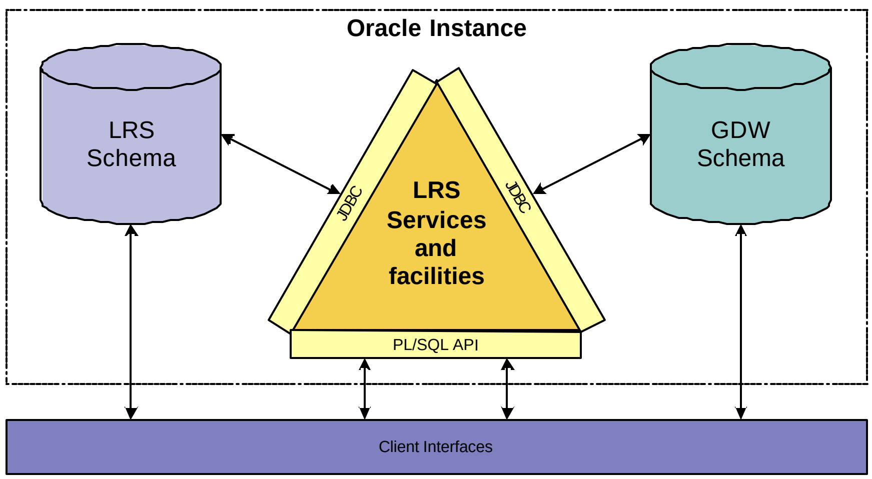
3.3.2. LRS Maintenance Clients

For maintenance operations, GeoMedia Pro provides the ability to manage and maintain the LRS schema and initiate stored procedures as necessary to perform workflows. GeoMedia Pro uses a read-write version of the Oracle GDO server to update the LRS components via its map and table interfaces. Staging of the data from the maintenance schema to the staged schema will be performed by stored procedures. These staging procedures could be initiated via custom commands in GeoMedia Pro or from a non-GIS environment such as SQL/Plus.

3.3.3. Business Logic

The LRS application will be written as a three-tier system but implemented in the pilot as two physical tiers by hosting the business logic functions within the database instance. This architecture is illustrated in Figure 5. The LRS Services and Facilities comprise the core of the business logic. The business logic functions will be implemented as libraries of Java classes. The Java libraries will be embedded in the Oracle Java RTE which is distributed as part of the Oracle 8i software.

Figure 5 - Organization of the Oracle Instance

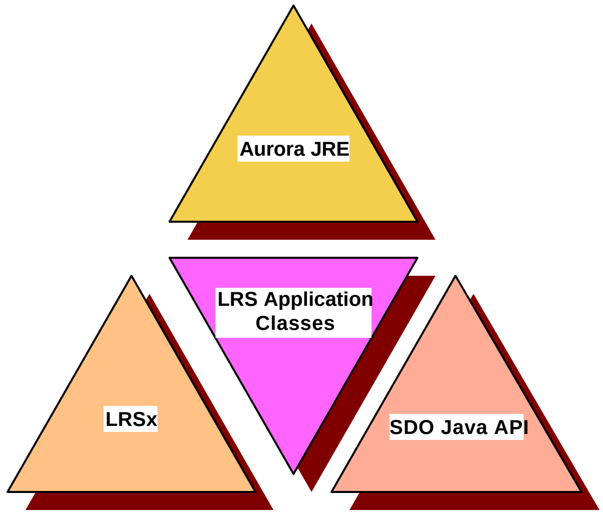


The primary way that clients (applications) will interface to the business logic is through a PL/SQL interface which wraps the Java coded business logic as a set of Oracle stored procedures. The stored procedures can be executed from any compliant environment including, but not limited to, SQL/Plus, Custom Applications, and Web-enabled environments (WebDB, OAS).

The LRS Services and Facilities are composed of four sets of Java classes illustrated in Figure 6. The LRS Application Classes are those that are developed specifically for the Iowa DOT project and consist of the linear transform and linear overlay operations along with classes designed to manage components of the system and stage data to the GDW.

The LRS Application Classes depend on the three sets of other classes. LRSx classes are the LRSx class library available from TransDecisions, Inc. The SDO Java API set contains Oracle's Spatial Data Objects Java classes (SDO Java API). The SDO Java API requires the installation and licensing of the Oracle Spatial extensions. The last set contains the Java run-time classes provided by the JServer environment in the Oracle instance (Aurora JRE). This set is distributed as part of the Oracle 8i Release 2 database software.

Figure 6 - Organization of the LRS Services and Facilities



3.3.4. Database Server

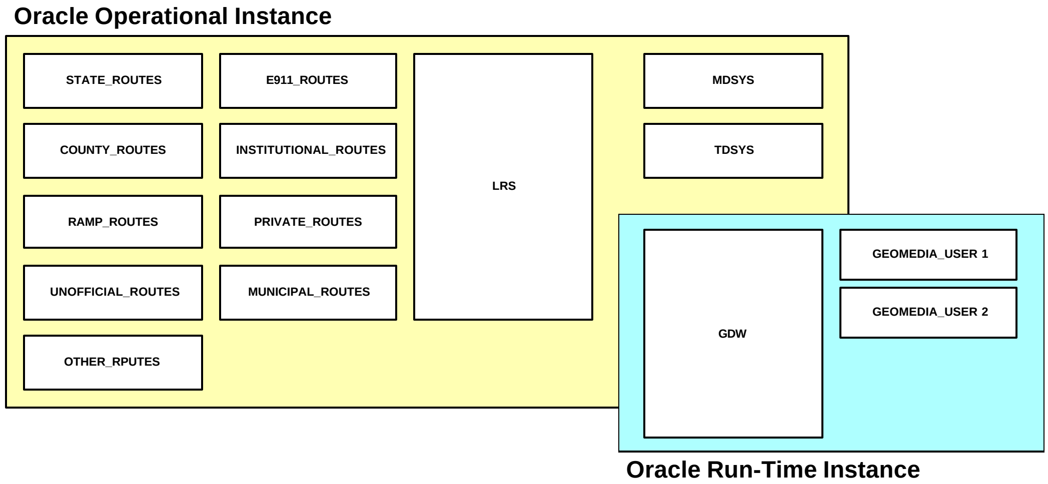
The database consists of two Oracle schemas. An Oracle schema is a predefined set of database objects. One schema contains GDW objects while the other schema contains the LRS objects. The GDW schema and the LRS schema are logically separated and can be easily physically separated into different database instances if required. An Oracle instance is a combination of processes and data. Having two separate instances for the LRS is illustrated in Figure 7.

As the numbers of users of the LRS increases over time, maintaining separate Oracle instances will provide better overall system performance at a lower cost per user. During implementation and initial field-testing phases, a single Oracle instance will be sufficient to meet the processing requirements.

Oracle 8i Release 2 is the targeted platform for the LRS Database Server. This server can be a Sun Solaris or Windows NT Server based Oracle instance. A single server can run both the GDW and the LRS systems, or the GDW and LRS can be placed on separate Oracle servers to better match hardware configurations to the performance requirements of the users.

Additional software to manage the Oracle instance and perform routine backup and restores should also be considered. Examples are dbArtisan from Embarcadero Technologies for managing, monitoring and tuning the database and ARCServe from CAI for backing the server(s) to offline storage media.

Figure 7 - Conceptual LRS and GDW Schema Organization



3.4. LRS Development Effort

The following table summarizes an initial approximate level of effort to construct, integrate, debug, and document the various LRS components. The technical document details the skills, development environments, and hours necessary to perform this work.

Table 1 - Component Development Estimated Level Of Effort

Tier	**Component**	**Hours**
Client	GeoMedia Custom Commands	Initial Database Setup: 8 hours Programming: 120 hours Debugging/System Documentation: 20 hours Use Manual Development: 40 hours
Maintenance[1]	Conflation Editing Commands	Design, provide specifications: 150 hours Programming/documentation: 1000 hours
Server	Transformation Algorithms	Programming/documentation: 280 Hours
	Linear Overlay	Programming/documentation: 40 Hours
	Staging Algorithms	Programming/documentation: 120 Hours
	API and documentation	Programming/documentation: 160 Hours
	Installation and Testing	80 Hours

[1] Intergraph has suggested that a GeoMedia Pro-based Network Manager product being developed will perform much of the functionality for these workflows.

4. GeoData Warehouse Specifications

The GeoData Warehouse (GDW) is an Oracle schema that contains the business and LRS data that has been staged from the business and LRS maintenance environments. The major access to the GDW will be through Intergraph's GeoMedia GIS client. GeoMedia will have the capability to view and map any of the data that has been staged into the GDW. GeoMedia will also, through the addition of the custom commands detailed below, be able to perform linear transformations and linear overlays against the LRS by utilizing the Business Logic tier of the system.

4.1. LRS User Interfaces

Three new user-interface tools will be developed specifically to perform linear operations against the GDW and LRS. These new tools will be available through the existing CTAMS / GeoMedia software and will extend the default GeoMedia user-interface. The three tools will be developed using GeoMedia pipe technology. The three tools are:

- Reference Calculator
- Linear Transform Wizard
- Linear Overlay Wizard

These three user-interface components will perform the following functions:

4.1.1. Reference Calculator

Allow the user to enter a location reference using one of the LRMs and generate either a) the equivalent location reference within another LRM or b) the equivalent location reference using another route within the same LRM (milepoint LRM only).

The Reference Calculator is an interactive tool that performs a single transformation at a time. The transformation is performed on the LRS server against the latest version of the linear datum.

4.1.2. Linear Transform Wizard

Allow the user to process a data set (called a recordset by GeoMedia) that is accessible to GeoMedia and convert the location references to either a) a datum value, b) another LRM, or c) a cartographic representation. This user-interface component will be an interactive "wizard" command that guides the user through the process of selecting recordsets, LRMs, columns, and output formats for the transformation.

4.1.3. Linear Overlay Wizard

Allow the user to overlay a recordset that is accessible to GeoMedia on top of data that is stored in the GDW. The result of the overlay will be a new table of features that contain attributes of both the input recordset and the features in the GDW upon which the input data was overlaid.

This user-interface component will also be an interactive "wizard" command that guides the user through the process of selecting recordsets, LRMs, columns, and output attributes for the overlay operation.

4.2. GDW Metadata

Data that is staged into the GDW will have a row inserted into a GDW Metadata table. The metadata table is designed to provide a guide for GeoMedia and other system users about the contents of the Oracle component of the GDW. The metadata table will contain contact information and other information, date of data collection, and date that the data was staged for each table in the GDW.

4.3. Data Staging

Many sources of data can be staged to the GDW. The approach and procedures to stage data is described in the Business Logic section of this report.

Some LRS data that exists as part of the LRS schema is also staged to the GDW. Only those components that have utility as part of the GDW are staged. These components are Centerlines, Datum (Anchor Sections, Anchor Points), Network (Transport Links, Transport Nodes), Routes, Reference Posts, and Improvement Projects (Project Sections, Project Nodes, and Station Posts).

During the staging process, the input LRS elements are transformed into GIS features as they are written to the GDW. In many cases this is a semantic transition. However, the purpose is to create geographical features from the linear elements of LRS which can be mapped, reported and analyzed using the GIS tools available as part of the GeoMedia toolkit.

Note that the GDW will support network processing (e.g., shortest path routing, network allocation, etc.). The structure of the features that comprise the network are consistent with the requirements for GeoMedia Network 4.0, which allows that software to be used as a network client.

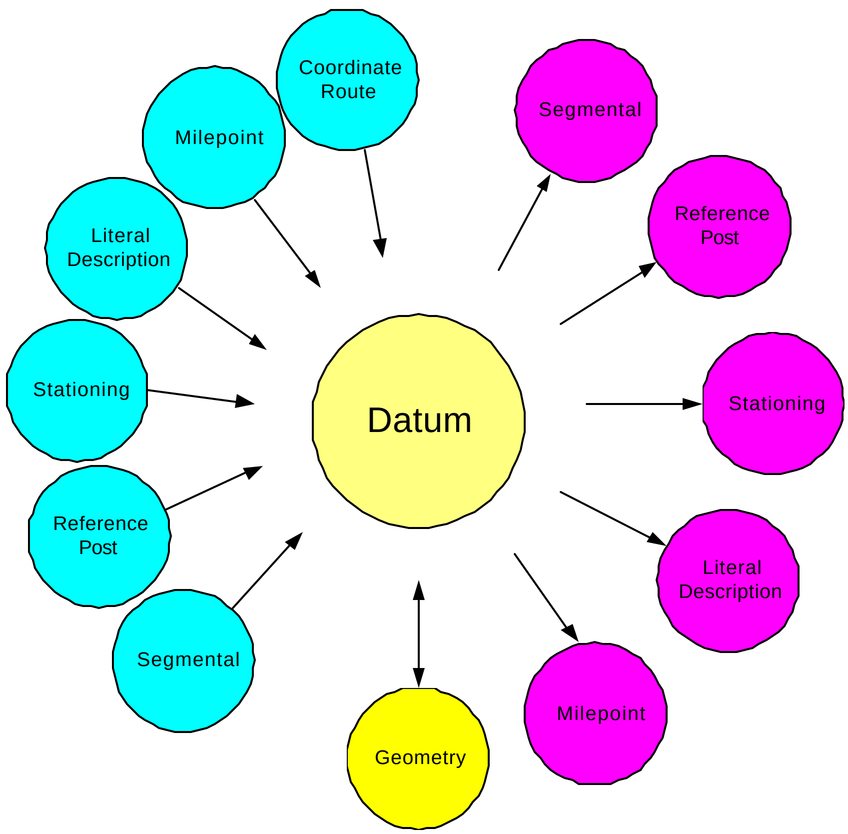
5. Business Logic Specifications

Business Logic comprises the set of code that implements the major functions of the LRS. These functions include code that performs linear transformations, linear analytical operations, and staging of data into the GDW. The Business Logic components provide the major interoperable interfaces to enable other applications on the network to communicate with, and use functions of, the LRS.

5.1. Transformation Operations

The physical design accommodates the NCHRP 20-27(2) approach of mapping all location references through the datum during a LRM-to-LRM transformation procedure. In general, the procedure to map a location reference between any two LRMs is a two-stage algorithm. The first stage is to transform the location reference to a datum reference. The second stage is to then convert the datum reference to the output LRM. This process is illustrated in Figure 8.

Figure 8 - Location Reference Transformations via the Datum



The notion of LRM-to-LRM transformations has been extended to include cartographic and datum references. Thus, the transformation tools available through the GeoMedia user interface will allow the user to convert location references stored in a particular LRM to another LRM, the same LRM but a different route, a datum reference, or a cartographic representation.

Linear transformations are the major code component of the business logic tier. The transformation algorithms are coded in Java and wrapped with a set of stored procedure interfaces. There will be a variety of programming interfaces for each algorithm that allow different input formats to be used. Depending on the type of transformation, the input parameters could take one of the three following forms:

- System Format – a format internal to the LRS schema that allows the user to specify foreign key values as transformation parameters. It applies database codes (foreign key) as parameters.
- Application Format – an external interface that allows the user to specify disaggregated individual parameters. The application format is designed for interoperable systems. For example, legacy business database may maintain route parameters in separate columns in a database table ("North", "Main", "Street"). This format uses the LRS function to return the foreign key for the route and then calls the System-format version of the transformation.
- Interface Format – a process designed to allow user interaction with the system. The interface format uses a parser to extract the route parameters from a standard format input string. For example, the interface could pass in "I 80 E' or "North Main Street". The interface format uses a parser to break the route string into its components and then calls the Application Format version of the transformation algorithm.

5.2. Data Staging

Data to be staged into the GDW can be categorized into the following three types.

- LRS components
- Business Data from legacy systems
- Other Business Data

LRS components such as the datum, routes, and reference posts are components that have a static format and will be staged at regular intervals. These components will follow exactly the same staging process each time they are staged. The Business data that comes from legacy systems, such as the bridge inventory systems, PMIS, etc., will be staged at regular intervals and will always be in the same format. For these two types of data, stored procedures will be written that allow GDW staff to quickly stage a new version of the data to the GDW. The stored procedures will be executable from a database command-line environment such as Oracle's SQL-Plus.

There are two options for business data that is staged on an *ad-hoc* basis or for data that is presented for staging in a different table structure each time. First, a staging procedure can be written in PL/SQL that accommodates the data structure and uses the LRM transformation stored procedures to perform a row-by-row stage of the data. If the data format changes each time the data is presented for staging, the stored procedure would need to be modified to accommodate the change. The second option is to use a GeoMedia Client to perform the transformation using the LRM Transformation Wizard and output the transformed data set to the GDW.

Data that is to be staged from a legacy, or other system, must be prepared before it can be staged. Data that has been loaded into an Oracle table (data will reside in a user-schema, not the GDW or LRS schema) must have column names and types formatted to ensure compatibility with GeoMedia and Oracle requirements. If the data exists in format not directly supported by the GDW, the LRM column structure must coincide with a stored procedure transformation API.

Once the data to be staged has been prepared and is accessible to the LRS schema, it can be staged. A GDW administrator who can write into the GDW, and use the schema objects stored in the LRS schema, will typically perform the staging process. A typical staging process will select the rows and columns to stage from the input database, create datum and geometric (cartographic) reference for each row in the output table, classify the temporal nature of the data (past, current, future) and insert metadata into GDW, LRSx, and SDO tables. The diagram in Figure 9 shows the result of the datum and geometric referencing added to the output table. Staging algorithms can be easily created by copying or modifying an existing stored procedure.

The staging procedures use the transformation algorithms to transform the LRM for a table to a staged Datum reference. Note that the LRM transformation algorithms operate against the LRS schema and not the data that is staged into the GDW. The staged LRS data are simplified views of the LRS schema to make general browse and query functions faster and easier.

5.3. Linear Overlay

The overlay process will calculate the resulting relationship between the linear locations of an input event and the linear locations of a reference event. Given these two linear events, there are four possible outcomes of an overlay operation. These relationships are illustrated in Figure 10.

The two events might be *disjoint*, one event might be *contained* or *covered* by the other event, or the events might overlap for some portion of their extent. Linear *equality* is an additional outcome wherein two linear features share the same linear space. This property is a generalization of *contained* as one linear feature exactly contains the other. If either of the overlay events are point events note that the set of linear relationships is restricted to *disjoint* or *contained.*

Figure 9 - Staging Steps for a Table Containing Typical Business Data

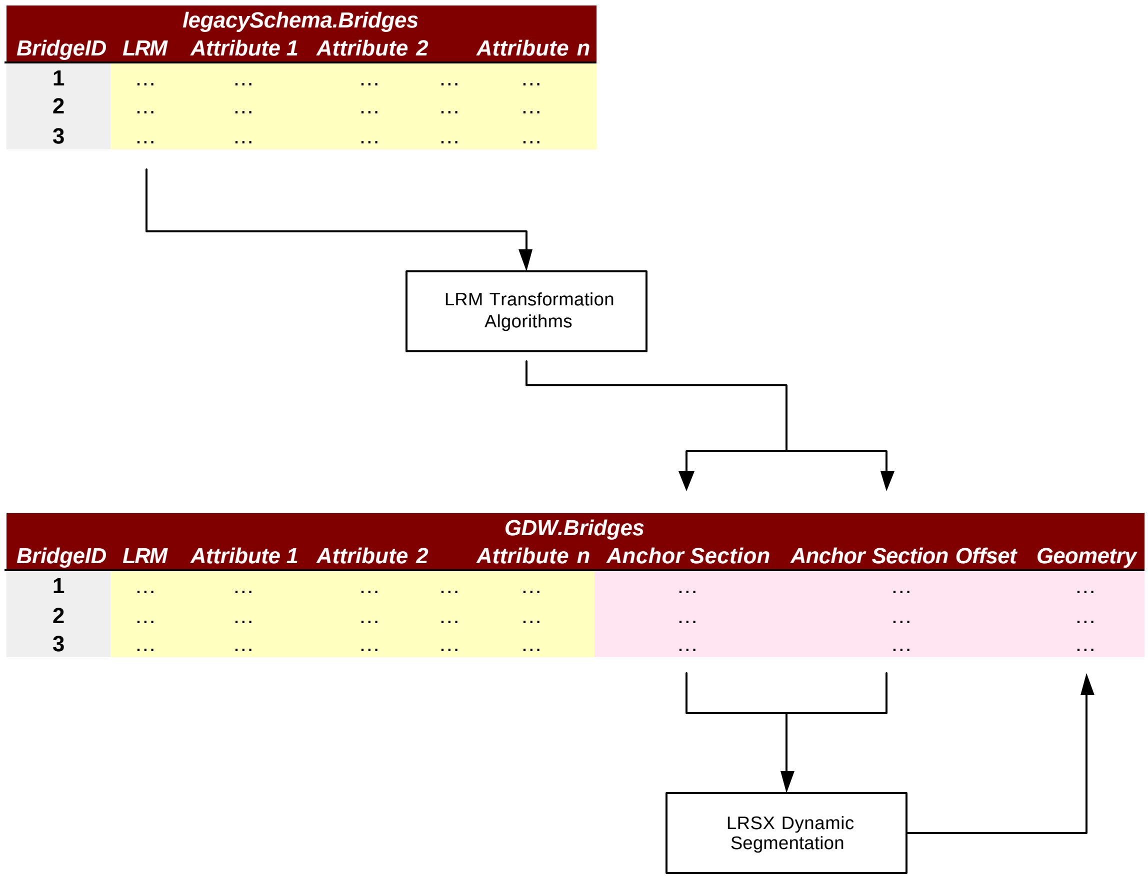
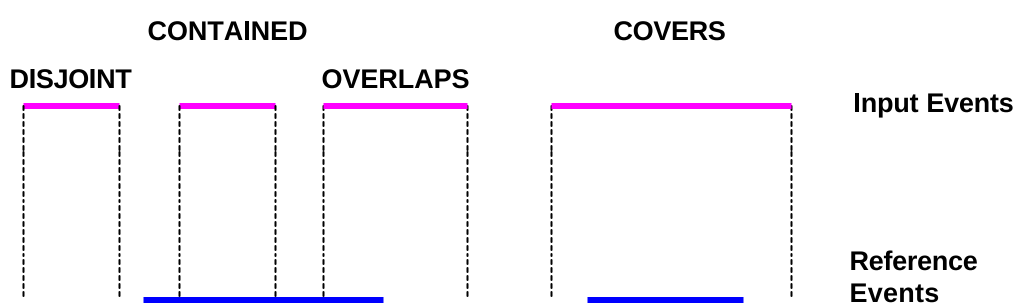
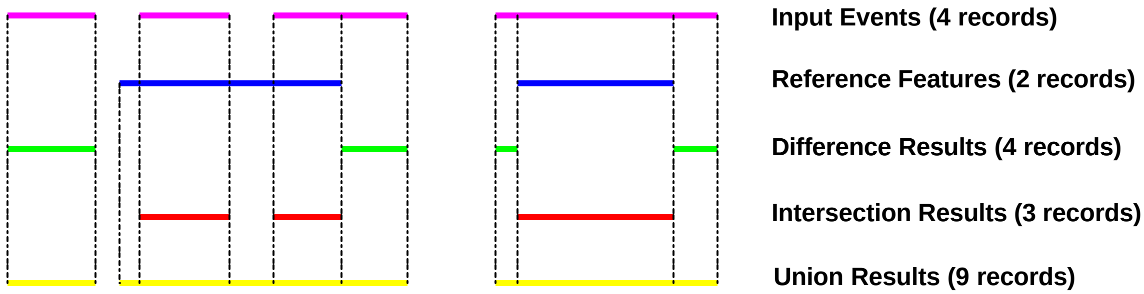


Figure 10 - Relationships between Linear Features



The overlay will support three set theory operators: linear difference, linear union, or linear intersection. Figure 11 illustrates the results of each of these. The difference operator returns the portions of the input events that are not contained by any feature in the reference table. The Intersection operator returns those portions of the input events that are contained by the one or more features in the reference table. The union operator returns the portion of each input event that is either disjoint or contained by a reference feature.

Figure 11 - Results of Linear Overlay Operations



Linear overlay operations are part of the business tier's functions. The actual overlay process is deferred to the LRSx engine that will perform the overlay operation. The LRSx functions will be wrapped with high-level code to make the overlay operations available to the GeoMedia clients via GeoMedia Pipe technology and will present a standard format API to the rest of the LRS application.

Additional operations can be combined with the overlay wizard to produce more complex results. Once two recordsets are overlaid, selected attributes from the two input recordsets will be merged (e.g., crash records can have pavement identifiers associated with them). GeoMedia then can be used to physically join two tables using the Join Query command to obtain additional attributes. This command will allow statistical and summary operations to be performed on the resultant recordset. For example, the number of fatal crashes associated with each pavement section, the pavement section with the most crashes, and the average number of crashes by pavement condition. These types of operations can be automated as necessary by creating new GeoMedia custom commands or by providing SQL statements to provide the results.

5.4. Dynamic Segmentation

Linear dynamic segmentation allows business data stored with linear locations (milepoint, reference post and offset) to be portrayed along cartography even though the business data and cartography begin and end at different points along the roadway.

Dynamic segmentation operations are part of the business tier's functions. The actual dynamic segmentation process is deferred to the LRSx engine which will perform the dynamic segmentation operation. The LRSx functions will be wrapped with high-level code to make the overlay operations available to the GeoMedia clients via GeoMedia Pipe technology and present a standard format API to the rest of the LRS application.

6. LRS Specifications

The Operational LRS is an Oracle schema that contains the LRS data that must be maintained. The Operational LRS is divided into eight interoperable subsystems: Datum, Route, Coordinate-Route, LRS Milepoint, Reference Post, Stationing, Segmental, and Literal Description.

The primary maintenance tasks within each of these subsystems are add, modify, and retire LRS data objects like anchor sections (Datum Subsystem), transport links (Route Subsystem), and routes (Route Subsystem). The same maintenance tasks are also performed on the relationships between data objects, like the anchor section and the transport link (Route Subsystem). For a rigorous review of the LRS database objects see the Physical Database Design Document.

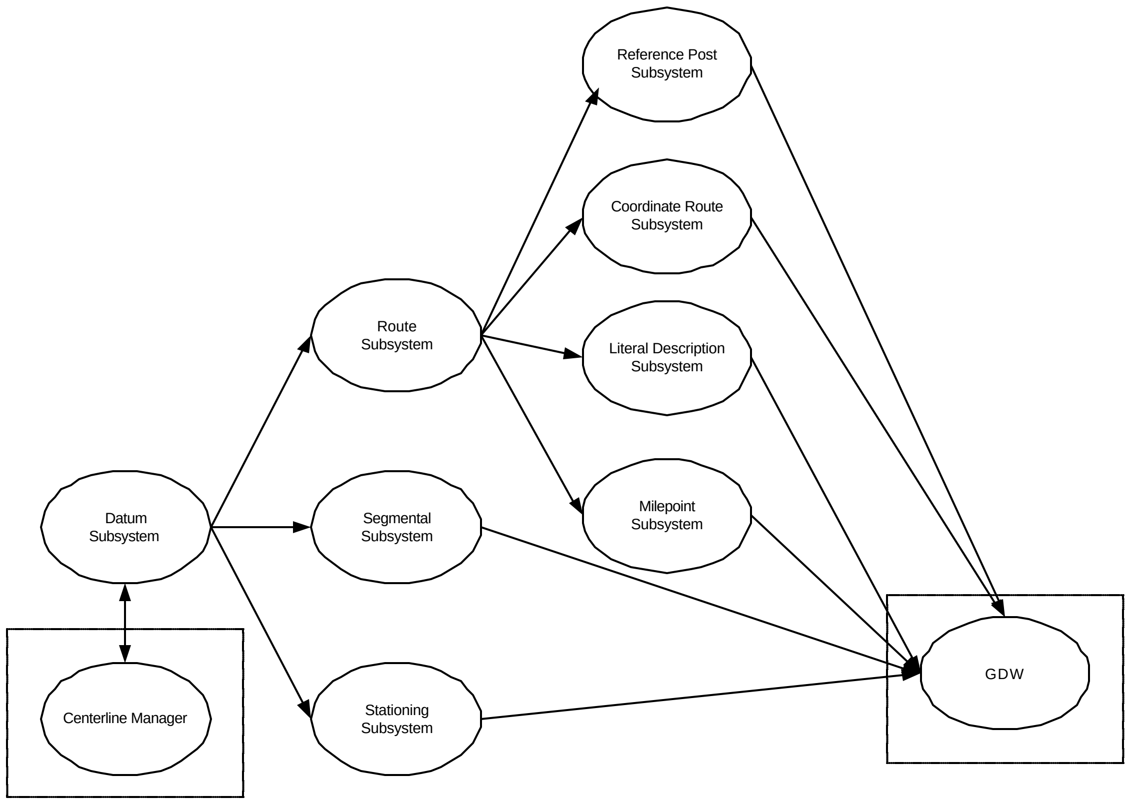
For these maintenance operations, GeoMedia Pro provides the ability to manage and maintain the LRS schema and initiate stored procedures as necessary to perform maintenance workflows. GeoMedia Pro uses a read-write version of Intergraph's Oracle GDO server to update the LRS components via its map and data view interfaces. Custom GeoMedia tools will provide the editing interface for datum and network layers of the LRS.

6.1. Event Propagation

As changes to the subsystems are made during normal maintenance operations of the LRS the changes are managed as events. Events are generated by one subsystem and provide notification to other subsystems that a change has occurred. Changes cascading through the system are managed by subsystems listening to events and propagating these events to higher-order subsystems. The event propagation chain is shown in Figure 12.

Although the Centerline manager is not a formal subsystem it has to respond to *requests* for changes from the Datum Subsystem and, once a request has been implemented has to receive notification that changes to the centerlines have been made. Similarly, the GDW is not a formal subsystem but acts as an event listener. The LRM subsystems do not propagate events among themselves. However, they provide notification that changes to business data stored in the GDW may need to be made.

Figure 12 - Event Propagation



6.2. Datum Management Subsystem

The Datum Management Subsystem is implemented as a set of tables and stored procedures in the LRS schema. The data tables of this subsystem are

- Datum tables: Anchor_Section, Anchor_Point, Anchor_Point_Monument, Anchor_Point_Elevation, Anchor_Section_History, Datum_Version, Anchor_Point_Centerline_Ctl
- Cartography tables: Centerline
- Improvement project tables: Improvement_Project, Improvement_Project_State, Subproject_Phase, Subproject_Type.

Within the Anchor_Section table, the LRSx Conflation Object provides the means for storing the relationships between the centerline and anchor section tables and between the anchor section table and the network layers. Custom commands developed for GeoMedia Pro will provide the means for editing the relationships between the anchor section table and the centerline layer.

6.3. Route Management Subsystem

The Route Management Subsystem is implemented as a set of tables and stored procedures in the LRS schema. The data tables for this subsystem are:

- Network tables: Transport_Link, Transport_Node, Link_Status, Node_Status, Transport_Link_AS_Xref, Transport_Node_Offset, Nested_Network_Xref, Aggregated_Element_Name

- Route tables: Route_Link, Route, Route_Alias, Route_System, Geographic Extent, Geographic_Category, Route_Jurisdication
- Route system tables: several occurrences of the same table structure exist for the following route systems: state, county, municipal, E911, private, institutional, unofficial, and ramp route systems
- Transport system tables: Transport_System, Transport_Mode, Transport_System_Xref

Within the Transport_Link table, the LRSx Conflation Object provides the means for storing the relationships between the anchor section table and the network layers. The same custom commands developed for managing the anchor section table can be used to edit the relationships between the anchor section table and network component.

6.4. Reference Post Management Subsystem

The Reference Post Management Subsystem is implemented as a set of stored procedures in the LRS schema. The only data table is the Reference_Post table. GeoMedia Pro will be used to assist in the positioning of reference posts. Stored procedures will provide the means to manage the changes to the datum, network, and route layers that affect the reference posts.

6.5. Coordinate - Route Management Subsystem

The Coordinate-Route Management Subsystem is implemented as a set of stored procedures in the LRS schema. There are no data tables maintained within this subsystem (this subsystem uses data from other subsystems). Functions available through the LRSx and SDO Oracle extensions provide the means to project input coordinate routes to a cartographic representation of the anchor sections and then LRS specific procedure will allow a datum reference to be associated with the coordinate route.

6.6. Literal Description Management Subsystem

The LRS Literal Description Management Subsystem is implemented as a set of stored procedures in the LRS schema. The data tables for this subsystem are Reference_Feature, Reference_Feature_Category, Ref_Feature_Route_Xref, and Transport_Node_Route_Xref.

This is a simple set of tables that can be managed via graphical or command line interfaces. Most of the data in the LRS Literal Description Subsystem is derived from other LRS data by using automated procedures.

6.7. LRS Milepoint Management Subsystem

The LRS Milepoint Management Subsystem is implemented as a set of stored procedures in the LRS schema. This is a simple set of tables that can be managed via graphical or command line interfaces. The only data table is the Transport_System_Milepoint table. LRS Milepoint Subsystem data is derived from other LRS data by using automated procedures.

6.8. Stationing Management Subsystem

The Stationing Management Subsystem is implemented as a set of stored procedures in the LRS schema. The data tables for this subsystem are Project_Section, Project_Section_Node, Project_Section_Node_Offset, Station_Marker, and Station_Marker_Type. GeoMedia Pro will be used to assist in the placing of project sections and station posts.

Within the Project_Section table, the LRSx Conflation Object provides the means for storing the relationships between the anchor section table and the project sections. The same custom commands developed for managing the anchor section table can be used to edit the relationships between the anchor section table and project sections.

6.9. LRS Components

The LRS Components are not part of any single subsystem. The LRS Components are implemented as a set of stored procedures in the LRS schema. The data tables for the LRS Components are LRS_Component, LRS_Tables, LRS_Subsystem, LRS_Component_Xref, LRS_Contact, LRS_Metadata, and Measurement_Methods. This is a simple set of tables that can be managed via graphical (tabular forms) or command line interfaces.

6.10. Segmental Management Subsystem

The Segmental Management Subsystem is implemented as a set of tables and stored procedures in the LRS schema. The data tables for this subsystem are GIMS_Control_Section and HPMS_Control_Section. All business data tables associated with these are not part of the LRS.

Within each control section table, the LRSx Conflation Object provides the means for storing the relationships between the anchor section table and the HPMS and GIMS sections. The same custom commands, developed for managing the relationship between the anchor section table and the centerline layer, can be used to edit the relationships between the anchor section table and sections.

7. ORGANIZATIONAL SPECIFICATIONS

The Iowa DOT must assign LRS subsystem management responsibility to specific DOT offices. The LRS subsystems are Datum, Route, LRS Milepoint, Reference Post, Segmental, Stationing, Coordinate Route, and Literal Description. There are two levels of responsibility for each particular LRS subsystem that must be assigned: individual management processes within a subsystem and the overall management of the subsystem. The Physical Design Team produced recommended office assignments for both levels for all subsystems.

The individual process assignments are itemized in Table 2. The processes are based on the logical design, but modified to accommodate the physical design. The Physical Design Team only analyzed Location Reference Maintenance processes from the Logical Design (see the Logical Design Process Model). The Physical Design Team did not analyze Location Reference Administration, Location Reference Operations, or Location Reference System Monitoring because these are outside the scope of the current project. The Team assigned responsibility to an office based on these office characteristics: understanding of LRS requirements, current skills and workflows related to these requirements, and technology capability.

The Physical Design Team then determined the overall management assignment based on several factors. A primary factor was whether an office is currently assigned a similar individual subsystem task. Another factor was recommended groupings of subsystems from the logical design. Another important consideration was an office's proactive involvement in the current LRS efforts. Table 3 shows the results of this analysis. In both tables, an 'X' indicates who would be ultimately responsible for the overall success of an LRS subsystem.

From the Logical Design Summary Document a key governing body for the LRS is the LRS Operations Work Team. That document proposed its members be the LRS Subsystem Managers and chaired by the LRS Manager. Given Table 3, the LRS Operations Work Team will be composed of managers from Office of Transportation Data, Office of Design, Office of Maintenance, Research Management Division, and the GIS Team in the Information Technology Division as LRS Manager.

The Logical Design Summary Document also describes the requirements for the LRS Board of Directors. This body would provide direction to the LRS Operations Work Team based on DOT priorities and objectives. The LRS Board of Directors would be composed of managers from each DOT Division. The Iowa DOT Divisions, working with the current LRS Steering Team members, should determine appropriate membership. The LRS Board of Directors must be advocates for LRS within their respective Divisions. The current LRS Sponsor and the LRS Steering Team should determine the new LRS Sponsor, who will then chair the LRS Board of Directors.

The Appendix in Section 8 provides details from the Physical Design Technical Document on how each of these DOT offices would be involved in LRS Management. The appendix summarizes the office's responsibilities to the LRS, why they were chosen, what would be new or different from current workflows, and what technology and skills would be needed.

Table 2 - Organization Assignments to LRS Processes

X = Perform this process; S = Support those who perform this process; I = Initial performer (X), but will move to support (S) or not be involved; H = Performs this process but for historic data.

Elementary Process	Trans Data - Sys Mon	Trans Data - Sys Mgmt	IT Division - GIS Team	IT Division - PMIS Support	IT Division - Oracle DBA	Office of Maintenance	Office of Traffic Engineering and Safety	District Offices	Office of Design	Office of Construction	Office of Bridges and Structures	Office of Rail Transportation	DOT Div Directors	Division Managers	GDW Manager	LRS Board of Directors	LRS Working Team	Office of Driver Services (MV)	Research Management Division	Comments
Establish LRS Controls																	**X**			
Establish LRS Parameters																	**X**			
Determine Transport System		**S**											**S**	**X**		**S**	**S**			
Determine First Order Datum Design		**X**	**I**																	
Determine Second Order Datum Design		**X**	**I**																	
Determine Third Order Datum Design		**X**	**I**																	
Plan Linear Datum Survey (P)	**X**	**S**	**I**																	
Prepare Measurement Device (P)	**X**	**S**																		
Place Anchor Point	**X**	**S**																		
Monument Anchor Point	**S**	**S**				**S**		**X**	**S**	**S**										
Measure Anchor Point Span	**X**	**S**																		

Elementary Process	Trans Data - Sys Mon	Trans Data - Sys Mgmt	IT Division - GIS Team	IT Division - PMIS Support	IT Division - Oracle DBA	Office of Maintenance	Office of Traffic Engineering and Safety	District Offices	Office of Design	Office of Construction	Office of Bridges and Structures	Office of Rail Transportation	DOT Div Directors	Division Managers	GDW Manager	LRS Board of Directors	LRS Working Team	Office of Driver Services (MV)	Research Management Division	Comments
Determine Anchor Section Distance		**X**	**I**																	
Adjust Linear Datum		**X**	**I**																	
Position Anchor Point (includes centerline)		**X**																		
Position Anchor Section (includes centerline)		**X**																		
Publish Linear Datum		**X**	**S**		**S**										**I**					
Add Transport Node	**S**	**X**																		
Add Transport Link	**S**	**X**																		
Change Link State	**S**	**X**																		
Change Node State	**S**	**X**																		
Remove Transport Link		**X**																		
Remove Transport Node		**X**																		
Assign Route Name		**X**																**S**		MV to assist with Unofficial routes.
Add Route Link		**X**																**S**		MV to assist with Unofficial routes.
Remove Route Link		**X**																**S**		MV to assist with Unofficial routes.

Elementary Process	Trans Data - Sys Mon	Trans Data - Sys Mgmt	IT Division - GIS Team	IT Division - PMIS Support	IT Division - Oracle DBA	Office of Maintenance	Office of Traffic Engineering and Safety	District Offices	Office of Design	Office of Construction	Office of Bridges and Structures	Office of Rail Transportation	DOT Div Directors	Division Managers	GDW Manager	LRS Board of Directors	LRS Working Team	Office of Driver Services (MV)	Research Management Division	Comments
Remove Signed Route		**X**																**S**		MV to assist with Unofficial routes.
Determine Route Link Distance		**X**																**S**		MV to assist with Unofficial routes.
Publish Transport System Route		**X**			**S**										**I**					
Place Reference Post				**S**		**S**	**S**	**X**												Placed during construction / maintenance.
Position Reference Post	**S**	**S**		**X**		**S**														Trans Data only because videolog collection and GIMS milepoint used to currently support RP positioning.
Publish Reference Post				**X**	**S**	**S**									**I**					
Place Station Marker (Post)						**S**		**X**	**S**	**S**										
Determine Project Section Location								**H**	**X**											
Position Project Section								**H**	**X**											
Position Station (Marker) Post								**H**	**X**											
Publish Project Section					**S**			**H**	**X**						**I**					
Publish Station (Marker) Post					**S**			**H**	**X**						**I**					

Elementary Process	Trans Data - Sys Mon	Trans Data - Sys Mgmt	IT Division - GIS Team	IT Division - PMIS Support	IT Division - Oracle DBA	Office of Maintenance	Office of Traffic Engineering and Safety	District Offices	Office of Design	Office of Construction	Office of Bridges and Structures	Office of Rail Transportation	DOT Div Directors	Division Managers	GDW Manager	LRS Board of Directors	LRS Working Team	Office of Driver Services (MV)	Research Management Division	Comments
Establish Reference Feature (Bridge or RR Crossing)		**S**									**X**	**X**								
Publish Reference Feature		**X**			**S**										**I**					
Determine HPMS Section Location		**X**																		
Position HPMS Section		**X**																		
Publish HPMS Section Location		**X**			**S**										**I**					
Determine Transportation Feature Location (Bridge or RR Crossing)											**X**	**X**								Part of business data maintenance, not part of LRS.
Position Transportation Feature (Bridge or RR Crossing)											**X**	**X**								Part of business data maintenance, not part of LRS.
Publish Transportation Feature Location (Bridge or RR Crossing)											**X**	**X**			**I**					Part of business data maintenance, not part of LRS.
Determine GIMS Segment Extents		**X**																		Part of business data maintenance, not part of LRS.
Position GIMS Segment		**X**																		
Publish GIMS Segment Location		**X**			**S**										**I**					Part of business data maintenance, not part of LRS.

Table 3 - Organization Assigments to LRS Subsystem Management

X = Perform this process; S = Support those who perform this process; I = Initial performer (X), but will move to support (S) or not be involved; H = Performs this process but for historic data. The heavy lines groupings of subsystems based on data, process, and technology similarities.

Elementary Process	Trans Data - Sys Mon	Trans Data - Sys Mgmt	IT Division - GIS Team	IT Division - PMIS Support	IT Division - Oracle DBA	Office of Maintenance	Office of Traffic Engineering and Safety	District Offices	Office of Design	Office of Construction	Office of Bridge and Structures	Office of Rail Transportation	DOT Div Directors	Division Managers	GDW Manager	LRS Board of Directors	LRS Working Team	Office of Driver Services (MVD)	Research Management Division	Comments
LRS Manager			**X**																	
Datum Subsystem Manager	**S**	**X**	**I**			**S**		**S**	**S**	**S**										
Centerline Data		**X**																		
Stationing Subsystem Manager		**S**				**S**		**S**	**X**	**S**										
Route Subsystem Manager	**S**	**X**																**S**		
Individual Route Systems	**S**	**X**																**S**		
Milepoint Subsystem Manager		**X**																**S**		
Literal Description Subsystem Manager		**X**									**S**	**S**						**S**		
Coordinate Route Subsystem Manager																			**I**	Need an X (Research to determine)

Elementary Process	Trans Data - Sys Mon	Trans Data - Sys Mgmt	IT Division - GIS Team	IT Division - PMIS Support	IT Division - Oracle DBA	Office of Maintenance	Office of Traffic Engineering and Safety	District Offices	Office of Design	Office of Construction	Office of Bridge and Structures	Office of Rail Transportation	DOT Div Directors	Division Managers	GDW Manager	LRS Board of Directors	LRS Working Team	Office of Driver Services (MVD)	Research Management Division	Comments
Reference Post Subsystem Manager	**S**	**S**		**S**		**X**	**S**	**S**	**S**											
Segmental Subsystem Manager		**X**																		
GDW Manager			**X**		**S**															

8. Appendix – Organizational Assignments to LRS Management

This Appendix provides the details found in the Physical Design Technical Document. Each section summarizes how different DOT offices would be involved in LRS management. Each section describes what the office would do for the LRS, why they were chosen, what would be new or different from current workflows, and what technology and skills would be needed.

Some general statements regarding the assignment of LRS management are provided here. First, only responsibilities for production processes are described in these sections. Initial data creation and loading are one-time processes not included here. Second, some of the existing workflow procedures and corresponding technologies do not support the LRS accuracy requirements determined during the Needs Assessment. This was expected, and the pilot phase of this project will reveal additional methods and technologies that existing workflows can adopt over time to meet these accuracy requirements.

The third general assignment regards LRS data publishing. Data publishing includes notifying LRS subsystem users of data changes and staging new versions of LRS subsystem data to the GeoData Warehouse (GDW). While LRS subsystem managers will notify users of data changes, the GDW Manager will initially perform all GDW data staging processes. This assignment will continue until the processes and procedures stabilize. Table 2 indicates who would perform these processes.

Finally, the Logical Design Summary Document outlines the necessary skill and knowledge requirements to manage each subsystem. That document identified general skills and knowledge that all offices should possess: GIS-T and relational database concepts and practices, business process and quality improvement, interoperable architecture design, and marketing within government agencies. Please see the Logical Design Summary Document for individual subsystem skill definitions.

8.1. Office of Transportation Data, System Management

The System Management Section should be responsible for managing and maintaining centerline data and several LRS subsystems: Datum, Route, Segmental, Literal Description, and Milepoint. System Management has the strongest competencies at Iowa DOT in data maintenance for linear and spatially referenced transportation data. Their current workflows include data maintenance for all Iowa public roadways.

System Management currently maintains and should continue to maintain the cartographic centerline data for Iowa DOT. System Management will be enhancing the cartography for GIS purposes (topologically structured, divided roadways additions, and ramp geometry additions). The results of these enhancements should be used as the centerline data for the LRS. The long-term strategy is to have the DOT cartography independent of the GIMS Segmental

LRM and tied directly to the datum. Therefore, the centerline maintenance will require maintaining the new relationship between the cartography and the datum.

For Datum Subsystem management, System Management should manage new data at Iowa DOT. The management processes will include datum design, datum collection, datum database maintenance, and datum publishing. All but publishing are briefly described here. Datum design means determining where anchor points and sections will be located. Initially, the process would be performed under the guidance of the GIS Team (see Information Technology Division, GIS Team).

System Management would collect datum data when field collection methods are not used (see the Office of Transportation Data, System Monitoring for field collection responsibilities). The exact collection methods (and related technology) and collection extent is not known at this time (the results of the field pilot portion of the project will guide these decisions). Datum database maintenance means making changes to database records. Datum management will require an increased effort, especially to meet the temporal data requirements of the LRS (data must be available prior to the road opening to traffic).

For Route Subsystem management, System Management would manage new data at Iowa DOT and also enhance existing data already managed by System Management. Transport Links and Nodes (the network) and their relationship to the datum will be new data. The design requires basic traffic direction data to be directly integrated with the Transport Links. System Management maintains some of the required traffic direction data in GIMS, which must be made part of the Route Subsystem. Enhancements to this data are required before it can be fully utilized in the Route Subsystem. Any information that currently resides in GIMS could then be automatically updated from the network data using LRS transform and overlay tools. These network maintenance activities will require an increase in effort. The cartographic centerline topologic processing should be leveraged to help reduce this effort.

The Transport System and LRS Milepoint data will also be new, but the staffing requirements for these will be minimal. Transport Systems change infrequently after the initial load. Milepoint data is derived using automated processes.

Another component of Route Subsystem management is route name maintenance. Route name maintenance is a current System Management activity done in GIMS. However, the LRS requires more rigorous name management. The unique list of route names will be managed in tables. Route names must be partitioned into prefix, name, type and suffix (e.g., North, Maple, Avenue, Southwest), and must be assigned to a geography and a jurisdiction.

A final component of Route Subsystem management is mapping names to roadway segments to create routes. System Management currently maps route names to GIMS segments and orders the segments for routing purposes on the primary roadways. This activity is still required, but the LRS needs to map routes to Transport Links (the result is called Route Links) for all public roadways. The route names on GIMS segments can subsequently be derived using the LRS transform tools.

Another LRS subsystem for which System Management should be responsible is the Literal Description Subsystem. System Management already maintains a literal description on the ends of the GIMS segments for city streets, but only limited descriptions on other road systems. The LRS Literal Description is derived from LRS data using Route Subsystem data and automated processes. The LRS Literal Description LRM can be used to automatically populate the descriptions on the ends of the GIMS segments using the LRS transform tools. Some, but not all, of the effort used to maintain the LRS data should come from the effort that was used to tag the GIMS segments.

System Management should be responsible for running the automated process for loading literal descriptions on roadway intersections (see the Office of Bridge and Structures and the Office of Rail Transportation for responsibilities for non-intersection features used in the Literal Description LRS). Automating the GIMS end point naming task is expected to save some staff effort that should be allocated to new route management processes within System Management.

Finally, System Management should continue to perform HPMS and GIMS segment maintenance. These maintenance efforts will need to include new processes of mapping these segments to the datum.

In summary, System Management should be responsible for 5 subsystems and the centerline data. These responsibilities include new and enhanced data maintenance activities that will require an increase in staff resources. This is especially true when maintenance activities are first implemented. Iowa DOT should explore creating the LRS in phases if additional staffing will be minimal.

System Management staff would require additional training and education. Knowledge of LRS and linear datum concepts and theories would be necessary for all staff involved in the LRS subsystem maintenance. Some special skill sets include geodesy or surveying for the Datum Subsystem, and network analysis, routing, and geocoding for the Route Subsystem.

From a technology perspective, System Management is already targeting technologies that are the same as the LRS technology architecture. They have recently migrated to Oracle, are considering GeoMedia Pro as a client interface, and are willing to explore Oracle Spatial as a spatial data base storage mechanism.

8.2. Office of Transportation Data, System Monitoring

The System Monitoring Section should be responsible for planning and executing field collection of the datum data (anchor point locations, anchor point monuments when necessary and anchor section distances) and network data (transport node locations, transport link directions). System Monitoring has a well-established data collection competency at Iowa DOT. Such skills are required for these critical components of the LRS. The exact collection methods (and related technology) and collection extent of the transportation network are not known at this time (the results of the field pilot portion of the project will guide these decisions).

System Monitoring staff would need to acquire basic knowledge and skills in linear datum theory and concepts, applying business rules for locating anchor points, identifying anchor point monument needs, determining anchor section distance, and determining transport node locations.

System Monitoring would need GeoMedia Pro technology. They will continue to supply videolog data to aid in positioning reference posts until the Office of Maintenance applies more accurate location methods.

8.3. Information Technology Division, GIS Team

The Information Technology Division, GIS Team, should be initially responsible for datum design and datum distance calculation. The GIS Team should be responsible for the processes, procedures and datum stability, while the Office of Transportation Data should collect and maintain the datum data. The reason for this assignment is based on experience. The GIS Team has been directly involved in the development of the LRS and is most familiar with the Datum Subsystem. Because the datum is the foundation of the LRS, it is critical that past datum knowledge be used directly in the implementation of the datum. As the procedures become stable and the knowledge transfer is completed, the responsibility should be transferred to the Office of Transportation Data.

The GIS Team, more specifically the GIS Coordinator, should also take on the LRS Manager responsibility. The LRS Manager role has informally existed at DOT for some time and is currently filled by the GIS Coordinator who is part of the GIS Team. The GIS Coordinator is also the Co-Project Manager for this project. The Coordinator has detailed knowledge about this project, the Iowa DOT LRS vision, strategy, and immediate next steps. This role will demand significant time as the LRS continues into prototyping and implementation. The LRS Manager will need to establish the organizational architecture (Logical Design Summary Document) and heavily promote the LRS within, and external to, the DOT. The GIS Coordinator already has been marketing and informing DOT staff about the LRS. The LRS Manager also manages modifications to the business logic of the LRS. The GIS Coordinator has an in-depth understanding of the business logic components. Finally, assigning this role to the GIS Coordinator also disseminates LRS responsibilities among the different offices involved in LRS management.

The GIS Team also already fulfills the responsibilities of GDW Manager. To assign the LRS component of the GDW to the GIS Team is a logical extension of the current role. They possess in depth knowledge of both the LRS and the GDW. In addition, this assignment helps disseminate LRS responsibilities among the different offices involved in LRS management.

The GIS Team would need to expand its knowledge and skills in data warehousing. Due to existing resource limitations, it is anticipated that additional staff would be required for the GIS Team. The GIS Team already possesses GeoMedia Pro and Oracle technology.

8.4. Information Technology Division, PMIS Support

PMIS Support currently identifies reference post maintenance needs via videolog technologies and supplies that information to the District Offices for placing reference posts in the field. PMIS Support also creates LRS positions for the reference posts in the database. The Physical Design Team recommends that Iowa DOT consider migrating these tasks to the Office of Maintenance. Please see Office of Maintenance in this section for more information.

8.5. Engineering Bureau, Office of Design

The Office of Design should manage the Stationing Subsystem. Management of this subsystem includes the initial data entry and maintenance for the stationing LRM (entering historic projects would be handled by the District Offices). The Office staff possesses a very strong competency in stationing practices and has significant knowledge about improvement project details. The staff is centralized for better quality control. The Office is also responsible for making any alignment modifications discovered during construction, and therefore possesses first-hand knowledge of as-built information. It is not clear at this time what staffing would be required to support the Subsystem, especially if the data is entered in the LRS during the centerline design task.

The Office would need to acquire a working knowledge of the LRS datum and most likely would need to acquire GeoMedia Pro and Oracle technology.

The Office of Design should also continue to provide a support role for the initial placement of station markers (posts or stamps) due to its responsibility to assign these locations during roadway design. The Office of Design should also support the initial placement of anchor point monuments.

8.6. Engineering Bureau, Office of Bridges and Structures

The Office of Bridges and Structures would be most effective at populating the necessary bridge information in the Literal Description Reference Feature tables. The Office is responsible for DOT bridge data and the location of bridges. They have first-hand knowledge of bridge changes and will be responsible for locating bridges using one of DOT's standard LRMs. The Office is also currently moving the bridge data for the primary road system into Oracle.

The DOT can automate the process to populate the LRS tables from the bridge database. This will help minimize additional staffing needs. The Office may need to acquire GeoMedia Pro to enhance the maintenance process. Office staff will need working knowledge and skills on datum and literal description theories and concepts.

The primary impacts to this Office would most likely be the need to meet LRS requirements for choosing points of reference and to meet LRS accuracy and temporal requirements. An example LRS point of reference for a bridge is the southern and then westernmost expansion joint. This point of reference would be used to locate features along the road that the bridge supports (versus roadways the bridge goes over). The point of reference distance from an anchor point must possess accuracy within 3-5 meters. The LRS requirements regarding timely updates suggest that database changes to bridge records must be made as soon as possible. These changes are required prior to the bridge opening to traffic. If the accuracy and temporal requirements cannot be met initially, actions need to be taken to plan and implement them in the future.

8.7. Modal Division, Office of Rail Transportation

The Office of Rail Transportation would be most effective at populating the necessary railroad crossing information in the Literal Description Reference Feature tables. The Office is currently responsible for railroad crossing data and the location of the crossings. They have first-hand knowledge of crossing changes and will be responsible for locating the crossings using one of DOT's standard LRMs.

The DOT can automate the process to populate the LRS tables from the crossing database. This would help minimize impacts to staff resources. The Office would need to acquire Oracle and may need to acquire GeoMedia Pro to enhance the maintenance process. Office staff would need intimate knowledge of datum and literal description theories and concepts.

The primary impacts to the Office would most likely be the need to meet LRS requirements for choosing points of reference and to meet LRS accuracy and temporal requirements. An example LRS point of reference for a crossing is the southern and then westernmost rail at a railway crossing. The point of reference distance from an anchor point must possess accuracy within 3-5 meters. The LRS requirements regarding timely updates suggest rail crossing database changes must be made as soon as possible. These changes are required prior to the crossing opening to traffic. If the accuracy and temporal requirements cannot be met initially, actions need to be taken to plan and implement them in the future.

8.8. District Offices

The District Offices would continue their role in placing both Reference Posts and Station Markers (posts or stamps) in the field for either construction or maintenance. They would also be assigned the new task of placing Anchor Point Monuments in the field for either construction or maintenance (the Office of Transportation Data would identify the need for a monument). The later phases of this project will provide some insight on the number of monuments to be placed.

The current procedures for field marker placement that the District Offices use would need to be modified to include processes for locating Reference Posts, Station Markers, and Anchor Point Monuments. This would most likely require the District Offices to invest in more efficient field data collection technology, such as GPS, to assist in locating these field markers. The field pilot phase of this project will influence this decision and the level of effort to meet these requirements. The District Offices would need training in the Coordinate Route LRM and new collection technologies.

The District Offices should also be responsible for entering Stationing LRM data from past improvement projects. They are the primary users of project stationing. This data entry task would involve extracting stationing information from the design or construction plans and referencing them to the linear datum. This process would replace the current workflows of attempting to manually integrate plan data from various sources. To perform this process, District Offices would need training in LRS, linear datums, the stationing LRM, and the Reference Post LRM. District Offices would also need access to and training in GeoMedia Pro and Oracle.

8.9. Statewide Operations Bureau, Office of Construction

The Office of Construction is responsible for supporting the District Office in the initial placement of station markers (posts or stamps) during an improvement project. The Office of Construction would have a new responsibility for supporting the District Office in the initial placement of anchor point monuments. The Office would need to modify procedures to include the process of positioning a station marker or anchor point monument, and recording their position relative to the LRS. The procedural changes will depend on results of the field pilot phase of this project and the most appropriate strategy for the District Offices.

The Office staff would need to obtain knowledge and skills on linear datum concepts and theories. The Office would not need to acquire any new technologies unless required to support the District Offices.

8.10. Engineering Bureau, Office of Traffic Engineering and Safety

The Office of Traffic Engineering plans the placement of reference posts. The Office should have a support role in how reference posts are designed and placed along the roadway. The Office would need to modify procedures to include how the position of a reference post is measured and recorded relative to the LRS. The procedural changes will depend on results of the field pilot phase of this project and the most appropriate strategy for the District Offices.

The Office staff would need to obtain knowledge and skills on linear datum concepts and theories. The Physical Design Team expects no new technologies are needed to perform this task.

8.11. Statewide Operations Bureau, Office of Maintenance

The Office of Maintenance currently has support roles in managing the Stationing and Reference Post Subsystems.

The Office of Maintenance would continue its support role in the field placement of station markers for the Stationing Subsystem. The Office would assume a new support role in the field placement of anchor point monuments. The Office would need to modify procedures to include how the position of a station marker and anchor point monument are measured and recorded relative to the LRS. The Office staff would need to obtain knowledge and skills on linear datum concepts and theories. The Office most likely would not need to acquire any new technologies unless required by changes to support the District Offices.

Regarding the Reference Post Subsystem, the Physical Design Team recommends the Office of Maintenance assume the overall Reference Post Subsystem management role. In the past, the Office implicitly performed such a role. The Office also should be considered for acquiring the

Reference Post management tasks currently performed by the Information Technology Division, PMIS Support staff. PMIS Support currently identifies the need for replacement reference posts in the field (the District Office actually places the posts), and creates positions for the reference posts in the database. This reassignment is recommended for several reasons. First, the Office of Maintenance currently holds a coordination role for Reference Post management tasks. The reassignment would simplify managing the Reference Post Subsystem. Second, the Office establishes maintenance policies and procedures, which includes these tasks. Third, the Office has a direct relationship with the District Offices' maintenance staff through formal and normal business operations.

In addition to these organizational changes, the Physical Design Team also recommends data, technology, and workflow improvements. These recommendations are primarily driven by the need to meet new LRS requirements and take advantage of more efficient technologies (GIS, relational databases, GPS, etc.).

The data improvement involves inventorying all reference posts. The LRS requires all reference posts be inventoried and their positions along the roadways be referenced to the datum based on LRS accuracy requirements (the distance along an anchor section must be accurate to within 3-5 meters). Currently, only the locations of North / East roadway posts are inventoried (South / West posts are assumed to be directly across from the North / East posts). In order to meet the LRS accuracy requirement, all posts will need to be inventoried.

The Physical Design Team also recommends that newer technologies be used to determine reference post LRS positions. The current technology for collecting post positions (videolog inventory) also does not meet the LRS accuracy requirement. The Iowa DOT will need to consider more accurate location referencing technologies. One solution is to provide District Offices with GPS equipment and have them collect the locations of new posts when they install them, using the Coordinate Route LRM. This solution would require the District Offices to enter the location data into the LRS or pass the data to the Office of Maintenance who would enter the data.

The Physical Design Team also recommends that a new reference post database be designed in the LRS environment to replace the existing mainframe database. The current mainframe reference post database does not support new LRS requirements. The LRS requires that Reference Posts be stored with Transport Link location formats. The current mainframe database does not support this format. The current format is GIMS PI milepoint. This LRM is not an appropriate location format for reference posts. It introduces location error into the reference post locations because it does not provide the same accumulative route locations as required for the reference post system. To make these changes to the existing mainframe system would not be as effective as redesigning the mainframe system in the new LRS environment.

Provided these improvements are implemented, the Office of Maintenance would require training on LRS, the linear datum, and reference post procedures. In addition, staffing required to perform these processes would be met by reallocating resources currently assigned to PMIS Support. Additional resources would be needed to meet the inventory requirements of South / West roadway posts and other additional LRS management responsibilities. The workflow and technology changes would require additional technology (Oracle and GeoMedia Pro) and additional training (any new LRMs that would be implemented to support Reference Post management).

8.12. Research Management Division

The Research Management Division should initially manage the Coordinate Route Subsystem. The Coordinate Route Subsystem has no data maintenance functions because it relies on the maintenance functions of the cartographic centerline layer and other LRS subsystems (Route and Datum). The Coordinate Route Subsystem relies on the newest technologies for field and office location data collection at Iowa DOT (GIS, GPS, cellular). The purpose of this management role is to assess, market, and help move newer technologies into standard practice in DOT offices that produce data. The current situation is in alignment with a Research Management objective to study and then integrate new technologies into the organization.

This assignment is contrary to the recommendations from the Logical Design Summary Document. It states that the Coordinate Route Subsystem be assigned to the same office responsible for the Route Subsystem, Datum Subsystem, or cartography centerline management. However, this proposed assignment is only until the use of these specific technologies stabilizes at Iowa DOT. Research Management must identify a permanent organizational unit once this happens.

8.13. Motor Vehicle Division, Office of Driver Services

The Motor Vehicles Division, Office of Driver Services, should assist in the maintenance of at least the Unofficial Route System in the LRS. Unofficial routes are routes familiar to local officials or the local public, but are not part of the formally posted route systems (e.g., ‘Old Miller’s Road’, or the ‘Southwest By-pass”). The staff in this Office is typically the first to encounter and require use of these route types. Office staff would need to be able to enter new route names in the Unofficial Assigned Routes table and enter route paths in the Route Link table. This would be a new process. The Office staff would need to become familiar with the route naming and route link mapping constructs of the LRS. The Office would need Oracle and GeoMedia Pro technology.

8.14. Information Technology Division, Oracle Database Administration

The DOT Oracle Database Administrator (DBA) should play a key support role to the GDW staging processes. Staging processes take raw operational data and format it for GDW purposes. The Oracle DBA should assist in data staging requirement analysis, table definitions, Oracle instance and schema management, security, etc. The Oracle DBA should play a very significant role in the prototype and initial implementation of the LRS. Assignments and direction given to the DOT Oracle Database Administrator will come from the Office assigned the LRS Manager and the GDW Manager roles (Information Technology Division, GIS Coordinator)

The Physical Design Team will work with the Information Technology Division to identify the staff responsible for maintaining code within the LRS business logic tier (e.g., the transformation algorithms). Regardless, this person(s) would receive assignments and direction from the Office assigned the LRS Manager and GDW Manager roles (Information Technology Division, GIS Coordinator).

The Oracle DBA would need intimate knowledge and skills with Oracle, Oracle Spatial, and Oracle Spatial LRSx constructs. The Oracle DBA also would need to expand skills and knowledge in data warehousing concepts and practices. The Oracle DBA would need Oracle and GeoMedia Pro technology.

8.15. Transport System – Multiple Participants

Transport Systems define the extent of the datum and the different ways in which the DOT will subdivide the transportation system to support DOT policy. Example Transport Systems include the Farm-to-Market Transport System and the City of Ames Roadway System

The primary decision-makers regarding new or changing DOT policy are the DOT Division Directors. However, the Division Managers would most likely define the actions to implement the policy. The LRS Board of Directors, with support from the LRS Working Team, would need to support the Division Managers so these actions include changes to the LRS. The Office of Transportation Data, System Management has been targeted to perform data maintenance to Transport Systems.

9. APPENDIX - IOWA DOT PHYSICAL DESIGN REVIEW ISSUES

During the week of June 19, 2000, the Project Physical Design Team, in cooperation with the Iowa DOT Core Team, held Physical Design review sessions at Iowa DOT. The objective of the sessions was to gain acceptance of the Physical Design from Iowa DOT management and staff who would be directly involved in using or managing the LRS. To accomplish this objective, sessions were structured so the Physical Design Team spent most of the time answering specific questions Iowa DOT management staff had about the design.

During these sessions, issues with the current LRS Design were identified. This appendix describes issues that are directly relevant to the Physical Design of the LRS. Included with each issue is how or when the Project members will resolve the issue.

1. <u>GIMS Segment ID (data and process design)</u>: Currently, when a GIMS segment is split, the GIMS identifier of the original GIMS segment is used as the identifier for one of the new segments. In order to support historical views of the LRS, the LRS requires an existing identifier to be retired and not used again. Therefore, there is a conflict in business rules between GIMS and the LRS. For the pilot phase of this project, the GIMS database extract is frozen, so the segment ID will be treated as if it was a permanent and unique id over time. The Project members will resolve this design conflict in the redesign phase.

2. <u>Stationing for Multi-lane divided roadways (data and process)</u>: The current design does not allow for stationing to be uniquely assigned to either roadway since there is no way in the current design to capture multiple applications of the same stationing along a given highway. For the pilot phase of the project, the stationing in the non-cardinal direction will be increased by a factor of 10,000 or 100,000 to make a distinction between two separate roadways. The Project members will determine the most suitable implementation solution in the redesign phase.

3. <u>Security among LRS subsystems (technology)</u>: The current technology architecture has the LRS as one Oracle instance. Since the LRS subsystems (e.g., Datum, Route, Reference Post) will be maintained by different DOT offices, there was concern on how to restrict write access by subsystem. One approach is to have different schemas for each subsystem. However this would increase Oracle database administration effort significantly. Instead, Oracle views of the Oracle instance will be created to represent each LRS subsystem. Oracle views can restrict access and are much easier to maintain.

4. <u>The Office of Design and the Stationing LRM (organizational design)</u>: The purpose of the stationing LRM is to expedite access to roadway improvement plan information when there is a significant amount of information needed and it must be integrated with data referenced by some other linear reference method (e.g., Milepost). Prior to the design review sessions, the Physical Design Team understood that only the District Offices had such a need for old plans, and recommended the District Office be responsible for entering stationing LRM data for historical projects when necessary. During the design review sessions, the Physical Design Team discovered that the Office of Design also has similar

needs to the District Offices. Therefore, the Office of Design will most likely share in the responsibility for entering stationing LRM data for historical projects. The Project members will attempt to resolve this assignment issue before the end of this project.

5. Office of Maintenance as Reference Post Maintainers (organizational design): The Physical Design suggests that the Office of Maintenance becomes sole maintainers of the Reference Post system and that PMIS Support in the Information Technology Division would not longer perform these tasks. However, as part of the recent reorganization, the DOT changed the focus of the Office of Maintenance and reduced Office staff. The LRS Steering Team is concerned that the Office of Maintenance may not be able to incorporate such tasks into their workloads. The Project members will attempt to resolve this assignment conflict before the end of this project.

6. District Representation in the Organizational Model (organizational design): The recent reorganization has given more authority to the transportation districts. However, the current LRS organizational model was designed with a centralized authority. The Project members will attempt to incorporate these changes into the model before the end of this project.

7. External Involvement (organizational design): There is no direct link between external organizations (cities, counties, MPOs, etc.) and the LRS organizational model, yet the outside organizations will contribute a significant amount of data to the LRS and will be consumers of the LRS. The Project members will attempt to resolve this LRS management participation issue before the end of this project.

10. APPENDIX – GLOSSARY OF TERMS

API – Application Programming Interface

Cartographic Representation - A set of lines that can be mapped to a linear datum. The set of lines can be either fully or partially connected. That is, the set can consist of groups that are externally unconnected but internally connected. Cartographic representations have a "source" attribute that denotes the source (scale and lineage) of the object. Scale values are expressed as ratios or as equations that relate distances measured on the source form of the cartographic representation to distances measured on the ground. Cartographic representations provide coordinate references; the basis for to-scale visualization of other components of the linear referencing system model; and linkages to extended topological, vector-based GIS data models.

Component - A part or element of a system.

CRUD - Create, read, update, and delete; these are the basic actions one can apply to a data entity or attribute; and is typically used in system requirements gathering models.

CVO - Commercial Vehicle Operations

Entity - Basically, a table of similar, grouped information

ERD - Entity Relationship Diagram

FGDC – Federal Geographic Data Committee

GDW – GeoData Warehouse

GUI – Graphical User Interface

Instance – an Oracle term for a set of memory structures and background processes that access a set of database files.

Interoperability - The ability for a system or components of a system to provide information portability and inter-application, cooperative process control. Interoperability, in the context of the Open GIS (OGIS) Specification, are software components operating reciprocally (working with each other) to overcome tedious batch conversion tasks, import/export obstacles, and distributed resource access barriers imposed by heterogeneous processing environments and heterogeneous data.

ISP - Internet Service Provider.

ITS - Intelligent Transportation Systems

Legacy system – An existing application or business system that involves activities necessary to administer transportation programs and to develop and maintain transportation components. These activities are outside the scope of this analysis.

Linear Datum - The collection of objects that serve as the basis for locating the linear referencing system in the real world. The datum relates the database representation to the real world and provides the domain for transformations among cartographic representations. The datum consists of a connected set of anchor sections that have anchor points at their junctions and termini. No attributes are assigned to the datum.

Linear Event - A one-dimensional phenomenon that occurs along a traversal and is described in terms of its attributes in the extended database. Each linear event has "start traversal measure" and "end traversal measure" attributes that locate the linear event along the traversal. The traversal measures are offsets measured from the traversal reference points that they individually reference. Linear event traversal measures are in the same units as the traversal measures of the traversal reference points that they reference. Rules for direction of measurement are identical to those of point event traversal measures.

MDSYS: A standard Oracle schema containing database objects used in the storage and management of Oracle Spatial data types.

Network - Within the context of the linear referencing system data model, a network is an aggregate of nodes and links and is, thus, a purely topological object. The network component of the model provides the basis for analytical operations such as path finding and flow. A network is without two-dimensional objects or chains. If projected onto a two-dimensional surface, a network can have either more than one node at a point and (or) intersecting links without corresponding nodes. **Note:** This is a modification of the definition provided by SDTS. Modification is necessary to exclude chains.

NSDI - National Spatial Data Infrastructure; see website at http://www.nsdi.usgs.gov

Objective - A statement of direction and extent for the availability, quality or performance of a system.

OGIS - Open Geographic Information System; see consortium details at www.opengis.org

OLAP - On-line analytical processing. A term from the Information Technology community, specifically the Data Warehouse community. Basically, it means analyzing and making decisions from data while using and interacting with computer applications.

OLTP - On-line transactional processing. A term from the Information Technology community, specifically the Data Warehouse community. Basically, it means making updates to data while using and interacting with computer applications, instead of in batch mode.

Performance - The functional effectiveness of a system component.

Point Event - A zero-dimensional phenomenon, that occurs along a traversal and is described in terms of its attributes in the extended database. Each point event has a "traversal measure" attribute. "Traversal measure" is an offset measured from the referenced traversal reference point to the point event. Point event traversal measures are in the same units as the traversal measures of the traversal reference points that they reference. A positive point event traversal measure expresses measurement in the direction of the traversal. A negative point event traversal measure expresses measurement against the direction of traversal.

Policy - A declaration of transportation related public value, formal public mandates, mobility constraints or vision.

Recordset – a working set of data which can be all or a part of an entire data set (primarily used when discussing GeoMedia development).

SAS – The SAS System is an integrated suite of software for enterprise-wide information delivery. Available from the SAS Institute, Inc (see www. sas. com). http://www.mcmcweb.er.usgs.gov/sdts/

Scalability – The LRS must be designed to meet requirements that are beyond the business functions scoped for this project. For example, Iowa DOT should be able to apply the design to railways, pedestrian ways, waterways, etc – only roadways are within the scope of the project. Another example would include cartography. Iowa DOT should be able to integrate the DOT's linear-referenced data with cartography at different map scales and levels of detail, and with cartography from sources external to DOT (local governments).

Schema – an Oracle term for a set of database objects owned by a user account.

SDTS - Spatial Data Transfer Standard. See homepage at www. mcmcweb. er. usgs. gov/sdts/

SMMS – Spatial Metadata Management System. A software program from Enabling Technologies that allows metadata to be put out into HTML format so it can be accessed via the web.

SQL – Standard Query Language. The syntax and format typically used to interact with tabular databases.

State - A physical or operational condition of being.

TDSYS: An Oracle schema containing database objects used in the storage and management of TransDecisions' custom LRSx data types.

Traversal - An ordered and directed, but necessarily connected, set of whole links. Coding conventions are required for establishing traversal directionality (in contrast to link directionality) and for specifying non-connected traversals. No attributes are assigned to traversals.