MULTI-LEVEL LINEAR REFERENCING SYSTEM (MLLRS) COST/BENEFIT VALUE ANALYSIS STUDY

Requested by:

American Association of State Highway and Transportation Officials (AASHTO)

Standing Committee on Highways

Prepared by:

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The Value Analysis Study, which provided the information for this report, required the use of the SAVE International Value Analysis 6-Step Job Plan and was administered by Renee L. Hoekstra, a Certified Value Specialist. The VA Study Team providing the information in this document included the following members; Jerome “Joe” Breyer, Works Consulting, LLC, Gilbert, Arizona, is identified as a technical expert and also represented the Arizona Department of Transportation, Multimodal Planning Division; Jun Wu, North Carolina Department of Transportation, IT-GIS Division; Michael Ney Sheffer, Maryland State Highway Administration; Thomas Martin, Minnesota Department of Transportation; Peggi Knight, Iowa Department of Transportation; Eric Abrams, Iowa Department of Transportation; Michael Clement, Iowa Department of Transportation; Karen Carroll, Iowa Department of Transportation; Ryan Wyllie, Iowa Department of Transportation; Oscar Jarquin, Caltrans IT Department; Reg Souleyrette, Iowa State University; Bruce Aquila, Intergraph; and Gary Waters, ESRI.

Disclaimer

The opinions and conclusions expressed or implied are those of the team that performed the research and are not necessarily those of the Transportation Research Board or its sponsors. The information contained in this document was taken directly from the submission of the author(s). This document is not a report of the Transportation Research Board or of the National Research Council.

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ABSTRACT

This report documents the outcome of the Value Analysis (VA) Study which was conducted at the Iowa Department of Transportation in Ames Iowa on April 6-8, 2011. The purpose of the VA Study was to identify the costs and benefits of implementing and maintaining a statewide Multi-Level Linear Referencing System (MLLRS). The VA Study followed the SAVE International 6-step job plan which helped to identify the various aspects of a statewide MLLRS including; System Needs, Constraints, Performance Attributes, Qualitative and Quantitative Benefits, Defined Users/Business Units, System Functions, Alignment with the 10 Functional Requirements of Report 20-27, Costs for Developing and Maintaining a Baseline MLLRS and Implementation Considerations. The findings of the study represent a 5-year breakeven point for the baseline and the optional functional elements with potential overall cost/benefit savings of $12.6 million for a state with 25,000 miles of road network.

Chapter 1 - Executive Summary

Introduction

Many technical reports have been completed about developing and integrating a Linear Referencing System (LRS) within a state transportation agency. The magnitude of costs related to the development of a LRS and the commitment required by an agency can be overwhelming, especially if there are no data to support the costs or expected benefits. This report will help the state by providing credible quantitative and qualitative benefits obtained from a state's investment as well as sample costs and requirements for implementing and maintaining a Multi-Level Linear Referencing System (MLLRS). The use of the word *"baseline system"* throughout this report represents the minimum requirements for a fully functioning MLLRS. The use of the term *"optional functional elements"* refers to supplemental elements that will improve the baseline MLLRS.

Definition of Multi-Level Linear Referencing System (MLLRS)

Efficient planning, design, construction, and maintenance operations require accurate, dependable and electronically based methods of positioning and locating specific facilities, operations, and needs. These methods must be logically linked with other organizational electronic management systems to optimize overall operational efficiency. The MLLRS is essentially the multi-dimensional LRS (MDLRS) defined in the NCHRP Report 460 as follows:

"The NCHRP 20-27(2) linear referencing system data model was developed in response to a growing awareness of the need to integrate increasing amounts of linearly referenced data used by the transportation community (*1*). The 20-27(2) data model includes multiple linear referencing methods, multiple cartographic representations, and multiple network representations. Data integration is supported through transformations among methods, networks, and cartographic representations by associating with a central object referred to as a linear datum."

While the above definition uses the "multiple" adjective with three separate characteristics, this study relates specifically to the linear referencing methods, or LRMs, as the key aspect that differentiates a MLLRS from a LRS. This does not diminish the importance of cartographic representations and network representations in MLLRS – but instead allows the study team to address perhaps the most significant existing deterrent in efficient data sharing – the inability to cross-relate information from different data stores.

NCHRP 20-07 Value Analysis for MLLRS

Research Approach and Study Objectives

The research for this paper was completed during a 3-day Value Analysis (VA) Study using the SAVE International 6-Step Job Plan. The Job Plan included the following Phases: Information, Function Analysis, Creativity, Evaluation, and Development; the 6th phase, Presentation, was not performed. A complete description of the process can be found in Chapter 2.

A VA Study approach was used to bring together several state DOTs to discuss the merits, benefits, constraints, impacts and the implementation of a MLLRS. This also allowed this research to be conducted in a team approach allowing for integration of data and the sharing of information in real time. The VA approach enabled the team to discuss approaches and reach consensus in a very short time. The objectives included:

- Providing a definition for what is required in a baseline MLLRS, which means, what are the minimum requirements versus supplemental or supporting functions
- Providing a definition of Multi-Level in the context of a LRS
- Identifying all costs associated with both a baseline MLLRS and any potential additive functional features in the system
- Understanding all benefits – including quantitative and qualitative – with implementing a MLLRS
- Identifying the current and potential uses of a MLLRS
- Providing the potential impacts of not implementing a MLLRS
- Providing implementation considerations for both the initial system development as well as maintaining a MLLRS

Basic Assumption

It is necessary to first identify that this study and the findings are predicated on a basic assumption. This assumption is that "each state implementing a MLLRS already has 25,000 miles of road and some type of an existing LRS – including multiple LRMs that do not share a common linear datum". This is important as the costs and efforts identified to establish an initial LRS is not included.

Why It is Important to Implement ML into LRS

1) Data and information are more readily available from different sources which reference the same linear datum,
2) Improvements are made related to quality, timeliness, and the efficiency in many reports which are often required to meet a state's internal mission and/or needs as well as external requests and mandates,
3) Improve analysis leading to more data-driven decision support which will also lead to more consistency in the decision-making process within the agency over time,
4) Improve communication within the agency across departments and greater involvement with other agency partners and stakeholders by sharing information,
5) The ability to improve customer service by allowing information and data to be more readily accessed and disseminated in a more timely manner,

6) Able to integrate with legacy systems and ultimately eliminate dependencies on obsolete technology,
7) Establish standards to increase LRS consistency throughout the agency and industry-wide, and
8) Lower the life cycle cost impacts of system ownership.

Although many of the items stated above represent benefits of a MLLRS, the team also identified both quantitative and qualitative benefits to implementing a MLLRS. Other benefits were also identified by the study team. These benefits are identified in detail, including the definition, rating and ranking, within Chapter 3.

Quantitative Benefits

The quantitative benefits identified for a MLLRS are related to saving time and costs for the agency. Time and cost savings are defined as a reduction in staff hours, operational hours, and hours associated with other departments. Additionally, there will be an improved stewardship of data and business/ operational unit improvements. Sample business/operational units were used for this study to show improvement savings and they were defined as safety improvements, reduced risk for litigation, reduced impacts to the project, and reduced impacts to maintenance. A complete definition and the savings associated with each of these benefits are provided within Chapter 3.

The overall annual quantitative savings for the benefits as described above can be summarized as follows:

Baseline System

- $10,000 per FTE for a reduction in staff hours
- $20,000 per FTE for a reduction in operational hours
- $2,000 per FTE for a reduction in staff hours for other departments

Optional Functional Elements – These are described as additional elements which will increase the functionality of the baseline system including Managing Change and Modeling Connectivity.

Manage Change

- $10,000 FTE for a reduction in staff hours
- $20,000 per FTE for a reduction in operational hours
- $2,000 per FTE for a reduction in staff hours for other Departments

Model Connectivity

- $10,000 FTE for a reduction in staff hours
- $20,000 per FTE for a reduction in operational hours
- $2,000 per FTE for a reduction in staff hours for other departments

***Business/Operational Unit Improvements* –** Each of the benefits identified above provides a different level of savings. This team identified several business/operational units as a representation of potential savings and established a sample budget for each of the business/operational units. The annual savings calculation used the sample budget to determine the overall savings as a percentage of the identified budget. Using the four business/operational units; safety improvements, reduced level of risk for litigation, reduced impacts to projects, and reduced maintenance, the estimated annual savings for the agency for the baseline and the optional functional elements can be summarized as:

- Baseline - $1,168,000
- Manage Change - $1,208,000
- Model Connectivity - $1,220,000

Qualitative Benefits

Qualitative benefits are much more difficult to measure, however of equal importance to the DOT. The study team identified the following qualitative benefits:

- Ease of use and accessibility
- Flexibility and integration
- Quality of data
- Internal and external collaboration
- Data-driven decision making

A full description of each of these benefits can be found in Chapter 3.

Implementation Considerations

Cost to Implement a MLLRS

The basic assumption made by this team, as expressed on the previous page, is "that a LRS already exists" within the agency wanting to implement a MLLRS. A complete listing of the associated costs is included in Chapter 5 and includes both capital and annual maintenance costs. The costs shown are exclusive of what is already available within the agency, including hardware. Additionally, in order to develop the overall costs, labor rates are represented by an integrated agency and consultant rate as well as a singular civil service rate.

The baseline costs are also based on 25,000 miles of centerline per state, a good existing primary road network, includes a spatial representation, hardware, software, and assumes the agency uses some LRM already. The baseline development cost is approximately $2 million.

There are additional functional elements that can be added to the baseline to add value to the MLLRS. These additional total costs, including labor and as needed, software and hardware, required to establish the MLLRS is as follows:

- Managing Change - $31,650
- Modeling Connectivity - $793,400
- LRM Development - $40,000 each

Maintenance Costs

Maintenance annual costs including labor, hardware and software, will vary, but on an average for the baseline system, considering the 25,000 miles of centerline assumption, are $251,700.

Maintenance costs for the optional functional elements are very minor and will have very little impact on the overall annual budget.

A breakeven timeframe that can be expected is approximately five (5) years after the installation of a complete system. The schedule for implementation is estimated at (2) years after a contract, as needed, has been let with a selected consultant.

Benefit Cost Analysis to Implement and Maintain a MLLRS

The study team realized other benefits to having an agency-wide MLLRS. This includes a life cycle cost savings over the life of the system. However, in this instance, a 5-year breakeven period was used to show the estimated cost benefit. If a DOT wanted to understand the full life cycle/cost benefit savings, these numbers can be multiplied out to the life of the system, the total savings can be very beneficial to the DOT. There is on-going maintenance that will be required, but with the adoption of a MLLRS, a savings can be calculated for both the baseline system and the additional elements. The savings was calculated over a 5-year period with an escalation rate of 3%.

The overall cost-to-benefit (C/B) savings is as shown:

- *Baseline - $2,437,874*
- *Optional Functional Elements - $10,120,428*

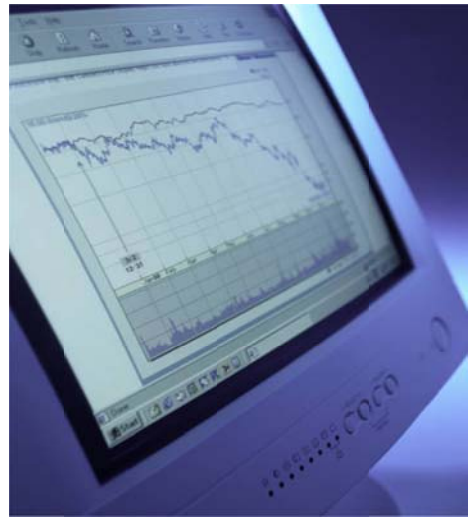
When expressed as a C/B ratio, the baseline effort yields a C/B ratio of 1.8:1 while the optional functional elements yield an aggregate 21.4:1 ratio of benefits to cost. These figures were generated from empirical values generated by several of the participating states as workshop participants. These aggregate C/B ratios are bound to be different when each particular state is analyzed separately for their own costs versus benefits using their individual operating conditions.

Critical Implementation Considerations

Critical implementation considerations as well as the potential impacts to not implementing a MLLRS need to be considered by each DOT. This is a critical step for the agency as they consider taking the next steps into developing a MLLRS. The agency should be fully prepared to address each of the considerations to ensure success of a MLLRS. A complete listing of these considerations can be found in Chapter 6.

Chapter 2 – Introduction and Methodology

Problem Statement



Efficient planning, design, construction and maintenance operations require accurate, dependable and electronically based methods of positioning and locating specific facilities, operations, and needs. These methods must be logically linked with other organizational electronic management systems to optimize overall operational efficiency. Recognizing these objectives, NCHRP Project 20-27 was initiated with the objectives of: (1) establishing consensus-based functional requirements for a multi-dimensional LRS data model for multimodal transportation systems, (2) developing an improved LRS data model, and (3) developing guidelines to implement an improved LRS data model in transportation organizations. The results of that research are published via NCHRP Report 460.

Some states have implemented Multi-Level Linear Referencing Systems (MLLRS) to various degrees. An example is the linear referencing system developed by Iowa DOT that represents state of the art technology in location referencing systems. Iowa DOT nominated this technology to the AASHTO Technology Implementation Group (TIG). This technology was selected by the TIG for marketing assistance and a TIG lead states team was formed to provide helpful information for other State DOTs which are currently, or in the near future, developing a new location referencing system.

Development of a linear referencing system can require several million dollars and several years of resource commitments. The magnitude of resource commitment for a state to implement a linear referencing system requires a credible and quantitative determination of costs and benefits to aid in the decision-making process. Anecdotal information suggests that the rate of return is very substantial, but a more definitive estimation of benefits is critical to inform state DOTs as they are considering making this investment.

Research / Value Analysis Study Approach

The research for this report was conducted using a value analysis study approach and was conducted using team members from state transportation agencies including the Arizona Department of Transportation (ADOT), Caltrans (CT), Iowa Department of Transportation (IADOT), North Carolina Department of Transportation (NCDOT), Maryland State Highway Administration (MSHA), and Minnesota Department of Transportation (MNDOT). Three additional team members included two members from industry representing products and programs for LRS and MLLRS systems. Faculty at Iowa State University's Center for Transportation Research and Education (CTRE) rounded out the team.

Value analysis studies use team members that have experience and expertise in the topic under study. To help the reader better understand what occurred during this study and obtain the necessary background for this report, a description of the SAVE International (formerly known as the Society for American Value Engineers) 6-Step Job Plan used during this study is listed on the next page. The specific outcomes of each of the steps in the job plan can be found in the various chapters of the report.

SAVE International Value Analysis (VA) Job Plan

Step 1 - Information Phase
This phase of the process allowed the team members to discuss the overall problem statement and to establish the following study elements:

- VA study goals and objectives
- Defined the needs of a MLLRS
- Performance attributes were developed and defined to outline a successful MLLRS
- Defined how a MLLRS is used within state agencies
- A list of VA study assumptions
- Defined the constraints/challenges to implementing a MLLRS

Step 2 - Function Analysis Phase
The function analysis activity is a recognized VA technique to identify the functions of a successful, fully functioning MLLRS. This ensured that the study team understood what was to be studied and the importance and critical elements of a functioning system.

Step 3 - Creativity Phase
The study team members discussed the various elements as identified in the function analysis Phase. The team identified the benefits of a MLLRS including qualitative, quantitative and other benefits as well as the cost impacts to implement a MLLRS.

Step 4 - Evaluation Phase
A traditional evaluation phase was not needed for this study. The elements identified during the function analysis and creativity phases provided additional information to aid the team in the development phase.

Step 5 - Development Phase
The development phase included further defining and then refining the objectives as stated above. This included identifying, defining and quantifying the uses, benefits, costs and implementation impacts.

Step 6 – Presentation Phase
It was not necessary to complete the presentation phase for this study.

Chapter 3 – Measures of MLLRS Success

Introduction

As the study began, it was important for the study team to have a shared understanding of the reasons or needs for implementing a MLLRS within a state agency. Several elements include an understanding of need, the defined performance measures for a successful system, and the benefits to be obtained by implementing a MLLRS.

Needs for Implementing a MLLRS in Your Agency

1) A Data and information are more readily available from different sources which references the same linear datum,
2) Improvements are made related to quality, timeliness, and the efficiency in many reports which are often required to meet a state's internal mission and/or needs as well as external requests and mandates,
3) Improve analysis leading to more data-driven decision support which will also lead to more consistency in the decision-making process within the agency over time,
4) Improve communication within the agency across departments and greater involvement with other agency partners and stakeholders by sharing information,
5) The ability to improve customer service by allowing information and data to be more readily accessed and disseminated in a more timely manner,
6) Able to integrate with legacy systems and ultimately eliminate dependencies on obsolete technology,
7) Establish standards to increase LRS consistency throughout the agency and industry-wide, and
8) Lower the life cycle cost impacts of system ownership.

How Must a MLLRS Perform

A successful MLLRS requires many things. This is one of the important issues to understand when endeavoring to develop a successful system. The following list represents the necessary performance attributes, each with a definition that should be considered when deciding on the best approach for the agency.

Performance Attributes

The following attributes will garner user acceptance of MLLRS by helping to reduce customer complaints and to gain high-level champions to maintain organizational support.

1) ***User transparency*** **-** Location data will automatically populate with minimal additional manual resources needed; other thematic information is automatically accessed when it shares the same linear datum
2) ***Responsiveness*** **–** A reasonable amount of elapsed processing time based on the request
3) ***Time Savings*** **–** Improvements to reporting requirements based on needs and cycles, data reconciliation, analysis, data entry, and usage
4) ***Data Governance*** **–** Eliminates or minimizes the duplication of data, ensures consistency of data and promotes database usage versus the use of spreadsheets, and provides an understanding of data through use of metadata
5) ***Quality Data*** **–** To ensure accuracy, consistency and stable referential integrity to the underlying linear datum
6) ***Ease of Maintenance*** **–** Reduction in time (hours) used to manage change propagation when the linear datum is updated
7) ***Improved Business/Operational Unit Use*** **–** an increase in use is defined as the number of system hits and the number of business/operational units using the system
8) ***Ease of Integration*** **–** Level of effort and time required to integrate with existing systems, accommodating propagation of linear datum change, data validation, and extensibility to support other modes like pedestrian, bicycle, rail, and bus, as well as be extensible to other local, regional and federal agencies

Expected Outcomes or Benefits from a MLLRS

When implementing an MLLRS in the agency there are many benefits to be attained. These are identified as Quantitative, Qualitative, and Other. The following lists the benefits that should be expected, especially if the performance attributes, as identified above, are established and applied.

Assumptions for Developing Benefits

While developing both the quantitative and qualitative benefits, it was important to identify several assumptions and definitions of the baseline element versus two optional functional elements. They include:

1) There are two hourly rates, one is a blended rate of consultant costs and civil service costs and is $150.00 per hour, the second is a civil service rate of $50.00 per hour.
2) Baseline – this originally represented a simple visualization of data from various business/operational units using different LRMs. The definition ultimately expanded to reflect that COTS GIS software can easily overlay (or integrate) data from different LRMs once those LRMs are able to reference the linear datum. Therefore, baseline objectives include the “integration of data” as the end goal of a baseline system.

3) Manage Change – this optional functional element pertains to system-to-system edits carried out on the linear datum – and the cascading and propagating of changes to the events using the MLLRS.
4) Model Connectivity – multiple routable networks – including differing modes (bicycles, trucks, transit, etc.) which interconnect to represent realistic travel movements. This optional functional element essentially enables the "multiple network representations" in NCHRP Report 460 to be an additional working functionality delivered in the NCHRP data model.
5) Scoring of additional optional functional elements is based on a cumulative benefit of the baseline and the optional elements.
6) The complexity of the additional optional functional elements may increase overall complexity, but users that do not need access to the optional functional elements will not be exposed to the complexity to maintain ease of use.

Quantitative Benefits

1) Quantitative benefits are defined by saving time and costs including:
   a. A reduction in GIS staff hours by increasing efficiencies for maintaining a linear datum, integrating multiple linear referencing methods to that datum, and analyzing the validity of LRS data.
   b. A reduction in operational staff hours by increasing efficiencies in the day-to-day operations by providing additional valuable services within the organization, and/or reducing overall operational costs (i.e. fuel, wear and tear, material uses, etc.)
   c. A reduction in administrative hours provided by other departments within the agency by increasing efficiencies of the business/operational units which use the MLLRS or are involved in maintaining, integrating and analyzing business data.
   d. Business/operational unit improvements are identified with the optional functional elements and not specifically with the baseline. Savings in staff hours are described below:
      i. Safety improvements by increasing efficiencies through the identification of safety related information for both active and reactive safety improvement measures.
      ii. Reduce the level of risk due to litigation by improving access to the data needed to support the agency's position, i.e. environmental, tort liability, safety, and others.
      iii. Reduce impacts during construction by improving access to data which would allow a reduction in change orders during construction. This would allow the agency to identify impacts, i.e. utilities, right of way, etc., in a more timely manner.

iv. Reducing impacts to maintenance departments by improving access to data that is necessary to reduce operational activity costs.

v. Reducing impacts to overall project costs by improving access to data that will improve planning and design by creating less impacts and improved communication with the public.

e. An improved stewardship of data by providing the agency with the ability to automate the synchronization of business data using MLLRS leading to a more efficient use of staff hours.

f. In order to determine the annual savings for the business/operational units, sample budgets were established for the identified business/operational units.

2) ***Table 1*** represents the quantitative benefits for the baseline and the optional functional elements for the MLLRS for reduced staff hours, operational hours and hours used by other departments. The numbers in the table are represented as a benefit savings per FTE that is employed working on the system. As an example, Iowa DOT has 2.5 FTE's in the GIS branch which would account for a $25,000 savings per year in the reduction of staff hours. Since DOTs will typically provide cross-trained redundancy to accommodate potential staff turnover, there might never be less than two staff dedicated to MLLRS datum maintenance and related tasks – regardless of the length of centerline mileage. However, the typical MLLRS staff would be capable of also providing more general GIS and spatial information services to the organization allowing them to work on other initiatives within the department – adding further value that may also be quantified.

3) ***Table 2*** represents the quantitative annual benefits for the baseline and the optional functional elements for the improvements to business/operational units working with the MLLRS. The representative business/operational units used during this study include safety improvements, reduced level of risk for litigation, reduced impacts to a project and reduced maintenance costs. The numbers represent an overall cost savings based on a percentage of the transportation department's overall budget for that business unit. (The budget shown below in Table 2 is based on a sample budget and used only to represent the possible cost and savings.)

4) ***Table 3*** is a sample representation of savings for Caltrans in their various business/ operational units.

Table 1 – Quantitative Annual Benefits/Savings for Baseline MLLRS

Benefits	Baseline	Manage Change	Model Connectivity
Reduced Staff Hours	$10,000 per FTE	$10,000 per FTE	$10,000 per FTE
Reduced Operational Hours	$20,000 per FTE	$20,000 per FTE	$20,000 per FTE
Reduced Hours for other	$2,000 per FTE	$2,000 per FTE	$2,000 per FTE

Table 2 – Quantitative Annual Benefits for Sample Business/Operational Unit Improvements/ Savings

Benefits	Sample Budget	Baseline	Manage Change	Model Connectivity
Safety Improvements	$20,000,000	.07% $14,000	.09% $18,000	.10% $20,000
Reduced Level of Risk for Litigation	$50,000,000	1.8% $900,000	1.8% $900,000	1.8% $900,000
Reduced Impacts to Projects (i.e. Construction)	$300,000,000	.08% $240,000	.08% $240,000	.08% $240,000
Reduced Maintenance Costs	$50,000,000	.07% $14,000	.10% $50,000	.10% $50,000

Table 3 – Sample Caltrans Annual Benefits for Business/Operational Unit Cost Improvements/Savings

Benefits	Budget	Baseline	Manage Change	Model Connectivity
Safety Improvements	$117,000,000	$81,900	$105,300	$117,000
Reduced Litigation Costs	$800,000,000	$14,400,000	$14,400,000	$14,400,000
Reduced Project Costs	$6,400,000,000	$5,120,000	$5,120,000	$5,120,000
Reduced Maintenance Costs	$1,800,000,000	$1,260,000	$1,800,000	$1,800,000
TOTAL	$9,117,000,000	$20,861,900	$21,425,300	$21,437,000

Qualitative Benefits

Qualitative benefits are difficult to quantify but are as important to understand as the quantitative benefits. Implementing a MLLRS should also provide the following qualitative benefits:

1) ***Ease of use/accessibility*** – This occurs through the completion of more timely and consistent reports by being able to access more information and interrelate different themes of data, thereby improving service to customers.

2) ***Flexibility/Integration*** **–** The ability to share data and information throughout the DOT, including local, state and federal agencies based on common methods of relating to a linear datum. This will allow the coordination of inter-agency investments in data and information resources.
3) ***Quality of data*** **–** Provides for accurate, consistent and complete data sets to support further data collection, data driven decision support, and the elimination of institutional barriers to sharing data and information.
4) ***Internal/external collaboration*** **–** An increase in collaboration and cooperation among political jurisdictions, private organizations and internal organizational units for the benefit of the public.
5) ***Data-driven decision support*** **–** Ensures that decisions are made in a manner more responsive to factual information based on all available data, by inter-relating the data through the use of the MLLRS.

In the evaluation phase and the development phase of this study, objective criteria were developed to aid in the evaluation of the various qualitative benefits of the MLLRS. Each of the qualitative benefits was then ranked based on an improvement gained for adding the baseline MLLRS – and then adding the subsequent optional functional elements. The rankings are as follows:

3 = High Improvement ***2 = Moderate Improvement*** ***1 = Low Improvement***

Table 4 – Qualitative Benefit Ratings for Baseline and Optional Functional Elements

Benefits	**Baseline**	**Manage**	**Model**
Ease of Use/Accessibility	2	3	3
Flexibility/Integration	3	3	3
Quality of Data	1	3	3
Internal/External Collaboration	1	2	3
Data Driven Decision-making	1	3	3

Other Opportunities/Benefits

1) The continual advances in technology make this a better time to adopt an MLLRS.
   a. It will be less expensive to adopt it now – though the benefits will be delayed until MLLRS actually is implemented.
   b. Easier to visualize data with each newer generation of GIS software.
2) MLLRS is implemented with an enterprise architecture and thereby facilitates the breakdown of departmental silos internal to many agencies. There is a feeling that "if you build it, they will come". Other business/operational units will be attracted to the MLLRS if it is available and they understand the benefits to be obtained through its

adoption and use.

3) It is now more possible to exploit external resources to help build a case for MLLRS (i.e. Google Earth and cloud-based web services) prior to making full capital commitments for the purpose of pilot projects.
4) With today’s mobile advances, there is an increased opportunity for integrating MLLRS into the field operations.

A sample of typical benefits to be gained by implementing a MLLRS is taken from the Iowa DOT (IADOT) report:

“The LRS approach at IADOT will provide benefits even while the LRS is being implemented. The LRS implementation strategy breaks the LRS down into components, so some of the LRS can be operating while other components are not yet implemented. The implementation plan includes end user application development projects, thus allowing benefits to be realized as soon as possible. Many current and future information systems development projects that are not part of the LRS implementation plan will also benefit from applying the LRS as part of their solution. The LRS approach also allows the DOT business areas to find benefits without having to completely redesign existing systems. This is quite different from other enterprise system integration solutions (e.g., enterprise resource planning (ERP) and data warehousing efforts).”

“The LRS approach defined for Iowa DOT is a very good approach to meet the DOT data integration needs identified above. It is based on sound information systems development practices and industry-accepted approaches to the problem. The cost of the LRS is very comparable to what other state DOTs are investing to implement their LRS. The price includes investments that will also benefit the GIS program, Geographic Information Management System (GIMS), and technology and related training to be used on other business applications. ***If the DOT does not implement the LRS, the DOT will still expend the money and effort to meet the DOT’s data integration needs. However, the effort will most likely continue as it does today: disjointed and duplicative, with certain requirements not being met.”***

Chapter 4 – Defining the Use and Functions of a MLLRS

Ten core functional requirements were synthesized from the results of the NCHRP 20-27(3) workshop. These core functional requirements form the essence of the MDLRS data model. Supporting each functional requirement is a set of functional specifications. The following is a list of the ten functional requirements from section 1.6 of NCHRP Report 460:

Functional Requirements I: Spatiotemporal Referencing Methods – A comprehensive, multi-dimensional LRS data model must support the location, place, and position processes for objects and events in three dimensions and time relative to the roadway.

Functional Requirements II: Temporal Referencing System/Temporal Datum – A comprehensive, multi-dimensional LRS data model must accommodate a temporal datum that relates the database representation to the real world and must provide the domain for transformations among temporal referencing methods.

Functional Requirements III: Transformation of Data Sets – A comprehensive, multi-dimensional LRS data model must support transformation among linear, non-linear, and temporal referencing methods without loss of spatiotemporal accuracy, precision, and resolution.

Functional Requirements IV: Multiple Cartographic/Spatial Topological Representations – A comprehensive, multi-dimensional LRS data model must support multiple cartographic and topological representations at both the same level and varying levels of generalization of transportation objects.

Functional Requirements V: Resolution – A comprehensive, multi-dimensional LRS data model must support the display and analysis of objects and events at multiple spatial and temporal resolutions.

Functional Requirements VI: Dynamics – A comprehensive, multi-dimensional LRS data model must support the navigation of objects in near real time and contingent on various criteria, along a traversal in a transportation network.

Functional Requirements VII: Historical Databases – A comprehensive, multi-dimensional LRS data model must support regeneration of object and network states over time and maintain the network event history.

Functional Requirements VIII: Accuracy and Error Propagation – A comprehensive, multi-dimensional LRS data model must support association of error measures with spatiotemporal data at the object level and support propagation of those errors through analytical processes.

Functional Requirements IX: Object-Level Metadata – A comprehensive, multi-dimensional LRS data model must store and express object-level metadata to guide general data use.

Functional Requirements X: Temporal Topology/Latency – A comprehensive, multi-dimensional LRS data model must support temporal relationships among objects and events and support the latency of events (i.e. the difference in time between scheduled events and actual events occurring at a particular location).

MLLRS Function Analysis

A VA Study is predicated on the discussion of functions, as described in Chapter 2. The functional requirements from Report 460 were also considered as the basis for implementing a fully functioning MLLRS under this VA Study. It is important to differentiate that function analysis in a VA Study is not directly associated with the list of functional requirements presented in Report 460.

Also, the discussion during the Step 1 Information Phase of the VA Study constrained the team to regard "multiple LRMs" as the prime differentiating factor between MLLRS and singular LRS – the listing of ten functional requirements from Report 460 could not be regarded in its entirety.

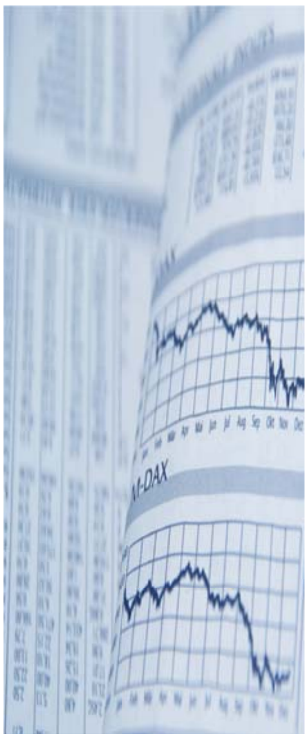
Therefore, the study team identified all of the functions that were required for a fully functioning MLLRS under the constraints of our VA study. The team then identified what functions are required in the baseline system and what functions were optional functional elements. Functions are listed in essentially two words, shown as an active verb and a measurable noun. A simple verb/noun description ensures complete understanding of the functions of the system. Function analysis is completed as a brainstorming effort. Note that some of the identified functions are repetitious or overlapping. The overall functions for a fully functioning MLLRS (compared to singular LRS) are listed below in the order that they were generated by the study team (down columns from left to right).

Table 1 – Function Analysis

Minimize Redundancy	Enhance Cartography	Improve Relationships
Optimize Efficiencies	**Maintain Datum**	Ensure Consistency
Model Reality	Leverage Investments	Define Routes
Store Datum	Improve Accuracy	**Establish Framework**
Ensure Better Decisions	**Support Temporality**	**Stabilize Location**
Integrate Data	Support Business/ Operational Units	**Support Multi-modes**
Manage Change	Enable Visualization	Model Connectivity
Identify Locations	Save Money	**Enhance LRS**
Reduce Impacts	Associate Attributes	Support Design
Integrate Systems	Save Time	**Useable API**
Translate Positions		

The study team used a scoring process and identified the **baseline functions** necessary for a MLLRS (minimum required) to establish a useable system. The two-word functions that received a score of 5 votes or more are listed in **bold** in ***Table 1*** above.

Team members were then assigned to define each of the 11 baseline functions. Those descriptions were then consolidated into the following narrative which describes the Baseline Functions **(shown in bold)**:



The MLLRS must store a **linear datum**. The datum is the complete set of anchor sections and anchor points constituting a mutually exclusive and totally exhaustive ordered set of linear locations. The MLLRS must **integrate data** by providing a mechanism to correlate data from systems that use different referencing methods. Ultimately, the MLLRS can **integrate systems** as legacy systems are replaced with contemporary systems that are designed to use the MLLRS directly. As long as location or spatial referencing methods can be related to the datum – disparate systems can **translate positions** among the multiple potential levels of the system.

The MLLRS must also include functionality to **maintain the datum** with regards to changes in the transportation network and evolving business applications. Evolving business applications since earlier versions of NCHRP 20-27 elevated the need for MLLRS to **support temporality –** thereby enhancing the linear datum with beginning and ending date-time values that specify the operational status of the elements of the network (hence datum). This can be translated to the time-based events that are managed in the business applications.

In NCHRP 20-27(3) the network is tied to the linear datum through linear referencing methods. An **established framework** provided by MLLRS should allow for the ability to add LRMs as they are determined to be necessary.

The MLLRS must **stabilize location** of objects and events when a transportation system is changed. The correctness and the accuracy of spatial location of objects and events must not be compromised when routes (or segments thereof) are renamed, renumbered, realigned, extended, retired, or obliterated.

By virtue of multiple LRMs, the MLLRS will naturally **enhance LRS** as it provides **support for multiple modes** (rail, transit, pedestrians, bike paths, and airports in addition to roads).

Finally, the MLLRS needs to have a **useable application programming interface** (API) which delivers the full MLLRS maintenance abilities to the GIS/LRS update team. This full interface will typically be utilized to manage all 10 of the NCHRP 20-27(3) functional requirements whereas a smaller footprint of the API can be exposed to the business/operational units or web clients that attach to or utilize the MLLRS.

In consideration of the Functional Requirements I through X of Report 460 shown above, the baseline application programming interface shall therefore address:

Functional Requirements I: Spatiotemporal Referencing Methods – must be able to create and modify traversals (i.e. routes) and the events that occur along traversals – and these routes and events have beginning and ending time durations.

Functional Requirements II: Temporal Referencing System/Temporal Datum – must be able to generate a datum which relates the electronic link-node topology to the real world positions and distances over the history of each and each transport link, with time being an element.

Functional Requirements III: Transformation of Data Sets – must be able to utilize the datum to transform business datasets between disparate business systems.

Functional Requirements VII: Historical Databases – must utilize the time component between active traversal dates and event dates to display network states and events over history.

Functional Requirements IX: Object-Level Metadata – must access object level metadata to guide general data use.

The other five functional requirements (IV-multiple cartographic representations, V-resolution, VI-dynamics, VIII-accuracy and error propagation, X-temporal topology/latency) can ultimately be accommodated by the same application programming interface (API), or even by the base GIS functionality if the model incorporates the framework provisions of NCHRP 20-27 (3). APIs can be structured to provide functionality to specific uses.

Two optional functional elements where identified from the remaining set of functions that did not score into the baseline functions category. The purpose of analyzing these functions was to establish some costs/benefits for typical additions above the baseline functions.

The optional functional elements include:

1) **LRM Development** is defined as the opportunity to integrate perhaps even more data than is part of the baseline plan – extending the MLLRS to a more obscure LRM type that was not as highly considered during the baseline development.
2) **Manage Change** is defined as data from one business system to another business system and the synchronization of business data, cascading the changes to the network to integrate into the MLLRS.
3) **Model Connectivity** is defined as enabling a routable network that is aware of turning possibilities and other connectivity issues like unconnected grade separations.

Use of MLLRS

There are many different uses for a MLLRS which will improve an integrated level of information from the available data to facilitate better decision-making, improved communication, reduced liability and reduced duplication of efforts. A MLLRS highlights method to method translation through a common linear datum. The following is a list of how a MLLRS is being used in many agencies throughout the United States. This is not an all-encompassing list. However, it provides information in support of adopting a MLLRS within an agency.

Table 2 – Business/Operational Unit and Use or Benefit within the Unit

Business/Operational Unit	Use or Benefit
LRS Maintenance	Creation, maintenance of the LRS geometry, routes, measures
Asset Management	Collection, creation, maintenance of asset data in a digital fashion
Sign/Signal Inventory	Capture, management, analysis of sign and signal assets
Maintenance Management	Provide resource allocation, work scheduling for maintenance activities and reporting of work performed
Pavement Management System	Collection, creation, reporting, maintenance and analysis of pavement condition data
Structures/Bridge Management System	Collection, creation, reporting, maintenance and analysis of bridge, overpass and other structure information
Inter-agency Planning and Data Sharing	Collection, planning and sharing of transportation projects between local governments, regional planning agencies and the state DOT
Safety Management System	Collection, management and analysis of accident and safety related information
Highway Performance Monitoring System (HPMS)	Collection and maintenance of HPMS data and provision of the HPMS regulatory reports

Business/Operational Unit	**Use or Benefit**
Executive Dashboard	Easily accessed and easily used presentation and visualization of Key Performance Indicators and associated data to support decision making. Uses charts, graphs, maps and reports for presentation purposes
511	Collection and maintenance of data to communicate to travelers; potentially includes weather-related road conditions, construction, congestion, alternative travel options, etc.
Traffic Management Center	Traffic or transportation operations center that provides situational awareness and control of transportation devices. Signal control, traffic flow control, variable message sign control, dispatch, etc.
Environmental Impact Review/NEPA Compliance	Perform environmental impact studies for project work to determine NEPA compliance. Looking at factors such as wetlands, endangered species, archaeological sites, etc.
Roadway Photo Log	Land based photographs of the system
Program Management	Report and track on funding that has been provided
Equipment Management	GPS-AVL, tracking equipment locations
Material Management	GPS tracking of material locations/storage locations
Roadway Inventory	Supports HPMS reporting, but also tracks other data
Finance Department	Supports reporting duties for state and federal agencies
Reporting	Supports all other types of required or requested reporting
Evaluation Routing/Planning	Used to coordinate statewide evacuation models
Legislative	Provides reports and data to meet requests
Intersections	Useful for traffic and planning to store turning movement points
Legal	Provides multi-level, accessible data to support tort liability issues/cases
Outdoor Advertising	Tracking locations for signage and billboards

Example Usages

Iowa Department of Transportation – HPMS 2010+

The state of Iowa uses MLLRS to submit Highway Performance Monitoring System (HPMS) reports to the Federal Highway Administration (FHWA). All states were faced with a challenge over the past 18 months to change to the new HPMS 2010+ submittal format which is a GIS/LRS based database with a more normalized structure rather than the old segmented system.

The HPMS 2010+ data model uses a mile point type linear referencing method (LRM) to locate all business data even on local roads.

Iowa needed to be able to locate all data used for HPMS on their road network and convert them all to mile point LRM with consistent routes. If there is a good LRS System with the ability to do transformations, it is easy to collect the data in the data's native location method and convert everything to mile point for HPMS submittal.

Local data authorities usually will not use mile points or reference posts to locate data. They will probably use more of an intersection offset or GPS location with a route. State data is collected by reference post offset, GPS location and mile point.

Being able to combine data from different systems on the fly is the key in saving time. In the past IADOT could spend weeks or months trying to match mile points to reference post locations to combine pavement data with inventory data, as an example. An LRS system allows this process to eliminate the user perspective and the users/analyst can focus on making the data itself better rather than worrying about its location.

Arizona Department of Transportation – Crashes, then HPMS

The Arizona Department of Transportation (ADOT) has been using MLLRS to process disparately referenced data to a common linear datum for business purposes. Initially this was done for crash data analysis and then to meet HPMS requirements. Arizona's MLLRS accomplishes MLLRS by allowing data stewards to utilize any of the multiple supported LRMs - even in the same business table.

For example, a traffic crash, HPMS event or other event can use any LRM of choice – usually one that makes the most sense to the data provider. Linear events can even utilize different LRMs for each end of the same event making the description of each event customizable to the data steward's need and understanding.

All business tables using the MLLRS adopt a compliant schema in order to become MLLRS-enabled. This allows the entire enterprise to use any accessible business table having records that have been validated against the linear datum. In Arizona, this validation process is called "LRS Geocoding". Once an event is LRS-geocoded, its route and measure are relatively stable – pending future realignments.

For this purpose, the last validation date is stored on each event record and is expected to be later than the last build date of the route that it is measured upon. Otherwise a precautionary LRS Geocode is advised (resulting in an update to the last validation date value) before overlaying different business datasets. Geoprocessing routines enable business tables across the organization to be quickly validated – in whole, or as individual routes are built/rebuilt.

The availability of up-to-date LRS-geocoded business tables provides analysts with the capability to quickly assemble reports from different datasets into submittals like the HPMS. The MLLRS increases efficiency by minimizing the effort necessary to keep track of – and validate – positional aspects of an event. The saved time-effort can be used to improve the validity of the other aspects of the event (i.e. the actual shoulder width, year of construction, etc.) to make the overall datasets more reliable and accurate for better decision-making support.

Chapter 5 – Costs, Savings and Improvement Statistics

It is important to understand the benefits, as discussed in Chapter 3, when implementing a MLLRS to help in the decision-making process. Along with the actual costs associated with implementing the MLLRS, there are also improvements and cost savings that can be realized. The following information lists the costs to implement the baseline system and the two optional functional elements, as described in Chapter 4. The costs for maintenance are also provided. The cost savings, including some life cycle benefit/cost savings and improvements are also provided for the baseline, optional functional elements and maintenance of the system.

There are several assumptions that have been made to help understand both the cost and saving implications.

- The costs shown are exclusive of what is already available within the state agency, including hardware. For example, data migration costs (i.e. development of LRMs) would be reduced if existing LRMs are already in place. Fixed hardware and COTS software expenses might already be encumbered by the enterprise prior to a MLLRS initiative.

- For labor rates, both costs and savings, an integrated rate of both consultant and civil service rates, of $150.00 per hour was used. However, where annual maintenance is covered by agency staff after implementation has succeeded and the agency is autonomous, a $50.00 rate for civil service was used.

- The MLLRS will be implemented from scratch by specialists, the contribution of the agency staff during implementation is gauged at the equivalent cost of project management by the consultant during implementation.

- Either nothing exists or the current system will not integrate, or the existing manpower expertise and learning costs to make it work is too high.

- 25,000 miles of centerline per state was used as the baseline for costs. Though the average state has over three times this mileage in total, some state DOTs may choose to implement MLLRS for only the fraction of the public network that is maintained by the state highway agency. As costs are determined for the agency, judiciously factor the centerline mileage to help determine the total cost. As an example, the annual maintenance labor costs for Application Management are presented in Table 3 below is

$75,000, but are likely not factored to total mileage – depending upon the relationship between the DOT and the application provider. However, linear datum maintenance cost is dependent upon the overall centerline mileage and is also influenced by the rate of growth/change in the areas covered by the MLLRS. For the Iowa Department of Transportation, they are maintaining 100,000 miles of roadway at a cost of $300,000.

- There already exists a good primary road network (+/– 3 meter accuracy from true centerline).
- All important open-to-public roads are included and the state agency is able to easily access local road information through agreements, digitization, or purchase.
- A spatial representation is available such as recent aerial imagery perhaps supplemented by GPS roadway traces to confirm the above two issues. The “Purchase Data” line item under the annual maintenance cost provides an annual figure for confirming the extent of roads in a 25,000 mile of road state.
- The existing business system targeted for integration is using some LRM method (i.e. it does have some type of spatial descriptive component already incumbent in the database schema which can be leveraged).
- Some staging work will be required within a business system for integration to occur.

Table 1 - Baseline System Costs

Cost Categories	**Total Cost**
Hardware	$42,500
Core System Software (COTS)	$190,000
Annual Maintenance of COTS	Included in Table 4
Total Baseline System	**$232,500**

Table 2 – Baseline Development Costs

Labor Cost Category	**Parameter**	**Consultant**	**Staff Costs**	**Combined**
Application Management	State	$242,400	$77,481	$319,881
Data Development & Input	25k miles	$176,400	$56,385	$232,785
Training	State	$26,400	$8,439	$34,839
System Integration	5 business	$288,000	$92,057	$380,057
Project Management, Business Analysis & Coordination	State	$517,200	$165,319	$682,519
LRM Development	3 LRMs	$93,600	$29,919	$123,519
TOTAL		**$1,344,000**	**$429,600**	**$1,773,600**

Table 3 – Annual Maintenance Costs – Baseline

Cost Categories	**FTE's**	**Hourly Rate**	**Total Hours**	**Total Cost**
Labor – Application Management	.75	$50.00	1500	$75,000
Labor – Training	0.9	$150.00	120	$16,200
Labor – System Integration (Per Business System) Includes Reports (Actual integration costs are dependent on the size of the business/operational unit. Much smaller organizations will experience a potential reduction in cost to almost 1/10th of the cost shown.)	0.5 0.5	$50.00 $150.00	1600 400	$40,000 $30,000
Labor – System Oversight	0.1 0.1	$50.00 $150.00	1600 400	$8,000 $6,000
Hardware	Budget 20% of baseline costs for hardware depreciation and COTS software maintenance fees			$8,500
Software				$38,000
Purchase Data	Annually updated aerial imagery			$30,000
TOTAL				**$251,700**

Table 4 - Optional Functional Element Costs

Cost Categories	**LRM Development**	**Manage Change**	**Model Connectivity**
Labor – Application Management	0	$12,000	$275,000
Labor – Data Development/Input	$40,000/each	$12,000/system	$206,550
Labor – Training	0	0	$6,000
Labor – System Oversight	0	$5,250	$5,250

Table 5 - Maintenance Costs – Optional Functional Elements

Cost Categories	**LRM Development**	**Manage Change**	**Model Connectivity**
Labor – Application Management	0	$1,800	0
Labor – Training	0	$600	$600
Labor – System Oversight	$6,000	0	0
Software	$5,000	0	0

Cost Benefit Analysis

Total cost/benefit is important to evaluate to aid in the important decision-making process to understand the total impacts of the system. A cost/benefit analysis was performed on the baseline MLLRS. ***(See Table 6 – Life Cycle Cost - Baseline).*** The cost/benefit analysis for the Optional Functional Elements can be found in ***Table 7 – Cost Benefit Analysis – Optional***. The analyses were done with an estimated breakeven time of 5 years and an escalation rate of 3%. Note that the annual benefits are significant over the 5-year period. It is important for the agency to understand that these savings can be continued throughout the actual life of the system and can lead to substantial overall system savings for the agency.

When expressed as a cost-to-benefit ratio (C/B), the baseline effort yields a C/B ratio of 1.8:1 while the optional functional elements yield an aggregate 21.4:1 ratio of benefits to cost. These figures were generated from empirical values generated by several of the participating states through the workshop participants. These aggregate C/B ratios are bound to be different when each particular state is analyzed separately for their own benefits versus costs using their individual operating conditions.

From a Value Analysis perspective, it is not outside of expectations to yield significantly higher B/C ratios in VA studies. Within this study, the disparity between 1.8:1 for baseline elements versus 21.4:1 optional functional elements, is within reasonable expectation compared to other topics of VA studies. The numbers - though subject to the limitations of the particular aggregated conditions of the states that could provide data - still reflect that building the baseline MLLRS is a cost-beneficial endeavor by itself. Once built, the MLLRS real value to the organization comes from further exploitation of the single framework for assimilating previously disparate data to the same linear datum. Each added functionality built onto the baseline framework, yields significant savings rewards with very little added capital costs.

Therefore, it is important to have a single linear datum in a framework that accommodates the multiple methods of linear referencing. Expanding that same framework to extend further across the enterprise - as well as handle other functional objectives of NCHRP 20-27(3) - will provide exponential benefits for relatively incremental additional cost.

Table 6 and 7 are located on the next two pages.

Table 6 – Cost/Benefit Analysis Baseline MLLRS

	Cost Benefit Analysis ***MLLRS Baseline Cost/Benefit***	
	TITLE:	
	Life Cycle Period 5 Years Real Discount Rate 3.00%	
A.	**INITIAL COST**	
	Service Life-Original ______ Years Service Life-Alternative Years **INITIAL COST:**	$2,006,100
B.	**SUBSEQUENT ANNUAL MAINTENANCE COSTS**	
	1. Labor	$175,200
	2. Software	$46,500
C.	**SUBSEQUENT ANNUAL BENEFITS/SAVINGS**	
	1. Staff Hours	($7,500)
	2. Operational Hours	($15,000)
	3. Business/Operational Unit Improvements	($1,168,000)
	4. Other Departmental Hours	($1,500)
	Total Subsequent Annual Costs:	$221,700
	Total Subsequent Annual Benefits/Savings:	($1,192,000)
	Present Value Factor (P/A):	4.580
	PRESENT VALUE OF SUBSEQUENT ANNUAL COSTS:	$1,015,386
	PRESENT VALUE OF TOTAL COSTS:	$3,021,486
	PRESENT VALUE OF SESEQUENT ANNUAL BENEFITS:	($5,459,360)
F.	**TOTAL PRESENT VALUE BENEFIT (A+D+E)**	($2,437,874)
	TOTAL COST BENEFIT:	$2,437,874
	COST BENEFIT RATIO:	1.8:1

Table 7 – Cost/Benefit Analysis Optional Functional Elements

Cost Benefit Analysis ***MLLRS Optional Functional Elements***	
TITLE:	
Life Cycle Period 5 Years Real Discount Rate 3.00%	
A. INITIAL COST	
Service Life-Original ____ Years Service Life-Alternative ____ Years **INITIAL COST:**	$492,800
B. SUBSEQUENT ANNUAL MAINTENANCE COSTS	
1. Labor	$22,050
2. Software	$5,000
C. SUBSEQUENT ANNUAL BENEFITS	
Sample Business Unit Improvements	
1. Safety Improvements	($52,000)
2. Reduced Level of Risk for Litigation	($2,700,000)
3. Reduced Impacts to Projects (i.e. construction)	($720,000)
4. Reduced Maintenance costs	($114,000)
Total Subsequent Annual Costs:	$27,050
Total Subsequent Annual Benefits:	($3,471,980)
Present Value Factor (P/A):	4.580
PRESENT VALUE OF SUBSEQUENT ANNUAL COSTS:	$123,889
PRESENT VALUE OF TOTAL COSTS:	$616,689
PRESENT VALUE OF SESEQUENT ANNUAL BENEFITS:	($15,901,668)
F. TOTAL PRESENT VALUE COST (A+D+E)	($15,284,979)
TOTAL COST BENEFIT:	$15,284,979
TOTAL COST BENEFIT RATIO:	21.4:1

SCHEDULE

To implement a MLLRS it is reasonable to expect that approximately 2 years for completion after award of the contract to a consultant and then full use of the MLLRS.

Chapter 6 – Implementation of a MLLRS

Agencies often face numerous challenges related to implementation of new systems or even upgraded systems. Prior to making a final decision on implementing a MLLRS, the following requirements should be identified and action plans put into place to ensure success.

Key Implementation Requirements

1) Organizational Support
    a. The organization must have established policies and procedures in place that support the MLLRS including;
        i. An enterprise information technology infrastructure
        ii. As business/operational units begin or continue to develop information, legacy data can be adapted until legacy systems are replaced with conforming MLLRS components
    b. High level (i.e. upper management) champion to lead the effort
    c. This must fit within agency's mission or the mission must be changed
    d. Develop a business case
        i. Include savings expected once implemented and even during implementation
        ii. Develop a lessons learned plan and milestones to ensure activities are being done in a timely manner and on schedule
        iii. Complete a risk analysis and mitigation plan
2) Establish model specifications and a scope of work to be used to obtain outside services and/or complete the work with existing staff
3) Identify functional requirements needed within your agency to meet the baseline performance attributes
4) Establish a maintenance plan and approach, capitalizing on lessons learned
5) Establish a training plan and approach
6) Secure resources – manpower, funding, staffing, contingency for staff turnover, etc.
7) Determine the schedule progress timeline and monitor it
8) Set and manage internal expectations
9) Develop an outreach plan internally with staff and management

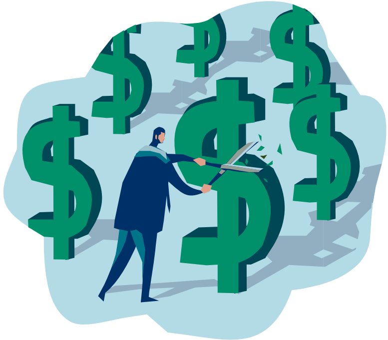
Impacts of Not Implementing MLLRS

It is also important for the agency to understand some of the pitfalls and concerns with not implementing a MLLRS. The ones identified by the study team are as follows:

1) Continued “silos and stovepipes” of data internal to the agency
2) Inability to adequately and factually defend budget requests for allocation
3) Continued political pressure to be more responsive and provide more accurate data
4) Continued responsiveness issues to meeting requests as they will increase as the need for more timely information increases
5) Lack of transparency and potential public perception issues because the agency is not able to provide the necessary data
6) A need to increase resources to meet increasing demands, which are not available
7) Delays to project schedules will continue or increase because requirements and demands are changing and increasing

The impact of not implementing MLLRS is probably best qualified by the anecdote from the Iowa report presented at the end of Chapter 3:

> “…If the DOT does not implement the LRS, the DOT will still expend the money and effort to meet the DOT’s data integration needs. However, the effort will most likely continue as it does today: disjointed and duplicative, with certain requirements not being met.”



Chapter 7 – Glossary of Terms

AASHTO .... american association of state highway transportation officials

API .... application programming interface

COTS .... commercial off-the-shelf

DOT .... department of transportation

ERP .... enterprise resource planning

FTE .... full time employee

GIS .... geographic information system

GIMS.. geographic management information system

GPS .... geographic position system

GPS-AVL................................. geographic position system for automatic vehicle location

HPMS.. highway pavement management system

LRM .... linear referencing method

LRS .... linear referencing system

MDLRS... multi-dimensional linear referencing system

MLLRS .... multi-level linear referencing system

NCHRP .... national cooperative highway research program

NEPA .... national environmental protection agency

PM... post mile

SAVE International................................ (formerly) Society of American Value Engineers

TASAS .... traffic accident surveillance and analysis system

TIG .... technology implementation group

VA.. value analysis

Chapter 8 – References

……….NCHRP Report 460, Guidelines for the Implementation of Multimodal Transportation Location Referencing Systems

……….SAVE International Body of Knowledge