Asset Management Implementation Framework for Colorado Department of Transportation By Deighton Associates Limited

Submitted by:
Deighton Associates Limited
11 Stanley Court, Unit 1
Whitby, Ontario, Canada
L1N 8P9
Ph. (905) 665-6605
Fax (905) 665-6645
http://www.deighton.com

Submitted to:
Colorado Department of Transportation
Division of Transportation Development
Performance Measures and Policy Analysis Unit
Shumate Building
4201 E Arkansas Ave
Denver CO 80222

September 1, 2010

Deighton

Table of Contents

List of Figures

List of Tables

1. Introduction

Declining tax revenues, increasing construction and maintenance costs coupled with aging infrastructures and increasing user demands have greatly increased the need for effective asset management by transportation agencies throughout the world. New performance measures and the ability to investigate transferring funds from one program area to another to trade-off different levels of service against limited resources, have been recognized as key needs for managing transportation networks going forward in this tough economic climate.

Colorado Department of Transportation (CDOT) has recognized the need to make "tough choices" regarding the financing of transportation projects throughout Colorado. The **2035 Statewide Transportation Plan**[1] (March 2008) clearly outlines that declining revenues will lead to reduced funding in some program areas so that funding can be applied on the most critical transportation system program needs.

The Statewide Plan provides several responses to the funding shortfall including the following:

> "Improved tools will be developed to aid the Transportation Commission in analyzing and making the best tradeoffs when establishing funding priorities. These could include establishing and focusing investments primarily on priority roadways using possible criteria such as roadway

[1] 2035 Statewide Transportation Plan, "Moving Colorado: Vision for the Future", March 20, 2008, Colorado Department of Transportation, Statewide Planning Group

usage, truck traffic, system connectivity, and / or lifeline routes to communities."

In order to help demonstrate the effects of increasing or decreasing funding changes on different program areas, CDOT requires strategic level asset management analysis tools to supplement existing tactical asset management tools implemented within CDOT.

In 2010 CDOT contracted with Deighton Associates Limited (Deighton) to investigate the use of the Deighton asset management system (dTIMS CT) for strategic planning and cross asset trade-offs within CDOT. CDOT has been a Deighton client since 1997 and uses dTIMS CT as a decision support tool for the CDOT Pavement Management System (PMS).

Recognizing that the CDOT PMS, implemented within dTIMS CT, could also be used for strategic planning and cross asset trade-offs, CDOT sought to determine how dTIMS CT could be implemented within the Planning Division for strategic planning and economic trade-offs and which assets might be included. By undertaking a framework development study Deighton and CDOT would investigate the current management systems implemented within the agency and determine the following:

- Data Flows;
- Data Management Support Requirements
- I.T. Support Requirements;
- Staff Support Requirements;
- Consultant Support Requirements; and

- Analysis Outcomes.

During the week of June 7th to June 11th, 2010, Deighton travelled to CDOT to meet with the various asset managers to discuss the current management philosophy and methodology as well as the current management systems used within the asset group to manage the assets under their jurisdiction.

This report "CDOT Asset Management Implementation Framework" provides a summary of the meetings held that week and provides a framework for implementing dTIMS CT for Strategic Planning and Analysis.

The remainder of this section will introduce Deighton and the dTIMS CT Asset Management System.

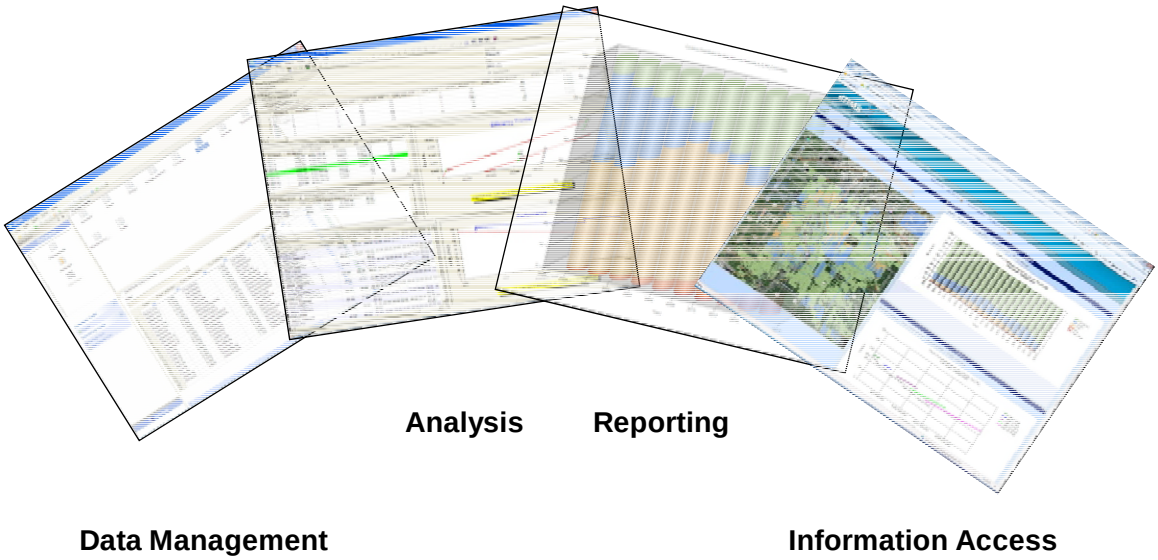
Chapter 2 will discuss the implementation of dTIMS CT for Strategic Asset Management within an Agency and provide the conceptual and technical details of the implementation. Following that, the report will investigate the asset groups analyzed (Maintenance, Pavement, Bridge, ITS, Fleet) and then provide proposed analysis methodologies and estimates of resources to implement the assets within the strategic asset management analysis for CDOT.

1.1 Deighton Associates Limited (Deighton)

Deighton has been in business for over 25 years and today is a leader in Transportation Infrastructure Asset Management.[2] Over the past two decades, Deighton has evolved from a small engineering firm producing client specific applications for pavement management, into a world class software

[2] Deighton provides asset management services based on dTIMS CT to 19 US state DOT's and over 400 agencies around the world.

development organization continually developing and supporting one of the most recognized Commercial Off-The-Shelf (COTS) Asset Management Solutions available today, Deighton's Total Infrastructure Management System, more commonly known as: dTIMS CT.



From humble beginnings as a simple data warehouse of road network information, dTIMS CT matured into a full featured decision support tool providing performance modeling capabilities that can deliver current strategic details, historical information and future projections on infrastructure condition for an agency's entire transportation infrastructure network based on arrays of definable budget scenarios. This powerful application developed into an essential planning tool for asset managers in charge of transportation networks of any size, from small towns to entire countries.

Our clients want to know the answers to:

- What is the current condition of my network?

- How much is it going to cost me to maintain the condition of my network over a five, ten, fifteen or twenty year planning horizon?

- What type of construction / maintenance program is necessary to maintain or improve the condition of my network?

- What will my network look like in ten years based on projected budget scenarios?

dTIMS can answer these questions and many more regarding transportation infrastructure.

As dTIMS CT matured over its 23 year history, Deighton began expanding its expertise beyond just pavement. Our clients wanted to apply the advanced analysis capabilities within dTIMS CT to their other assets, such as roadside assets, bridges and sub-surface utilities. Deighton then developed partnerships with companies with expertise in bridge condition assessment and subsurface utility management. By leveraging the expertise gained through these strategic partnerships, Deighton is now able to deliver software tools and valuable expertise in not only pavement, but also bridges, subsurface utilities, roadside assets, etc. Our most progressive clients are using dTIMS CT to manage not only pavement and bridges, but also safety and traffic data and then incorporate it into the entire network analysis by using the advanced cross-asset analysis capabilities within dTIMS CT.

Today, dTIMS CT is in use around the world to manage many different types of assets. There are over 400 agencies worldwide that are using dTIMS CT, including 19 of the state Departments of Transportation (DOTs) in the United States.

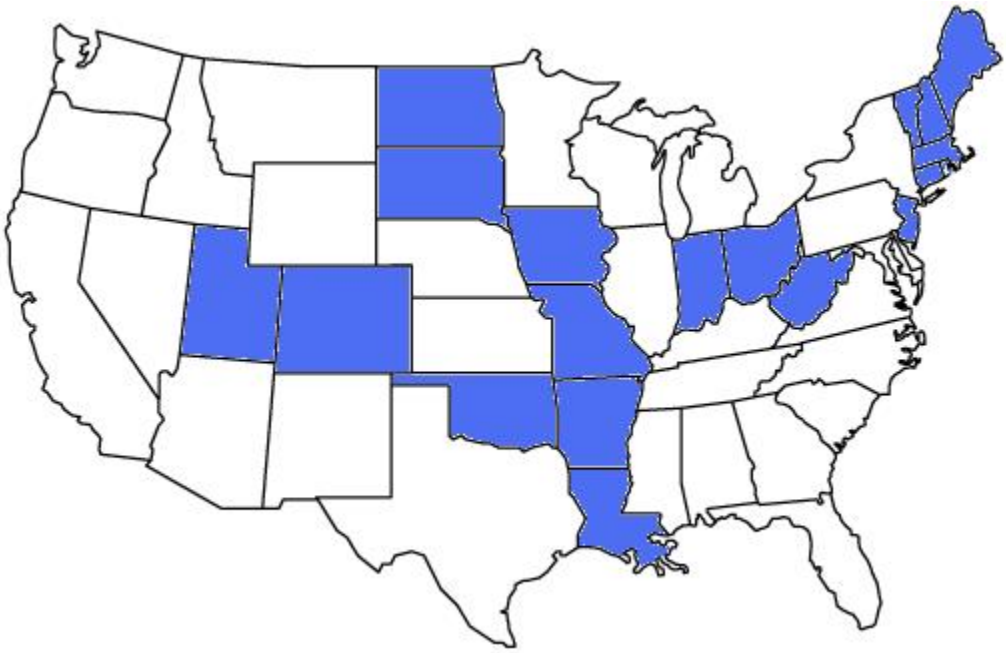


Figure 1: United States State Level dTIMS CT Implementations

Each state level user of dTIMS CT has an implementation which provides an enterprise solution to manage their pavement assets. Many of the state level dTIMS CT users manage additional assets, including bridges and culverts.

Deighton offers tremendous sustainability to its clients as indicated by the longevity of their business relationship. Eleven active state DOTs have reached, or are within, three years of celebrating 20 years of customer support and continued software maintenance with Deighton.

The recent shift towards multiple asset management, cross asset co-ordination and optimization has given our clients the added benefit of pursuing the management of those assets using the same proven and familiar software platform that they have implemented at the tactical and operational level for pavement management. The benefits have come in the form of financial and time savings that were realized by being able to remain with the same software platform for multiple asset management and avoiding the inherent risks associated with introducing new software into the management process.

Expanding into a multiple asset management system for an agency using dTIMS CT is a relatively simple process. Deighton has designed dTIMS CT from the ground-up to be a user-accessible, open framework platform, not a modular platform as is typical for other software vendors. A modular structure would require the purchase of additional modules to expand the functionality of the software, whereas an open framework platform, specifically dTIMS CT, provides the user with the ultimate freedom to expand to a limitless number of assets, each having a limitless number of attributes.

Deighton's Total Infrastructure Management System (dTIMS CT) combines network data storage, external application integration, powerful analysis tools such as dynamic segmentation and Concurrent Transformation™ as well as comprehensive reporting tools to provide transportation asset managers with an indispensable decision support and planning tool for their road networks.

1.2 dTIMS CT

dTIMS CT is the core application in Deighton's asset management offering and is implemented for pavement management within CDOT. It is a sophisticated engineering tool designed to provide an asset inventory of multiple asset types,

related to one another using a Linear Referencing System (LRS). It is designed to achieve maximum efficiency when dealing with linear transportation infrastructure networks such as roadway or bridge assets.

In addition to the asset inventory, dTIMS CT offers sophisticated deterioration modeling tools; which, when coupled with the planning and budgeting tools, makes for an extremely powerful capital investment and provides maintenance planning tools for all transportation related assets in CDOT. Over the past 25 years, dTIMS CT has become the industry leader in transportation infrastructure management software.

dTIMS CT KEY FEATURES

- **Manage Multiple Assets**

  Manage all assets including, but not limited to: roads, bridges, fleet vehicles, buildings, signs and sub-surface utilities in a single application.

- **Decision Support Tool**

  Predict future conditions for every asset and show how each will perform under existing conditions.

- **Work Program**

  Provide multi-year project analysis for establishing priorities for work programs.

- **Optimization**

Multi objective optimization using feasible solutions for each element constrained by user defined budgets, resources or restrictions (maximize benefits, minimize agency cost, reduce public costs and delays, maximize performance measures) as defined by your organization.

- **Preventative Maintenance**

Predict the best time to perform preventative maintenance and the estimated cost to keep assets in good order and to minimize annual operating costs.

- **Strategies**

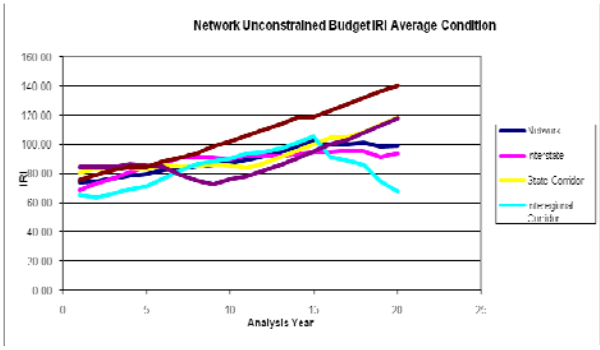
Show multiple engineering strategies for each project, including do-nothing, and quantify the impact of delaying or moving forward the timing of a treatment. dTIMS CT can also help managers to coordinate strategies across the network for different assets through the dTIMS CT map based reporting and strip map functionality.

- **Agency Goals**

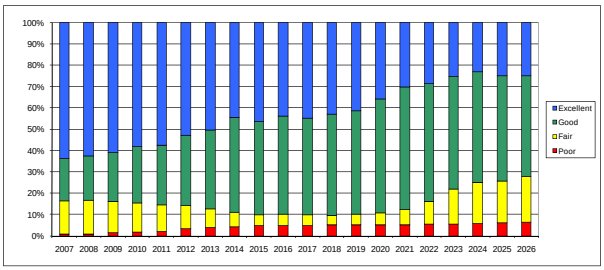
Determine affordable future levels of service or set performance goals for performance based budgeting.

- **Budgeting**

Show the effect of individual project budget goals for individual work divisions, managers and districts based on network-wide goals and needs for multiple assets. dTIMS CT will allow CDOT to prioritize work by corridor, traffic levels, facility category using CDOT established hierarchies.



dTIMS CT combines the convenience and cost advantage of COTS software with the potential for any agency to make it as "custom" as it wishes by incorporating its very own database structure and analysis parameters that have been refined over time. dTIMS CT will be configured during implementation to provide CDOT staff with the asset management and data integration tools they require. The flexibility of dTIMS CT leaves the door open for future modifications to the database structure or expansion of the initial analysis methodology to include future data availability.



Where dTIMS CT stands out from the competition is that it allows users to customize their Asset Management System themselves, without having to pay for additional

programming for existing product modifications. In fact, all implementations of dTIMS CT are built on a single source code. Therefore, all dTIMS CT users, whether they are located in Utah, Louisiana or New Zealand, are using the same software, built on the unique code. This approach, adopted by Deighton in its early days, ensures a robust universal product, reduces the risks of errors and helps to mitigate development costs. These benefits translate into lower technical and financial risks for users.

Please note that dTIMS CT is not a Management Suite comprised of a number of modules that need to be purchased, implemented, maintained and supported separately. dTIMS CT is an open architecture framework that provides users with the flexibility to creatively model the type of asset they wish to manage, using the management philosophy that they wish to employ and the analysis parameters that are specific to their assets. The benefit that this will give to an agency is twofold:

- During implementation there is no data transformation required to accommodate external data, data is loaded into the dTIMS CT or linked into dTIMS CT based on how that data is collected and maintained, it does not have to be transformed into any one set of sections to be used within dTIMS CT.

- Once implementation is complete the database structure and analysis models are available in their entirety for review, modification and expansion

It is important to note that the open architecture design of dTIMS CT makes it easy for CDOT to expand the Asset Management System (AMS) to other transportation related assets at any time without the added expenditure of supplementary software modules, support and maintenance. Even if CDOT began with only tangible assets such as bridge and maintenance, additional

assets, models, management philosophies and analysis parameters may be configured at any time into dTIMS CT. This would enable CDOT to measure and analyze safety and mobility as assets in the future. dTIMS CT goes beyond offering users the mere ability to store data related to other assets within their AMS. A user can choose to store other asset data in dTIMS CT independent of its final use. Initially, it can be used simply for query and reporting purposes, then as an enhancement to the AMS and finally as the basis for a complete management system for that asset. All within the same software application, dTIMS CT, with "right click" simplicity. As the AMS matures, CDOT will be able to concurrently analyze assets such as roads, bridges, structures, culverts, traffic, safety and other roadside appurtenances and optimize budgets across those same assets.

2. Proposed Implementation Framework

2.1 Asset Management Philosophy

Much has been written about asset management and many different definitions of asset management have been published by transportation agencies around the world. There is no shortage of information regarding asset management best practice and many handbooks / guides on asset management are readily available. Many of these definitions make little distinction between asset management and an asset management system.

Deighton, however, makes a clear and concise distinction between asset management and an AMS. This is critical to the successful implementation of asset management and any subsequent implementation of an AMS at CDOT.

Asset management for transportation agencies is not just a set of computer tools that enable the economic analysis of assets within and across all asset groups, but rather, **a broad based business approach to managing assets that clearly links the actions of the transportation agency to outcomes** (specific measurable goals and objectives) documented and published in the agency's transportation service strategic plan.

Any decision support software tools that form the basis of an AMS are considered only pieces of the broader asset management puzzle that assists decision makers to make better decisions with respect to their strategic transportation goals and objectives.

The difference between asset management and an AMS can best be thought of as follows:

"An agency practices asset management so it can deliver a transportation service to its community. At the same time, an agency uses an asset management system so it can use a systematic practical approach to practicing asset management."[3]

To Deighton, the philosophy of asset management can be summarized as the business processes ensuring that all **actions** performed by the department are **linked** to desired **outcomes**.

The philosophy of an AMS can then be summarized as a management system that inventories, analyzes and demonstrates **outcomes** for alternative **actions**.

CDOT has established many asset management best practice initiatives within the department and the implementation of asset management best practice is not one of the primary purposes of this study or the proposed implementation framework, but Deighton believes that the distinction between asset management and an AMS is so crucial to an agency that it warrants mention in this document.

The proposed asset management framework documented in this report will assist CDOT in prioritizing funding across and within asset groups.

[3] Zavitski, Jeffrey L., B.A., "Implementing a Strategic Highway Transportation Asset Management System in Utah", Presented at the 6th National Conference on Transportation Asset Management, November, 2005, Kansas City Missouri.

Implementing dTIMS CT for strategic level asset management will enable CDOT to evaluate outcomes for alternative actions (investment scenarios) for the assets included within the AMS, based upon:

- Unlimited number of assets or asset groups;
- Unlimited key performance measures (condition, environmental, economical, societal);
- Unlimited budget categories for investment (maintenance, preservation, rehabilitation, replacement);
- Unlimited budget scenarios to demonstrate the effects on the key performance measures based on alternative distributions of resources to the different budget categories and alternative funding amounts;
- Strategic Analysis Module slider based tools for illustrating the results of transferring funding from one asset group to another;
- True Cross Asset Analysis and Optimization for determining the best distribution of funding based on desired Key Performance Measures.

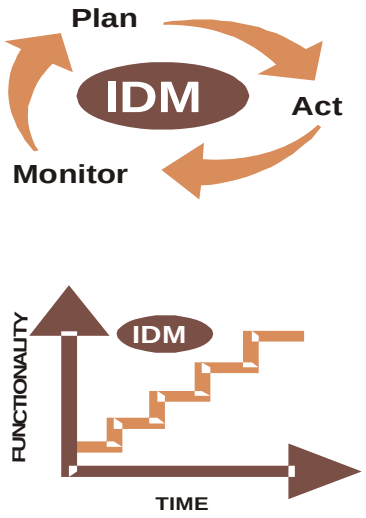
2.2 An Incremental Development Approach

Since inception Deighton has always prided itself on delivering solutions to transportation agencies that allow the agency to implement the Deighton tools (dROAD, dTIMS, dTIMS CT, dTIMS CT Enterprise) according to how that agency does business. Unlike a canned "black box" approach, Deighton never forces an agency into a specific approach, a specific set of required data or a specific analysis methodology. Nor does Deighton take an approach used in one agency, change the name and sell that exact approach to the next agency.

Deighton has been successful over the last 23 years by tailoring an approach to a project on an agency by agency bases and customizing our software tools through parameters and not through programming to meet the agency's needs.

> *A complex system that works is invariably found to have evolved from a simple system that worked… A complex system designed from scratch never works and cannot be patched up to make it work. You have to start over, beginning with a working simple system.*[4]

Early on, Deighton recognized that simple systems can grow into quite sophisticated systems over time as small improvements are made. Somewhere between current practice and best practice in asset management is where an agency will define an appropriate level of sophistication for their asset management system. The move from current to appropriate is a journey that takes time and is accomplished by implementing a series of discrete incremental improvements known as Incremental Development Methodology (IDM).



Throughout the proposed implementation framework documented within this report, Deighton will make recommendations on the initial configuration for integrating the asset group data and models into dTIMS CT for the CDOT strategic analysis recognizing that the initial implementation will gain in

[4] Levy, H, Capability – Based Computer Systems, Digital Press, MA, 1984

sophistication through incremental development as the understanding and use of the system expands at CDOT and more and more is demanded from it.

2.3 Top Down / Bottom Up Asset Management

In its simplest form, an asset management system is a decision support tool composed of two main components, the asset management database and the asset management analysis. dTIMS CT has been designed to perform both of these functions for strategic and tactical level asset management.

Deighton describes the implementation of asset management as a "top down / bottom up" approach featuring vertical and horizontal integration amongst the three levels of asset management planning: Strategic, Tactical, and Operational and across the different asset groups (pavement, bridge, maintenance...).

Figure 2 illustrates the integration across asset groups (pavement, bridges, signs, accidents, safety, mobility, etc.) and throughout the different planning levels (Stakeholders, Strategic, Tactical, and Operational).

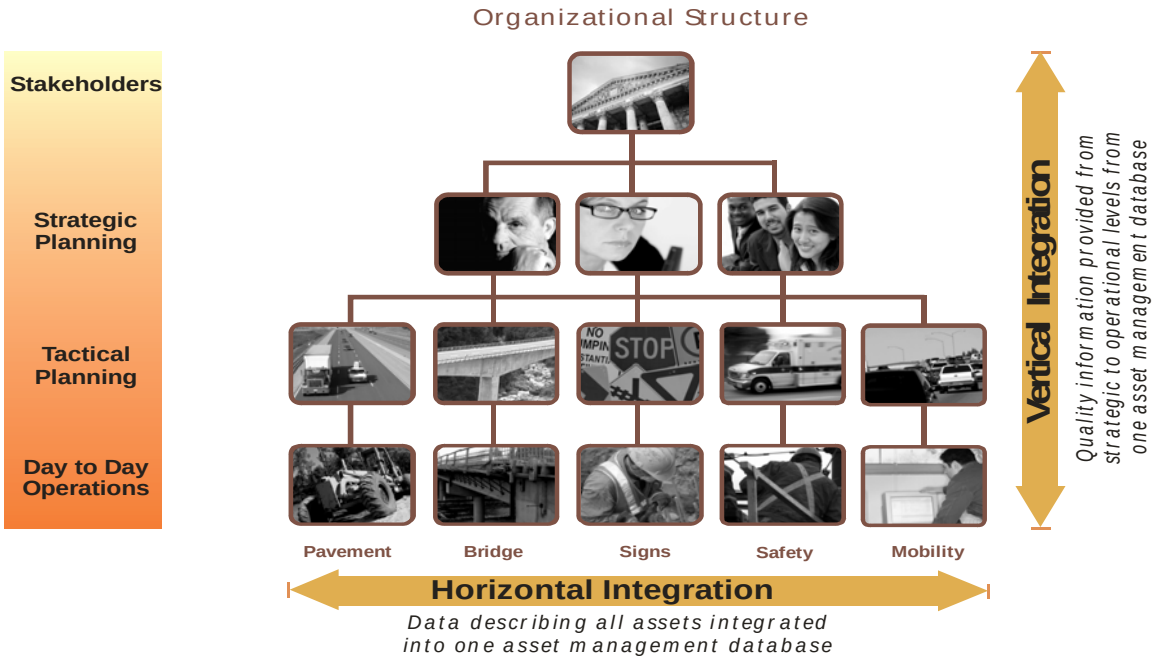


Figure 2: Asset Management System Integration

There are many important concepts illustrated within Figure 2 that require further explanation as they form the basis of the asset management implementation framework that Deighton is proposing to implement at CDOT.

2.3.1 Stakeholders

The Stakeholders are the ultimate users and owners of the transportation system that is maintained by CDOT. CDOT is responsible for providing transportation service that allows for safe, efficient and economical movement of people and freight throughout the state. A stakeholder can then be thought of as anyone who is directly or indirectly influenced by actions the department takes and includes citizens of Colorado, CDOT staff, the Federal Highway Administration and many others. These stakeholders are primarily represented by the State Legislature and the Transportation Commission at CDOT.

2.3.2 Strategic Asset Management

Strategic level asset management deals with managing the transportation network using a long-term strategic management approach and examines the network as a whole and not on an individual asset by asset basis. Strategic level asset management focuses on translating customer needs into providing a transportation service in a safe, efficient and economical manner.

At the strategic level, performance is measured in strategic terms where the impact of the transportation network on society, the economy and the environment (triple bottom line performance measures) are much more important than the condition and performance of any one individual asset. For example, put in simple terms the transportation assets in the network might be maintained in near perfect condition but be underutilized if they do not take people where they want to go. Strategic level asset management relies on the synergy of the transportation system where the system itself is considerably greater than the sum of its individual asset group components.

Strategic level asset management allocates resources (natural, physical, financial, etc.) across the entire transportation network where needed and expects tactical level asset management teams to use those allocated resources economically to achieve the overall strategic goals of the department by setting level of service requirements on the individual asset group components.

2.3.3 Tactical Asset Management

Tactical level asset management translates the strategic goals of the organization into specific goals and objectives for individual components of the transportation network. At the tactical level, managers are concerned with how their individual asset group contributes to the transportation system and how that component

can be maintained in the most cost effective and beneficial manner to achieve performance targets in terms of levels of service.

Tactical asset management develops strategies that allocate resources (natural, physical, financial, etc.) to achieve the strategic goals of the organization by achieving defined levels of service as stated in the organization's Long Range Strategic Plan. The tactical asset management plans usually examine a mid range or 5 to 10 year time frame. From the Tactical Asset Management Plan, the short term (1-3) year operational plans are developed.

For example, the State of Utah Department of Transportation uses a series of Plans for each type of work performed as follows:

- Blue Book for major rehabilitation and reconstruction projects;
- Purple Book for minor rehabilitation and functional improvements;
- Orange Book for minor seals and maintenance type treatments.

The Orange Book projects are developed based on keeping projects that are slated for future work (5-10 year) plans intact until Purple Book or Blue Book projects can be completed upon those sections. Orange Book projects are also used on segments not yet programmed for Purple or Blue book projects.[5]

2.3.4 Operational Level Asset Management

Operational level asset management deals with short term planning and the day to day operations of the department. Asset management planning at the

[5] Pavement Management Systems Peer Exchange Program Report, May 8, 2008, U.S. Department of Transportation, Federal Highway Administration

operational level develops action plans and short term plans (1-3) years that achieve the required levels of service as outlined at the strategic and tactical levels.

If tactical asset management translates the strategic goals of the organization into mid – range plans to achieve the required levels of service for each asset group, then the operational level asset management can then be thought of as being short term strategies that, when examined in succession, will achieve the strategies outlined in the tactical level mid range plans. Again, consider the UDOT example where Orange Book projects are used to hold segments intact until other projects can be completed.

2.3.5 Vertical Integration

The asset management framework relies on quality data and analysis results throughout all three asset management planning levels.

Strategic planning requires tactical and operational level data and models to ensure that policy decisions regarding levels of service are in fact realistic and attainable. Allocating resources at an overall strategic level based on social, economic and environmental factors cannot be completed without consideration of the impacts on the individual asset group levels of service.

Tactical level asset management requires strategic level data and models to ensure that tactical asset management plans meet level of service policies while still maintaining the overall strategic levels of service in terms of the triple bottom line performance measures. As well, tactical plans must be consistent with operational asset management capabilities to ensure that operations can translate the tactical asset management plans into reality over their consecutive operational asset management plan cycles.

Operational level asset management requires strategic level and tactical level asset management data and models to ensure that the consecutive short term operational plans meet and achieve the strategic and tactical level of service goals.

The asset management database is a key component of the asset management framework that enables the vertical integration to take place. dTIMS CT as the asset management database allows unlimited user defined tables to store any asset management data regarding the transportation network. Once data is stored within the asset management database it can be integrated with asset data from any other asset group.

2.3.6 Horizontal Integration

Data integration between asset groups is a key component of asset management as tactical and operational asset management plans within one asset group can affect the levels of service within many other asset groups. CDOT currently has several data integration initiatives on-going within the department, so data integration is not a key component of the AMS framework presented within this report. That being said though, the data integration functions of dTIMS CT will certainly be required when bringing in data required for the strategic analysis.

2.4 Funding Needs and Tradeoffs

Figure 3 provides a more detailed examination of the asset management framework that is proposed for CDOT.

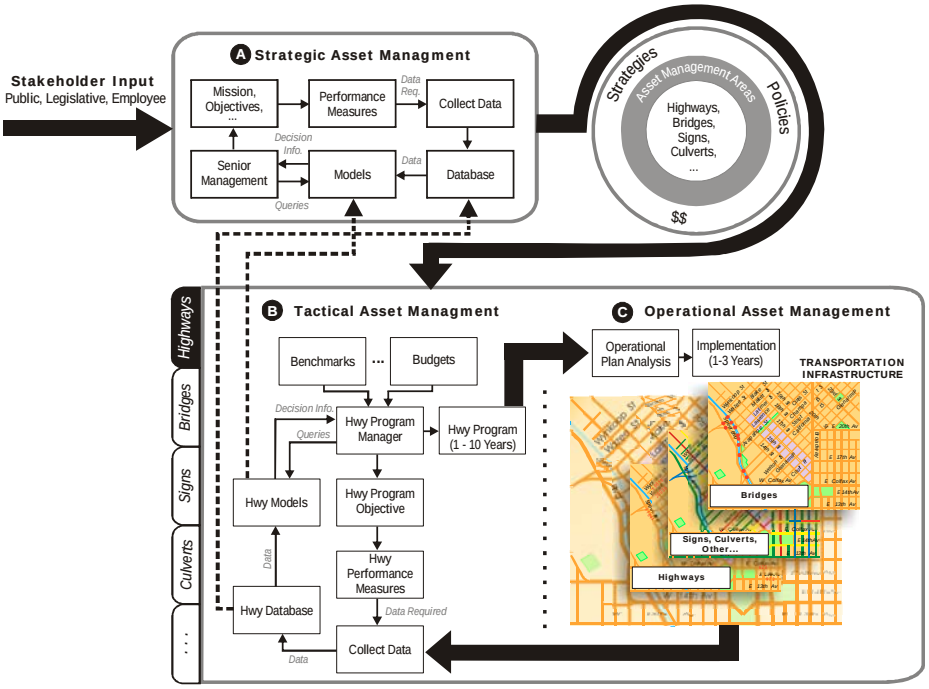


Figure 3: Advanced Asset Management Framework

2.4.1 Strategic Level Analysis

At the strategic level (A in Figure 3) an asset management analysis is completed using data and models passed in from the tactical and operational levels into dTIMS CT.

This data and models from the asset groups are supplemented with additional performance data that can be used to perform the strategic analysis using the triple bottom line approach. These two sets of performance measures, condition related from the asset groups and economic, societal, and environmental from the strategic level asset management data collection, are then analyzed and the results used to help set level of service guidelines, transportation policy and resource allocations (budgets) between the various asset groups within the department.

In the initial phases of the CDOT implementation, the strategic analysis will focus on providing the funding needs to maintain the asset groups at or above the current level of service guidelines established by CDOT policy. As more and more demands are placed upon CDOT by the stakeholders and as more and more external (other agencies within Colorado) and internal groups (within CDOT) are vying for less and less available state revenue funding, CDOT will need to expand the strategic analysis to more of a triple bottom line approach where funding allocation decisions are made based upon the overall benefit of the transportation network to the Colorado's economy, society and the environment as opposed to an analysis based entirely on condition based levels of service.

The results of the strategic analysis are the outcomes for various alternative investment strategies (Figure 4). Outcomes are reported in terms of the key performance measures used during the analysis through slider tools and graphic reports in dTIMS CT. The alternative investment strategies can include changes in total funding or the distribution of that funding in different budget categories and in different asset groups.

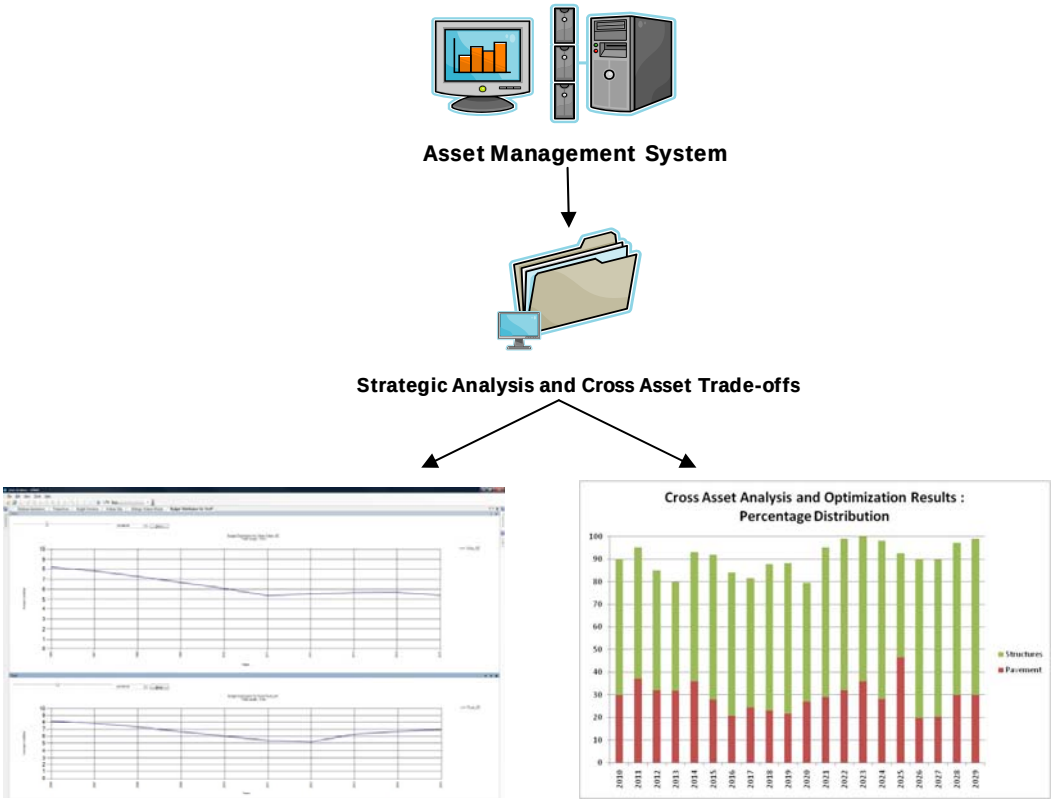


Figure 4: Asset Management Strategic Planning

2.4.2 Tactical Level

At the tactical level (B in Figure 3) the asset group analysis process begins with strategies, policies, directives and allocated resources resulting from the strategic analysis. Quite simply, the strategic level sets the level of service to be attained and the available dollars to be used to attain the set levels. After that, the tactical asset management groups can develop their respective asset management plans including their own strategies, objectives, performance measures and analysis models to develop the asset group program.

Within CDOT, the asset groups, for the most part, have a tactical level asset management system or initiatives in place to develop or acquire systems for asset groups without a current system. Within the proposed implementation for CDOT, some assets may require a tactical level management analysis to be completed in dTIMS CT prior to those assets being included within the strategic analysis. For example, Fleet management does not currently utilize a management system analysis so the tactical level analysis is being proposed to be developed in dTIMS CT prior to the Fleet being included within the strategic analysis. As can be seen in the systems view of the AMS, the AMS includes the functionality to complete an asset group analysis for individual assets groups as well as the ability to analyze across asset groups.

2.5 The AMS from A Systems Viewpoint

As discussed in the previous sections, the approach to asset management available in dTIMS CT is a top down / bottom up approach. When looking at the actual asset management analysis implementation in dTIMS CT, that approach necessitates loading the data and models from the tactical asset management systems into dTIMS CT for the strategic analysis. These data and models can then be supplemented with strategic level performance measures for the strategic analysis.

In a typical tactical asset management system analysis such as a PMS (Figure 5), the data is integrated together within the respective management system. Once the data is aggregated for analysis; maintenance, preservation, rehabilitation and replacement strategies for the assets are generated and then various "what-if" budget scenarios are optimized to determine outcomes for the various budget scenario resources and budget category distributions.

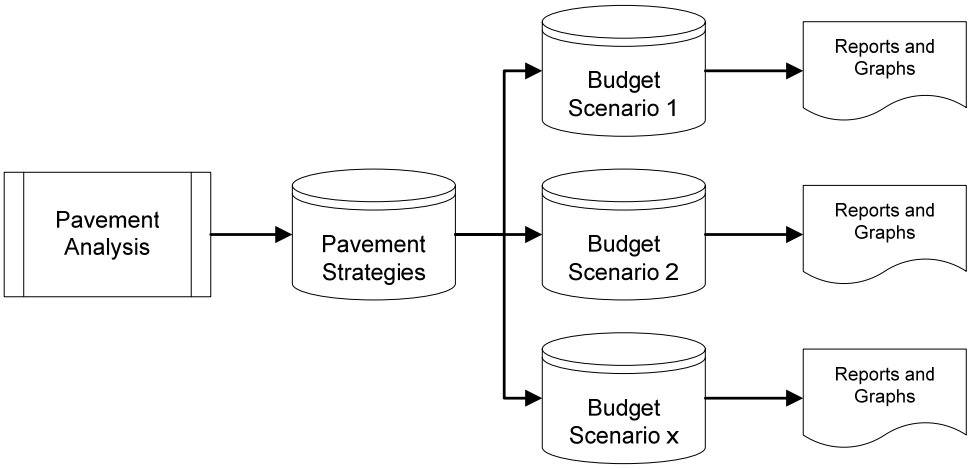


Figure 5: Typical Tactical Asset Management System Analysis

When the agency is satisfied with the results of the analysis and no more changes to the analysis parameters (key performance models, deterioration rates, treatment costs, etc.) are required, the results of the analysis for the selected budget scenario are then used to form the first-cut maintenance and rehabilitation plan for the asset and are used to generate projects for review and scoping prior to inclusion in the Statewide Transportation Improvement Plan (STIP). The built in dTIMS CT reports and graphs are also used to report expected outcomes based on the budget amounts and distributions contained within the budget categories for any of the key performance measures included within the analysis.

In a strategic asset management analysis (Figure 6), data and models are imported from the respective asset groups and integrated together. Then for each asset group included within the analysis, strategies are generated in dTIMS CT (if necessary) or the strategies are imported (if available) from the respective tactical level asset management system and then the cross asset analysis and strategic analysis module slider tools are used to determine funding needs based on the outcomes from the actions analyzed (Figure 6).

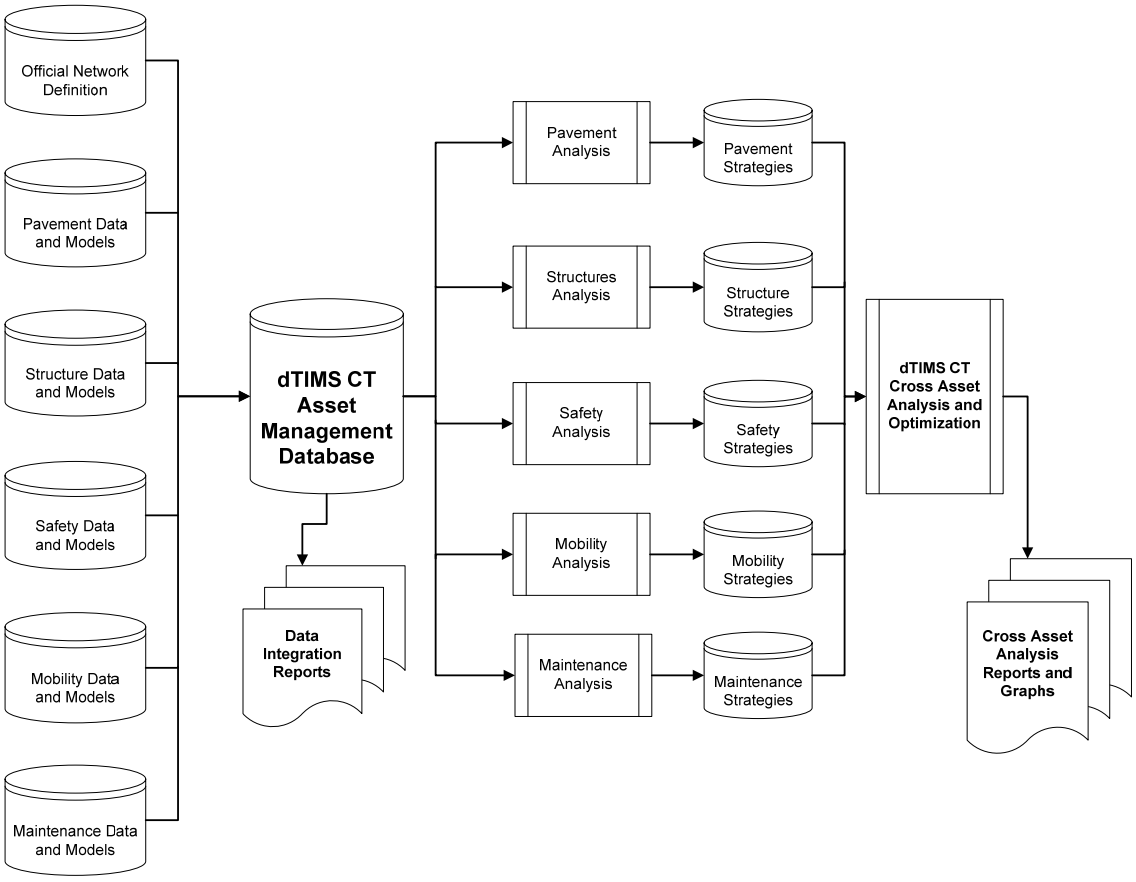


Figure 6: Typical Strategic Asset Management Analysis

Figure 6 displays the typical system framework for the strategic analysis being proposed at CDOT. Data and models are imported from the tactical level asset management system so that strategies can be generated in dTIMS CT and the economic trade-off analysis can be completed.

2.6 The AMS Analysis

The flexibility of dTIMS CT as an asset management system enables an agency to determine the level of analysis sophistication for each asset being analyzed and configure that level of sophistication within dTIMS CT through the extensive flexibility of the analysis parameters. The following subsections will discuss the

different types of analysis available within dTIMS CT so that these can be expanded for CDOT specific asset groups later in this report.

2.6.1 Asset Specific Analysis

In an Asset Specific Analysis, individual maintenance, preservation, rehabilitation and replacement strategies are generated and optimized for each asset in the asset group. This is the most sophisticated form of analysis available within dTIMS CT as it considers each asset individually and outcomes for the network are based on the optimized strategies for each of the individual assets included within the analysis. CDOT's PMS implemented in dTIMS CT uses an asset specific analysis where each pavement section is analyzed separately and the results summarized for the network based on maximizing the benefit to the network as a whole during the optimization.

In an asset specific analysis users can customize the level of sophistication of this analysis through the analysis parameters which can be completely customized for each asset. These parameters include:

- Performance measures (condition, use, classification)
- Deterioration models (site specific, family, deterministic, probabilistic)
- Treatments models (maintenance, preservation, rehabilitation, replacement)
- Treatment costing models
- Treatment trigger models
- Treatment reset and impact models
- Budget and Analysis parameters

For assets that currently do not have a tactical level management system (such as CDOT Fleet assets), the initial asset specific analysis can be configured with basic

models and basic parameters and then incrementally developed and enhanced over time to increase the level of sophistication of the analysis and the accuracy of the results.

2.6.2 Remaining Life Analysis

In a Remaining Life Analysis, all assets are analyzed individually based upon the age of the asset. The age of the asset increases each year and treatments and strategies are generated based upon the age only. In the future, a simple remaining life analysis can easily turn into an asset specific analysis as condition assessments and model development occurs.

2.6.3 Categorized Grouped Asset Analysis

In a categorized grouped asset analysis, assets are not analyzed individually but grouped into condition categories and analyzed by category. Assets are grouped into categories of Good, Fair and Poor and then simple aggregated deterioration rates, by quantity or by percentage, are used to deteriorate the assets from one condition category to the next. Treatments are configured to move a percentage of assets from one category to another category and optimization selects the best percentage to move each year based on the available budget. The higher the budget amount the higher the percentage of the assets that can be rehabilitated or replaced each year.

2.6.4 Grouped Asset Analysis

In a grouped asset analysis, assets are analyzed for replacement strategies only and all assets are analyzed in one group. dTIMS CT optimizes the number of assets that can be replaced each year with higher budget amounts increasing the

number of assets that can be replaced each year and decreasing the time it take to replace all of the assets.

2.6.5 Level of Service Budget Analysis

Maintenance activity budgeting typically works on level of service grades in relation to available funding. When this analysis is configured in dTIMS CT, each of the activities are loaded into dTIMS CT by area (region / maintenance section / planning area) and treatments generated to maintain each of the different levels of service over the analysis period. Optimization then is used to prioritize the activities and areas based on the available budget supplied to the optimization.

3. Implementing dTIMS CT for Strategic Analysis at CDOT

This section of the report will examine the implementation of dTIMS CT for Strategic Analysis at CDOT and outline for each asset group the resources needed to complete the initial implementation of the assets in dTIMS CT and maintenance of the asset management system going forward.

3.1 A Note About Data

Implementing the AMS within dTIMS CT will add new technology to the existing capabilities of CDOT for analysis and optimization. The purpose of the AMS is to increase capabilities for strategic analysis and optimization by leveraging data and models in existing systems and not to replace any existing systems.

In order for the strategic analysis to be successful within the AMS, data and models from existing management systems must be loaded into dTIMS CT for analysis. Where possible, data will be supplied by DTD's Information Management Branch through the IRIS database and imported into dTIMS CT. When required asset data is not contained within the IRIS database, dTIMS CT will link to existing systems (through ODBC and data transformation services) where possible and when linking is not possible, data exports and data imports will be completed.

3.2 Initial Asset Management System Configuration

As a starting point, the current CDOT PMS will be used for the initial configuration of the Asset Management System. The PMS databases will be used for defining the current CDOT network definition and for the initial pavement management analysis component of the strategic analysis.

Deighton envisions that the strategic analysis using slider based tools and the cross asset analysis and optimization will be completed based on condition and levels of service only and will not include factors for the triple bottom line. These additional factors can be developed in future phases of the strategic analysis.

As other assets are added to the asset management system, additional perspective tables (data tables) will be added and the analysis configured as necessary, depending on the type of analysis being performed for each asset.

Once the initial configuration is completed, CDOT can then move forward to developing the data and models necessary to enhance the strategic analysis so that additional performance measures are considered.

The resource estimates (in hours) necessary for the initial AMS configuration and setup of dTIMS CT are shown in Table 1.

Task	Description	Deighton Staff Resources	Planning Staff Resources	Information Technology Resources	Pavement Management Resources
1.1	Deliver PMS to Deighton	0	0	2	2
1.2	Configure AMS based on CDOT PMS	64	0	0	0
1.3	Software Installation and Database Configuration	6	6	2	0

1.4	dTIMS CT Training	34	92	2	0

Table 1: Initial AMS Configuration Resources

The 92 hours for training consists of training for two users for 34 hours and 8 additional staff for 2 hours for an executive overview of the AMS.

Annual database maintenance includes shrinking and compacting the databases as well as backup / restore and disaster recovery archiving.

3.3 Integrating Pavement Management within the AMS

Pavement management planning and programming at CDOT begins with the integration of collected data within the DOT. The data is loaded and processed by the pavement management group over a two to three month time period culminating in a set of analysis sections to analyze in dTIMS CT.

Before the pavement management analysis is completed, the integrated data is used to calculate RSL and to calculate site-specific performance models and default family curves to use within the PMS analysis.

The pavement management analysis is generally completed using 4 different draft analysis results as follows:

- First Draft - Used to verify pavement type data and other data as well as adding completed projects that HQ is unaware of;
- Second Draft - Used to gather more feedback regarding projects and analysis and is reviewed internally only.

- Third Draft - Internal HQ and External Region review of the recommendations. Changes to curves and RSL values can be made at this time.

- Final Draft - Regions can make minor changes to the final list of projects, but CDOT Policy Memo 10 specifies the project match that must be attained by the regions with respect to the recommendations coming out of HQ.

As the Pavement Management System will form the basis of the AMS and is implemented in dTIMS CT already, very little initial work must be done and yearly maintenance will be minor.

The current CDOT network definition is maintained and updated within dTIMS CT by the pavement management staff on an annual basis and this definition will be loaded into the AMS when the update cycle by the pavement management staff is complete.

Required data from the PMS will also be loaded annually into the AMS for the pavement analysis component within the AMS. Changes to analysis parameters will also need to be maintained between the two systems. These analysis parameters include treatment costs, treatment triggers and deterioration models.

Task	Description	Deighton Staff Resources	Planning Staff Resources	Information Technology Resources	Pavement Management Resources
2.1	Configure PMS within AMS	40	32	0	32
2.2	Annual Network Updates to PMS Data	0	40	0	40
2.3	Annual Updates to PMS Models	0	32	0	32

Table 2: Pavement Management Integration Resources

Once implemented in dTIMS CT for Asset Management, the strategic analysis module (slider tools) can be utilized as well as the cross asset analysis and optimization functionality for funding needs and resource allocations.

3.4 Integrating Bridge Management within the AMS

Bridge Management at CDOT is completed through the use of manual inspections and semi-automated processes using PONTIS and other software packages.

Data collection and processing of bridge inspection data culminates in the NBI update report submission to the Federal Government in April of each year. Once the Federal Submission is completed Staff Bridge completes the planning and programming process for delivering the "Select List" and the "Allocation Program Report" to the CDOT Regions where final planning and programming is completed.

Projection Reports on system condition are completed using a custom model developed in Excel based on the Age of the Structures and based on the Average Replacement Age. The report assumes that all bridges will be replaced according to current code and projected capacity and geometric needs. The projection report specifies replacement and rehabilitation and does not include preventive maintenance.

Within the AMS, Deighton is proposing to initially implement the Remaining Life and Replacement model as currently implemented within the Excel Calculations performed by Staff Bridge.

Once the initial implementation is complete, CDOT may want to investigate using dTIMS CT for analyzing the structures at the component level (Deck, Superstructure and Substructure) or at the element level to aid in making funding allocation decisions and to aid in making planning, preventive maintenance, and programming recommendations to the CDOT Regions.

The resource estimates for the initial configuration of the Bridge assets in the AMS are as follows:

Task	Description	Deighton Staff Resources	Planning Staff Resources	Information Technology Resources	Staff Bridge Resources
3.1	Develop Data Extraction Routines and data import routines	40	40	16	40
3.2	Configure Remaining Life Analysis for Bridges within AMS	100	40	0	80
3.3	Annual Network Updates to Bridge Data	0	8	8	8
3.4	Annual Updates to Bridge Models	0	40	0	40

Table 3: Bridge Management Integration Resources

Once implemented in dTIMS CT for Asset Management, the strategic analysis module (slider tools) can be utilized as well as the cross asset analysis and optimization functionality for funding needs and resource allocations. The remaining life analysis could also be expanded to include preventive maintenance and rehabilitation recommendations based on age of the structure once the initial replacement has been completed.

3.5 *Maintenance Levels of Service*

Maintenance Levels of Service budgets and targets are based upon 9 different Maintenance Program Areas (MPAs) and 15 Maintenance Sections consisting of 9 maintenance sections and 6 traffic areas.

Objectives and budgets are set at the activity level with the expectation that the Sections meet target LOS and Budgets at the MPA Level. There are 9 MPAs spread across the 15 Maintenance Sections which would then require an analysis of 135 elements.

Budget processing begins in August of each year and usually ends 8 to 10 weeks later in October. MPAs are assigned grades (A+ through F-) and MLOS staff calculates the budget amount to maintain each grade.

In order to integrate the MLOS budgeting into dTIMS CT, Deighton will implement a Level of Service Budgeting Analysis in dTIMS CT with data provided from MLOS staff at the Section Level. A sample of the data (major grades only) supplied by MLOS staff is shown in Table 4 for the Greeley Maintenance Section:

Section	MPA	LOS	Budget	LOS	Budget	LOS	Budget	LOS	Budget	LOS	Budget
Greeley Maint.	100	F	$ 1,199,768.87	D	$ 1,480,128.53	C	$ 1,826,002.09	B	$ 2,252,698.72	A	$ 2,779,104.98
	150	F	$ 6,260,611.38	D	$ 7,273,792.68	C	$ 8,450,941.43	B	$ 13,359,900.88	A	$ 55,101,638.32
	200	F	$ 1,512,030.12	D	$ 1,756,728.40	C	$ 2,041,027.16	B	$ 2,371,335.29	A	$ 2,755,098.54
	250	F	$ 978,929.18	D	$ 1,137,353.44	C	$ 1,321,416.17	B	$ 1,535,266.56	A	$ 1,783,725.25
	300	F	$ 1,430,481.86	D	$ 1,644,388.11	C	$ 1,892,911.71	B	$ 4,275,183.25	A	$ 5,828,937.28
	350	F	$ 761,141.87	D	$ 830,383.11	C	$ 911,548.55	B	$ 1,296,021.48	A	$ 2,759,913.68
	400	F	$ 3,875,450.39	D	$ 4,502,630.97	C	$ 5,231,310.84	B	$ 6,077,916.07	A	$ 7,087,800.79
	450	F	$ 1,577,924.76	D	$ 1,945,824.40	C	$ 2,399,694.12	B	$ 2,959,623.25	A	$ 3,650,395.51
Section Total			**$ 17,596,338.43**		**$ 20,571,229.64**		**$ 24,074,852.07**		**$ 34,127,945.50**		**$ 81,746,614.35**

Table 4: MLOS Budget Data for Greeley Maintenance Section

The analysis will be configured so that dTIMS CT will enable each activity and maintenance section to be maintained at each grade each year. The budgets supplied during the funding needs analysis and the asset trade-off analysis level optimization within the AMS through the slider tools and the cross asset analysis and optimization tools will then determine the outcomes for each section and program area. Once the analysis is complete, the budgets and goals for each Activity and Section can be transformed into the pavement management sections for reporting along specific corridors and for coordination with pavement management recommendations.

The resource estimates for the implementation of the MLOS service budget analysis in the AMS are as follows:

Task	Description	Deighton Staff Resources	Planning Staff Resources	Information Technology Resources	MLOS Staff Resources
4.1	Configure Level of Service Budget Analysis within AMS	120	32	0	32
4.2	Annual Network Updates to MLOS Data	0	32	0	32
4.3	Annual Updates to MLOS Models	0	24	0	24

Table 5: MLOS Integration Resources

3.6 ITS Management

ITS assets are managed using inventory and warehouse facilities provided within CDOT's SAP environment. Much like Staff Bridge, ITS relies on data

extracts and manual processes to develop Capital Replacement Programs and Capital Replacement Budgets.

Implementation of the ITS assets within dTIMS CT for funding allocations and cross asset trade-offs will be similar to the bridge implementation within dTIMS CT where a remaining life analysis will be used.

Average replacement life for ITS assets can be determined using data from the SAP database, manufacturers' guidelines and staff expertise and implemented for each asset in dTIMS CT. An example of the information that can be obtained out of the SAP Equipment Master Data which will be used to develop replacement life for each asset is shown in the following figure:

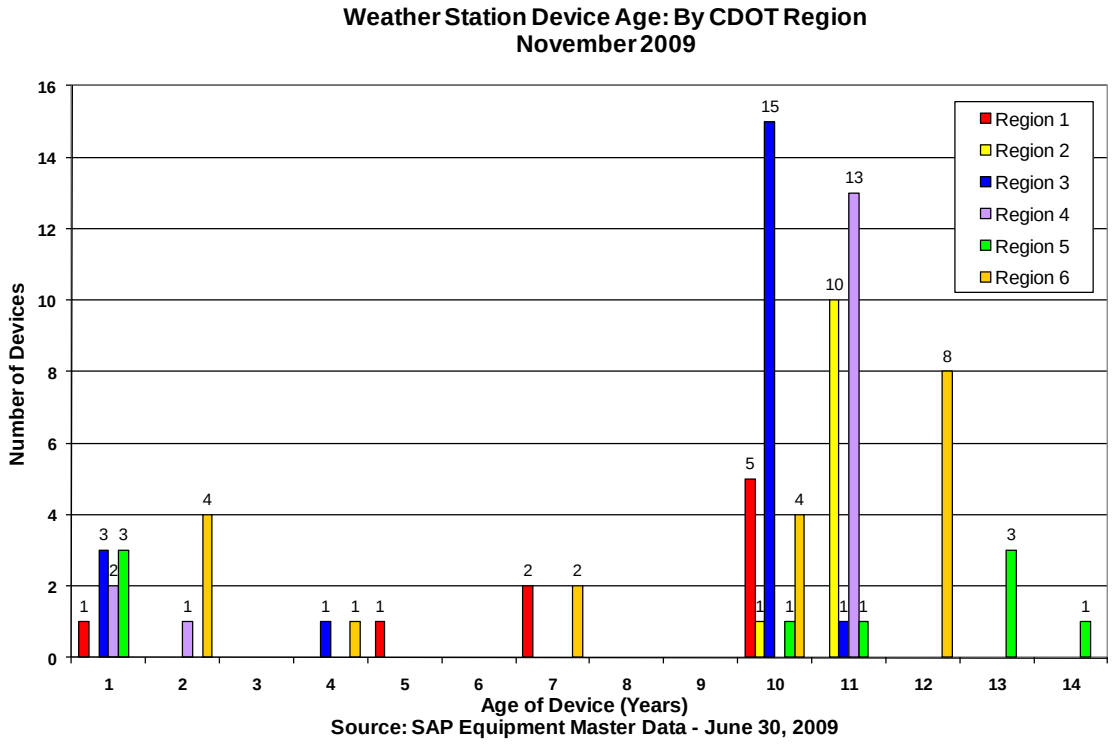


Figure 7: Example Device Age Report from SAP Equipment Master Data

The resource estimates for the initial configuration of the ITS assets in the AMS are as follows:

Task	Description	Deighton Staff Resources	Planning Staff Resources	Information Technology Resources	ITS Staff Resources
5.1	Develop Data Extraction Routines and data import routines	40	0	16	0
5.2	Configure Remaining Life Analysis for ITS assets within AMS	100	24	0	24
5.3	Annual Network Updates to ITS Data	0	8	8	8
5.4	Annual Updates to ITS Models	0	16	0	16

Table 6: ITS Asset Integration Resources

3.7 Fleet Management

During the initial framework development meetings, Deighton briefly discussed the implementation of Fleet Assets within dTIMS CT. Deighton believes that the implementation of the Fleet Assets within dTIMS CT could be used to help demonstrate savings in annual operating and maintenance costs.

Using an analysis similar to the Remaining Life analysis proposed for bridges and ITS assets with the addition of maintenance cost and availability data, dTIMS CT can help illustrate the savings in maintenance costs and downtime by replacing an aging fleet.

The resources to configure the Fleet assets in dTIMS CT are as follows:

		Deighton Staff	Planning Staff	Information Technology	Fleet Staff

Task	Description	Resources	Resources	Resources	Resources
6.1	Develop Data Extraction Routines and data import routines	40	0	16	0
6.2	Configure Fleet Remaining Life Analysis for Fleet Assets	120	24	0	24
6.3	Annual Network Updates to Fleet Data	0	8	8	8
6.4	Annual Updates to Fleet Models	0	16	0	16

Table 7: Fleet Asset Integration Resources

3.8 Initial Asset Management Analysis

Once the assets have been selected for the initial implementation and configured within dTIMS CT, the strategic analysis parameters will need to be configured within dTIMS CT. When the parameters are configured, the analysis can be executed and the analysis results reported.

The resource estimates for configuring the initial strategic analysis within dTIMS CT are as follows:

Task	Description	Deighton Staff Resources	Planning Staff Resources	Information Technology Resources
7.1	Configure Analysis Sets and Budget Scenarios for Strategic Analysis	32	64	0
7.2	Configure Strategic Analysis Module	16	64	0
7.3	Configure Cross Asset Analysis and Optimization Module	16	40	0
7.4	Execute the Strategic Analysis, test, and refine parameters as necessary	56	40	0
7.5	Report Results and produce implementation final report	120	80	0

Table 8: Fleet Asset Integration Resources

3.9 Annual Asset Management Analysis

Once the analysis has been configured within dTIMS CT, Planning Staff will then be responsible for the annual tasks of loading data, updating parameters, running the analysis and producing the reports for resource allocation and asset trade-offs.

The nature and complexity of any requests from internal sources (Budget and Finance, Planning, etc.) and the timing and current stage of the planning cycle within CDOT will determine the amount of analysis runs that are completed within the AMS.

In the initial stages of the AMS, the strategic analysis module and the cross asset trade-offs will be based on the condition of the assets and the benefits and costs of maintaining those conditions without consideration of other factors.

In the future, other factors such as those previously mentioned (environmental, economical, and societal factors) may need to be developed to make more accurate resource allocation decisions and the annual maintenance requirements of the AMS may change as new data is added to the system and new models developed. The data required for the initial analysis exists in the systems where data is linked or extracted, but if new data is to be gathered and collected against existing assets, that data will need to be stored within the AMS or within the respective management system for the underlying asset.

Initially Deighton estimates the annual maintenance and analysis resources required for the AMS as follows:

		Deighton Staff	**Planning Staff**	**Informatio n**

Task	Description	Resources	Resources	Technology Resources
8.1	Updating Strategic Analysis (slider tools) parameters	0	40	0
8.2	Updating Cross Asset Analysis and Optimization parameters	0	40	0
8.3	Executing the Analysis	0	200	0
8.4	Extracting Analysis Results for Reports	0	40	0
8.5	Database Maintenance	0	24	24
8.6	Extended AMS Support	120	0	0

Table 9: Annual Asset Management Maintenance and Analysis Resources

4. Conclusions

4.1 Analysis Outcomes

When the analysis is configured for each asset within dTIMS CT, CDOT can execute both a tactical analysis for each asset and a strategic analysis where the asset can be included with other assets implemented within dTIMS CT.

At the tactical level, the AMS will generate, optimize and report recommended strategies for each asset group consisting of multiple treatments over the time period being analyzed. For each asset group, the type of analysis being implemented and the level of that implementation will determine the type of tactical level strategies that result. As an example, consider the implementation of the bridge assets in dTIMS CT. If the bridges are implemented as initially envisioned within this document, the initial analysis will output funding needs and strategies based on bridge replacements only. In future phases, preventive maintenance, minor repair and major rehab treatments could be added to the bridge analysis to increase the sophistication of the analysis.

The Strategic Analysis capabilities of dTIMS CT are dependent upon on the tactical asset management analysis completed for each asset group.

The strategic analysis module (slider tools) specifies various budgets for each tactical level asset group analysis and then presents the results in graphical format with sliders for the user to adjust funding and see the impacts of funding decisions.

The Cross Asset Analysis and Optimization functionality of dTIMS CT optimizes all of the strategies from the tactical level analysis at once as a whole. The more sophisticated the tactical level analysis, the more sophisticated the results of the strategic analysis.

The following table summarizes the type of analysis implemented for each asset group and indicates the level of detail that will be included in the initial phases of the AMS implementation.

Asset Group	**Type of Analysis**	**Level of Service Only**	**Preventive Maintenance**	**Rehab or Repair**	**Replacement**
Pavement	Asset Specific Analysis		Current	Current	Current
Bridge	Asset Specific - Remaining Life		Future	Future	Current
MLOS	Level of Service	X			
ITS	Asset Specific - Remaining Life				X
Fleet	Asset Specific - Remaining Life				X

Table 10: Asset Analysis Summary: Current Phase and Future Phases

As the implementation of the AMS continues in the future and as tactical asset management systems are implemented for the Bridge, ITS and Fleet assets, the level of detail in terms of available treatment recommendations should increase.

4.2 *Summary of Resource Estimates*

In order to present a total view of the resource estimates required to implement that initial version of the AMS, the resource estimates from the previous section have been amalgamated together and presented in the following table.

Initial Asset Management System Configuration									
Task	**Description**	**Deighton**	**Planning**	**IT**	**Pavement**	**Bridge**	**MLOS**	**ITS**	**Fleet**
1.1	Deliver PMS to Deighton	0	0	2	2	0	0	0	0
1.2	Configure AMS based on CDOT PMS	64	0	0	0	0	0	0	0
1.3	Software Installation and Database Configuration	6	6	2	0	0	0	0	0
1.4	dTIMS CT Training	34	92	2	0	0	0	0	0
Configuring Pavment Assets within AMS									
Task	**Description**	**Deighton**	**Planning**	**IT**	**Pavement**	**Bridge**	**MLOS**	**ITS**	**Fleet**
2.1	Configure PMS within AMS	40	32	0	32	0	0	0	0
2.2	Annual Network Updates to PMS Data	0	40	0	40	0	0	0	0
2.3	Annual Updates to PMS Models		32	0	32	0	0	0	0
Configuring Bridge Assets within AMS									
Task	**Description**	**Deighton**	**Planning**	**IT**	**Pavement**	**Bridge**	**MLOS**	**ITS**	**Fleet**
3.1	Develop Data Extraction Routines	40	40	16	0	40	0	0	0
3.2	Configure Remaining Life Analysis for Bridges	100	40	0	0	80	0	0	0
3.3	Annual Network Updates to Bridge Data	0	8	8	0	8	0	0	0
3.4	Annual Updates to Bridge Models	0	40	0	0	40	0	0	0
Configuring MLOS Assets within AMS									
Task	**Description**	**Deighton**	**Planning**	**IT**	**Pavement**	**Bridge**	**MLOS**	**ITS**	**Fleet**
4.1	Configure Level of Service Budget Analysis	120	32	0	0	0	32	0	0
4.2	Annual Network Updates to MLOS Data	0	32	0	0	0	32	0	0
4.3	Annual Updates to MLOS Models	0	24	0	0	0	24	0	0
Configuring ITS Assets within AMS									
Task	**Description**	**Deighton**	**Planning**	**IT**	**Pavement**	**Bridge**	**MLOS**	**ITS**	**Fleet**
5.1	Develop Data Extraction Routines	40	0	16	0	0	0	0	0
5.2	Configure Remaining Life Analysis for ITS	100	24	0	0	0	0	24	0
5.3	Annual Network Updates to ITS Data	0	8	8	0	0	0	8	0
5.4	Annual Updates to ITS Models	0	16	0	0	0	0	16	0
Configuring Fleet Assets within AMS									
Task	**Description**	**Deighton**	**Planning**	**IT**	**Pavement**	**Bridge**	**MLOS**	**ITS**	**Fleet**
6.1	Develop Data Extraction Routines	40	0	16	0	0	0	0	0
6.2	Configure Fleet Remaining Life Analysis for Fleet	120	24	0	0	0	0	0	24
6.3	Annual Network Updates to Fleet Data	0	8	8	0	0	0	0	8
6.4	Annual Updates to Fleet Models	0	16	0	0	0	0	0	16
Initial AMS Analysis Configuration									
Task	**Description**	**Deighton**	**Planning**	**IT**	**Pavement**	**Bridge**	**MLOS**	**ITS**	**Fleet**
7.1	Configure Analysis Sets and Budget Scenarios	32	64	0	0	0	0	0	0
7.2	Configure Strategic Analysis Module	16	64	0	0	0	0	0	0
7.3	Configure Cross Asset Analysis and Optimization	16	40	0	0	0	0	0	0
7.4	Execute the Strategic Analysis, test	56	40	0	0	0	0	0	0
7.5	Report Results and produce final report	120	80	0	0	0	0	0	0
Initial Implementation Resources		**944**	**802**	**78**	**106**	**168**	**88**	**48**	**48**
Subsequent Annual AMS Analysis Resources									
Task	**Description**	**Deighton**	**Planning**	**IT**	**Pavement**	**Bridge**	**MLOS**	**ITS**	**Fleet**
8.1	Updating Strategic Analysis	0	40	0	16	16	16	16	16
8.2	Updating Cross Asset Analysis and Optimization pa	0	40	0	16	16	16	16	16
8.3	Executing the Analysis	0	200	0	0	0	0	0	0
8.4	Extracting Analysis Results for Reports	0	40	0	0	0	0	0	0
8.5	Database Maintenance	0	24	24	0	0	0	0	0
8.6	Extended AMS Support	120	0	0	0	0	0	0	0
Subsequent Year Implementation Resources		**120**	**344**	**24**	**32**	**32**	**32**	**32**	**32**

Table 11: Summary of Resource Estimates

4.3 Project Phases

In keeping with the Incremental Development Methodology, Deighton recommends a Phased Approach be adopted for the implementation of the Strategic Asset Management analysis at CDOT. This approach will enable CDOT to include assets within the strategic analysis slowly and not entirely at once. Deighton envisions the following phases:

Project Phases		
1	Initial Implementation and Configuration of 3 Assets	2010 - 2011
2	Implementation of Remainign Assets	2011 - 2012
3	Implementation of Tripple Bottom Line Measures and KPIs	2012 - 2013

Table 12: Project Phases