

Transportation Asset Management Case Studies

Presented by



U.S. Department
of Transportation
**Federal Highway
Administration**

D A T A I N T E G R A T I O N

The Virginia Experience





Note From the Director

The Federal Highway Administration Office of Asset Management is aggressively promoting a different way for transportation agencies to distribute their resources among alternative investment options. This new way of doing business, referred to as "Asset Management," is a strategic approach to maximizing the benefits resulting from the expenditure of agency resources.

For any transportation agency, the progression toward effective Asset Management practices will involve a range of activities. These endeavors will differ from State to State. For example, some agencies will pursue a data integration strategy in order to ensure comparable data for the evaluation of investment alternatives across different asset classes. Others will move to deploy economic analysis tools to generate fact-based information for decision-makers. Still others will want to integrate new inventory assessment methods into their decisionmaking processes.

Much can be learned from those who are readying their organizations for Asset Management. To spark the exchange of information, we initiated a series of case studies last year, focused on agencies that are leading the way. The series involves four tracks: data integration, economics in Asset Management, the Highway Economic Requirements System–State Version, and life-cycle cost analysis. Through the years, we will add new State reports to each of the tracks and create new tracks addressing other facets of Asset Management, such as change management and performance measurement.

On behalf of the Office of Asset Management, I am pleased to add this case study on data integration to the series. We believe the case studies will help agencies meet the challenges of implementing Asset Management programs.



David R. Geiger
Director, Office of Asset Management
May 2004

Note to the Reader

The Transportation Asset Management Case Study Series is the result of a partnership between State departments of transportation and the Federal Highway Administration (FHWA) Office of Asset Management. FHWA provides the forum in which to share information, and the individual States provide the details of their experiences. For each case study report, FHWA interviewed State transportation staff, and the resulting material was approved by the State. As such, the reports rely on the agencies' own assessment of their experience. Readers should note that the reported results may or may not be reproducible in other organizations. ■

Hampton Roads
Harbor Bridge-
Tunnel on I-64



Executive Summary

Virginia has the third-largest State-maintained highway system in the country. State legislation requires the Virginia Department of Transportation (VDOT) to fund the maintenance of this system before funding capital improvements. To ensure the best possible maintenance investment decisions, VDOT initiated a comprehensive maintenance and operations business process reengineering (BPR) effort in 1995. This effort laid the groundwork for what is now widely known as Transportation Asset Management.

Based on recommendations from the BPR effort, VDOT initiated the development of infrastructure decision-support systems and a large data collection program, referred to as the Inventory and Condition Assessment System (ICAS).

In 2002, the Virginia General Assembly passed legislation that requires VDOT to incorporate the principles of asset management into its maintenance and operations practices and to submit biennial reports that document performance targets and compare actual conditions to those targets. This legislation was one of the main drivers for VDOT to modernize its effort to develop an integrated asset management system.

VDOT's new data integration strategy has enabled it to make significant progress in the development of decision-support tools and the integration of asset management data without waiting for the details of the final Asset Management System. This system may evolve, for example, into a suite of individual tools or into a large, enterprise resource management system. If all relevant data are cleansed, normalized, and stored in a single data repository, VDOT will be able to export data to any future system.

In 2003, VDOT completed the Needs-Based Budget Request Module of the Asset Management System. This module enables VDOT staff to develop maintenance budgets that reflect the current condition of its assets. The module has already made an impact through its ability to provide information to decisionmakers on VDOT's executive board. Based on these initial success stories, VDOT is moving forward with additional components of what will eventually be a fully integrated infrastructure Asset Management System. VDOT expects to realize a 15 percent return on its investments in the system by 2006. ■

AGENCY FACTS

VDOT is responsible for the third-largest, State-maintained highway system in the country.

Virginia's transportation system is a vital element in the State's economy, providing the safe and efficient movement of people and products throughout the Old Dominion.

VDOT is responsible for building, maintaining and operating the State's roads, bridges, and tunnels. It also provides funding for airports, seaports, rail, and public transportation through the Commonwealth Transportation Board. Virginia has the third-largest, State-maintained highway system in the country, just behind North Carolina and Texas. This system is divided into the following categories:

- **Interstate**—1,118 miles of 4-to-10-lane highways that connect States and major cities.
- **Primary**—8,050 miles of 2-to-6-lane roads that connect cities and towns with each other and with interstate highways.
- **Secondary**—47,582 miles of local connector or county roads, generally numbered 600 and above. Two counties, Arlington and Henrico, maintain their own county roads.
- **Frontage**—333 miles of frontage roads.

VDOT is legislatively mandated to fund the maintenance of Virginia's existing transportation assets before funding capital improvements. VDOT's commitment to maintenance is apparent: nearly \$1 billion of its \$3.4 billion annual budget is allocated for maintenance activities. These resources have enabled VDOT to maintain its highway network in relatively good condition—as a result, approximately 80 percent of interstate and primary highways are in good condition.

VDOT is a decentralized organization with approximately 10,000 employees located in nine districts and the central office. The agency recently completed a major reorganization effort that established a new Asset Management Division, a combination of the previous Maintenance and Equipment Divisions. The new division also assumed responsibility for roadside development and outdoor advertising activities that were previously performed by the Environmental Division. The Asset

Management Division is now responsible for operating and maintaining all of VDOT's assets, including the highway network, right-of-way, rest areas, buildings, and equipment.

SETTING THE STAGE

What Does VDOT Have?

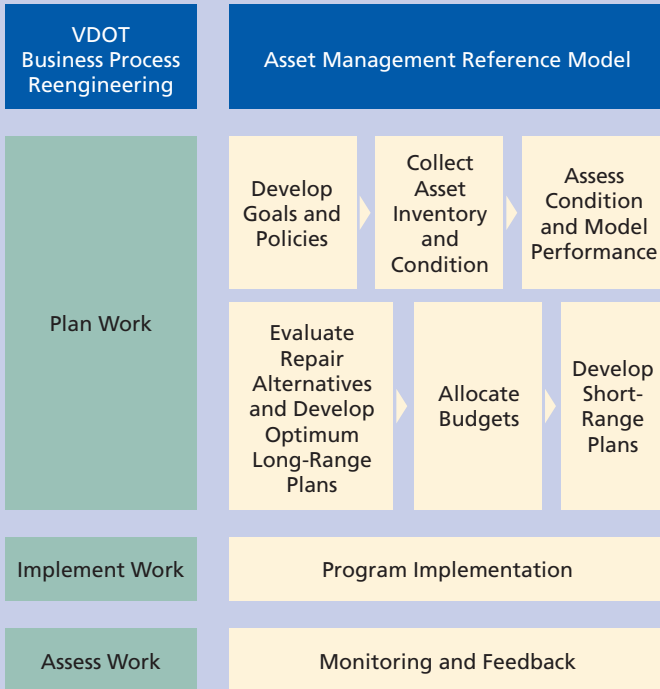
VDOT initiated a comprehensive maintenance and operations business process reengineering (BPR) effort in 1995. At that time, VDOT did not have a complete picture of the State's transportation infrastructure and its condition. Consequently, the agency was unsure that it was making the best possible investments, was unable to evaluate the results of strategies and investments, and was in a weak position to advocate maintenance policies and plans. The initial review in 1995 recommended several improvements:

VDOT's approach to asset management is focused on the maintenance and operations of the existing highway system.

- Produce a comprehensive inventory
- Strive for the “best” investment strategies
- Manage assets throughout their life cycle rather than by stage
- Optimize investments across all assets
- Move toward a more proactive maintenance approach
- Develop a consistent approach to statewide service delivery

These BPR recommendations reflected asset management principles even before the term was widely adopted by the transportation community. Since 1995, VDOT's approach to asset management has evolved and has been fully institutionalized. Virginia law now defines “asset management” as “a systematic process of operating and maintaining the system of highways by combining engineering practices and analysis with sound business practices and economic theory to achieve cost-effective outcomes.” The following figure illustrates the major functions of VDOT's current asset management model in the context of the organizational structure of the original BPR.

Virginia Department of Transportation (VDOT) New Asset Management Framework



In support of recommendations from the BPR, VDOT initiated the development of infrastructure decision-support systems and a large data collection program, referred to as the Inventory and Condition Assessment System (ICAS). The ICAS pilot is the primary mechanism for collecting and assimilating asset data in VDOT. It provides decisionmakers with current and accurate information on the location and condition of all VDOT assets other than pavements and bridges; VDOT uses a pavement management system and a bridge management system to store and manage data on these two assets.

Through the BPR, VDOT envisioned the management of assets through their entire life cycle—condition assessment, planning, alternatives evaluation, project development, and implementation. Decision-support tools would provide resource management capabilities, such as attributing financial, equipment, and human resource investments to specific groups of assets. These systems would also enable VDOT to manage the use of its assets, and provide an integrated approach for managing information such as land use permits, hauling permits, routing traffic flow, capacity, impact, trip, and travel analysis. To expand these requirements across all of the agency’s functional areas, VDOT attempted to implement a large, off-the-shelf, enterprise resource planning (ERP) system. However, the cost and time required to fully implement this system exceeded VDOT’s expectations, and the ERP project was eventually shelved due to budget constraints.

What Does VDOT Want?

In 2002, the Virginia General Assembly passed legislation that requires VDOT to incorporate the principles of asset management into its maintenance and operations practices and to submit biennial reports to the Commonwealth Transportation Board. The reports must present (a) performance targets that can be achieved over the next two years based on the anticipated maintenance budget; and (b) the actual condition of VDOT’s assets as compared to the expected condition.

To comply with this recent legislation, build on the foundation for improvement established during the initial BPR effort, and address agency priorities established by a new administration, VDOT has modernized its effort to develop an integrated asset management system. This system will provide VDOT with a complete inventory and condition assessment of its high value assets (e.g., pavements, bridges, roadside features) and enable decisionmakers to develop strategic and operational performance targets for each asset type.

An integrated asset management system will allow VDOT to manage assets throughout their life cycle.

HOW IS VDOT GETTING THERE?

Overall Approach

VDOT began development of the Asset Management System by revisiting the original requirements of the BPR. In contrast to the single off-the-shelf system envisioned in early efforts, VDOT staff divided the BPR requirements into a series of components that could be developed individually and integrated incrementally. The new Asset Management System has six key components:

- Condition Assessment Module
- Needs-Based Budget Request Module
- Planning and Scheduling Module
- Work Order and Accomplishment Module
- Inventory Module
- Analysis Tools Module

As part of previous information technology (IT) initiatives, VDOT has developed agency-wide architecture standards and metadata. VDOT plans to adhere to these standards for all future decision-support systems, including the Asset Management System. Adherence to these standards will help ensure that all of VDOT's decision-support tools are eventually fully integrated.

Data Integration Process

Work on the first two components of the Asset Management System—the Condition Assessment Module and the Needs-Based Budget Request Module—began in 2003. In developing these modules, VDOT followed a formal systems development process designed to provide consistency between the individual development efforts and ensure that data required for the Asset Management System is fully integrated. This two-phase process consists of the following steps:

Phase I

- Document and review systems that will provide source data, and interview system owners
- Investigate alternatives for the system's data repository and reach consensus on the best approach

- Develop metadata (i.e., identify all data items required for the system and the key characteristics of each item)
- Design the data repository
- Map required data from its source to its eventual location in the data repository
- Develop data queries and routines required to export data from other systems and convert them for use in the system
- Populate the data repository

Phase II

- Connect the data repository to the new software tool
- Connect the data repository to other systems and data repositories as required

From an organizational point of view, key conditions would be required for the success of VDOT's development effort:

- Upper management will support the business objectives of the project and the creation of a new system to meet these objectives.
- Project managers will be provided with the budget, staff, and IT resources necessary to initiate and complete the development process.
- All stakeholders and eventual system users from the districts and headquarters will cooperate with the project team throughout the development efforts.

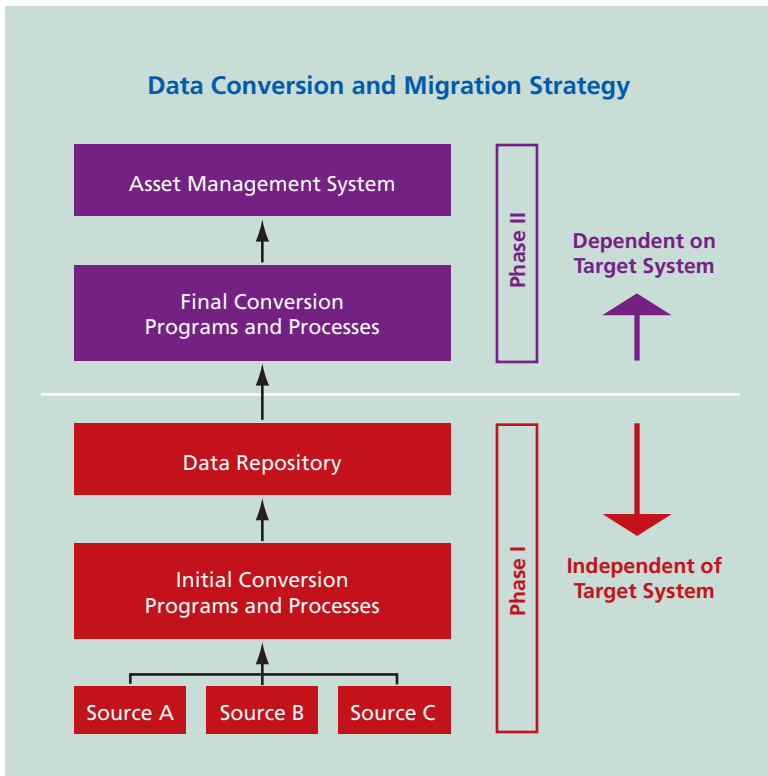
Data Integration Strategy

The following figure illustrates VDOT's new data integration strategy. Relevant data from various systems are being processed and imported into a data repository. VDOT is proceeding with this work without fully understanding the details of the "target" Asset Management System. This work is independent of what the final system will look like. For example, the final Asset Management System may consist of a series of individual tools, or it

VDOT's new data integration strategy has enabled it to make significant progress without waiting for the details of the "target" Asset Management System to be finalized.

may resemble the comprehensive enterprise resource planning system once proposed. It is anticipated that if all relevant data are cleansed, normalized, and stored in a single data repository, VDOT will be able to export data to any future system.

This strategy provides VDOT with tremendous flexibility in designing the final Asset Management System. The design will continue to evolve based on organizational requirements, funding availability, and emerging technologies. In the meantime, this approach has enabled VDOT to make significant progress both in the development of individual maintenance decision-support tools and in the integration of maintenance data, without waiting for the final details of the comprehensive Asset Management System to be developed.



Needs-Based Budget Request Module

VDOT's Needs-Based Budget Request Module enables users to develop maintenance budgets that reflect the current condition of its assets. In the context of the data integration strategy described above, this system is not the target system: it is an interim module that relies on data stored in the data repository. The architecture of the Needs-Based Budget Module consists of three tiers:

- The **Data Tier** resembles a mini data warehouse. The system relies on inventory and condition data stored in VDOT's pavement management system, bridge management system, and condition assessment module. Relevant data are exported from these systems, transformed, and loaded into an Oracle database. The database uses a data model that is optimal for performing queries. The database stores both raw data and results generated by the application.
- The **Application Logic Tier** includes an analytic engine that processes business rules and models stored in the database. This design enables VDOT to update its rules and models without modifying the application. For some types of assets (e.g., pavement, pavement markings, guardrail, culverts, grass), the application includes models and generates results based on these models. For other types of assets (e.g., bridges and traffic signals), the system reports results that have been pre-calculated by other systems.
- The **Front-End Tier** provides users with an interface to the system. A Web-based application enables users to perform queries, modify business rules and model assumptions, and generate reports based on the results.

Linear Referencing System

A linear referencing system (LRS) provides the foundation for VDOT's data integration efforts and has three functions:

- Defining location in space and on the network (i.e., spatial referencing)
- Defining connectivity of assets to the network and of parts of the network to itself (i.e., establish topology)
- Defining temporal versions of the spatial and attribute data to support planning scenario evaluations

For the ICAS project, VDOT adopted the standards and methods recommended in the National Cooperative Highway Research Program (NCHRP) 20-27 Project on Linear Referencing Systems Implementation. The Highways by Exor program was selected for the ICAS project in part because it meets the requirements of the NCHRP 20-27 data model, and was therefore able to perform the linear data management and temporal data management required by ICAS. VDOT has since implemented the ESRI transportation data model known as UNETRANS, which incorporates elements of NCHRP 20-27 but is also flexible. UNETRANS includes temporal data versioning, which reduces the need for a proprietary program such as Highways by Exor.

IS IT WORTH IT?

By 2006, VDOT expects a 15 percent return on its investments in the Asset Management System.

According to its project charter, the Asset Management System will “enable VDOT to more efficiently and effectively manage roadway assets.” Based on the results of a cost-benefit analysis of the Asset

Management System, VDOT expects a 15 percent return on investment by 2006. This rate of return is possible because the system will enable VDOT to implement its management strategies:

- Maintain accurate and current inventory and condition data
- Develop statewide maintenance budget requests based on needs identified during a formal condition assessment process
- Plan and prioritize maintenance and operations work based on an understanding of available resources
- Improve the cost-effectiveness of maintenance and operations activities
- Determine the impact of deferred maintenance strategies on network performance and resulting needs
- Maintain a record of work on an asset throughout its life cycle
- Automate aspects of the current maintenance management function that are currently performed manually

In addition, implementation of the Asset Management System will help bring VDOT into compliance with recommendations developed through

an audit performed by Virginia's Joint Legislative Audit and Review Commission and a study conducted by the Virginia Auditor of Public Accounts.

WHAT HAS VDOT LEARNED?

Organizational Lessons

- Throughout large IT initiatives, it is important to maintain the ability to adapt to organizational change. Over the course of the Asset Management System initiative, VDOT's approach to delivering IT projects evolved from outsourcing work to performing it in-house. If VDOT had been unable to ramp up its in-house IT staff, development of the Asset Management System would not have been possible.
- Improving an organization's data resources and system capabilities requires a long-term commitment. The Asset Management System requires data of a specified accuracy to be collected and updated periodically. Future success of the system is possible only if VDOT is able to fund and staff the required data collection program.
- Data needs to be consistent across an entire agency. VDOT is a decentralized agency with staff in nine districts and the central office. These districts have geographic, organizational, and technological differences that had to be accounted for when developing the data collection program required to populate the Asset Management System.
- Retention of key staff is critical for the success of large IT and business process reengineering efforts. Work on VDOT's maintenance management improvements has spanned nearly 10 years. Over that time, the agency has acquired significant institutional knowledge. VDOT has been able to retain a critical mass of IT and business process staff who are familiar with the effort.
- Influence external to a DOT can provide significant impetus for change. A series of audits by statewide and legislative organizations increased scrutiny of VDOT's maintenance program, validated business process improvements, and strengthened the need for an integrated Asset Management System.
- The Asset Management System project is a joint effort between VDOT's Asset Management Division and Information Technology Applications Division. A high level of cooperation is required for this effort because the staffs are separated both physically and functionally.

Process Lessons

- It is important for IT staff to understand the fundamentals of the business practices that will be supported by an IT effort. In the past, VDOT's IT staff have been spread among the agency's functional divisions but have recently been consolidated into the Information Technology Applications Division. The experience that IT staff members gained while previously working in the Maintenance Division has made a significant impact on the Asset Management System project.
- Pilot-level rollout programs provide the opportunity to test the validity of a system before undertaking a large-scale implementation. VDOT initially implemented ICAS in three counties—rural, urban, mixed rural/urban. Based on the results of this pilot program, data collection processes and technologies were fine-tuned for use throughout the rest of the State.
- A key to the success of the Needs-Based Budget Module was the availability of a standard project management process. Project staff followed VDOT's protocol for software development projects throughout the effort.
- VDOT is following an incremental process that delivers a critical piece of the Asset Management System project every 90 days. This approach has helped project staff maintain buy-in for the system and minimize the risks inherent in any system development project.
- VDOT has followed an “outside-in” design approach, which emphasizes the use of prototypes that can be refined through an iterative process.
- Project staff have developed feedback mechanisms that will enable managers and field staff to validate critical aspects of the system's design. This type of feedback is important in order to keep the Asset Management System directly in line with business process requirements.

Technical Lessons

- VDOT is a large organization with approximately 10,000 employees and an annual maintenance budget of close to \$1 billion. This environment drives the need for robust decision-support systems. However, large systems and the efforts required to develop them can

be cumbersome. An incremental approach in which a large system is split into a series of individual modules can increase the overall success of IT projects.

- It is important to maintain flexibility in terms of how a set of functional requirements can be met. Often there is no single path for success in large IT projects.
- Managing an asset throughout its life cycle is a complicated process with many dimensions. VDOT's attempt to standardize the process through a customized off-the-shelf product was only partly successful. Even so, the process provided some valuable lessons in determining the most appropriate role for the off-the-shelf solution vis-à-vis other custom solutions. Given the broad range of Asset Management activities in a DOT, it is difficult for any one product to provide a comprehensive solution.
- In large IT efforts, it is important to maintain an application orientation. Focusing on tangible products for which benefits can be easily communicated is important for maintaining widespread acceptance and managing expectations of the end users.
- VDOT continues to utilize Highways by Exor, but in a more limited role than originally envisioned. Based on this experience, VDOT has learned important lessons:
 - Choose the software based on the data model
 - Fully understand the data model
 - Define business requirements and rules in relationship to the data model
 - Start with the smallest possible asset data sets
 - Prototype business requirements and push them through the system during testing.
- Maximizing the utilization of existing systems and hardware is necessary for the rapid implementation of new systems. Significant cost and time savings can be achieved by developing inexpensive data exchanges that pull data from existing systems.
- Data-driven system architectures can minimize the need for software code to be modified as business processes evolve.

WHAT'S NEXT?

VDOT completed the first two components of the Asset Management System—the Condition Assessment Module, and the Needs-Based Budget Request Module—in 2003. Based on the success of this initial effort, the agency is developing the Planning Module and will continue with the development of a new Work Order and Accomplishment Module. It is anticipated that VDOT will complete its integrated Asset Management System by the end of 2004.

Looking beyond this next milestone, VDOT will work to integrate the Asset Management System with the statewide geographic information system. Also, to date, the scope of VDOT's Asset Management System has been focused on maintenance and operations. It is anticipated that upon completion of the work in these areas, the system may be further enhanced to provide additional decision support for VDOT's equipment program.

VDOT has learned not to rely on a single-vendor solution, but to pursue open standards as much as possible. The agency is interested in implementing standards that may emerge from the National Spatial Data Infrastructure Framework Project with respect to the transportation data layer, and in coordinating with the I-95 Corridor Coalition regarding a regional multistate transportation network, at least for the interstate and State routes. VDOT is also embracing Web-based services, and view Internet map servers as an integral part of its enterprise architecture. In the future, VDOT anticipates that more services will be accessed remotely via the Internet; including data uploads from local handheld computers, as well as the ability to query data and applications in the field, perhaps via wireless communications. The rapid changes in technology require a flexible, open-systems approach. VDOT is conscious of the need to take small steps to take advantage of these improvements within the context of an enterprise data architecture.

Closing Thoughts

VDOT has already used results from the Needs-Based Budget Request Module of its Integrated Management System in presentations to its executive board. Although there is much work to be done, VDOT's ability to get meaningful information into the hands of decision-makers has solidified support for further enhancements and provided a glimpse of the power of a fully developed Asset Management System.

Further Information

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Credits and Sources

Code of Virginia 33.1-23.02 (2002).
Commonwealth of Virginia. *Interim Balanced Score Card Project Evaluation for the Asset Management System Project*, Version 2.0 (Dec 2003).
Joint Legislative Audit and Review Commission of the Virginia General Assembly. *Adequacy and Management of VDOT's Highway Maintenance Program* (2000).
Sami, Naveed. *Asset Management Data Integration at the Virginia DOT—Technology Issues*. Presentation slides (Jan 2004).
Virginia Auditor of Public Accounts. *Annual Report 2003* (Oct 2003).
Virginia DOT. *Asset Management System Project Charter*. Version 2.1 (Sept 2003).
———. *VDOT Completes Most Extensive Reorganization Ever*. Bulletin—the VDOT online employee newspaper (Jan/Feb 2003).

Photographs courtesy of Virginia Department of Transportation
Front cover: I-81 near Arcadia, Botetourt County
Inside front cover: Pocahontas Parkway, Route 895; toll connector between I-95 and I-295, Greater Richmond



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