REPORT OF THE
VIRGINIA DEPARTMENT OF TRANSPORTATION ON

THE STUDY OF APPROPRIATE METHODOLOGIES FOR DETERMINING LIFE-CYCLE COSTS FOR HIGHWAY SYSTEM MAINTENANCE AND FACILITIES

TO THE GOVERNOR AND
THE GENERAL ASSEMBLY OF VIRGINIA

SENATE DOCUMENT NO. 10

COMMONWEALTH OF VIRGINIA
RICHMOND
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PREFACE

Senate Joint Resolution (SJR) 21 was passed during the 1994 General Assembly Session. This resolution requests that the Commonwealth Transportation Commissioner study appropriate methodologies for determining life-cycle costs for highway system maintenance and facilities. Recommendations are to be developed for improving the effectiveness, efficiency and economy of that maintenance.

The Virginia Department of Transportation (VDOT) provided an interim report on SJR 21 to the 1995 Session of the General Assembly in Senate Document Number 33.

This report documents the final response on life-cycle cost analysis of VDOT's maintenance systems and facilities as required by SJR 21.

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EXECUTIVE SUMMARY

Life-cycle cost analysis (LCCA) refers to an economic evaluation or methodology for determining present and future costs of an investment action. Principles of engineering economics such as interest rates and cash flow analysis are applied to proposed investment alternatives and are used to determine what the costs for the life of the project will be, beginning with design and culminating with salvage.

The Virginia Department of Transportation's (VDOT) value engineering (VE) program has applied LCCA on numerous projects since value engineering became a permanent program in 1986. Sixty VE studies were conducted in FY 94-95 on construction and maintenance projects resulting in a savings of over $18 million. Although not all the VE projects or items within the projects were deemed candidates for LCCA, the VE program routinely evaluates all projects for functional value and the desired life-cycle of the product.

VDOT's Integrated Maintenance Management System (IMMS) project is currently reengineering all maintenance business processes, including the practices for the Pavement Management System, Bridge Management System, drainage, roadside, traffic items, and special facilities (rest areas, tunnels, etc.). A major element of this reengineering is the redefining of the levels of service for maintenance assets and the assignment of conditions, costs, and expected life. Specific LCCA strategies and asset alternatives are also being evaluated by IMMS. Examples of these reengineering processes include the analysis of statewide asset rating procedures based on professional standards, the evaluation of budget and allocation processes driven by performance targets, and the identification of performance targets driven by customer requirements. In addition, strategies will include analyses of "repair versus replacement" of assets, "make versus buy" decision models, customer service planning, and quality management principles built into performance approaches.

The Virginia Department of Planning and Budget (DPB) is responsible for the policies and procedures governing the funding of new or renovated state buildings. Although VDOT's Administrative Services Division manages and monitors the capital outlay program, DPB's approval is required for all facilities and buildings in the Six-Year Capital Outlay Plan. A copy of this response and a copy of SJR 21 will be forwarded to DPB for their comments on LCCA of buildings.

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INTRODUCTION

Senate Joint Resolution 21 requests that the Commonwealth Transportation Commissioner investigate ways that Virginia's transportation systems and facilities might better implement the principles of life-cycle cost analysis. In particular, the resolution asks that the Virginia Department of Transportation (VDOT) look at methodologies for determining life-cycle costs for its assets and provide recommendations as to how these principles might best be applied to improve the efficiency and effectiveness of VDOT's maintenance practices.

Life-cycle cost analysis (LCCA) is defined as "an economic evaluation of all current and future costs associated with investment alternatives" (see Appendix C). It is a method for identifying an action with the lowest present value of costs over its lifetime. LCCA is particularly useful in assessing agency costs and documenting the tradeoffs in expending extra dollars on maintenance versus capital improvements. The Department's Management Services Division has been using LCCA on many of its projects in its value engineering (VE) program for over 10 years. The VE program became permanent with the assignment of a full-time coordinator in 1986 and is responsible to conduct studies on all projects with estimated construction costs exceeding $2 million. Most of these projects involve construction and maintenance studies, including highway construction projects at the field inspection stage and maintenance projects and plans.

VDOT's Integrated Maintenance Management System (IMMS) project will play a pivotal role in the assessment of methodologies that are appropriate for life-cycle cost analysis in highway maintenance systems and programs. Reengineering efforts are currently being applied to all facets of maintenance operations and activities by IMMS' Business Process Reengineering (BPR) teams. These BPR teams are assessing and developing a statewide asset inventory rating process, assigning budgets and allocations based on performance targets, analyzing "repair versus replacement" of assets, and "make versus buy" decision models. Reengineering includes the fundamental rethinking of all major maintenance business processes, and interfaces with other VDOT systems including the Pavement Management System (PMS), Bridge Management System (BMS), Financial Management System, and others.

The administration and funding of highway maintenance buildings are under the purview of VDOT's Administration Services Division (ASD) using the approval policies and procedures issued by the Virginia Department of Planning and Budget (DPB) for the Six-Year Capital Outlay Plan. Through the use of criticality surveys, a numerical weighted scale, and DPB instructions, ASD prepares the Six-Year Capital Outlay Plan for VDOT and submits it to DPB for approval. Although LCCA is not formally conducted in the capital outlay process, LCCA techniques and strategies such as project costs, client needs, analysis of alternatives, and cost saving efficiencies are documented and justified.

VDOT's Maintenance Division has taken lead responsibility for this study. Supplemental information and support were received from the IMMS' Manager, Booz, Allen & Hamilton Inc., IMMS BPR Teams, the VE Sections of Management Services Division and Richmond District, Administrative Services Division's Capital Outlay Section, and Maintenance Division's Pavement Management and Bridge Management Sections.

INTEGRATED MAINTENANCE MANAGEMENT SYSTEM

For many years VDOT recognized the increasing demand for maintenance work and the limitation on the availability of increasingly sophisticated services. Maintenance managers and engineers will have to consider maintenance with options other than the canned approaches developed in the 1960s for generic maintenance management systems. A vitalized new vision will be necessary to effectively and efficiently respond to increasing maintenance needs and public expectations; increasing policies, procedures, and mandates; and the ever-growing transportation inventories.

In 1992 VDOT initiated the Integrated Maintenance Management System (IMMS) project to assess strategically and qualitatively the current business environment within the agency. The purpose of the assessment was to reengineer the VDOT environment with the overall mission of applying fundamental rethinking and significant redesigning of business processes to implement dramatic improvements in performance. A private consultant, Booz, Allen & Hamilton Inc., was hired and several teams of VDOT maintenance managers and engineers were formed in order to respond more effectively to taxpayers' needs and to merge and amend the increasing systems of heterogeneous, stand-alone processes that did not communicate with each other. IMMS is a project to design and implement streamlined and effective business processes and systems to support them. Through the IMMS project, the concept of a coordinated and integrated approach to system development was initiated to avoid duplication of effort through effective information sharing.

Globally, the IMMS project will have far reaching impacts now and into the 21st Century for Virginia's citizens. Its need and significance has been identified in the following documents:

- **Virginia Connections: Strategic Plan for Transportation.** Initiated by Virginia Secretary of Transportation Robert E. Martínez in 1994 to develop a vision for the future direction of transportation in the Commonwealth. The IMMS project is reported in the Action Plan of *Economic Development & Markets* section to "support decision-making based upon inventory, condition, and life-cycle cost analysis."
- **National Cooperative Highway Research Program Report 363 *Role of Highway Maintenance in Integrated Management Systems*** (Transportation Research Board, 1994). This report outlines a framework for integrating maintenance management with other highway and administrative management functions.
- **Management Information Systems 2000.** Developed by VDOT, it included significant enhancements to existing systems that will permit VDOT to meet its obligations and concentrate its attention and resources on those needs that are essential to carry out its mission. The plan also calls for consideration and implementation of a number of closely related initiatives to utilize technology in order to function more efficiently and productively. One of these major initiatives is IMMS.

IMMS Goals

IMMS' overall goals are to integrate stand alone applications, provide a common architecture, and share homogeneous data that is easily understood and applied by users. Plans and informed decisions can then be made consistently with the benefit of multiple programs and systems. The IMMS is also expected to help planners and managers stay current with policies and procedures, and interactively provide guidelines and implementation. The IMMS will be an integrated, automated system that employs current technology to provide users accurate information that is relevant, reliable, and timely.

To accomplish improvements in the quality and value of the services provided, an interactive method is being used to transform and streamline the way VDOT conducts its maintenance business. The Integration Team, represented by senior level thought leaders, is responsible for coordinating improvements, directing the reengineering of critical maintenance program processes, and implementing the redesigned processes. This interactive method, called Business Process Reengineering (BPR), involves comprehensive analyses of the way VDOT business is currently conducted, followed by the reengineering of these practices and processes by strategic improvements. Business practices are being carefully reviewed and processes streamlined to meet the challenges of today and tomorrow. These BPR reviews include quantitative measures, including life-cycle cost analysis and benefit/cost analysis.

The IMMS program is comprised of five BPR Teams who are responsible for reengineering VDOT's maintenance business processes. These five BPR teams are:

- **Inventory & Condition Assessment**—identifies asset inventories, assesses conditions of inventories, and maintains/updates inventory systems
- **Maintenance Programs Planning**—develops procedures for prioritizing maintenance work and allocates funding
- **Maintenance Operations**—develops policies and procedures for scheduling best ways to accomplish work, and measures performance
- **Emergency Management**—reviews current incident response plans and improving, integrating, and developing, where necessary, procedures to ensure consistency and sufficient capability to manage emergencies and other incidents
- **Technical Implementation Review**—documents the processes of existing automated information systems including Maintenance Management Budgeting System and Hauling Permits

Three BPR teams will have direct linkage to life-cycle cost analysis—Inventory & Condition Assessment, Maintenance Programs Planning, and Maintenance Operations. BPR team members, comprised of managers and engineers from the field and Central Office, are currently assessing, developing, and redesigning new business processes to assess performance targets for all transportation assets based on condition of inventory and customer expectations. This reengineering will include the identification of assets and assessment of their condition and life. It also includes user costs, development of financial plans and budgets, and positive response to customer needs. The IMMS BPR process addresses life-cycle cost analysis by determining the needs of the assets and effectively and efficiently responding to those needs by ensuring that tax dollars are spent wisely in the condition and life of assets at the right time. Life-cycle costing and benefit/cost analysis will be key enablers of the reengineered processes.

LIFE-CYCLE COST ANALYSIS

Life-cycle cost analysis is a method for identifying maintenance actions with the lowest costs over the lifetime of assets. It is particularly useful in assessing agency costs and illuminating the tradeoffs in expending extra dollars on maintenance versus capital improvements. Life-cycle cost calculations take into account the "time value of money", the rate that equates the satisfaction a person gets from receiving a dollar tomorrow (say 1 year from now) and receiving a dollar today. The time value of money also reflects the "opportunity cost", defined as the rate of return one might earn in the next best use of funds.

Benefit/cost analysis is frequently used in transportation analysis to compare the benefits and costs resulting from various project alternatives. The costs are often **life-cycle costs**, where the time streams of benefits and costs are converted to discounted present values as explained above. The benefits are frequently expressed in terms of savings in user costs—accidents, travel time and motor vehicle operating costs. When facilities have multiple project alternatives, incremental benefit/cost analysis can efficiently find a near-optimal set of alternatives that maximize the total benefit achieved.

The fundamentals of life-cycle cost analysis (LCCA) are listed in Appendix C.

VDOT STATUS ON LCCA

VDOT began an active value engineering (VE) program in the mid-1970's. At that time, the program consisted of one or two 40-hour training workshops per year. The VE program became permanent within the Management Services Division (MSD) in 1986 when a full-time coordinator was assigned. Between 1986 and June 1990, VDOT conducted over 60 studies, with accepted value opportunities averaging savings of approximately 10% of the overall project costs.

During the 1990 session, the Virginia General Assembly passed House Bill 423, which added § 33.1-190.1 to the Code of Virginia. This section required that VDOT apply value engineering to any highway project costing more than $2 million. The new law was effective on July 1, 1990.

VDOT's VE program operates in five geographical regions, each with a Regional VE Coordinator. In the spring of each year, the VE coordinators identify potential study projects for the upcoming fiscal year. Types of studies include:

- Construction projects
- Maintenance projects
- Scoping stage studies
- Special studies

An important element in VE's investigation phase of engineering and design is life-cycle costs. MSD's Value Engineering Participants' Handbook states that in considering the value of an item or process, the "team should consider the overall, life-cycle cost of the item or process." The VE teams consider the following major factors when determining life-cycle costs:

- Expected life of item
- Construction (initial) cost
- Maintenance and operation cost
- Salvage value
- Discount rate

The different types of VE projects and studies are explained in detail in MSD's Value Engineering Program Administration Manual. The manual contains an "Exemption Clause" for maintenance projects that states:

> "Projects/contracts repetitive in nature, such as plant mix overlays, sign overlays, bridge painting, surface treatments, slurry seals, guardrail maintenance, pavement repairs, pavement markings, and epoxy or latex overlays do not lend themselves to VE study as the costs of such contracts are multiples of the same project. Projects of this repetitive nature will be Value Engineered as components of the VDOT Standards and Policies and Procedures Studies."

A good example of a LCCA project, conducted by VE, was the rehabilitation of I-64 over the Southern Branch of the Elizabeth River in the City of Chesapeake (BR-5A-94). The basic function of this project was to improve the efficiency of the existing double leaf bascule span bridge. Although a number of recommendations and suggestions resulted from the VE analyses, two recommendations were directly related to LCCA:

- Replace six neon traffic signs with six variable message signs, which resulted in total life cycle savings of $70,310
- Replace existing taillock motors, which resulted in a total life cycle savings of $8,820

VDOT's VE program continues to have successes each year. Its Annual Report for FY 1994-95 stated that "during the year, 54% of all opportunities presented to management were accepted, resulting in $18.6 million in savings and cost avoidance. This savings was 86 times the cost of maintaining the program within VDOT". This factor represented a 86:1 return on investment. A copy of VDOT's VE Annual Report is presented to each member of the General Assembly and others annually in the fall.

Intermodal Surface Transportation Efficiency Act

With the enactment of the Intermodal Surface Transportation Efficiency Act (ISTEA), which required the adoption of a comprehensive Pavement Management System and Bridge Management System, VDOT reexamined its PMS and BMS programs. The vision and goals of IMMS will greatly assist in the advancement of PMS and BMS programs by integrating program attributes and providing a common architecture for maintenance systems. Enhancements to PMS and BMS will include the history and type of construction, rehabilitation, and maintenance data. These enhancements will be consistent with ISTEA regulations. IMMS is also reengineering the physical features of the structure and roadway network and the processes used in collection, storage, and retrieval. This reengineering will include identification, location, number, cost data, referencing, type, dimensions, general and specific conditions, and other characteristics. Life-cycle costing or benefit/cost analysis is a critical link in these enhancements and reengineering processes.

Pavement Management System

VDOT recently awarded a contract to Pavement Management Systems Limited (PMSL) to develop a comprehensive and fully operational pavement management system that meets VDOT needs and ISTEA requirements. PMSL will provide their developed State Pavement Management System (SPMS) as the base system with customizations to meet VDOT's PMS needs. The current SPMS provides life-cycle cost analysis within the project level module. The network level analysis module provides partial life cycle cost analysis (i.e., salvage value is not calculated). Network salvage value is currently being expanded for use in PMSL's implementation in South Carolina and will also be investigated for VDOT's use.

In addition, the SPMS uses AASHTO approved site-specific prediction models for predicting the roughness and distress-based indices. This modeling approach evaluates the history of each analysis section to determine model coefficients specific to that section.

A routine for conducting Life-Cycle Cost Analysis (LCCA) is integrated within the PMS application. This provides a tool for the evaluation of maintenance and rehabilitation strategies that helps pavement management decision makers in selecting the best design alternatives. Thus, the primary objective of the LCCA tool is to provide a systematic process for comparing project level designs of new or rehabilitated pavements. The approach used for comparison is based on the benefit to cost ratio. This concept relies on the performance models to monitor the pavement condition over the forecasted life of each alternative and estimates their corresponding benefits and total service costs.

These analyses consider the deterioration of pavements based on available performance models and account for future conditions and costs to repair each pavement segment in selecting the optimum network work program. Performance models are used for each alternative to project the service life of various alternatives and the probability that various treatments are selected in the future, based upon a set of defined alternatives and life-cycle strategies including the probabilities of pavement deterioration, cost of each treatment, and a discount rate for evaluating the effects of future expenditures. The analysis identifies the least total life-cycle cost that meets the design life for the pavement. With this LCCA tool, objective analysis of various alternatives can be conducted to determine the optimum design that provides the highest benefit to cost ratio, which will provide the best improvement strategies for implementation.

Bridge Management System

The enactment of ISTEA gave impetus to the evolution of Pontis, a network-level tool to enhance VDOT's Bridge Management System (BMS). Pontis was developed under the Federal Highway Administration's Demonstration Project 71 with participation of six states. Shortly after its release in 1992, a panel of 13 states and one local agency was selected to beta-test the software and the bridge inspection procedures. Virginia was one of the beta-test states. Pontis version 3.0 was released on July 1, 1995 and incorporates dynamic, probabilistic models, and a detailed bridge database to predict maintenance and improvement needs, recommend optimal policies, and schedule projects within budget and policy constraints. VDOT, along with 43 other states in the nation, is currently implementing Pontis into its statewide BMS program.

Pontis provides bridge engineers and managers the capability to use benefit/cost analysis in decision making. Benefits are the value of taking actions to address preservation or functional improvement needs. The benefit of addressing preservation needs is defined in Pontis as the cost savings resulting from performing all recommended MR&R (maintenance, repair, and rehabilitation) work on a bridge in the current year versus postponing it for one period and then following the recommended actions for the condition that the bridge would be in at that time. Pontis also employs a Cost Matrix table that contains unit costs and benefits for improvement actions. These costs and benefits can vary for different combinations of average daily traffic, functional class, funding responsibility, and National Highway System status. They are used to estimate improvement costs at the network level. Optimization routines are then applied and used to select the best alternative MR&R or improvement strategies.

Comparing the bridge-level optimization and statistical profiles over time also makes it very straightforward to estimate prediction models. Pontis deterioration models consist of transition probabilities, which predict the probability that a given structural element in a given environment and condition state will remain in the current condition state or change to another state. As an example, if we know that in 1995 that a bridge had 12,336 linear feet of reinforced concrete floor beams in condition state 1 (no deterioration), which were in a moderate environment with no action taken, then we can in principle track the condition of the beams over time to see what it will be two years later. If 889 feet of these floor beams were in condition state 2 in 1997, then we can say that the transition probability from state 1 to state 2 is 889/12,336 or 7 percent. Given enough data over time, the life cycle of bridge structural elements, and collectivel the entire bridge itself and the entire bridge network system, can be determined and alternate remedial actions to correct structural deficiencies at the optimal time can be programmed and funded.

With the development of Pontis and other BMS improvements, VDOT will be able to enhance its BMS program by promoting strategic decision-making in bridge management policy, support the development and consistent application of cost-effective policies, find strategies that can maximize the benefit gained from a limited amount of funding, and develop the quantitative information necessary to produce and vigorously defend a healthy bridge program.

Other Maintenance Management Programs

VDOT's IMMS will not only facilitate the reengineering of PMS and BMS, but also other maintenance programs and activities such as pipes and drainage, roadside, traffic items, and special facilities (rest areas, tunnels, etc.). IMMS will assist VDOT to establish, update and maintain an inventory of maintainable items; plan, forecast, and budget resources; identify and schedule work; monitor and analyze outcomes; incorporate historical factors into future planning efforts; and develop a comprehensive program to continually review and update the business process. IMMS will not duplicate existing data bases or analytical software, but will improve automated access and interfacing with strategic and tactical enhancements to improve efficiencies and effectiveness in terms of performance targets.

In its reengineering processes, IMMS will analyze statewide asset rating procedures based on professional standards, evaluate budget and allocation processes driven by performance targets, and identify performance targets driven by customer requirements. Strategies will include analyses of "repair versus replacement" of assets, "make versus buy" decision models, customer service planning, and quality management principles built into performance approaches.

A major element of this reengineering is the redefining of the levels of service for maintenance inventories and the assignment of condition and costs. A draft working "Data Definition Table" is shown in Appendix B, which lists the six major categories of maintenance inventories into data items that are being reengineered by IMMS BPR teams. The six major categories are: pipes and drainage, roadside, pavements, bridges, traffic items, and special facilities. Asset maintenance actions in each category are identified as being primarily driven by project, repair/failure, condition, or prevention. Some are of course driven by a combination of factors. Performance targets for these categories are being identified to focus on asset life and condition. Each of these drivers are defined below:

- **Project Driven.** Work on an asset driven by work on associated assets, for example, paving project driving work to correct guardrail height or resurfacing project driving work to replace recessed pavement markers

- **Repair/Failure Driven.** Work on an asset driven by unpredictable events or accidents, for example, repair of damaged impact attenuators

- **Condition Driven.** Work driven by systematic assessment of asset conditions, for example, needed repair or replacement work found during bridge inspection ratings or pavement inspection ratings

- **Prevention Driven.** Work performed to pre-empt the need for repairs, based on predictable deterioration or failure rates, for example, replacement of traffic lights

Maintenance Buildings

VDOT's Administrative Services Division under the auspices of the Virginia Department of Planning and Budget is responsible for the administration of the capital outlay program. DPB approves the funding and construction/renovation of VDOT's buildings in VDOT's Six-Year Capital Outlay Plan.

The process for developing the prioritization criteria used in the capital outlay program's decision making matrix is an adapted version of the Delphi Technique, combined with the Nominal Group Technique. It consists of three steps and requires involvement from VDOT's Resident Engineers and District Administrators through two surveys. These steps are:

- **Needs Survey.** Survey the field for criteria currently used to prioritize projects, including safety, environmental issues, life-cycle issues and costs, impact of delays, existing condition of building, and other factors.

- **Criticality Survey.** Review the responses from the first survey for redundant or unclear responses. After a clear and comprehensive list is developed, the list will be distributed with survey questions on ranking the critical nature of each request.

- **Weighted Scale.** Evaluate each project under the assigned criteria and assign a weighted rating based on a qualitative scale and prioritize each project accordingly.

ASD uses the matrices, ratings, and information provided by the districts and Central Office to document and rate the statewide needs for the Six-Year Capital Outlay Plan. Using biennium instructions from DPB, building needs are addressed in terms of costs, benefits, and financing mechanisms. DPB's instructions for the 1994-96 biennium required that capital project requests include quantitative and qualitative information, including:

- **Project Justification.** Document how the project supports VDOT's programs in relevant current and projected activities in terms of the program's objectives, services, and clients.
- **Facility Information.** Document current and project program demands, including age and condition of facility, interruptions of services or backlogs of service, safety hazards to clients and employees, and future use of existing facilities.
- **Analysis of Alternatives.** Demonstrate different alternatives to explain why the proposal is the best alternative. Criteria includes what alternatives were considered (minimum of three), what factors were used in selection, and documented conclusion on the best alternative.
- **Project Costs.** Clearly detail costs and methodology for property, design fees, site development, demolition, and all associated costs, including funding source.
- **Facility Operating Budget.** Provide estimates for cost saving efficiencies to be derived as a result of the project with a comparison of the dollar amount of these savings in relation to the total cost of the project.

DPB's memorandum dated March 15, 1995, to budget officers of all state agencies stated that there were "significant concerns about the cost and accuracy of preplanning studies" for capital outlay projects. This memorandum continued, "In response to these findings, the General Assembly put language in the 1995 budget bill which gives the Executive some flexibility to make changes in the capital outlay process." This memorandum also included instructions for the preparation of the 1996-98 Biennium Capital Budget to more effectively define the size, scope, and cost of requested capital outlay projects. The revised instructions included the following items:

- A single submission instead of a two-tier budget submission
- Project definitions are not required for projects that DPB previously approved
- A multi-agency project team will be established early in the capital budget process
- Mandatory design meetings will be held early during the design phase
- More emphasis will be placed on long-term planning

In summary, the Virginia Department of Planning and Budget is ultimately responsible for the preparation of capital outlay projects, criteria, and requirements, including provisions for life-cycle costs analysis. VDOT will submit to DPB a copy of this final response to SJR 21 requesting their comments and recommendations, which will be implemented by VDOT in the Six-Year Capital Outlay process.

CONCLUSIONS and RECOMMENDATIONS

VDOT's IMMS initiative to reengineer and integrate all maintenance business processes will play a major role in responding to SJR 21. This reengineering will include the identification of assets and assessment of their condition and life, analysis of "make versus buy" and "repair versus replacement", identification of performance targets driven by customer requirements, and development of budgets. All these attributes of the IMMS BPR processes will directly address life-cycle cost analysis or benefit/cost analysis by determining the needs of the assets and effectively and efficiently responding to those needs by ensuring that tax dollars are wisely in assets at the right time.

VDOT's value engineering program is also a major factor in the response to SJR 21. VE teams routinely include the overall, life-cycle cost of an item or process in their investigation phase of engineering and design of construction and maintenance projects. Expected life of an item, construction cost, maintenance and operation cost, salvage value, and a discount rate are integral components in VE's life-cycle cost analysis (LCCA). Although not all VE studies are formal LCCA projects, the VE program in FY 1995 evaluated 74 studies that resulted in $18.6 million in savings and an 86 to 1 return on the investment.

Quantitative, analytical cost assessments will also be conducted by the two largest maintenance management programs in VDOT — pavements and bridges. VDOT's proactive responses to these management systems and the selection of a Pavement Management System consultant and the implementation of ISTEA/FHWA's Pontis for the Bridge Management System will ensure the proper cost analysis of assets and the optimal use of public funds.

The following recommendations will be implemented by VDOT:

- IMMS continue its proactive efforts to reengineer maintenance business process including asset identification, condition, and efficient funding analysis

- The Value Engineering program continue its analytical cost assessment of construction and maintenance projects and other projects deemed beneficial to LCCA

- The PMS and BMS programs continue their life-cycle cost and benefit/cost analyses

- A copy of this final report on SJR-21 be submitted to the Virginia Department of Planning and Budget for their response to life-cycle cost analysis of VDOT buildings

Appendix A—SENATE JOINT RESOLUTION Number 21

SENATE JOINT RESOLUTION NO. 21

Requesting the Commonwealth Transportation Commissioner to study appropriate methodologies for determining life cycle costs for maintenance of the Commonwealth's highway system and facilities and to develop recommendations for improving the effectiveness, efficiency and economy in the maintenance of its systems and facilities.

Agreed to by the Senate, February 14, 1994
Agreed to by the House of Delegates, February 25, 1994

WHEREAS, the costs of improving, operating and maintaining the nation's third largest highway system continue to increase even though the unit costs for improvement, operation and maintenance remain low; and

WHEREAS, the Virginia Department of Transportation has undertaken value engineering and other cost-saving initiatives to reduce the costs of improvement, operation and maintenance; and

WHEREAS, the Department of Transportation currently uses life cycle cost analysis in the development, comparison and selection of project alternatives for improvement projects and maintenance replacement projects; and

WHEREAS, the use of life cycle cost analysis has resulted in reduced costs for improvement and maintenance replacement projects; and

WHEREAS, the use of life cycle cost analysis in other areas of maintenance and operation planning and implementation may provide additional economies, efficiencies and cost savings; now, therefore, be it

RESOLVED by the Senate, the House of Delegates concurring, That the Commonwealth Transportation Commissioner be requested to study appropriate methodologies for determining life cycle costs for maintenance of the Commonwealth's highway system and facilities and to develop recommendations for improving the effectiveness, efficiency and economy in the maintenance of its systems and facilities. The Commissioner is further requested to adopt procedures that show the greatest potential for ensuring that the most cost-effective methods are used in highway and facility maintenance; and, be it

RESOLVED FURTHER, That the Commonwealth Transportation Commissioner report his findings to the Senate Transportation Committee and the House Committee on Roads and Internal Navigation prior to the 1995 and 1996 Regular Sessions of the General Assembly.

The Commonwealth Transportation Commissioner shall complete his work in time to submit an interim report in 1995, if appropriate, and a final report to the Governor and the 1996 Session of the General Assembly as provided in the procedures of the Division of Legislative Automated Systems for the processing of legislative documents.

Appendix B—Data Definition Table

Major Category	Data Items	Project Driven	Repair/Failure Driven	Condition Driven	Prevention Driven
Pipes and Drainage	Pipes, C.M. & Concrete		✪	✪	
	Box Culverts		✪	✪	
	Curb & Gutter		✪		
	Drop Inlet		✪	✪	
	Storm Drains		✪	✪	
	Ditches	✪	✪	✪	
	Underdrains		✪		
	Edge Drains		✪		
Roadside	Fence		✪	✪	
	Mowing/Litter				✪
	Landscaping				✪
	Brush Control				✪
	Sidewalks			✪	
	Entrances			✪	
	Historical Markers			✪	
	Retaining Walls			✪	
	Sound Barriers			✪	
	Traffic Barriers			✪	
Pavements	Shoulders	✪	✪	✪	
	Paved Lanes		✪	✪	
	Stabilized Lanes		✪		
Bridges	Deck			✪	
	Substructure			✪	
	Superstructure			✪	
	Paint			✪	
	Joints			✪	

✪ indicates that IMMS will reengineer this data item for this particular driver.

Appendix B—Data Definition Table, cont.

Major Category	Data Items	Project Driven	Repair/Failure Driven	Condition Driven	Prevention Driven
Traffic Items	Signals		✪		✪
	Signs		✪	✪	✪
	Pavement Messages	✪			✪
	Pavement Markings	✪			✪
	Pavement Markers	✪			✪
	Guardrail	✪	✪		
	Overhead Sign Structures		✪	✪	
	Traffic Detector Loops		✪		✪
	Impact Attenuators		✪		
	Highway Lighting		✪		
Special Facilities	Traffic Mngt. Systems		✪		
	Tunnels		✪	✪	
	Rest Areas			✪	
	Weigh Stations			✪	
	Ferries			✪	
	Parking Lots/Decks			✪	
	Bus Shelters		✪		
	Asphalt Tanks		✪	✪	

✪ indicates that IMMS will reengineer this data item for this particular driver.

Appendix C—FUNDAMENTALS OF LIFE-CYCLE COST ANALYSIS

LCCA is explained on page 10 of this report. It can also be described as "...an economic evaluation of all current and future costs associated with investment alternatives" (Federal Highway Administration's interim policy statement issued by the Federal Register in July 1994). A major factor in this evaluation is the process of conducting cashflow discounting. Three of the most often used methods are discussed in a National Highway Research Program (NCHRP) Synthesis of Practice 122 (Peterson, 1985). These are:

- **Present Worth.** The conversion of all present and future expenses to a base of today's total costs and comparing these costs with alternatives.
- **Annualized Expenses**. The conversion of all present and future expenses to a uniform annual cost. Smallest total annual cost is preferred.
- **Rate of Return.** The identification of the discount rate at which two different alternatives have annual costs or present worths that are equal. Requires the calculation of rates of return on a large number of projects and on alternatives within projects.

LCCA also requires an adequate treatment of discounted cashflow analysis involving *discount rate* and *analysis periods* used to affect this discounting:

- **Discount Rate.** The interest rate used to reduce future costs or benefits to present-day terms. Present and future costs and benefits need to be represented in equivalent annual costs. The discount rate should reflect the difference between the market interest rate and the inflation rate.
- **Analysis Periods.** Analysis periods cover life of facility and account for all foreseeable future actions. They include the real cost of capital and the opportunity costs of money invested.

In addition, NCHRP 122 suggests that the following cost factors are most relevant to analysis of state highways and facilities:

- **Design Costs** - includes materials, site evaluation, traffic analysis, engineering design, plans and specifications.
- **Construction Costs** - costs to construct in accordance with plans and specifications.
- **Maintenance Costs** - includes corrective and preventive maintenance (whatever it takes to maintain at a predetermined level-of-service).
- **Rehabilitation Costs** - rehabilitation or restoring to acceptable performance.
- **User Costs** - associated with increased vehicle operating and delay costs anticipated over the life of the facility. They will include those costs incurred by the user due to decreased levels of service, as well as for delays around and through maintenance and construction work zones.
- **Salvage Value** - value at end of life cycle or analysis period. May be positive or negative depending on whether facility maintains some economic value or cost of demolition and removal exceeds value.
- **Energy Use** - relative energy consumption, may fall under construction, maintenance, or rehabilitation costs. Very appropriate when considering items such as lighting, ventilation, and movable bridge span systems.