FINAL REPORT

CONSIDERATIONS IN THE DEVELOPMENT OF PROCEDURES FOR PRIORITIZING TRANSPORTATION IMPROVEMENT PROJECTS IN VIRGINIA

John S. Miller, Ph.D., P.E.
Senior Research Scientist

Rod E. Turochy, Ph.D., P.E.
Research Scientist

James H. Lambert, Ph.D., P.E.
Research Assistant Professor
Department of Systems Engineering
University of Virginia

Virginia Transportation Research Council
(A Cooperative Organization Sponsored Jointly by the
Virginia Department of Transportation and
the University of Virginia)

In Cooperation with the U.S. Department of Transportation
Federal Highway Administration

Charlottesville, Virginia

March 2002
VTRC 02-R6

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Virginia Department of Transportation, the Commonwealth Transportation Board, or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

ABSTRACT

The transportation programming process is undergoing a fundamental change akin to that which transpired with the advent of the Intermodal Surface Transportation Efficiency Act in 1991. Some stakeholders have expressed a desire that the programming process be transparent, and some have expressed an interest in using data-driven performance measures. Although there is widespread agreement with broad criteria, stakeholders may disagree over specific performance measures. Thus, transportation agencies have become interested in methods for selecting projects based on their merits rather than the more traditional approach of "first in first out."

Accordingly, the Virginia Department of Transportation (VDOT) requested that the Virginia Transportation Research Council develop a template that VDOT could use to prioritize capital improvement projects. The role of the template is to help VDOT decide which project should be undertaken first. The scope of the template is limited to projects that are already being programmed.

A template based on 14 of 75 performance measures examined was developed and applied to two projects. The template is oriented toward projects relating to the interstate and primary systems, but it is flexible enough that key policy choices can be made in its framework. These include controversial issues, such as access management and land use configurations, and more tedious but critical considerations, such as the relative importance of crash risk, infrastructure maintenance, economic development, and congestion relief.

A promising benefit of the template is that it provides an opportunity to manage the debate as to the approach for deciding the order in which projects are programmed. The template will not eliminate disagreement, but it can foster discussion when parties have legitimate and differing opinions as to how projects should be prioritized. To that end, the template may be used as a discussion instrument between VDOT and some of its key stakeholders, including metropolitan planning organizations, planning district commissions, the Commonwealth Transportation Board, and advocacy groups who influence transportation infrastructure decisions.

FINAL REPORT

CONSIDERATIONS IN THE DEVELOPMENT OF PROCEDURES FOR PRIORITIZING TRANSPORTATION IMPROVEMENT PROJECTS IN VIRGINIA

John S. Miller, Ph.D., P.E.
Senior Research Scientist

Rod E. Turochy, Ph.D., P.E.
Research Scientist

James H. Lambert, Ph.D., P.E.
Research Assistant Professor
Department of Systems Engineering
University of Virginia

INTRODUCTION

Many persons involved in the project programming process agree that that the transportation programming process should reflect the fundamental change that the Intermodal Surface Transportation Efficiency Act (ISTEA) and the Transportation Equity Act for the 21st Century (TEA-21) fostered in the process. *Transportation planning* is the process of defining problems, identifying candidate solutions, evaluating the alternatives, gathering public input, and recommending a set of specific projects. *Transportation programming* entails deciding when chosen projects should be funded, or programmed, in budgetary constraints. In the planning process, the fundamental change is the shift from using one criterion, notably congestion relief, to evaluate projects to using multiple criteria, such as the seven planning factors outlined in TEA-21 (accessibility and mobility, economic development, efficiency, environment, connectivity, safety, and system preservation).

The recent Governor's Commission on Transportation Policy (GCTP) in Virginia, established by former Governor James Gilmore, proposed six evaluation criteria for programming projects: safety, leveraging options, economic development, land use and environmental considerations, quantitative measures of use, and innovation. The commission mandated that the Virginia Department of Transportation (VDOT) consider these six categories to develop a process for temporally programming capital improvement projects.

Within these six categories, one can consider diverse "performance measures." NCHRP Report 446 notes that performance measures may "be used in measuring or assessing the relevant outputs, service levels, and outcomes of each program activity."[1] As an illustration, an evaluation criterion might be *safety*, a program activity might be a state's *Highway Safety Improvement Program* (which allocates funds for enforcement, education, and engineering efforts), and possible performance measures might be the *crash rate*, defined as the number of crashes per 100 million vehicle miles traveled (VMT). The crash rate qualifies as a performance measure because it enables the program administrator to evaluate the impacts of each program activity: for example, the administrator could compare the crash rates of 100 sections of two lane roadways before and after they were restriped with high-visibility pavement markings.

The challenge to developing procedures for prioritizing transportation improvement projects arises not with terminology or at the level of general categories, but rather at the level of choosing specific performance measures in each category. For example, no entity will disagree that safety is a critical criterion when it comes to choosing a transportation project. Disagreement will occur at two points in the programming process: the specific performance measure and the relative importance of the performance measure. With regard to the former, as an example, should the measure be the absolute number of crashes or accidents on a segment, the crash rate, the use of known geometric deficiencies, or the amount of coverage by the press? Each measure could be defended. Using the total number of crashes, for example, means that one targets a facility that poses largest net risk; using geometric deficiencies can be a sign that one proactively solves problems rather than waiting for a crash to occur. With regard to the relative importance of the measure, how important is the fact that a project will reduce carbon monoxide emissions (by smoothing traffic flow at a bottleneck) relative to the fact that the project will reduce crash risk by improving horizontal alignment? Implicit issues in these two areas of disagreement are data needs, methods of analysis, and transparency of computation.

A recognition of potential areas of disagreement coupled with the need for a practical scoring procedure (that VDOT could implement for the 1,400 projects in the 2000-2001 Capital Improvement Program) guided the formation of a template that was presented to VDOT but not implemented. A VDOT committee comprised of VDOT staff in the Programming & Scheduling Division, the Assistant Commissioner for Finance, and the Administrator of the Transportation Planning Division identified four key constraints for the development of an interim template, or scoring procedure, that can be used to program capital improvement projects:

1. *It must be transparent*. The computation should be repeatable by another analyst and yield the same answer. For example, if a state department of transportation (DOT) scores a value of *x* under a performance measure, a regional planning body questioning the programming of a project should be able to see how the score of *x* was obtained. The transparency requirement is critical to facilitate cooperation with entities outside VDOT such as planning district commissions (PDCs), metropolitan planning organizations (MPOs), and advocacy groups (e.g., environmental interest groups).

2. *It must be computationally feasible*. With approximately 1,400 primary and interstate system projects that must be considered annually, VDOT needs to consider methods that can be realized on a large scale given staff limitations. This constraint does not mean that sophisticated methods of analysis must be discarded, but it does necessitate that detailed methods provide insights that justify the effort.

3. *It must be driven by available data or data that one can reasonably expect to become available in the future*. As an initial effort, VDOT requested that the template use

existing data that are archived to various degrees in its diverse information systems or are at least available on paper. As development proceeded, this constraint was relaxed by the developers to allow for the inclusion of promising performance measures that use data that are available in limited instances to encourage different work units to start maintaining these data. The benefit of using existing information systems became apparent with the application of two sample projects.

4. *It must reflect current issues*. In the past decade, land use considerations have become especially important, yet in the decades to come, their relevance may increase or wane. The template should be flexible enough to allow for modification of the performance measures. For example, suppose that in the future, an important criterion is adequate transportation for the disadvantaged is to become more pivotal. The template should be structured in such a way that it is possible to insert a new performance measure that reflects this criterion (such a measure might be percentage of disadvantaged users served) into the template.

PURPOSE AND SCOPE

The purpose of this effort was to explore issues related to and to offer a prototype template for a selection process that the Commonwealth Transportation Board and VDOT could use to prioritize construction projects in a transparent manner. Accordingly, the template should be as objective as possible, use data that are accessible, and be understandable by VDOT staff and stakeholders. The template should be based on multiple performance measures and should mesh with TEA-21 planning factors.

In terms of specific VDOT practices, the template can help prioritize projects within the capital improvements phase as these projects are fully refined. by itself, the template is not appropriate for use in deciding which projects will move from the feasibility phase to the capital improvements phase given that the transition requires completion of environmental review documents and other regulations, although the template does offer computational methods that may be appropriate in that regard.

METHODS

Five key steps comprised the methodology.

1. A literature review of the seven TEA-21 planning factors, the criteria from the GCTP, and previous prioritization efforts in Virginia was conducted to establish a framework for the template.

2. Performance measures used in other states were reviewed.

3. Redundant measures and those that appeared infeasible to apply empirically were removed, culminating in a list of 14 performance measures, modified for use in Virginia, that comprise the basis of the prototype template.

4. Policy and data issues were documented by studying the performance measures.

5. The mechanics of the computations and the judgment that must be exercised were examined by applying the performance measures to two projects. (These decisions apply whether this procedure is done manually or with the help of software subroutines.)

LITERATURE REVIEW

The TEA-21 Criteria

TEA-21 requires that state DOTs follow seven criteria, or planning factors, when making decisions regarding the funding of projects that will use federal money (see Table 1). The seven criteria are broad, giving states the flexibility they need to make effective decisions with respect to potential transportation projects. Because the TEA-21 factors are required by law to be considered in metropolitan and statewide transportation planning processes, however, they are a suitable starting point for any process that aims to prioritize potential transportation projects.

Table 1. Alignment of Categories and TEA-21 Criteria

VTRC Category Name	TEA-21 Description[2,3]
1. Accessibility and mobility	"Increase the accessibility and mobility options for people and for freight."
2. Economic development	"Support the economic vitality of the metropolitan area [or region or state] by enabling global competitiveness, productivity, and efficiency."
3. Efficiency	"Promote efficient system management and operation."
4. Environment	"Protect and enhance the environment, promote energy conservation, and improve quality of life."
5. Connectivity	"Enhance the integration and connectivity of the transportation system across and between modes for people and for freight."
6. Safety	"Increase the safety and security of the transportation system for users of motorized and nonmotorized modes."
7. System preservation	"Preserve the existing transportation system."

For the purposes of this paper, the factors are described as follows:

1. Accessibility and mobility cover three transportation system goals: ensuring that land use planning makes destinations as accessible as possible for a given transportation system; ensuring that all transportation customers (whether stratified by mode or economic group) have equal access to the transportation system; and offering customers modal choices, such as being able to use single-occupant automobile, carpool, transit, or bicycling for a given trip.

Although accessibility and mobility are in the same category in Table 1 and in the TEA-21 planning factors, there is a distinction. A project that widens a freeway or reduces transit headways without affecting travel patterns might be largely a mobility improvement. If the same widening, however, improved transportation to the inner city such that the development of vacant brownfield (infill) sites was encouraged, the project might also be an accessibility improvement. These two categories overlap; thus, they reflect different areas of emphasis for potential project impacts.

2. Economic development denotes the concept that transportation investments may stimulate economic growth in a region. The authors acknowledge the debate as to whether transportation investments stimulate or merely redistribute growth, but a review of the economic literature is beyond the scope of this report.

3. *Efficiency* might be accomplished through funds for a traffic management system that enables motorists to receive real-time traffic information such that they can follow alternate routes when main routes are congested. Making the most of existing funds (e.g., selecting projects that are accompanied by the highest federal match) is likely closer to the category of *efficiency* than any of the other six factors. The documentation alone does not distinguish between system and economic efficiency.

4. Environment includes air quality and "quality of life."

5. Connectivity pertains to integration of modes and transfers between them.

6. S*afety* reflects a belief roadway improvements can bring about measurable improvements in crash risk reduction. In fact, some persons distinguish between the terms *crash* and *accident*, where the former signifies that the conflict was indeed preventable (through some combination of driver, vehicle, and roadway countermeasures) and the latter indicates that the conflict was not preventable or had a probabilistic element. Although acknowledging that some readers view this distinction as fundamental, this report uses the terms interchangeably so as to be consistent with the literature. (For example, the 1984 Statewide Highway Plan[5] uses the term *accident* although the plan viewed accidents as being an item that were preventable through transportation improvements.)

7. S*ystem preservation* means maintaining the existing system infrastructure (e.g., the Woodrow Wilson Bridge replacement might be viewed as a massive system preservation effort).

Criteria from the Governor's Commission on Transportation Policy

The GCTP also offered six broad criteria for the prioritization of transportation improvements, as shown in Table 2. Some overlap with the TEA-21 factors. Similar to the TEA-21 factors, these six criteria are broad. The GCTP descriptions are quoted almost verbatim.

Table 2. Criteria from the Governor's Commission on Transportation Policy

Category	GCTP Description[4]
Safety	Use of "quantitative data to measure the safety of a road or highway project or enhancement. These data would include, but not be limited to, accident and fatality rates."
Leveraging options	"Includes examining projects based on cost efficiency, local financial involvement, use of public-private partnerships, and other financial options available to support the project."
Economic development	"Includes the basic economic impact that a new facility or enhancement will have on the area around the facility or enhancement. This could be measured by, but not be limited to, job creation and other economic impact factors"
Land use and environmental considerations	"Examine how the project or enhancement follows the overall land use guidelines set by local comprehensive plans. This would also consider other environmental factors and the use of non-highway or multimodal solutions."
Quantitative measures of use	"Examine different factors and data including levels of service on roads and highways that measure traffic and congestion to determine the use or projected use of the facility and impact on traffic and congestion. Also this would examine the management of resources for the project or enhancement to determine if this is indeed the best use of available funds."
Innovation	"Could measure other innovative factors not covered by the aforementioned criteria; this could include financing, modal choices or strategies, and other factors."

Although both TEA-21 and the GCTP suggest broad categories that should influence the programming process, the idea of a comprehensive, holistic approach to assessing projects is not unique. Before proceeding further with this interim selection process, it is instructive to examine previous attempts to prioritize projects in the Commonwealth.

History of Prioritization Efforts in Virginia

Statewide highway needs assessments, formerly required by the *Code of Virginia* (§33.1-23.03), have been documented by VDOT since at least the 1980s and may well have been conducted prior to that period, although formal documentation is lacking. For the first such needs assessment, a numerical scoring scheme was applied to all projects addressed in the *1984 Statewide Highway Plan*.[5] A method that grouped proposed projects into categories of high, medium, and low priority was employed in the development of the 1989 *Virginia 2010 Statewide Highway Plan*.[6]

1984 Statewide Highway Plan

The 1984 statewide highway plan employed a prioritization scheme that was first applied by VDOT in 1982. This method included the use of the nine evaluation criteria listed in Table 3 (McGeehan and Samuel, 1990).[7] The table also indicates the maximum number of points available for each criterion. For each project, the scores received for each evaluation criterion were summed to yield a total project score; the relative merit of projects was not evaluated.

Table 3. Evaluation Criteria Used in 1984 VDOT Statewide Highway Plan

Performance Measure	Points
Ratio of existing volume to service volume (v/sv, existing)	30
Ratio of forecast volume to service volume (v/sv, future)	20
Adequacy of geometrics	5
Functional classification of roadway	6
Existing traffic volume	6
Forecast traffic volume	6
Route continuity	5
Estimated project cost divided by future traffic volume	5
Accident rate	5

A potential transportation improvement could receive a maximum score of 88 under this method. Interestingly, 57% of the available points related directly to traffic congestion, reflected as the volume divided by the service volume (v/sv). The evaluation criteria also employed in the 1984 plan addressed mobility, safety, and cost-efficiency of proposed projects but did not address many of the planning factors included in the subsequent guidance given by ISTEA and TEA-21 or found in the prioritization methods used in many states and localities. A key strength of this method was the employment of evaluation criteria that were largely data driven and, therefore, easily reproducible from one analyst to the next; however, its chief disadvantages were the high correlation among many criteria (such as those related to traffic volumes, congestion, and functional classification), the variability in scoring ranges among the criteria, and the use of subjective weighting assignments to the values of each of the criteria. (*Subjective* in this sense simply means that the user applies the weighting without documented guidance as to how that weighting should be determined.)

Project priorities were presented based on the scores received by proposed projects using this method at the locality level for secondary and urban system projects; at the transportation district, planning district, and local levels for primary system projects; and at the statewide and all other levels for interstate system projects. The largest geographic level of prioritization for each system corresponded to the level at which funds were allocated for each.

2010 Statewide Highway Plan

The prioritization method applied in the 1989 plan was adapted from work performed by McGheehan and Samuel and published as a VTRC report in 1990.[6,7] Perceived drawbacks of the previous method were noted to be the use of many highly correlated variables, a lack of sensitivity to individual variables, difficulties in assigning points to variables with a wide range of units, and the subjective assignment of weights to the criterion variables. The method, as presented in the report, used four criteria to evaluate proposed projects:

1. ratio of current volume (vehicles per day) to service volume

2. average daily traffic (ADT)

3. accident rate

4. pavement condition rating.

Each criterion was applied sequentially to a highway segment or proposed project; in each criterion, a project was classified as high, medium, or low priority based on threshold values. A proposed project was assigned a high, medium, or low priority based on its value for the first criterion variable. The second criterion variable was then applied, and each proposed project was assigned a new priority based on the relationship of its value to the critical threshold values. The process continued until all criteria had been applied. The result was a classification of each potential improvement as high, medium, or low priority, rather than point scores for each project. The proposed method was data driven and highly objective in that of the four variables, three were based solely on data and pavement condition was based on a combination of objective data and opinions of pavement experts. Separate evaluation criteria and threshold values were to be established for each administrative system (interstate, primary, secondary, and urban), rather than on a project type or improvement class basis (bridge replacement/rehabilitation, spot improvements, pavement widening, etc.).

This method, although accounting for factors of common interest such as traffic volumes and accident rate, did not account for factors such as estimated project cost, economic benefits, and environmental impacts. In addition, two of the four criteria were based solely on measures of traffic volume and congestion. Expected conditions upon completion of improvements or at design years were not directly considered; for example, the method employed existing accident rates but not expected reductions in accident rate after improvements.

The structure of this method was used by VDOT in the 2010 Statewide Highway Plan. After highway needs were identified, they were prioritized according to three criteria (in order): ratio of existing ADT to service volume, existing ADT, and ratio of future estimated ADT to existing service volume. These criteria are potentially highly correlated. Although safety and pavement condition were factors in the prioritization method developed by McGeehan and Samuel,[7] they were not used in the evaluation of potential improvements to arterials and collectors in the 2010 plan.

Summary

VDOT has used both prioritization methods in only selected instances, and they have not been implemented on a broad scale. The priorities established in the 1984 and 1989 plans were not directly linked to the allocations to projects in the state's six-year improvement program. Since the 1989 plan, only one highway needs assessment has been developed (1994); although costs to meet the identified needs in a series of need-threshold scenarios were estimated, projects identified in the process were not prioritized.

Further, the evolution of prioritization methods shows how priorities have shifted from relieving congestion to encompassing other modes. For example, the 1984 method is a snapshot of how prioritization weighting has shifted over time: in the 1960s, when the four-step travel demand process (trip generation, trip distribution, mode choice, and traffic assignment) came into full use, traffic congestion appeared to account for 100% of the available points. By 1984, congestion accounted for slightly more than half of the available points in Virginia. With the advent of ISTEA and TEA-21 in the 1990s, congestion was only one of several factors mandated by Congress that should be considered in terms of selecting transportation improvements.

It has since been suggested that one way for a congested metropolitan area to prioritize projects is to model the transportation network with expected future demand and no improvements, then incrementally to make improvements that improve the level of service to an acceptable threshold, and then to prioritize these congestion-reducing improvements based on the other factors (e.g., pavement condition, safety, environment). This approach is feasible and may in fact make logical sense for an area facing heavy congestion, but it may not reflect the full intent of TEA-21 in that such an approach would place congestion well above the other planning factors in terms of importance.

REVIEWING POTENTIAL PERFORMANCE MEASURES FROM OTHER STATES

A variety of states have developed performance measures that reflect different criteria, such as the TEA-21 planning factors shown in Table 1, the GCTP criteria shown in Table 2, and other criteria that are not emphasized by either TEA-21 or the GCTP. Each performance measure has strengths and weaknesses: some are extremely objective in that two persons using them will arrive at the same answer, some encourage multimodal approaches, and most have an implicit or explicit policy choice. None is perfect. As a first step for developing an interim selection process, the performance measures used by Ohio, Delaware, Alaska, Oregon, and California (for the City of Sacramento) were identified.[8,9,10,11,12,13] These states were chosen because they had project prioritization methods that were readily available over the Internet and as a set they offered a range of performance measures that corresponded to the TEA-21 planning factors.

The approximately 75 performance measures identified spanned a broad range of priorities (e.g., environmental, congestion relief, and safety), data needs (AADT, costs, and land use plans), and measures of objectivity.

SELECTING AND TAILORING PERFORMANCE MEASURES FOR VIRGINIA

From this list of approximately 75 performance measures, VTRC identified 14 for demonstration purposes. The measures, shown in Table 4, were chosen for these reasons:

- The data appeared to be either readily available or obtainable from a VDOT division, district, or outside source in the Commonwealth. The determination was made based upon an examination of two projects and consideration of application

Table 4. Alignment of TEA-21 Planning Factors and the 14 Performance Measures

TEA-21 Planning Factor	GCTP Factor	Performance Measure
Connectivity	Innovation	1. Intermodal connectivity (Delaware and Alaska)
Economic development	Economic development	2. Freight mobility (Delaware and Ohio) 3. Relative unemployment rate (Ohio)
Efficiency	Quantitative measures of use	4. AADT (truck and auto) (Ohio) 5. Relative priority in the local, MPO, or PDC plan or TIP (Oregon)
Environment	Land use and environmental considerations	6. Community support/consistency with local and MPO plans (Delaware) 7. Environmental approval readiness (Alaska) 8. Growth management (Oregon)
Accessibility and mobility	Quantitative measures of use	9. Volume-to-capacity ratio (Ohio)
Safety	Safety	10. Accident rate (Ohio) 11. Geometric deficiencies such as width, grade, or alignment (Alaska)
System preservation	None	12. Bridge deficiencies (Alaska) 13. Surface rehabilitation (Alaska)
Efficiency	Innovation	14. Total estimated cost

to other projects but was not a field test of application to the full set of capital improvement projects.

- The performance measure could be determined either objectively or by a consistent set of rules.

- The performance measures could be linked to the seven TEA-21 planning factors. (Some performance measures linked to more than one planning factor. For example, although growth management is listed as being in the *environment* TEA-21 planning factor because of its community emphasis, it could also be placed in the *efficiency* planning factor because growth management rewards projects that make use of existing infrastructure.)

- As a set, the performance measures gave agency management a choice as to what measures should be used in that it is easier to eliminate measures than to derive them anew.

- The performance measures eliminate the overlap present in the larger list of measures. (For example, one state measured accessibility with three performance measures: one focusing on freight, one focusing on passenger intermodalism, and one focusing on connectivity in a mode.)

VDOT need not choose all 14 performance measures, and further, it is possible to modify their application. For example, if VDOT wanted simply to ensure that projects have the support of the community but did not want to take a policy position regarding land use, VDOT might emphasize the sixth performance measure, which assesses community support, and avoid the eighth performance measure, which looks at how a transportation project influences local land use. Table 4 shows how the 14 performance measures may be related to the TEA-21 planning factors.

A PRACTICAL SCORING TEMPLATE FOR VIRGINIA

Explicit Policy Questions That Only VDOT Leadership Can Answer

Computation of any given performance measure, although not being an automated or mundane task, generally can be done in a reproducible fashion such that two people will probably give a project the same score for *surface rehabilitation* or *accident rate.* The selection of the performance measures and their subsequent weighting, however, ultimately reflect a policy decision that agency management cannot escape. Any template—this one included—can be tweaked to favor particular modes or regions depending on how weights are established.

An Example of Contrasting Policy Implications

For example, for just one performance measure, the *volume-to-capacity (v/c) ratio*, which indicates congestion, Northern Virginia and Hampton Roads have congestion problems far greater than those of other regions of the Commonwealth. Thus, by weighting the congestion quite heavily, particular regions of the state can be favored. Choosing the "proper" weights of these performance measures is impossible unless all stakeholders can agree on priorities. It is possible, however, to understand the underlying policy implications of each performance measure so that an educated decision can be made regarding how the performance measures will affect the temporal order in which projects are programmed.

Policy Implications of Specific Performance Measures

1. *Intermodal connectivity*. The underlying policy implication is that transportation investments should be favored if they will positively affect multiple modes (rail, bus transit, carpooling, pedestrian, bicycling) as compared to investments that help only one mode. For example, this performance measure would score a widening project that includes restriping for bicycle lanes higher than a similar widening project that would not affect bicyclists, assuming the projects were identical in all other regards.

2. *Freight mobility*. The underlying policy implication is that transportation investments can help freight movement, including modes in which VDOT does not traditionally invest. For example, this performance measure would favor a project that involves a freight transfer facility or a heavy truck volume.

3. *Relative unemployment rate*. As this measure relates a county's unemployment rate to the statewide unemployment rate, three policy implications of this performance measure are:

- Transportation investments will stimulate economic development or at least redistribute it to the affected area.

- The investments have a defined sphere of influence of a single county, construction district, or larger region.

- Economically disadvantaged districts are favored in project prioritization decisions.

Under this performance measure, a project in an economically disadvantaged area of the Commonwealth will score higher than a project in an area with a low unemployment rate.

4. *AADT (average annual daily traffic) (truck and auto)*. The policy implications of this performance measure are that facilities with the highest volume are favored, regardless of congestion on the facility. In contrast, the v/c ratio performance measure favors a facility that is heavily congested, regardless of whether it is a low-volume arterial or a high-volume interstate. For example, under the AADT performance measure, an improvement project for a primary road with 40,000 AADT would score higher than an improvement project for a primary road with 30,000 AADT, regardless of the congestion on either facility. In contrast, the v/c ratio performance measure would rate the project for the more congested facility higher.

5. *Relative priority in the local, MPO, or PDC plan or TIP (transportation improvement plan)*. The policy implication is that projects with the greatest local community support are favored. Although a community may have a list of several projects in which it is interested, some will have the support of the entire community, some will have the support of part of the community, and some may have very little support. A project that is not in a region's TIP would score poorly under this performance measure.

6. *Community support/consistency with local and MPO plans*. The policy implications are:

   - Community land use priorities are a factor in the decision for a project.

   - Community support is shown by consistency with a county plan and PDC/MPO plan.

7. *Environmental approval readiness*. The policy implication is that the likelihood of a project passing environmental hurdles (whether through a categorical exclusion having been obtained, an Environmental Impact Statement (EIS) having been approved, or a draft EIS being ready and a court challenge not expected) is a factor in approving projects. Thus, this performance measure favors projects where the environmental data or clearance to proceed has been obtained.

8. *Growth management*. The policy implication is that projects that support access management, travel demand management, and specific land development practices are supported. Proponents of a growth management performance measure can argue that it may encourage more efficient use of the transportation infrastructure; opponents can argue that such decisions are a local and not a state issue. For example, a project that improves a

transportation link serving a brownfield in a central business district will score higher under this performance measure than a project serving a new residential community on the suburban fringe.

The policy implications of the growth management measure are probably more complex than those of the other performance measures because land use decisions are involved. For example, whether VDOT adopts this measure will depend on how VDOT wants to influence land use planning at the local level. A hands-off approach would mean eliminating this measure.

9. *Volume-to-capacity ratio.* The policy implication of this performance measure is that highways with higher congestion levels are favored for improvements.

   The justification for such a measure is that a higher v/c ratio means a facility is more sensitive to sudden increases in delay from incidents (such as a crash that temporarily closes a lane). Even though two facilities can have radically different v/c ratios (e.g., 0.6 and 0.2) yet similar total delay, the facility with the higher ratio is more susceptible to a sudden increase in delay from an incident.

10. *Accident rate*. The policy implication is that accident rates are a suitable measure of crash risk and that projects that reduce this risk are necessary. In some cases, urbanized areas have argued against using accident rates and for using the absolute number of accidents, since a heavy traffic volume can result in a facility having a lower accident rate even though it poses a sizeable risk as reflected in the number of crashes.

11. *Geometric deficiencies*. The policy implications are twofold:

    - Projects that involve facilities with substandard lane widths, alignment, or grade are favored (e.g., a project that widens a two-lane road to a four-lane road if the widening will include changing the lane widths from 10 to 12 ft would fare better than a project that widens a two-lane road where the lane widths are 12 ft. Thus, projects that involve substandard facilities are favored.

    - *Safety* should be assessed not just through crashes (e.g., using the accident rate performance measure) but also through deficiencies that are thought to contribute to crashes.

12. *Bridge deficiencies*. The policy implication is that major bridge improvements should be construed as a construction improvement and not solely a maintenance improvement. This performance measure reflects the fact that bridge rehabilitation, although critical to existing infrastructure, tends to score low on many of the performance measures. If VDOT views bridge rehabilitation as more of a maintenance item than a construction item, however, it can eliminate this performance measure.

13. *Surface rehabilitation*. The policy implications are twofold:

- A project that also addresses a fundamental rehabilitation need in terms of pavement quality (e.g., a project that would be needed anyway based on the Pavement Management System [PMS]) is favored.

- Pavement rehabilitation is a construction need (not just a maintenance need).

Thus, under performance measures 12 and 13, projects that have bridge and pavement components (or that mesh with the recommendations under the respective pavement and management systems) will be favored.

14. *Total estimated cost*. The policy implication is that total project cost can stand alone as a performance measure; naturally, this performance measure will favor lower cost projects.

The Scoring Template

Table 5 describes how each of the 14 performance measures may be applied to Virginia. as well as the corresponding TEA-21 factor. For example, if AADT (the fourth performance measure) is used to score an interstate project on a scale from 0 to 10, if the AADT is greater than 80,000, the project scores 10 points; if the AADT is 73,000, the project scores 9 points; and so on.

A project can be scored using each performance measure, such that the highest total points a project could get is 140. This presumes that each performance measure has the same weight. Agency management can weight AADT, for example, more or less than 1/14th of the total score. Under such a scenario, the same 10-point scale for AADT would be used, but the score would be multiplied by a factor of 2 (if AADT were to count twice as much as the other performance measures), 3 (if AADT were to count 3 times as much as the other performance measures), and so on. (Additional methods for weighting performance measures are being researched by Lambert et al. at the University of Virginia.)

At the time of this writing, it was envisioned that the template would ideally be applied with all programmable projects in one category, given that all the projects are projects VDOT expects to implement. If, however, statutes or expectations evolved such that a particular diversity of projects was required, then the template could be applied across different categories, stratified by location (e.g., the nine districts), cost (e.g., under $10 million, $10 million to $50 million), mode, and so forth. Such a stratification is not recommended at this stage, but it is an option especially if, despite admonitions to the contrary, the programming process were to evolve into a surrogate for a statewide planning process. For example, the *Code of Virginia* (e.g., § 33.1-23.1) allocates 40% of available funds to the primary system, 30% to the secondary system, and 30% to the urban system, where available funds are those that remain after funds for maintenance, unpaved secondary roads, and the interstate match are removed. The template could still be applied within the constraints of those categories should that be desired.

TABLE 5. Potential Performance Measures

PERFORMANCE MEASURE	Intermodal Connectivity (1)	Freight Mobility (2)	Relative Unemployment Rate (3)	AADT, Interstate (4)	AADT, Primary (4)	Relative Priority in Local, MPO, or PDC Plan (5)	Community Support Consistent with Local/PDC Plan (6)
10 points	Serves 3 or more modes well (auto, bicycling, bus, rail, and pedestrians)	Expressly serves freight transfer facility and ADT >10,000	>100%	>80,000	>40,000	In top 5% of all projects shown for community	Project meshes with both local and PDC plans
9 points		Expressly serves freight transfer facility	90%–100%	72,000–79,999	36,000–39,999	In next 5%, as in 5.01%–10%	
8 points	Serves 2 modes well and a third mode somewhat	Truck ADT > 10,000	80%–89.9%	64,000–71,999	32,000–35,999	10.01%–20%	
7 points		Truck ADT > 8,000	70%–79.9%	56,000–63,999	28,000–31,999	20.01%–30%	
6 points		Truck ADT > 6,000	60%–69.9%	48,000–55,999	24,000–27,999	30.01%–40%	
5 points	Serves 2 modes well	Truck ADT > 5,000	50%–59.9%	40,000–47,999	20,000–23,999	40.01%–50%	Project meshes with either local or PDC plan
4 points		Truck ADT > 4,000	40%–49.9%	32,000–39,999	16,000–19,999	50.01%–60%	
3 points		Truck ADT > 3,000	30%–39.9%	24,000–31,999	12,000–15,999	60.01%–70%	
2 points		Truck ADT > 2,000	20%–29.9%	16,000–23,999	8,000–11,999	70.01%–80%	
1 points		Truck ADT > 1,000	10%–19.9%	8,000–15,999	4,000–7,999	80.01%–90%	
0 points	Serves only 1 mode	Truck ADT < 1,000	0%–9.9%	<8,000	<4,000	Bottom 10% or not shown	Project meshes with neither plan

TABLE 5. Potential Performance Measures (Continued)

PERFORMANCE MEASURE	Environmental Approval Readiness (7)	Growth Management (8)	Existing v/c Ratio* (9)	Accident Rate, Interstate (10)	Accident Rate, Primary (10)
10 points	EIS approved, EA approved, or categorical exclusion obtained	Award 3 points if project supports compact, infill, or mixed use development; otherwise award 0	>1.00	> 150 (acc./100 MVMT)	> 500 (acc./100 MVMT)
9 points			0.96–1.00	135–149	450–499
8 points			0.91–0.95	120–134	400–449
7 points	Draft EIS/EA complete, no court challenges anticipated	plus	0.86–0.90	105–119	350–399
6 points		Award 3 points if project includes travel demand management techniques, such as employer-sponsored ridesharing or transit coordination; otherwise award 0	0.81–0.85	90–104	300–349
5 points			0.75–0.80	75–89	250–299
4 points			0.68–0.74	60–74	200–249
3 points	No draft but no court challenges anticipated, or draft complete but major court challenge looming	plus	0.60–0.67	45–59	150–199
2 points		For arterial roadway projects: Award 4 points if project uses access management techniques.	0.50–0.59	30–44	100–149
1 points		For interstate projects: Award 4 points if project has an alternative arterial.	0.4 –0.49	15–29	50–99
0 points	Court challenge ahead. No draft.		<0.40	0–14	0–49

***Note that v/c ratios take on different values for different types of facilities. Although the distinction between interstates and some limited access freeways may not be large, the distinction is important when these facilities are compared to 2-lane highways, arterials with high signal density, and signalized intersections.**

TABLE 5. Potential Performance Measures (Continued)

PERFORMANCE MEASURE	Geometric Deficiencies, e.g., Width, Grade, Alignment (11) *	Bridge Deficiencies (12)	Surface Rehabilitation (13)	Total Estimated Cost (14)
10 points	Lane width, right shoulder, left shoulder, horizontal alignment, and vertical alignment all substandard	6 or more bridges have sufficiency rating below 30 according to VDOT's Bridge Management System (BMS).	Pavement Management System (PMS) classification of very poor	When ordering projects from least to most expensive, the project's estimated total cost ranks between 0% and 10%
9 points	4 of the 5 items substandard	5 bridges have sufficiency rating below 30		Total estimated cost between 10% and 20%
8 points	3 of the 5 items substandard	4 bridges have sufficiency rating below 30.	PMS classification of poor	Total estimated cost between 20% and 30%
7 points	2 of the 5 items substandard	3 bridges have sufficiency rating below 30.		Total estimated cost between 30% and 40%
6 points	1 of the 5 items substandard	2 bridges have sufficiency rating below 30	PMS classification of fair; ground loop detectors not recently installed	Total estimated cost between 40% and 50%
5 points		1 bridge has sufficiency rating below 30		Total estimated cost between 50% and 60%
4 points		Lowest bridge sufficiency rating is 30-39	PMS classification of fair; ground loop detectors recently installed	Total estimated cost between 60% and 70%
3 points	Another feature (such as lighting) substandard	Lowest bridge sufficiency rating is 40-49		Total estimated cost between 70% and 80%
2 points		Lowest bridge sufficiency rating is 50-59	PMS classification of good or excellent and ground loop detectors not recently installed	Total estimated cost between 80% and 90%
1 points		Lowest bridge sufficiency rating is 60-69		Total estimated cost between 90% and 100%
0 points	No substandard features	No bridges with sufficiency rating below 70	PMS classification of good or excellent, but ground loop detectors recently installed	Total estimated cost not available and cannot be determined

*Note that safety deficiencies may be determined from any of the following:

- posted speed reductions
- one or more curves at a running speed below the posted speed limit (data may be collected using a ball bank indicator)
- steep grades (using a slope meter) or truck warning sign
- visual observation of roadside obstacles (e.g., bridge abutments, retaining walls, near the road)
- pavement condition that is hazardous (e.g., well polished).

(Note that nonhazardous deficient pavement is covered in the surface rehabilitation performance measure.)

EXAMPLE OF HOW TO APPLY THE PERFORMANCE MEASURES TO TWO PROJECTS IN VIRGINIA

The 14 performance measures were applied to two projects: one on the interstate system (widening of I-64 in York County) and one on the primary system (widening of U.S. Route 1 in Fairfax County and Prince William County). The project on I-64 involves widening an 8-mile section from four to six lanes between Exits 247 and 255. The project on Route 1 involves adding turning lanes and improving traffic flow through access management; it extends from the north intersection of Route 235 to the south intersection of Route 235.

This application demonstrates how to apply the performance measures as described in Table 5; where data can be obtained or estimated; and the strengths and weaknesses of each performance measure, such as the necessary assumptions. Summary data are presented in Table 6, and details of computations follow. The score for each performance measure is provided.

Table 6. Summary Data for I-64 and Route 1 Widening Projects

Data Available	I-64 Project	Route 1 Project
Modes served	Highway only	auto, bus, pedestrian
Truck ADT (%)	11	6
ADT	76,000	38,000
County unemployment rate (%)	2.3	2.7
Priority in PDC plan	20th percentile	33rd percentile
Responsible PDC	Hampton Roads PDC	Metropolitan Washington Council of Governments
Environmental data available?	No	No
Lawsuit filed?	No	No
Supports compact, mixed, or infill development?	No	Yes
Supports TDM or ridesharing?	No	No
Supports access management or offers alternative route?	Yes	Yes
Geometric data and deficiencies	See example	See example
Crash rate (crashes per 100 million VMT)	107 (one section) 63 (another section)	630
Ground loop detectors recently installed?	No	No
Pavement Management System data available?	Some	Yes
Bridge Management System ratings	75.8, 75.6, 78.1, 78.8, 78.4, 78.7, 74.2, 74.2, 77.4, 77.1	69
Estimated total cost	$97,263,000	$22,472,000

Application of the Performance Measures to I-64 Project

1. *Intermodal connectivity.* No mention is made in the project description about providing multimodal access (e.g., a bus pullout for transit, parallel pedestrian crossovers). *Thus, the score is 0 of 10 points.* (Had it addressed even two modes, it would have scored 5 points.)

2. ***Freight mobility.*** The facility will not expressly serve any kind of freight transfer facility, but it has a total truck ADT of 11% (76,000) = 8,360. *Thus, the score is 7 of 10 points.*

3. *Relative unemployment rate.* The particular data for this project do not show the county location of the widening. However, unemployment data by VDOT construction district, county, mean statistical area (MSA), or some other category that VDOT decision makers view as appropriate can be used. Unemployment rates by city, county, planning district, or MSA can be obtained on the Internet. One source is the Virginia Employment Commission, which on March 5, 2002, contained unemployment figures for December 2001 at the site http://www.vec.state.va.us/pdf/lausclf.pdf. These data show that York County's annual unemployment rate (December 2001) was 2.3% and the statewide rate was 3.6%. *Thus, the score is 0 of 10 points.*

   It should also be possible to prioritize VDOT unemployment rates by construction district as an interim measure. Since the Ohio method prioritizes these rates relative to the statewide rate, these districts should be able to be compared relative to the average.[8] For example, the Hampton Roads District and the Northern Virginia District presumably have unemployment rates that are lower than the statewide unemployment rate. These same data are available from other websites, e.g., the Weldon Cooper Center maintains detailed employment information at http://www.virginia.edu/coopercenter/vastat/#emp. It is also of interest to note that these computations were previously done with 1999 data and although the county and statewide unemployment rates have changed since then, the scoring under the template was not affected since the York, Fairfax, and Prince William unemployment rates were still below the statewide average.

4. *AADT (truck and auto).* The project has an AADT of 76,000. *Thus, the score is 9 of 10 points.*

5. *Relative priority in the local, MPO, or PDC plan or TIP*. The project is under the purview of the Hampton Roads PDC. The PDC should be contacted to obtain the correct planning documents, or their staff should be asked the importance of this project relative to the other projects in Hampton Roads. According to their website, I-64 widenings are of interest to the PDC. The PDC was contacted and asked for a hypothetical answer. The representative pointed out that projects cannot be considered in a vacuum (e.g., network connectivity must be considered), that this project cannot be ranked in the sense that it is part of a complete package of needs, and that the project is one of five that fall in the category of *high priority major unfunded* project. *If the interpretation is made that this project falls into the 33rd percentile, the score is 6 of 10 points.*

6. *Community support/consistency with local and MPO plans.* The project is assumed to mesh with both the county and the PDC plans; in practice, both of these documents would be assessed. *If both plans (or staff from both the PDC and the county) agree that the widening supports a land use called for in each plan, the score is 10 of 10 points.*

7. *Environmental approval readiness*. The project has no EIS, Environmental Assessment (EA), or categorical exclusion available unless VDOT's Environmental Division indicates otherwise. Fortunately, no court challenge is expected (e.g., no groups or individuals have indicated their intent to file a suit to block the project). *Thus, the score is 3 of 10 points.*

8. *Growth management*. The project scores as follows:

   0 of 3 points for supporting compact, infill, or mixed development, plus

   0 of 3 points for travel demand management techniques (e.g., no ridesharing/transit coordination anticipated), plus

   4 of 4 points for having an alternative arterial (Route 60) that can serve as a good alternate route.

   Thus, the score is 4 of 10 points.

9. *Volume-to-capacity ratio.* To apply this criterion, theoretical highway capacity must be calculated. One commonly accepted method for calculating capacity (the 1998 *Highway Capacity Manual [HCM]* [15]) could be applied as described herein. For I-64, the capacity of a lane of freeway in level terrain, 12-ft lanes, 11% truck traffic, 10-ft shoulders, 3-to-10-ft right median width (3 ft was assumed for a worst case scenario), and 3-to-8-ft left median width, interchange density of 1 interchange per 4 miles, and peak hour factor of 1 can be computed as follows:

   Step 1: Determine the estimated free flow speed based on the *HCM.* For the 1998 *HCM,* this is given as:

   $FFS_i - f_{LW} - f_{LC} - f_N - f_{ID}$

   where

   FFS_i is the ideal free flow speed (75 mph for this project)

   f_{LW} is the adjustment factor for lane width (0 mph for this project)

   f_{LC} is the adjustment factor for right shoulder lateral clearance (1.8 mph for this project)

   f_N is the adjustment factor the number of lanes (4.5 mph for this project)

   f_{ID} is the adjustment factor for interchange density (0 mph for this project).

   Thus, the estimated free flow speed from the *HCM* is given as:

   75 mph - 0 mph - 1.8 mph - 4.5 mph - 0 mph = 68.7 mph.

Step 2: Determine the density as the volume/free flow speed.

The volume is given as 38,000 vehicles per day (in one direction), and a peak hour volume is assumed to be 10% of the 24-hr volume, or 3,800. The 1,900 vehicles per hour per lane (assuming traffic to be distributed evenly across two lanes) is then converted to passenger car equivalents (PCE) per hour per lane (pcphpl); in level terrain, the PCE value for trucks is 1.5. Using the 11% truck traffic and a 1.5 heavy vehicle factor, one obtains 1900*(1 - 0.11) + 1900*0.11*1.5 = 2005 pcphpl. Thus, the density is computed as:

2005 pcphpl/68.7 mph = 29.2 passenger cars per mile per lane (pcpmpl).

Step 3: Relate the density to a v/c ratio:

29.2 is classified as LOS D, which has a maximum v/c ratio of 0.87 (corresponding to a density of 32 pcpmpl) and a minimum v/c ratio of 0.72 (corresponding to a density of 24 pcpmpl).

A reasonable estimate is ([29.2 - 24]/[32 – 24])*(0.87 - 0.72) + 0.72 = 0.817.

With a v/c ratio of 0.817, the score is 6 of 10 points.

VDOT does not have to use this method to determine these ratios, however. Instead, there are engineers who may have a good intuitive grasp of the capacity (e.g., field data or observations have shown flat grade interstates to have a capacity of 2300 pcpmpl, which can eliminate the need to do the math shown in Steps 1, 2, and 3. Software is also widely available to do these computations.

10. *Accident rate*. I-64 has an overall crash rate of (107 + 63)/2 crashes/100 million VMT = 85 crashes/100 million VMT. *Thus, the score is 5 of 10 points*.

11. *Geometric deficiencies.* I-64 has two geometric deficiencies: the left shoulder and the right shoulder as shown for the median. *Thus, the score is 7 of 10 points.*

12. *Bridge deficiencies*. I-64 has no bridge with a sufficiency rating below 70 according to VDOT's Bridge Management System. *Thus, the score is 0 of 10 points.*

13. *Surface rehabilitation*. I-64 has a concrete section, and, unlike the asphalt pavements, concrete sections have not been fully quantified in VDOT's PMS. An expert from VDOT's Materials Division, however, looked at the available data for that portion of I-64 and estimated that he would place the condition as being *poor to very poor*. *Thus, the score is 9 of 10 points.*

14. *Total estimated cost*. The project shows a total estimated cost of $97,263,000. When all projects are ordered from most to least expensive, the cost for the project is 51st, 52nd, and

53rd of 3,546 lines of projects. Thus, the project easily ranks in the top 10% of projects. *Thus, the score is 1 of 10 points* (it is relatively expensive).

Application of the Performance Measures to Route 1

1. *Intermodal connectivity.* Since Route 1 is a suburban arterial without limits on access, much of the frontage is devoted to commercial activity and most of the corridor is served by bus. It is assumed that the project will have sidewalks and bus access amenities but not bicycle lanes. *Since this project is assumed to address 3 modes (bus, pedestrian, and automobile), the score is 10 points.*

2. *Freight mobility. Since Route 1 will not expressly serve any kind of freight transfer facility but has a total truck ADT of 6% (of 38,000) = 2,280, the score is 2 points.*

3. *Relative unemployment rate.* The project is in Fairfax County and Prince William County, whose annual unemployment rates (December 2001) are both 2.7%. *Since the rates are below the December 2001 statewide rate of 3.6%, the score is 0 points.*

4. *AADT (truck and auto).* The project has an AADT of 38,000 vehicles per day. *Thus, the score is 9 points.*

5. *Relative priority in the local, MPO, or PDC plan or TIP*. The project is in the Northern Virginia Planning District and is under the purview of the Metropolitan Washington Council of Governments (MWCOG) and the Northern Virginia Transportation Coordinating Council (TCC). According to the Northern Virginia 2020 Transportation Plan published by the TCC in 1999 [14] this corridor is planned for improvements by the year 2010 (the shortest term of three categories in the plan). Since a priority order is not presented in the plan, it can only be assumed that the project is in the highest of three tiers. *Thus, the score is 7 points.*

6. *Community support (consistent with local or PDC plan).* The project is assumed to be consistent with the Fairfax County Comprehensive Plan and is assumed to have the full support of both governments for it is consistent with the regional (TCC) plan; in practice, both of these documents would be assessed. *Thus, the score is 10 points.*

7. *Environmental approval readiness*. No information was made available regarding the EIS, EA, or categorical exclusion for the project (this can be updated if VDOT's Environmental Division indicates otherwise). Fortunately, no court challenge is expected (e.g., no groups or individuals have indicated their intent to file a suit to block the project). *Thus, the score is 3 points.*

8. *Growth management*. It is assumed that the project is expected to improve the economic vitality and redevelopment efforts in its corridor; therefore, it receives 3 of 3 points for supporting compact, infill, or mixed development. This type of project typically does not address potential travel demand management techniques; therefore, it is assumed that the project receives 0 of 3 points for travel demand management techniques. The design of the

project, if in concert with current typical practice for redesign of suburban arterials, is assumed to incorporate access management techniques (e.g., reduce the number of entrances and align them as to improve safety and traffic flow); therefore, it receives 4 of 4 points for access management techniques. *Thus, the score is 7 points.*

9. *Volume-to-capacity ratio.* To apply this criterion, data from several VDOT sources, including photocopied pages from a document simply described as the Route 1 Corridor Study were synthesized.. This criterion requires calculation of the v/c ratio for traffic in a basic segment. The report provides this for each signalized intersection along the corridor, but not for Route 1 in general; however, the study breaks the study area into nine sections with free flow speeds ranging from 40 mph to 50 mph. Since the entire corridor study area was selected as one sample project, to evaluate the project in this manner, a free flow speed of 45 mph was selected as a surrogate value for the entire corridor. Traffic volumes provided from VDOT indicate this section of Route 1 carries 38,000 vehicles per day with 6% trucks.

   Several assumptions were made: the directional split is 50%/50% and the peak hour carries 10% of the daily volume; 60% of the total cycle length at signalized intersections is green time for Route 1 traffic; the capacity of this arterial is 1,800 pcphpl adjusted for signalized intersections to 1,080 pcphpl.

   The volume is given as 19,000 vehicles per day (in one direction), and a peak hour volume is assumed to be 10% of the 24-hour volume, or 1,900. The 950 vehicles per hour per lane (assuming traffic to be distributed evenly across two lanes) is then converted to PCE per hour per lane; in level terrain, the PCE value for trucks is 1.5. Using the 6% truck traffic, there are 950*(1 - 0.06) + 950*0.06*1.5 = 978 pcphpl.

   The v/c ratio is then calculated as 978/1080 = 0.906.

   Thus, the score is 8 points using the interim method (when rounded to the nearest hundredth and the v/c ratio is 0.91).

10. *Accident rate.* According to data provided by VDOT, Route 1 has an overall crash rate of 630 crashes/100 million VMT. *Thus, the score is 10 points using the interim method (since the rate is greater than 500) for the accident rate criterion.*

11. *Geometric deficiencies.* The Route 1 corridor planned for improvement does not meet current standards for geometric design. Specifically, according to data provided by VDOT, the lane width of 10 ft in some sections is substandard, and in some sections, no shoulders exist. Without data regarding horizontal and vertical alignment, it is known that at least three design features (lane width, left shoulder, and right shoulder) are substandard. *Thus, the score is 8 points.*

12. *Bridge deficiencies*. Route 1 has one bridge with a bridge sufficiency rating of 69. *Thus, the score is 1 of 10 points.*

13. *Surface rehabilitation*. VDOT's PMS data show that this section of Route 1 has an average load-related distress rating (LDR) of 55.7 and an average non-load related distress rating (NDR) of 60.06. The critical condition index (CCI) is defined as the lower of the LDR and NDR, and, thus, the Route 1 CCI is 55.7, earning it a classification of *poor* in VDOT's PMS. *Thus, the score is 8 points.*

14. *Total estimated cost*. The total estimated cost is $22,472,000. When all the projects are ordered, the total estimated cost for the project is on lines 449-450. Thus, the project ranks between the 80th and 90th percentiles (it is expensive but not as expensive as the I-64 project). *Thus, the score is 2 of 10 points.*

Summary of How the Performance Measures Were Applied for the Two Projects

To understand how weighting can influence the scoring of projects, Tables 7 and 8 compare the scoring for the two projects with two weighting scenarios. Table 7 weights each of the 14 performance measures with 10 points apiece, and Table 8 weights each of the seven TEA-21 planning factors with 10 points apiece. For example, the two performance measures *freight mobility* and *relative unemployment rate* correspond to the TEA-21 planning factor *economic development,* so the total score of 7 (of 20 possible points) converts to 3.5 of 10 points.

In this particular case, the outcome is the same: the Route 1 project still scores higher than the I-64 project. An extension of this exercise to hundreds of projects, however, might yield a different result, where a project's score relative to other projects is influenced by the weighting scheme that is selected.

Since it was unclear whether the TEA-21 planning factor *efficiency* should include cost, Table 8 does not include *total estimated cost.* However, total estimated cost can easily be added as a line item or as part of the efficiency measure if VDOT prefers Table 8 to Table 7 and wants to include the cost element.

Table 7. Scoring for the Two Projects with Equal Weight by Performance Measure

Performance Measure	I-64	Route 1
1. Intermodal connectivity	0	10
2. Freight mobility	7	2
3. Relative unemployment rate	0	0
4. Auto and truck AADT	9	9
5. Relative priority in the local, MPO, or PDC plan or TIP	6	7
6. Community support/consistency with local and MPO plans	10	10
7. Environmental approval readiness	3	3
8. Growth management	4	7
9. Volume-to-capacity ratio	6	8
10. Accident rate	5	10
11. Geometric deficiencies such as width, grade, or alignment	7	8
12. Bridge deficiencies	0	1
13. Surface rehabilitation	9	8
14. Total estimated cost	1	2
Total (maximum possible is 140)	65	85

Table 8. Scoring for Sample Projects with Equal Weight by TEA-21 Planning Factor

Performance Measure	I-64	Route 1
1. Intermodal connectivity	0	10
2. Freight mobility 3. Relative unemployment rate	3.5	1
4. AADT (truck and auto) 5. Relative priority in the local, MPO, or PDC plan or TIP	7.5	8
6. Community support/consistency with local and MPO plans 7. Environmental approval readiness 8. Growth management	5.7	6.7
9. Volume-to-capacity ratio	6	8
10. Accident rate 11. Geometric deficiencies such as width, grade, or alignment	6	9
12. Bridge deficiencies 13. Surface rehabilitation	4.5	4.5
Total (maximum possible is 70)	33.2	47.2

In practice, no template—this one included—can remove the human element from programming decisions. Rather, the template serves as an advisory tool for decision support. Realistically, the final programming decisions rest with Virginia's Commonwealth Transportation Board.

CONCLUSION

Undoubtedly, conflict will arise as stakeholders move from broad TEA-21 planning factors to specific performance measures. Few people will indicate that the "environment" or "congestion" is unimportant, but it appears that people can readily disagree as to how much these should be weighted if they are ever in conflict or, perhaps, how they should be determined. Given a statewide database of traffic volume projections of varying quality, a person with high confidence in the forecasts might favor a computational method based on the *HCM,* whereas a person who doubted the integrity of the traffic forecasts might prefer an approach based on expert opinion.

RECOMMENDATIONS FOR IMPLEMENTATION

It is not critical that VDOT adopt all 14 performance measures as written. Instead, the most important recommendation is that VDOT implement a transparent method for programming projects with the understanding that after the initial application, VDOT will probably modify which performance measures are used and how they are weighted.

VDOT should implement the template as shown, or with simple modifications, for the full set of projects in the CIP. Then, during the year that follows initial implementation, VDOT should consider the following types of changes based on feedback from stakeholders and technical staff.

1. *VDOT may vary the weights for the 14 performance measures.* As proposed, each performance measure is weighted equally (e.g., congestion is just as important as environmental factors). Varying the weights serves the same purpose as changing the scoring scale. An example of how varying the weights influences scoring was shown. Additional research that addresses the question of weights is underway by Lambert et al.

2. *VDOT may vary the scoring criteria within each performance measure.* For example, within the congestion performance measure, a DOT may choose to have a heavily congested facility be favored 2, 3, or 4 times more than a facility with moderate congestion.

   This type of modification is appropriate if a state wishes to highlight comparative differences. For example, if a state thought a project were likely to fail unless it has complete support, the state would probably revise performance measure 6 (community support) to be scored as shown to the far right in Table 9. The change from 5 points to 1 point for meshing with only one plan but not both reflects the view that agreement with all stakeholders is critical.

Table 9. Revising Performance Measure 6 If Stakeholder Unanimity Is Required

Event	Number of Points Under Original Method	Number of Points Under Revised Method
Policy on stakeholder agreement	Stakeholder agreement nice but not essential	Stakeholder agreement essential
Project meshes with both local and PDC plans	10	10
Project meshes with either local or PDC plan	5	1
Project meshes with neither plan	0	0

3. *VDOT may wish to add or delete performance measures.* For example, a DOT that wants to focus on mitigating ground level ozone (even in attainment areas where conformity is not an issue) might replace the congestion performance measure with a performance measure that estimates emissions levels. In practice, ground level ozone results from combination of volatile organic compounds (VOCs) and nitrogen oxides (NOx) under specific atmospheric conditions. Because such emissions are produced by other stationary and household sources and motor vehicles, a performance measure for a specific region would probably need to consider which type of emission was more likely to affect ground level ozone production. Although conformity regulations can prevent certain projects from being programmed in nonattainment areas, a state has the ability, at least in attainment areas, to reward projects that will contribute to reductions in ground level ozone.)

4. *VDOT may wish to reduce or increase the number of performance measures.* Such a decision is driven by the number of issues that drive the transportation programming process. The extremes range from the sole goal of eliminating congestion (only one performance measure) to many objectives (community enhancement, social benefits, etc.) VTRC expressly chose to provide "more" measures, as it will be easier for VDOT in the coming years to strike unnecessary ones than to add new ones.

5. *VDOT may wish to change the computational methods or data sources used to determine each measure.* For example, congestion is measured herein with the v/c ratio, but other indices are possible, such as the total amount of delay. The performance measures can also be determined from simulation, the *Highway Capacity Manual,*[15] or sampling techniques (e.g., using data available from traffic management centers). As other information systems evolve, such as the concrete component of the VDOT's PMS information, VDOT will want to modify this template to continue to take advantage of those systems. Potential data sources are shown in the Appendix.

REFERENCES

1. Cambridge Systematics, Inc. 2000. *A Guidebook for Performance-Based Transportation Planning*. NCHRP Report 446. Transportation Research Board, Washington, D.C.

2. Pignataro, L. J., and Epling, J. W. The TELUS Story: Information Tool for Transportation Planning Makes Its Debut. *TR News 210*, September-October 2000, pp. 9-12.

3. Stout, R.W. *Programs of the Federal Transit Administration. National Parks: Transportation Alternatives and Advanced Technologies for the 21st Century, Conference Proceedings*, June 1999, pp. 36-39, Bozeman, Montana. Viewed at http://www.itsdocs.fhwa.dot.gov//JPODOCS/PROCEEDN/93V01!.PDF on March 4, 2002.

4. *Governor's Commission on Transportation Policy.* December 15, 2000. *Final Report.* Richmond.

5. Virginia Department of Highways and Transportation. April 1984. *Statewide Highway Plan, Summary Report*. Richmond.

6. Virginia Department of Transportation. October 1989. *Virginia 2010 Statewide Highway Plan*. Richmond.

7. McGeehan, D. D., and Samuel, L. H. 1990. *Procedures for the Prioritizing of Road Improvements Under the Statewide Highway Plan.* VTRC 90-R7. Virginia Transportation Research Council, Charlottesville.

8. Ohio Department of Transportation. February 2001. Transportation Review Advisory Council Policies for Selecting Major New Capacity Projects. Originally accessed at

http://www.dot.state.oh.us/trac/tracpolicy.htm. March 2001; verified at a new location http://www.dot.state.oh.us/trac/book.pdf on July 26, 2001.

9. Delaware Department of Transportation. 2000. Capital Improvement Program. http://www.state.de.us/deldot/cip00-05/execsumm/priorities/sample.html. Originally accessed March 2001; verified July 26, 2001.

10. Alaska Department of Transportation and Public Facilities. 2001. *2004-2006 Draft Project Evaluation Criteria,* http://www.dot.state.ak.us/external/state_wide/planning/04criteria_draft.pdf. Originally accessed March 2001; verified July 26, 2001.

11. Turochy, R. E. Prioritizing Proposed Transportation Improvements: Methods, Evaluation, and Research Needs. In *Transportation Research Record (forthcoming).* Transportation Research Board. Washington, D.C.

12. City of Sacramento, Department of Public Works. 2000. *Transportation Programming Guide*. Sacramento, California.

13. See also see also Myers, J., and D. Niemeier. 1996. *Evaluation Categories for ODOT Modernization Prioritization.* Draft Final Report. Institute of Transportation Studies, University of California, Davis.

14. Northern Virginia Transportation Coordinating Council. 1999. *2020 Transportation Plan*, Fairfax, Virginia. (Summary Report and plan map are viewable at http://www.virginiadot.org/projects/nova/nv2020/techdocs/summ_rpt.pdf and http://www.virginiadot.org/projects/nova/nv2020/techdocs/2020TransPlanMap.pdf).

15. Transportation Research Board. 1997. *TRB Special Report 209: Highway Capacity Manual.* Washington, D.C.

APPENDIX: DATA SOURCES FOR THE TEMPLATE

Suggested data sources include the following.

1. *Intermodal connectivity*. In practice, the data should come from either the project's purpose and need if an EIS is available, or, in most cases, individual judgment as to whether the project is unimodal. However, it would appear that if a project will support other modes, this is usually identified; thus, most projects will probably be unimodal and would score 0 points in this category.

2. *Freight mobility*. The data sources will eventually be, in the long term, truck origin-destination data, but in the short term, truck traffic and proximity to freight transfer facilities should be examined. In this instance, truck AADT is used as a surrogate for freight demand, which is an imperfect assumption.

3. *Relative unemployment rate*. Data for a jurisdiction's unemployment rate should be outside a state DOT. In Virginia, for example, potential sources are the Weldon Cooper Center for Public Service, local PDCs, and the Virginia Employment Commission's website at http://www.vec-velma.state.va.us/. Whether this number would be applied by construction district or county for interstates must be determined. Applying the unemployment rate for the construction district for primary system projects does not add information since allocations are made at that level.

4. *Auto and truck AADT*. The data source should be current traffic volumes (TED) and forecast traffic volumes (TPD).

5. *Relative priority in the local, MPO, or PDC plan or TIP*. Data include any of the following:

    - the relative ranking of the project from the community's TIP
    - a ranking of local projects that could be requested from the county, PDC, or MPO
    - the TIP
    - a prioritization of the proposed projects from the MPO/PDC or county representatives or county representatives.

6. *Community support/consistency with local and MPO plans*. The data sources are ultimately the comprehensive plans for individual counties and the plans from either PDCs or MPOs. In Northern Virginia, the Metropolitan Washington Council of Governments' plan would be used; in the Charlottesville area, the plan from the Thomas Jefferson PDC or MPO would be used). In the long term, VDOT would need to obtain current copies of all local comprehensive plans and PDC/MPO transportation plans.

7. *Environmental approval readiness*. The data source that makes sense in the short term is for VDOT's Environmental Division to comment on a sliding scale (*high* being the project is ready, *low* being the project will at least face a difficult, costly, protracted, or perhaps futile court battle) as to how easy or hard it will be to clear environmental hurdles. The division, in turn, may wish to use either the project's purpose and need, its draft versions of the EIS or EA, or its contacts with environmental organizations that can comment on each project.

8. *Growth management*. Data are project specific, and for the access management and travel demand management portions can be gleaned directly from the project's scope of work; data for the land development portion necessitate examination of the local land use plans.

9. *Volume-to-capacity ratio.* The data would come from TED or TPD; some calculations must be made to compute capacity (e.g., see the *HCM*), use field data, or use expert judgment). All of these options are doable, but they should be recognized as potential pitfalls.[15]

10. *Accident rate*. The data for accident rates should come from two sources in VDOT's Traffic Engineering Division: the total number of crashes as recorded by VDOT's HTRIS (Highway Traffic Records Information System) database and the total VMT (or millions of vehicles entering an intersection). An application issue is that the accident rate metric makes sense only if the project will reduce the crash rate. A project that one knows will not have an impact probably should receive 0 points for the accident rate metric.

11. *Geometric deficiencies*. The data include lane widths, degree of horizontal curvature, vertical curvature, the percent grade, and the functional classification; several VDOT divisions (construction, programming & scheduling, location & design, and traffic engineering) appear to have access to these data.

12. *Bridge deficiencies*. The data (e.g., whether the bridge needs replacement, repair, or is fine) should come from VDOT's Structure & Bridge Division. The division has an excellent rating scale already in place (the Bridge Sufficiency Index), and such a scale has been normalized to the 10-point scale shown in Table 5.

13. *Surface rehabilitation*. The data should come from the PMS maintained by VDOT's Maintenance Division. The template uses the conditions (excellent, good, fair, poor, very poor) that come from the PMS. At present, the PMS obtains those conditions for asphalt sections from the minimum of the LDR and the NDR as derived from a windshield data collection survey. For concrete sections, these data are still being obtained, but VDOT plans to have them be a part of improvements to its PMS.

14. *Total estimated cost*. The data should come from VDOT's Programming & Scheduling Division, which at this time is making the data available over VDOT's Intranet. The costs for each project are shown as total estimated cost. The projects can be sorted from most to least expensive and then the rank of the project of interest can be determined. It has been pointed out that total estimated cost (as with all data elements) is imperfect and better estimates will improve the quality of any scoring method that relies on such data.