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Access Management Performance Measures for Virginia: A Practical Approach for Public Accountability

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16. Abstract:

In order to develop performance measures to communicate the effect of Virginia's access management program, five tasks were performed: (1) the appropriate literature was reviewed, (2) a catalog of potential performance measures was developed, (3) potential users of the performance measures were surveyed, (4) promising measures were tested, and (5) measures were recommended.

The literature review yielded a catalog of 42 potential performance measures. These measures are based on five goals and nine objectives related to the desired outcomes of the access management program. The five goals are reduce congestion, enhance safety, support economic development, reduce the need for new highways, and preserve the public investment in highways. Seven objectives are design elements: reduce conflict points, provide adequate distance between signals, provide adequate distance between unsignalized access points, add medians and two way left turn lanes, add dedicated turn lanes, restrict median openings, and use frontage roads and supporting streets. Two objectives are administrative elements: to enhance cooperation between agencies, and plan for future development.

Professionals engaged in access management provided their views regarding aspects of performance measures. Performance measures that reflected improved safety, measures related to goals, and measures related to design elements were favored.

The literature review and comments from VDOT staff and other professionals yielded 23 candidate measures that were tested for ease of data collection and computation. The results showed substantial variation in the time required to estimate each measure.

Five criteria were used to determine performance measures for implementation: (1) Does VDOT control the measure? (2) Is improvement likely? (3) Is the measure an outcome, output, or input? (4) Does the survey support the measure? and (5) How much data collection effort is required? Each of the 23 measures was evaluated against the five criteria, and 7 measures were selected for review and refinement by the steering committee.

Five performance measures were recommended for implementation: crashes per million vehicle miles traveled, percentage of signals with spacing at or above standard distance, percentage of commercial entrance permits issued that meet access management standards, percentage of median openings with left turn lanes, and percentage of localities with a corridor access management plan. Appendix A describes how each of the five measures may be computed.

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FINAL REPORT

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EXECUTIVE SUMMARY

Introduction

Access management involves the coordination and regulation of entrances and intersections along a highway corridor. Access management limits the number of locations where vehicles can enter, exit, or cross the highway and includes techniques such as spacing intersections at adequate distances, consolidating multiple driveways, opening existing medians only where necessary, controlling the number of traffic signals, providing auxiliary lanes for turning vehicles, and ensuring an integrated street network that supports the corridor. In 2007, Virginia's General Assembly passed legislation, codified in the *Code of Virginia* § 33.1-198.1, directing the Commonwealth Transportation Commissioner to "develop and implement comprehensive highway access management standards for managing access to and preserving and improving the efficient operation of the state systems of highways." Further, the legislation provided that the "comprehensive highway access management standards shall include but not be limited to standards and guidelines for the location, number, spacing, and design of entrances, median openings, turn lanes, street intersections, traffic signals, and interchanges."

In 2008, the General Assembly enacted legislation that required the Virginia Department of Transportation (VDOT) to implement the regulations and design standards in two phases according to a highway's functional classification. The first phase allowed the access management regulations and standards for VDOT highways classified as principal arterials to take effect July 1, 2008. The second phase applied to VDOT highways classified as minor arterial, collector, and local. These regulations and standards took effect October 14, 2009. The regulations for both phases may be found in Appendix F of VDOT's *Road Design Manual* (VDOT, 2010a).

The appropriate use of access management techniques has been shown to improve the safety and traffic operations of a highway corridor (Gluck et al., 1999). Thus it is essential that the benefits of VDOT's access management program, which comprises the state access management regulations and standards and their implementation, be clearly understood and communicated. To achieve this goal, clear indicators, or performance measures (PMs), of the program's impact are needed. Access management PMs, if directly related to improvements in corridor mobility and safety, are a means by which the results of these corridor changes can be understood. These PMs should reflect the extent to which the program improves transportation system operations. This study identified, tested, and recommended PMs that could be used to measure the impact of VDOT's access management program on state highways.

Methodology to Identify Candidate Performance Measures

Four steps comprised the methodology that yielded a set of candidate PMs:

1. A review of the literature was conducted in two areas: access management and performance measurement.

2. The literature review was used to develop a catalog of 42 potential PMs reflecting three complementary areas of an access management program: outcomes (e.g., the

program's effect on crash frequency and travel speed); design elements (e.g., the frequency and geometry of these access points relative to established standards); and administrative procedures (e.g., compliance with access management regulations and planning for future growth).

3. A survey regarding types of access management PMs that might be useful was distributed to 443 planning and/or engineering professionals representing metropolitan planning organizations, planning district commissions, consulting firms, cities, towns, counties, and VDOT. The 143 responses indicated which PMs respondents thought were useful and/or important.

4. A data collection test application was conducted for the 23 candidate PMs to determine which PMs could be easily computed given existing staff resources and database capabilities. Data were obtained through corridor site visits; extraction of data from crash, planning, and land development databases; telephone interviews with county planners and VDOT residency staff; examination of planning documents and regulations; and in-house meetings with staff of VDOT's Fredericksburg District.

Criteria for Evaluation of Candidate Performance Measures

Five criteria were used to evaluate the 23 candidate PMs:

1. *Does VDOT control the measure?* Cambridge Systematics, Inc. (Cambridge Systematics) (2006) emphasized the importance of using metrics over which an agency exerts some influence. For example, although improved travel time is a goal of VDOT's access management program, travel time is influenced by factors beyond VDOT's control, such as roadway grade and through truck traffic. Thus, the change in such a measure could not reliably be attributed to the performance of the access management program.

2. *Is improvement likely?* Establishing a baseline against which values are compared is one component of performance measurement (Cambridge Systematics, 2006; Wye, 2002). The project steering committee expressed concern that PMs that are not likely to improve beyond an existing baseline, such as number of signals per mile, may be difficult to communicate to the public.

3. *Is the measure an outcome rather than an output or an input?* PMs should be clearly related to the goals of a program (Cambridge Systematics, 2006; Keel et al., 2006; Meyer and Miller, 2001). Cambridge Systematics (2006) noted: "The common wisdom today is that it is preferable to measure 'outcomes' rather than 'outputs' (and either of these is certainly better than measuring 'inputs') to achieve results oriented performance monitoring."

4. *Do survey results support the measure?* The audience for a PM should be identified, and a strategy for communicating the measure to that audience should be developed

(Wye, 2002). For example, a PM based on the number of local planning meetings attended by VDOT was rated as the most important measure by only 5.6% of respondents and thus was discontinued.

5. *Are the necessary data relatively easy to collect?* The cost of collecting data for a PM should not exceed the value of the measure to the implementing agency (Keel et al., 2006).

The 23 PMs were placed into three categories: outcome, design, and administration. The five criteria, along with additional feedback from the project steering committee, were used to select recommended PMs in each area.

Outcome Performance Measures

Overview

VDOT's access management program was established to achieve five goals. The *Code of Virginia* (§ 33.1-198.1) defines these as follows:

1. Reduce traffic congestion and impacts to the level of service of highways, leading to reduced fuel consumption and air pollution.
2. Enhance public safety by decreasing traffic crash rates.
3. Support economic development in the Commonwealth by promoting the efficient movement of people and goods.
4. Reduce the need for new highways and road widening by improving the performance of existing systems of state highways.
5. Preserve the public investment in new highways by maximizing their performance.

Each goal represents an outcome of the access management program that could be measured.

Recommended Measure

Crashes per million vehicle miles traveled was the only outcome PM recommended for implementation. The *Code of Virginia* (§ 33.1-198.1) indicates that improved highway safety is one of five goals for VDOT's access management program, and the crash rate measures progress toward that goal directly. Survey respondents indicated that crashes and/or crash rate was the most useful outcome measure (55.6% of respondents gave it that ranking). Further, crash rate was rated as medium/easy in terms of data collection (because these data can be obtained from existing information systems, such as VDOT's Crash and Traffic Monitoring System databases) compared to other outcome measures, which necessitate an intensive field visit.

Design Performance Measures

Overview

Design PMs are based on seven objectives that, in the researchers' judgment, captured the access management design principles published as part of the Transportation Research

Board's (TRB's) *Access Management Manual* (TRB, 2003): use dedicated left turn lanes; provide adequate distance between traffic signals; reduce conflict points; restrict median openings to appropriate locations; provide adequate distance between unsignalized access points; use medians and two-way left turn lanes (TWLTLs); and use frontage roads and supporting streets. The first two objectives were reflected in the recommended design PMs.

Recommended Measures

The first design PM recommended for implementation is *percentage of median openings with left turn lanes*. The average rating for "using dedicated turning lanes" by respondents was 3.2, making this the second highest rated design element in Question 9 of the survey. This measure is well within the control of VDOT, is likely to improve, and is easy to calculate.

The second design PM recommended for implementation is *percentage of signals with spacing at or above standard distance*. The inappropriate use of traffic signals is strongly related to diminished capacity and decreased safety (Gluck et al., 1999). This measure was selected because it is within VDOT's control, is likely to improve, and is not difficult to obtain. Survey support was modest in the sense that 52% of respondents ranked it as first or second most useful of the four design elements presented.

Administrative Performance Measures

Overview

TRB (2003) noted that the problems associated with not managing roadway access, such as increased crashes and cut-through traffic in neighborhoods, are "symptoms of inadequate coordination of transportation and land use decisions." By extension, therefore, administrative measures should improve this coordination. Conceptually, one way to improve this coordination is to have policies in place for addressing requests that will arise because of land development; thus, one administrative objective is to plan for future growth. In practice, however, such a plan cannot necessarily be implemented by a single entity because, as pointed out by TRB (2003), there is some separation of powers among various governmental units (e.g., although the state controls the network, localities influence land development, which will yield requests for access to the network). This necessitates a second administrative objective: cooperation between stakeholders.

Recommended Measures

The administrative objective this study supported measuring the most was planning for future growth, measured by *percentage of localities with a corridor access management plan,* which is a recommended PM. Such plans recommend specific access management procedures to preserve or improve highway operations or safety. This measure is influenced, but not fully controlled, by VDOT, and it should improve as new plans are made. Further, 42% of survey respondents ranked "planning by VDOT" as the most useful of the four administrative procedures presented, and 27% ranked it second most useful. The data collection for this measure is not difficult.

Compliance with the access management regulations is measured by the *percentage of commercial entrance permits issued that meet access management standards*. Compliance with the regulations shows that cooperation is taking place between VDOT and the property owners. Cooperation allows various agencies to use their individual powers to a mutual benefit (Williams, 2004). Fourteen (of 104) responses to Questions 7 and 13 referred to the design, uniformity, or consistent application of access management standards.

Conclusions

- *Many PMs are available for evaluating an access management program.* Forty-two such PMs were developed in this study. If a PM for an access management program is desired, there is an ample supply of measures from which to choose.

- *The process of implementing an access management program results in three disparate, yet complementary areas where performance can be assessed:* outcomes (e.g., crash rates and delay); design elements (e.g., the spacing and geometry of access points); and administrative procedures (e.g., communications among the state, local governments, and developers).

- *No single perfect PM exists.* Primarily, this is because each PM assesses only one of the three areas (i.e., outcomes, design, and administration) where performance can be assessed. Further, no single PM meets all five criteria established in this study for determining the best PM.

- *Stakeholders view PMs in all three areas (outcomes, design, and administration) as important.* When asked to select the set of measures that was most useful, survey respondents, who represented localities, metropolitan planning organizations / planning district commissions, consulting firms, and VDOT, indicated that outcome or design measures were more useful than administrative measures. However, when given specific PMs in all three areas, survey respondents' ratings for importance of these measures did not differ by area. For example, on a scale of 1 to 4 with 4 being the most important, the average rating for administrative measures (3.30) was slightly higher than that for outcome measures (3.20).

Recommendation

Five PMs are recommended for implementation as detailed in Appendix A:

1. *crashes per million vehicle miles traveled* (outcome measure)

2. *percentage of signals with spacing at or above standard distance*

3. *percentage of commercial entrance permits issued that meet access management spacing standards*

4. *percentage of median openings with left turn lanes*

5. *percentage of localities with a corridor access management plan.*

FINAL REPORT

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INTRODUCTION

Access management involves the coordination and regulation of entrances and intersections along a highway corridor. Access management limits the number of locations where vehicles can enter, exit, or cross the highway and includes techniques such as spacing intersections at adequate distances, consolidating multiple driveways, opening existing medians only where necessary, controlling the number of traffic signals, providing auxiliary lanes for turning vehicles, and ensuring an integrated street network that supports the corridor. In 2007, Virginia's General Assembly passed legislation, codified in the *Code of Virginia* § 33.1-198.1, directing the Commonwealth Transportation Commissioner to "develop and implement comprehensive highway access management standards for managing access to and preserving and improving the efficient operation of the state systems of highways." Further, the legislation provided that the "comprehensive highway access management standards shall include but not be limited to standards and guidelines for the location, number, spacing, and design of entrances, median openings, turn lanes, street intersections, traffic signals, and interchanges."

The 2007 legislation also enumerated the five goals of VDOT's access management program (*Code of Virginia,* § 33.1-198.1):

1. Reduce traffic congestion and impacts to the level of service of highways, leading to reduced fuel consumption and air pollution.
2. Enhance public safety by decreasing traffic crash rates.
3. Support economic development in the Commonwealth by promoting the efficient movement of people and goods.
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PURPOSE AND SCOPE

The purpose of this study was to develop PMs to assist elected officials and VDOT in evaluating VDOT's access management program. The specific objectives of the study were to identify, test, and recommend PMs that could be used to measure the impact of VDOT's access management program on state highways.

The scope of the study was limited in two ways: (1) only PMs that could be developed "with minimal cost and effort" (R. Hofrichter, personal communication, October 9, 2007) were considered, given VDOT's need to minimize the staff costs associated with the program, and (2) only PMs that incorporated public benefits and public costs were considered. Costs to the private sector were beyond the scope of this study.

METHODOLOGY

Five tasks were performed to achieve the study objectives:

1. Review appropriate literature.
2. Develop a catalog of potential access management PMs.
3. Survey expected users of PMs.
4. Apply candidate PMs at a test location.
5. Develop a performance measurement system.

Review Appropriate Literature

A literature review was conducted using the library resources of VDOT's Research Library and the University of Virginia, including the Transportation Research Information

Service (TRIS). Studies of various corridors in Virginia where access management solutions were proposed were also reviewed. The literature review emphasized two areas: performance measurement and access management.

Develop a Catalog of Potential Access Management Performance Measures

The results of the literature review were used to identify 14 goals and objectives of an access management program. For each goal or objective, at least 1 PM was identified, resulting in a catalog of 42 potential PMs.

Survey Expected Users of Performance Measures

Survey Development and Deployment

A survey was conducted of a sample of Virginia transportation professionals familiar with access management. This sample was selected as follows:

- Staff of VDOT's Transportation & Mobility Planning Division (TMPD) helped identify town, county, and city managers (who were asked to forward the survey to local planners) and planning staff of planning district commissions (PDCs) and metropolitan planning organizations (MPOs).

- Five VDOT operations engineers identified staff of VDOT's Traffic Engineering Division.

- A member of the project steering committee (Hofrichter, 2008) identified contractors who had participated in land development training concerning site impact analyses (VDOT, 2010b).

The survey was designed based on the literature review. For example, the five goals for VDOT's access management program enumerated in the *Code of Virginia* (§ 33.1-198.1) were used to develop four intended outcomes of the program, i.e., improvements in highway performance, crash risk, property values, and air pollution (measured as a change in emissions). Respondents were asked to rank these goals based on their usefulness. The 11-question survey asked about other PMs and the importance of various elements of an access management program.

The initial version of the survey was developed using the online survey program Zoomerang. Prior to implementation, the survey was modified and reviewed by VDOT staff. Subsequently, the survey was tested by members and friends of the Virginia Transportation Research Council's Transportation Planning Research Advisory Committee shortly after their fall meeting in November 2007. Comments received in response to the pilot surveys were used to modify the final survey instrument; for example, reviewers suggested enabling respondents to print the survey instrument.

Potential survey respondents fell into two categories: those for whom e-mail addresses were available, and those for whom e-mail contact was not practical. For those without an e-mail address, the version of the survey created with the Zoomerang program was used. A link to this survey was posted at http://vtrc.net/am, and respondents were mailed a letter instructing them to go to that site. For those with an e-mail address, a survey macro developed by the University of Virginia's McIntire School of Commerce was used to ask questions similar to those in the Zoomerang survey. Some of those respondents were mailed a letter asking them to participate in the survey, and subsequently all those in this category were sent an e-mail with a link to the survey. Table 1 summarizes the methods for contacting each group of respondents. The survey instruments are shown in Appendix B.

Table 1. Potential Survey Respondents and Method of Contact

Employer of Respondent	Number Contacted	Contact Method		Survey Version Used	Notes
		Mailed Letter	E-Mail		
County	95	X		Zoomerang	Mailed letter instructed appropriate planning staff to go to http://vtrc.net/am, where survey was posted
City	39	X		Zoomerang	
Town	42	X		Zoomerang	
VDOT	25	X	X	McIntire	Link to survey was in e-mail; mailed letter notified respondent to expect an e-mail in near future
MPO/PDC	26	X	X	McIntire	
Consulting firms	216		X	McIntire	Link to survey was in e-mail

VDOT = Virginia Department of Transportation; MPO = metropolitan planning organization; PDC = planning district commission; McIntire = University of Virginia's McIntire School of Commerce.

Align Survey Results and Ratings of Performance Measures

Some PMs were not captured by the survey. For those PMs, a value of 0.5 point was assigned. For the PMs that were captured by the survey, the highest of four possible values was given as shown in Table 2. For example, for Question 3, the measure *highway performance* was ranked as the first or second most useful outcome measure by 79.8% of respondents, which, as shown in Table 2 (Test 2), yields 1.5 points for the measures *travel time* and *level of service* as they are measures of highway performance.

Table 2. Rating of Performance Measures Based on Survey Results

Points[a]	Test 1 (based on Questions 3, 4, and 5)	Test 2 (based on Questions 3, 4, and 5)	Test 3 (based on Question 7)	(Test 4 based on Questions 8 and 9)
1.5	At least 50.00% ranked measure as 4	More than 66% ranked measure as 4 or 3	--	Average rating of 3.7 or greater
1.0	Between 33.33% and 49.99% ranked measure as 4	Number of persons rating measure as 4 or 3 significantly larger than 50%.[b]	Measure mentioned in response to Question 7	Average rating of 3.2 to 3.6
0.5	Less than 33.33% ranked measure as 4	Number of persons rating measure as 4 or 3 not significantly larger than 50%[b]	--	Average rating less than 3.2

[a] The highest rating was given based on all four columns in Table 2.
[b] A one-tailed test of proportions is given in Appendix B and is based on a review of Freund and Wilson (1997), Hogg and Ledolter (1992), Montgomery (2001), Newbold (1988), and Ross (2004).

Apply Candidate Performance Measures at a Test Location

The 42 potential PMs became the basis of the 23 candidate measures selected. The VDOT Fredericksburg District was the site used to validate the feasibility of these measures. Highway facilities and administrative subdivisions within the district that exhibited characteristics represented in an access management program were chosen. The PM test application was implemented at the following locations, also shown in Figure 1.

- *A highway corridor:* State Route 3 between Route 1942–Big Ben Boulevard (West Endpoint) and the border of Spotsylvania County / City of Fredericksburg (East Endpoint)

- *Arterial highways at an interchange area:* the arterials intersecting I-95 at Interchanges 126 and 133 (Route 1 and Route 17, respectively)

- *An administrative district:* either the entire Fredericksburg District or select counties within the district depending on the candidate measure being tested.

As discussed in detail later, data to compute the measures were acquired from three sources: (1) databases and Internet resources, (2) field data collected at the site, and (3) VDOT and county staff.

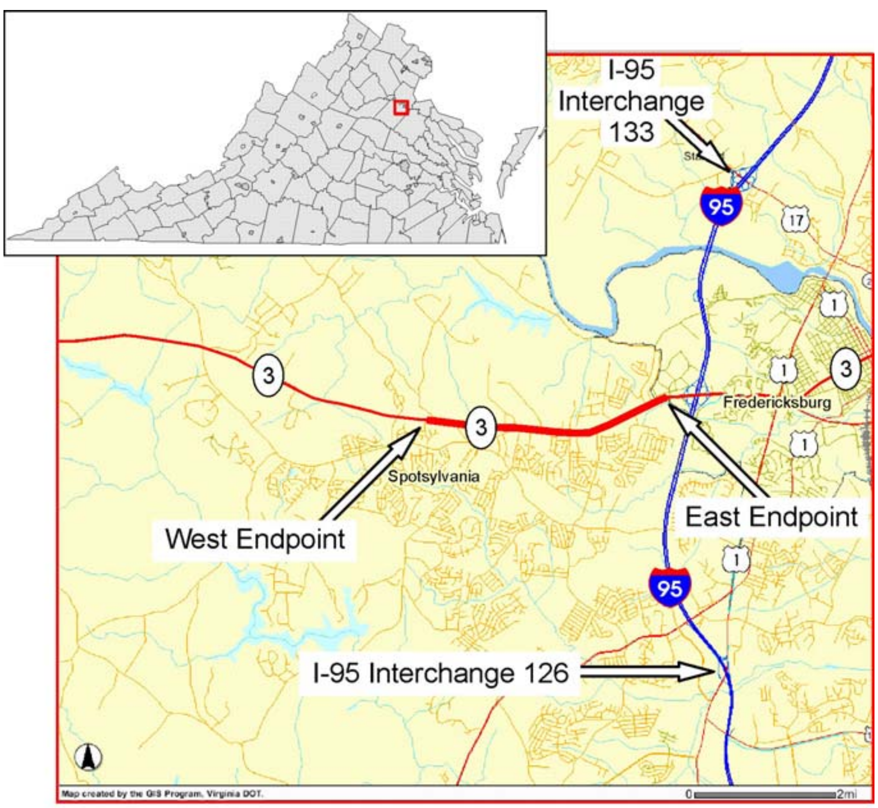


Figure 1. Location of State Route 3 and I-95 Interchanges, VDOT's Fredericksburg District

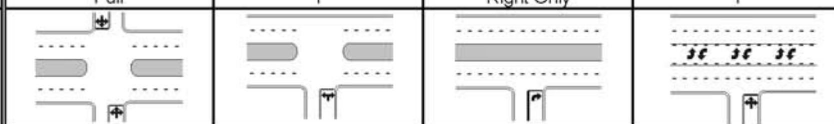
Databases

Data were collected from four VDOT databases: GIS Integrator, Statewide Planning System (SPS), VDOT's Crash Report Database, and VDOT's Traffic Monitoring System (TMS).

For determining the number of conflict points in particular, the data collection sheet shown in Figure 2 was used. For determining the length of segments (useful for determining the crash rate), the mileposts from VDOT databases and the software Google Maps were used.

Access Management Data Collection Sheet

Highway Number		Locality		AADT	
Highway Name		Date		AADT Source	
Starting Point		Evaluator		Area Type	
Ending Point		Data Source			
Segment Length (Mi)		Age of Data			



Type of Intersection	Full	T	Right Only	T	Other			
Picture								
Median Type	Divided			TWLTL				
Signalized								
Unsignalized								
Conflict Points	32	9	2	9				
Totals Signalized								
Totals Unsignalized								

	Total Conflict Points	Notes
Signalized		
Unsignalized		
Signalized Per Mile		
Unsignalized Per Mile		
Total Per Mile		

Figure 2. Data Collection Sheet for Determining Number of Conflict Points

Field Data

In addition to the Fredericksburg site, data were collected on U.S. Route 250 in Albemarle County. Photographs or videos were taken of the highway facilities and the adjacent driveways. The U.S. Route 250 site visit was added because it provided an opportunity to collect data at a location close to the University of Virginia. At both sites, travel time data were collected using a test vehicle.

VDOT and County Staff in Case Study Area

Three in-person meetings at the Fredericksburg District Office were conducted with the VDOT Fredericksburg District staff to discuss the feasibility of the proposed administrative PMs. The staff who participated had expertise in transportation planning, engineering, land development, and information systems used to track requests for entrance permits; as a consequence, these staff collectively explained the land development function as it related to potential administrative PMs.

To test the feasibility of the administrative measures, one residency in the Fredericksburg District (Saluda) was selected. For the counties served by that residency (Gloucester, King and Queen, Matthews, and Middlesex), information was sought regarding how access management was incorporated into specific ordinances, county comprehensive plans, and corridor studies. Although some of this information was available in printed form (e.g., Gloucester County and Virginia Department of Transportation [2001]), some information could be obtained only through emails with county and VDOT staff (e.g., Ducey-Ortiz [2009], Parker [2009]; Shaw [2009]).

Develop a Performance Measurement System

The process of selecting PMs consisted of three steps:

1. Establish a rating system.
2. Rate the measures.
3. Present the measures to the project steering committee, and revise accordingly.

Establish a Rating System

Five criteria were established based on the literature review and consultations with the project steering committee:

1. Does VDOT control the measure?
2. Is improvement likely?
3. Is the measure an outcome rather than an output or an input?
4. Does the survey show support for measure?
5. Are the necessary data relatively easy to collect?

For each PM and criterion, the extent to which the measure met, partially met, or did not meet the criterion was determined. For example, for the PM *crashes*, VDOT does not control this measure, so the PM received a score of 0 under Criterion 1. Generally, Criteria 1 and 3 could be determined by inspection (e.g., it is relatively straightforward to determine which PMs are controlled by VDOT and which are outcomes). Criteria 4 and 5 are based on an analysis of the survey responses and the data collection effort. Criterion 2 required some judgment to determine. To make this determination, each PM was considered in light of expected additional land development. For example, the PM *signals per mile* is not likely to improve because additional development will likely increase the demand for more signals.

Rate Measures

Each PM received a combined rating based on the five criteria. The PMs were listed in descending order of the rating. Those that received higher ratings were selected for further analysis except in situations where two measures appeared relatively similar. Except where otherwise noted in this report, in such cases, one of the two similar measures was chosen.

Present Measures to Project Steering Committee and Revise Accordingly

The project steering committee provided input regarding which PMs should be retained, modified, or eliminated. These comments, along with additional analysis of the PMs, also helped determine which measures had the potential for immediate implementation.

RESULTS

Literature Review

The concept of access management is well documented and mature. A 1953 *Highway Research Bulletin* (Reese, 1953) noted that access restrictions, coupled with other highway design elements, could reduce crash rates by 85%. This literature may be summarized in four categories:

1. access management goals
2. access management design elements
3. access management administrative procedures
4. criteria for comparing PMs.

Access Management Goals

As stated previously, VDOT's access management program was established to achieve five goals (*Code of Virginia,* § 33.1-198.1):

1. Reduce traffic congestion and impacts to the level of service of highways, leading to reduced fuel consumption and air pollution.
2. Enhance public safety by decreasing traffic crash rates.
3. Support economic development in the Commonwealth by promoting the efficient movement of people and goods.
4. Reduce the need for new highways and road widening by improving the performance of existing systems of state highways.
5. Preserve the public investment in new highways by maximizing their performance.

Goal 1: Reduce traffic congestion and impacts to the level of service of highways, leading to reduced fuel consumption and air pollution.

Level of service (LOS) is the characteristic used by the *Highway Capacity Manual* to depict "operational conditions within a traffic stream" using a rank of *A* (excellent) to *F* (intolerable) (TRB, 2000). For an arterial facility, LOS is based on flow rate, average speed, and free flow speed.

Speed and travel time will improve if access is properly managed. For every additional access point per mile, free flow speed is reduced by 0.15 mph (TRB, 2003). Substandard driveway spacing reduces average travel speeds by 5 to 10 mph, and each additional traffic signal per mile reduces speeds by 2 to 3 mph.

With regard to reduced fuel consumption and air pollution, the environmental effects of access management are complex, and a direct relationship between access management and the environment has not been established. Some positive environmental effects of access management have been identified as follows (TRB, 2003):

- New road construction can be reduced because the capacity of existing roads is preserved.
- Multiple driveways can be consolidated, thus reducing the total impervious surface area.

- Improved traffic operations can result in vehicles operating in a more fuel efficient manner.

Goal 2: Enhance public safety by decreasing traffic crash rates.

Two of the effects of access management are fewer driver conflicts and increased driver response time. The TRB's *Access Management Manual* (TRB, 2003) states the following:

1. As access density increases, crash rates increase.
2. Roadways with nontraversable medians are safer than undivided roadways or those with continuous two way left turn lanes (TWLTLs).
3. [Where median openings are provided] U-Turns are generally safer than direct left turns.
4. [Raised] medians improve pedestrian safety.

Gluck et al. (1999) showed that crash rates rise as the density of traffic signals, driveways, and intersections increases. They also showed that TWLTLs have lower crash rates than completely undivided facilities and that faculties with non-traversable medians have lower crash rates than TWLTLs.

Safety PMs may also be computed from microscopic simulation. Eisele and Toycen (2005) proposed *time to collision* as a predictor of roadway safety. They defined it as "the time that remains until a collision between two vehicles would have occurred if the collision course and relative speed difference had been maintained." Other simulation-based measures have been identified by Gettman and Head (2003), such as the deceleration rate that could "indicate the potential severity the conflict event."

Goal 3: Support economic development in the Commonwealth by promoting the efficient movement of people and goods.

The economic impacts of access management should be generally positive, since it is intended to improve traffic flow, resulting in fewer delays and crashes. At a national level, the interstate highway system has had a positive impact on economic development (Weisbrod, 2000). An example of a positive outcome is the conversion of U.S. Route 12, west of Minneapolis, from an arterial with at-grade intersections to “a freeway built to urban interstate standards” with no at-grade intersections or commercial driveways; the facility was renamed I-394. In their study of this corridor, Plazak and Preston (2005) found that although traffic volumes doubled, the peak traffic speed increased and the fatal and injury crash rate (e.g., the number of such crashes divided by the traffic volume) decreased. Economic indicators ranged from neutral to very positive; these indicators included land use intensity, income, business turnover, and commercial land values.

However, for individual corridors, the economic effects of controlled access highways are more nuanced. For example, a study on the economic effects of bypasses around small towns revealed a small negative effect on the towns studied (Helaakoski et al., 1992). In the aforementioned I-394 study (Plazak and Preston, 2005), a small number of businesses were negatively impacted.

At the scale of a single business, the economic effects of improvements in access management may be positive or negative. For example, constructing a median has been shown to have a positive impact on most businesses because it improves overall access to the commercial area, but it may also have a negative impact on some businesses such as gasoline stations and other establishments that depend on pass-by traffic (TRB, 2003). Some access management techniques reduce the quality of accessibility to certain properties but may also increase the volume of traffic passing that location. These effects compete to create both positive and negative economic effects (Gluck et al., 1999).

Goal 4: Reduce the need for new highways and road widening by improving the performance of existing systems of state highways.

An example of the effects of poor access management in a corridor is Highway 30 in Iowa south of Marshalltown. Plazak et al. (2004) stated:

> On that corridor, access was not carefully managed, resulting in a corridor with a high commercial driveway density, a relatively high crash rate, and a low travel speed. Eventually, a limited access bypass had to be built to replace the existing route. This cost millions of dollars that might not have needed to be spent if more attention had been paid in previous decades to corridor management.

Goal 5: Preserve the public investment in new highways by maximizing their performance.

According to the *Access Management Manual* (TRB, 2003):

> A four-lane divided major roadway with long, uniform signal spacing, directional openings between signals, and auxiliary lanes could accommodate a volume and a quality of service similar to those of a six-lane divided roadway having traffic signals at ¼ mi intervals, full access between the signals, and no auxiliary lanes.

Access Management Design Elements

The *Access Management Manual* lists 10 principles of access management (TRB, 2003). Recognizing that there is some commonality among these elements, it is possible to collapse these principles into seven design guidelines that can be used to develop PMs:

1. Reduce conflict points.
2. Provide adequate distance between traffic signals.
3. Provide adequate distance between unsignalized access points.
4. Use medians and TWLTLs.
5. Use dedicated left turn lanes.
6. Restrict median openings to appropriate locations.
7. Use frontage roads and supporting streets.

Design Guideline 1: Reduce conflict points.

When the paths of two vehicles merge, diverge, cross, or weave, a conflict can occur. These places are conflict points that create a potential for collision (TRB, 2003).

Design Guideline 2: Provide adequate distance between traffic signals.

The proper installation of traffic signals is one of the most important factors in ensuring that a roadway will operate efficiently. At a spacing of ¼ mi, progression speeds are 26 to 30 mph if traffic is spread out among many streets, cycle lengths are approximately 1 min, and two-phase operations dominate. For traffic on suburban highways where progression speeds of 45 mph are desired, ½-mi spacing is required. For traffic to progress through multiple signals without stopping, proper spacing is essential (Gluck et al., 1999).

The density of signalized intersections is a major contributor to the crash rate. When the number of signals per mile increases, crashes will increase. Having adequate turning lanes at signalized intersections is also an important factor in ensuring the safety of intersections (Gluck et al., 1999).

Design Guideline 3: Provide adequate distance between unsignalized access points.

According to *A Policy on Geometric Design of Highways and Streets,* driveways are "low volume intersections; thus their design and location merit special attention" (American Association of State Highway and Transportation Officials [AASHTO], 2004). The number of crashes at driveways is higher than at other intersections, making them an area of concern (AASHTO, 2004).

Driveways can adversely affect arterial highways, but they are needed on local roads to provide access to the surrounding land. Driveways should not be located in the functional area of intersections or in the influence area of an adjacent driveway. To be especially avoided are "large graded or paved areas adjacent to the traveled way upon which drivers can enter and leave the facility at will" (AASHTO, 2004).

Vehicle-to-vehicle conflict and friction increase when access opportunities are added to a highway corridor. By increasing the average distance between access points, traffic flow and safety should improve because the number of conflict points is reduced, thus increasing the distance provided for a motorist to anticipate and recover from turn maneuvers. In addition, the option to provide turning lanes is facilitated. A correlation exists between the number of access points per mile and the crash rate for the roadway (Gluck et al., 1999). Increasing the number of driveways per mile will reduce average travel speeds (Gluck et al., 1999) and "[d]irect property access along strategic and principal arterials should be discouraged. . . . However, where access must be provided, adequate spacing should be established to maintain safety and preserve movement" (Gluck et al., 1999).

Design Guideline 4: Use medians and TWLTLs.

At driveways where left turns are permitted, two thirds of collisions occur during a left turn either to exit or enter the property (TRB, 2003). Access management techniques that help mitigate the deleterious effect of left turns are median barriers that separate opposing traffic and TWLTLs. Median barriers separate opposing flows of traffic and eliminate the ability to make left turns, thus reducing the number of conflict points. They also provide a pedestrian refuge for pedestrians crossing the roadway. In addition, "TWLTLs and medians improve traffic operations and safety by removing left turns from through travel lanes" (Gluck et al., 1999). Installing a TWLTL produces a safer roadway facility, and medians produce safer roadways than do TWLTLs. Where median opening occur, there must be adequate capacity for traffic to make U-turns (Gluck et al., 1999).

Design Guideline 5: Use dedicated left turn lanes.

Left turn lanes have been used for decades to improve safety. For example, "as left turning motorists are removed from through lanes, the through traffic is able to move smoothly along the street, [resulting in a] 52% decrease in rear end accidents at previously non channelized intersections" (Thomas, 1966). Left turn lanes are effective because (1) left turning vehicles are removed from through lanes, thus reducing the risk of rear end collisions and increasing capacity; and (2) a motorist is better able to see oncoming traffic by offsetting the vehicle. Removing left turning traffic from through lanes can reduce accident rates by 18% to 77%, with the statistical median reduction more than 50% (Gluck et al., 1999).

Design Guideline 6: Restrict median openings to appropriate locations.

Median openings can take many forms, as illustrated in Figure 3. The safety of the median opening depends on its form. Accident rates at mid-block median openings are "substantially lower" than at intersections (Levinson et al., 2005). Potts et al. (2004) also noted for urban arterial facilities that crash rates for median openings are lower at midblock locations than in situations where the median is located at an intersection. As through traffic or left turn traffic becomes higher, it becomes more operationally advantageous to use right turns followed by U-turns rather than direct left turns (Zhou et al., 2002).

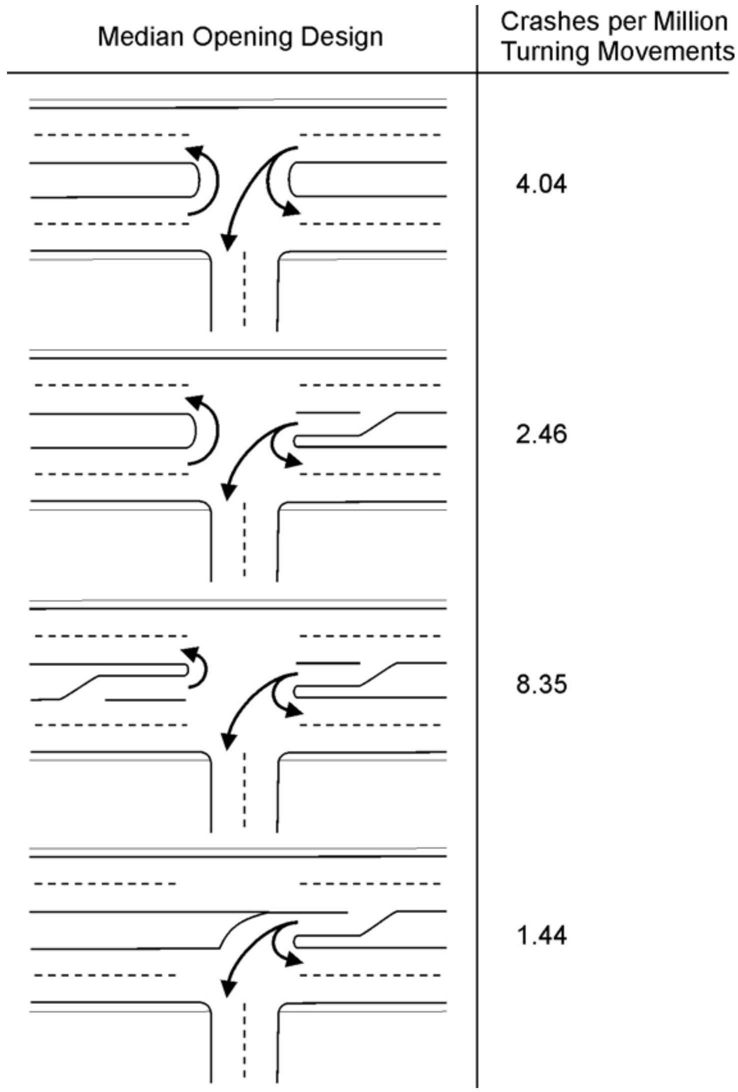


Figure 3. Different Types of Median Openings and Their Safety. Drawn from data presented by Levinson et al. (2005).

Design Guideline 7: Use frontage roads and supporting streets.

Well-designed frontage roads can be an effective access management technique. According to *A Policy on Geometric Design of Highways and Streets* (AASHTO, 2004), frontage roads run parallel to the main highway and can control access, serve adjoining properties, and maintain circulation of traffic along an arterial. The design of frontage roads becomes complicated when they must interact with cross streets. Sometimes it is advantageous to locate frontage roads at a substantial distance from the main roadway. The land between the arterial and the reverse frontage road is developed, but access is permitted only to the side of the land facing the reverse frontage road, not the side facing the arterial. These are called reverse frontage roads (Gluck et al., 1999).

A specialized network of supporting streets can improve corridor performance: each level in such a hierarchy is defined by the extent to which a given facility serves a mobility function or a local access function (TRB, 2003). Roadways can be classified as arterial, collector, or local. Arterial roadways provide mobility, and local roadways provide access (AASHTO, 2004). From an access management perspective, the difference between urban arterials and urban collectors is important. AASHTO (2004) described principal urban arterials as follows:

> The principal arterial system carries most of the trips entering and leaving the urban area, as well as most of the through movements bypassing the central city. In addition, significant intra-area travel, such as between central business districts and outlying residential areas, between major inner-city communities, and between major suburban centers, is served by this class of facility.

Minor arterial streets accommodate "trips of moderate length at a somewhat lower level of travel mobility than principal arterials do. . . . The urban collector street system provides both land access service and traffic circulation within residential neighborhoods and commercial and industrial areas" (AASHTO, 2004).

If urban collectors are not built, the circulating traffic from residential neighborhoods and commercial and industrial areas will be forced on to arterial highways. The *Access Management Manual* stresses the need for a supporting roadway network: "A well-conceived functional classification system is the foundation for an access management program" (TRB, 2003).

Access Management Administrative Procedures

Administrative procedures that have been shown to produce better managed access to the highway network fall into two broad categories: (1) cooperation between government agencies at different levels, and (2) planning for future growth.

Cooperation allows various agencies to use their individual powers to a mutual benefit (Williams, 2004). Cooperation also implies that parties should work together, increasing the chance that their final conclusions will be accepted (Urban Land Institute, 1994). Cooperation requires that a common vision be established for a highway corridor and that this vision be accepted by all interested parties. Once this vision is established, it should be formalized by local regulations (Williams, 2004). Cooperation also requires constant communication between stakeholders (Williams, 2004). Without cooperation, perpetual conflict can develop, thus increasing uncertainty and complicating planning (Urban Land Institute, 1994).

Proper planning for future development can prevent many access management problems since poorly managed access develops slowly as a highway corridor is built up. In rural areas, where access management is not a concern, it is important to preserve the mobility function of these facilities by encouraging municipalities to promote land development at interchanges rather than near at-grade intersections. Further, median breaks should be carefully controlled and additional access points should be prohibited where possible (Plazak et al., 2004). To manage access in the urban fringe, Plazak et al. (2004) recommended developing agreements with local governments and purchasing access rights where feasible. General procedures include reviewing the access classification of roadways, taking an inventory of driveways, identifying rural driveways that could become commercial, including access management in new capacity and reconstruction projects, and encouraging local governments to maintain up-to-date land use plans.

Criteria to Compare Performance Measures

PMs may be compared using five criteria:

1. degree of agency control of the measure
2. ability to choose an appropriate baseline
3. extent to which the measure is an outcome
4. stakeholder support for the measure
5. ease of data collection.

Criterion 1: Degree of Agency Control of the Measure

For a PM to be useful to a transportation agency, the agency must be able to connect its specific actions with the observed value and be able to make changes as needed. As noted by Meyer and Miller (2001), a PM should provide both "insensitivity to exogenous factors" and "discrimination between influences." PMs for a transportation program should provide an indication of the effect of that program. According to Cambridge Systematics, Inc. (Cambridge Systematics) (2006), a PM should "reflect characteristic(s) that can be controlled by the implementing agency." An understanding of the factors that control a PM can help an agency link it to actions it undertakes such that the effects of various scenarios can be predicted.

Criterion 2: Ability to Choose an Appropriate Baseline

Wye (2002) wrote: "No performance indicator can yield useful information until it is interpreted, explained, and set in context." One component of this context appears to be the baseline against which a particular PM value is compared. For example, Wye (2002) mentioned that customer ratings may be compared to an "original baseline" (presumably to show how some initiative has improved customer service). Cambridge Systematics (2006) also noted the importance of measuring "the current baseline level of performance." Thus, when presenting a measure, being able to choose an appropriate baseline against which to compare the measure's value is one important criterion.

Criterion 3: Extent to Which the Measure is an Outcome

Outcomes are the final goals of a program. Outputs are the intermediate results related to those goals. Inputs are the resources used to achieve outputs and outcomes. Many sources (Cambridge Systematics, 2006; Keel et al., 2006; Meyer and Miller, 2001) recommend that PMs be related to the goals of the program. Cambridge Systematics (2006), stated: "The common wisdom today is that it is preferable to measure 'outcomes' rather than 'outputs' (and either of these is certainly better than measuring 'inputs') to achieve results oriented performance monitoring." Wye (2002) made the point that although a measure of outcomes is desirable, if they cannot be measured, it is still possible to measure intermediate results.

Criterion 4: Stakeholder Support for the Measure

If a PM is not easily understood, it will be of little value. As noted by Wye (2002), the audience for a PM should be identified and a communication strategy developed considering that audience. The characteristics of a good PM include "clarity" (Meyer and Miller, 2001) and being "useful" (Keel et al., 2006). PMs for both technical and non-technical audiences are desirable (Cambridge Systematics, 2006).

Criterion 5: Ease of Data Collection

The cost of collecting data for a PM should not exceed the value of the measure to the implementing agency (Cambridge Systematics, 2006; Keel et al., 2006; Meyer and Miller, 2001). Wye (2002) stated that scientific precision is not necessary, and in most cases a simple indication of whether the program is on or off course will be sufficient.

Other Possible Criteria

Although the majority of the requirements presented by the literature are represented in the preceding five criteria, others are possible. According to Meyer and Miller (2001), a measure should possess "sensitivity and responsiveness" and should quantify something at the "appropriate level of detail." Keel et al. (2006) recommended that a measure "incorporate significant aspects of agency operations." Some measures quantify only a small aspect of an access management program. Cambridge Systematics (2006), and Meyer and Miller (2001) recommended that a PM be somewhat universal. Measures that are applicable to one situation are less desirable then measures that can be applied many places. For example, a measure that can be applied across multiple modes of transportation is more desirable than a measure of only highways.

Catalog of Performance Measures

The literature review identified five goals of VDOT's access management program, seven objectives related to design, and two objectives related to administrative procedures. Tables 3 and 4 summarize the catalog of the 42 PMs identified by reviewing the literature, with at least 1 PM based on each goal or objective. An additional 14 PMs, such as customer service rating per permit process and a composite measure based on traffic volume and the distance between driveways, were noted by Benware and Jukins (1995) and Rose et al. (2000, 2005).

Survey of Performance Measure Users

Sample of Respondents (Questions 1, 2, 11, and 12)

From the 443 potential respondents contacted, 143 responses were received, as indicated in Table 5. Of the 110 respondents who provided a title, most were planners (56) or engineers (33); other titles included city manager, director of public works, and traffic signal systems manager. The majority of respondents were involved in land development review but other

Table 3. Catalog of Performance Measures Based on Access Management Goals

Goal	Performance Measure	Supporting Literature
Reduce congestion	Travel time[a]	*Code of Virginia* § 33.1-198 (*Code*); Transportation Research Board (TRB), 2000; Rose et al., 2000
	Density of vehicles	*Code*; TRB, 2000
	Speed variation[a]	
	Level of service[a]	
	Emissions	*Code*; Rose et al., 2000
Enhance safety	Crash rate[a, b]	*Code*; Gluck et al., 1999; Rose et al., 2000
	Simulation-based safety measure	*Code*; Eisele and Toycen, 2005; Gettman and Head, 2003
Support economic development	Property values	*Code*; Plazak and Preston, 2005
	Business turnover	
	Income	
	Employment	
Reduce need for new highways	Highway construction	*Code*; Plazak et al., 2004
	Money spent on highways	
Preserve public investment in highways	Capacity in relation to number of lanes on highway	*Code*; TRB, 2003
	Change in capacity	

[a] PM was tested with field data.
[b] PM was recommended.

responses included developing access standards, conducting research, and developing corridor plans, with about one-half of the respondents spending at least 10% of their time on access management issues.

Aggregate survey results are summarized here. Responses are subdivided into cities, counties, towns, MPOs/PDCs, consulting firms, and VDOT; individual responses for Question 7 are available from the authors. (However, no identifying information is available.)

Usefulness of Outcome, Design, and Administrative Measures (Questions 3-7)

Within each category of possible metrics, respondents were presented with four measures and asked to rank each from 1 (least useful) to 4 (most useful) using each rank only once. Table 6 shows that in terms of outcomes, *crashes* and *highway performance* were ranked as substantially more useful than *property values* and *air pollution*. The two most useful design measures were conflict points and driveways per mile. Planning by VDOT and cooperation were the two most useful administrative measures.

By themselves, Questions 3, 4, and 5 do not compare the usefulness of measures across categories. Accordingly, Question 6 asked respondents to name which category of measures (outcomes, design elements, or administrative measures) was most useful: 50.4% chose outcome measures, whereas 39% chose design and 10.6% chose administrative measures.

Question 7 asked respondents to name other measures that could help describe the performance of Virginia's access management program. Many respondents offered measures that related to those given in the survey instrument, such as delay time (which relates to *highway performance)* and minimum distance between driveways (which relates to *number of commercial*

Table 4. Catalog of Performance Measures Based on Access Management Objectives

Objective	Performance Measure	Supporting Literature
Reduce conflict points	Conflict points per mile[a]	Rose et al., 2000; Transportation Research Board (TRB), 2003
Provide adequate distance between traffic signals	Number of signals[a]	Gluck et al., 1999
	Percentage of signals at standard spacing[a, b]	
	Bandwidth through signals	
Provide adequate distance between unsignalized access points	Number of driveways[a]	
	Driveways within functional area of an intersection[a]	
Use medians and two-way left turn lanes (TWLTLs)	Miles of highway with median	
	Illegal left turn movements	
Use dedicated left turn lanes	Use of left turn lanes[a, b]	Gluck et al., 1999; Thomas, 1966
	Length of left turn lanes	Gluck et al., 1999
Restrict median openings to appropriate locations	Number of median openings[a]	Levinson et al., 2005
	Sight distance at median openings	
	Full median openings that could be converted to directional median openings	
	Number of unsignalized locations with high volumes of crossing and left turning traffic	
Use frontage roads and supporting streets	Interconnectivity along a corridor	American Association of State Highway and Transportation Officials (AASHTO), 2004; Gluck et al., 1999; TRB, 2003
	Number of interparcel connections	
Establish cooperation among stakeholders	Agreements between VDOT and localities	Rose et al., 2000; Urban Land Institute, 1994; Williams, 2004
	Disputes between VDOT and a local agency or developer[a]	Urban Land Institute, 1994; Williams, 2004
	Disputes resolved through collaboration rather than legal action	
	VDOT observation of development by attending local meetings	
	Assistance provided to localities	
	Compliance with regulations[a, b]	Rose et al., 2000; Rose et al., 2005
Conduct planning for future growth	Amount of time since access classification of a highway has been reviewed	Plazak et al., 2004
	Planning in developing rural areas	
	VDOT ownership of access rights	Plazak et al., 2004; Rose et al., 2005
	Localities with up-to-date land use plan	Plazak et al., 2004; Rose et al., 2000
	Access management corridor plans[a, b]	

[a] PM was tested with field data.
[b] PM was recommended.

Table 5. Summary of Surveys Distributed and Received

Group	Distributed	Received
Cities	39	23
Counties	95	50
Towns	42	17
MPOs/PDCs	26	12
Consulting firms	216	21
VDOT	25	20
Total	443	143

MPOs = metropolitan planning organizations; PDCs = planning district commissions.

Table 6. Summary of Responses to Questions 3, 4, and 5: Rank Usefulness of PMs[a]

Category	Performance Measure (PM)	% Respondents Indicating PM Is	
		Most Useful	First or Second Most Useful
Outcome	Crashes (e.g., change in crash rate attributed to access management)	55.6	87.9[b]
	Highway performance (e.g., change in travel time attributed to access management)	38.7	79.8[b]
	Property values (e.g., change in value of property along a highway attributed to access management)	4.8	26.6
	Air pollution (e.g., change in emissions attributed to access management)	0.8	5.6
Design	Conflict points (e.g., number of conflict points along a highway)	42.9	63.5[b]
	Driveways (e.g., number of commercial driveways per mile of highway)	26.2	62.7[b]
	Traffic signals (e.g., number of signals per mile of highway)	19.8	51.6
	Supporting streets (e.g., number of parallel roadways supporting a highway)	11.1	22.2
Administration	Planning by VDOT (e.g., percent of highways in developing areas with an access management plan)	42.4	69.6[b]
	Cooperation (e.g., percent of localities that promote access management)	26.4	64.0[b]
	Providing assistance (e.g., number of development plans reviewed by VDOT)	25.6	50.4
	Observation of development (e.g., number of local planning meetings attended by VDOT employees)	5.6	16.0

[a] Within each category, respondents were asked to rank the usefulness of each measure from 1 (least useful) to 4 (most useful) using each rank only once.
[b] Significantly greater than 50% at the 0.05 confidence level based on the test in Appendix B.

driveways per mile of highway). However, a substantial number of responses was offered in two categories that did not directly relate to the survey questions. One category was the consistent application of access management standards, with specific responses citing number of waivers, enforcement from VDOT, and number of appeals made by landowners. The second category was support for alternative modes, with specific responses citing pedestrian and bicyclist safety, access, and design elements.

Importance of Elements of an Access Management Program (Questions 8-10)

Questions 8, 9, and 10 asked respondents to rate the importance of outcomes, design elements, and administrative procedures that are elements of Virginia's access management program. Table 7 shows that *improved highway safety* was the most important outcome and it was consistently high among all respondent groups (cities, counties, MPOs/PDCs, consulting firms, towns, and VDOT). The most important design element (*designing highways with a minimum number of conflict points*) was also named most important by all respondent groups. *Restricting movements at medians* received lower ratings from MPOs/PDCs and towns, and *use of medians and TWLTLs* received lower ratings from cities, counties, and VDOT. In terms of administrative procedures, *promoting cooperation* was highly rated, in terms of importance, by

Table 7. Average Rating for Each Access Management Program Element[a]

Category	Element	Average Rating
Outcome	Improved highway safety	3.8
	Reduced congestion	3.5
	Preservation of investment	3.3
	Lowered need for new construction	3.1
	Improved economy	2.9
	Reduced air pollution	2.6
Design	Designing highways with a minimum of conflict points	3.6
	Using dedicated turning lanes	3.2
	Constructing a supporting roadway network	3.1
	Spacing signals at long uniform distances	3.0
	Spacing unsignalized access points at long distances	2.9
	Using medians and two-way left turn lanes (TWLTLs)	2.9
	Restricting movements at median openings	2.9
Administration	Promoting cooperation	3.5
	Creating a plan for development of a corridor	3.5
	Providing up-to-date access management standards	3.4
	Developing agreements	3.3
	Developing an up-to-date land use plan	3.2
	Assisting localities	3.2
	Reviewing development plans to determine the current access management situation	2.9

[a] 1-4 (Not important to Very important). Users could use each rating more than once.

counties, towns, and consulting firms. Cities, MPOs/PDCs, and VDOT rated *creating a plan for the development of a corridor in a rapidly developing area* as most important. *Reviewing development plans* was generally given lower ratings, signifying less importance.

Test Application of Candidate Performance Measures

From the 42 PMs listed in the catalog of PMs, 23 candidate PMs were selected for a test application. The measures used in the test application are more precisely defined than the broad PMs in the catalog. The measures included in this test application were selected for the following reasons:

- The literature review suggested the measure would be useful.
- Preliminary results of the survey suggested the measure would be useful.
- VDOT staff recommended the investigation of the measure.

The test application yielded values for most of the PMs. It also provided information about the effort needed to collect data for each measure. Measures of administrative elements of the access management program—*disputes between VDOT and a local agency or developer, compliance with regulations,* and *access management corridor plans*—generally required more preliminary work and were less precisely defined than the other measures. For these measures, the test application focused more on the feasibility of implementing the measures than obtaining actual values. A summary of the 23 candidate PMs is shown in Table 8. The difficulty of data collection is categorized as follows.

Table 8. Summary of Test Application Results

No.	Performance Measure (PM) (units)	Values (year reflected by data)	Effort Required to Collect Data
1	Travel time (minutes to travel highway segment)	8.3 min (2008)	Hard (Site Visit)
2	Travel time (minutes to travel highway segment, less optimal travel time)	3.6 min (2008)	Hard (Site Visit)
3	Speed variation (stop time in minutes; and number of stops)	1.94 min, 3.7 stops (2008)	Hard (Site Visit)
4	Speed variation (number of times vehicles speed fell below 35 mph)	5 (2008)	Hard (Site Visit)
5	Level of service (*Highway Capacity Manual* level of service scale)	Western portion of segment: D Eastern portion of segment: C (2007 or 2008)	Varies depending on source of data: Medium/Hard
6	Travel time; number of driveways (free flow speed)	Western portion of segment: 46.9 Eastern portion of segment: 45.8 (2007 or 2008)	Varies depending on source of data: Medium/Hard
7	Crash rate for a highway segment (crashes per million VMT)	3.4 (2003) and 2.6 (2007)	Medium/Easy
8	Crash rate (crashes per mile)	71.1 (2003) and 53.8 (2007)	Easy
9	Conflict points (number per mile)	177 (2002)	Medium/Hard
10	Number of signals (number per mile)	2.8 (2002)	Easy
11	% of signals at standard spacing (percentage of signals)	0% (2002)	Medium
12	Driveways within the functional area of an intersection (number per signalized intersection)	5.7 (2002)	Medium/Hard
13	Number of median openings (number per mile)	6.2 (2002)	Easy
14	Use of left turn lanes (percentage of median openings with left turn lanes)	12 with and 4 without (2002)	Easy
15	Use of left turn lanes; number of median openings (number of directional median openings)	Zero (2002)	Unknown, Likely Easy
16	Travel time at an interchange (minutes to travel highway segment)	Exit 126-22 (2008) and Exit 133-31 (2008)	Hard (Site Visit)
17	Crash rate at an interchange (crashes per million vehicle miles of travel)	Exit 126-5.4 (2007) Exit 133-3.1 (2007)	Medium
18	Driveways within the functional area of an intersection (feet from terminal of an interchange ramp to first driveway)	Exit 126-369 ft (2002) Exit 133-264 ft (2002)	Medium
19	Multiple performance measures (percentage of interchanges meeting access standards)	Neither (2002)	Medium
20	Driveways within the functional area of an intersection (number of substandard intersections near interchanges)	Exit 126-6 intersections (2002)	Hard
21	Disputes between VDOT and a local agency or developer (percentage of entrance permits approved on first submittal)	No data available[a]	Hard
22	Compliance with regulations (percent of commercial entrance permits issued that meet entrance standards)	Data not yet available[a]	Medium[b]
23	Access management corridor plans (percent of localities with a corridor access management plan)	3 of 3 = 100% (2009)	Medium

[a] The values for these measures were calculated based on meetings with staff from the VDOT Fredericksburg District. For PM 21, district staff did not think the measure would be worthwhile; therefore, a value was not calculated. For PM 22, data were not available at the time this research was undertaken, although staff were developing software applications that could potentially track such data if the data were entered (Haynes, 2008, 2009).

[b] A "medium" effort is expected, but this was not verified through application as with the other measures.

- *Easy*: data readily available, little transportation analysis experience necessary, and maximum time required per highway segment is ¼ day

- *Medium*: data require more effort to obtain, some transportation experience is helpful, and maximum time required per highway segment is ½ day

- *Hard*: multiple data sources must be organized and tabulated; transportation experience required to understand formulas and notations, or a site visit is required.

Development of a Recommended Performance Measurement System

Establishment of a Rating System

Five criteria were used to evaluate the 23 candidate PMs:

1. *Does VDOT control the measure?* A score of 1, 0.5, or 0 was given depending on whether VDOT controls the measure, potentially controls the measure but may be hampered by cost or political authority, or does not control the measure because of other factors.

2. *Is improvement likely?* Because Cambridge Systematics (2002) and Wye (2006) noted the importance of choosing a baseline against which to assess performance, and because the project steering committee noted the importance of choosing measures that could improve (or at least not degrade) over time, the Criterion 2 ("ability to choose an appropriate baseline") was renamed "is improvement likely?" A score of 1, 0.5, or 0 was given depending on whether improvement is likely, possible but difficult to predict, or not expected.

3. *Is the measure an outcome rather than an output or an input?* A scores of 1, 0.5, or 0 was given depending on whether the measure is an outcome, output, or input.

4. *Does the survey show support?* A score of 1.5, 1, or 0.5 was given depending on whether the measure received support as shown in Table 2.

5. *Are the necessary data relatively easy to collect?* A scores of 1.0, 0.5, or 0 was given depending on whether data collection is easy, medium, or hard as shown in Table 8.

Presentation of Measures to Project Steering Committee

Table 9 shows the ratings for the 23 PMs and which 7 were recommended to the project steering committee. Instead of simply recommending the seven PMs that had the highest sum of scores, the researchers removed PMs that were closely related such that only 1 of 3 PMs related to median openings, only 1 of 3 PMs related to crashes, and only 1 of 4 PMs related to travel time were recommended. The exception to this approach was that the researchers included 2 PMs related to signals.

Table 9. Scores for the Performance Measures in Descending Order of the Sum of the Criteria Scores

PM No.	PM Description	Criteria						Initial Decision
		1	2	3	4	5	Sum	
14	Use of left turn lanes (percentage of median openings with left turn lanes)	1	1	0.5	1[a]	1	4.50	Avoid: this median-related PM resembles PM 13
23	Access management corridor plans (percentage of localities with corridor access management plan)	0.5	1	0.5	1.5[b]	0.5	4.00	Recommend to steering committee
8	Crash rate (crashes per mile)	0	0.5	1	1.5[c]	1	4.00	
13	Number of median openings (number per mile)	1	1	0.5	0.5[d]	1	4.00	
15	Use of left turn lanes; number of median openings (number of directional median openings)	1	1	0.5	0.5[d]	1	4.00	Avoid: this median-related PM resembles PM 13
7	Crash rate (crashes per million VMT)	0	0.5	1	1.5[c]	0.75	3.75	Avoid: these crash-related PMs resemble PM 8
17	Crash rate at an interchange (crashes per million VMT)	0	0.5	1	1.5[c]	0.5	3.50	
22	Compliance with regulations (percentage of entrance permits issued that meet access management spacing standards)	1	0.5	0.5	1[e]	0.5	3.50	Recommend to steering committee
5	Level of service (HCM level of service scale)	0	0.5	1	1.5[c]	0.25	3.25	
10	Number of signals (number per mile)	1	0	0.5	0.5[f]	1	3.00	
11	% of signals at substandard spacing (percentage of signals)	1	0.5	0.5	0.5[f]	0.5	3.00	
1	Travel time (minutes to travel highway segment)	0	0.5	1	1.5[c]	0	3.00	Avoid: these travel-related PMs resemble PM 5
2	Travel time (minutes to travel highway segment, less optimal time)	0	0.5	1	1.5[c]	0	3.00	
16	Travel time at an interchange (minutes to travel highway segment)	0	0.5	1	1.5[c]	0	3.00	
18	Driveways within functional area of an Intersection (feet from terminal of an interchange ramp to first driveway)	0.5	0.5	0.5	0.5[d]	0.5	2.50	Not recommended
21	Disputes between VDOT and a local agency or developer (percentage of entrance permits approved on first submittal)	1	0.5	0.5	0.5[d]	0	2.50	
6	Travel time; number of driveways (free flow speed)	0.5	0.5	0.5	0.5[d]	0.25	2.25	
9	Conflict points (number per mile)	0.5	0	0.5	1[f]	0.25	2.25	
12	Driveways within functional area of an intersection (number per intersection)	0.5	0.5	0.5	0.5[d]	0.25	2.25	
3	Speed variation (stop time in minutes; number of stops)	0	0.5	1	0.5[d]	0	2.00	
4	Speed variation (number of times vehicle's speed fell below 35 mph)	0	0.5	1	0.5[d]	0	2.00	
19	Multiple performance measures (percentage of interchanges meeting access standards)	0.5	0	0.5	0.5[d]	0.5	2.00	
20	Driveways within functional area of an intersection (number of substandard intersections near interchanges)	0.5	0.5	0.5	0.5[d]	0	2.00	

Criteria: 1 = Does VDOT control the measure; 2 = Is improvement likely; 3 = Is the measure an outcome rather than an output or an input; 4 = Does the survey show support; 5 = Are the necessary data relatively easy to collect?

[a] Based on Question 9 of the survey.

[b] Based on Question 5 of the survey.

[c] Based on Questions 3 and 8 of the survey.

[d] Not included on the survey.

[e] Based on Question 7 of the survey.

[f] Based on Questions 4 and 9 of the survey.

Incorporation of Comments of Project Steering Committee

The project steering committee reiterated four key principles: (1) measures should improve over time or at least not degrade over time; (2) the data collection effort for recommended measures should be minimal and not require a site visit; (3) measures should be easy to understand, ideally phrased as a percentage, and framed positively; and (4) the recommended measures should relate to the specific standards and regulations that are part of VDOT's access management program. In addition, some terminology was modified to make the PMs more specific. The following changes were made to the seven recommended measures:

- *Number of corridor miles with an access management plan* was changed to *percentage of localities with a corridor access management plan. Corridor miles* was changed to *localities* to capture cooperation and local support for access management with this measure. The word *corridor* was added to exclude general plans that are not focused on a specific highway.

- *Crashes per mile* was changed to *crashes per million vehicle miles traveled* since the latter was expected to be more easily understood. This measure may be obtained from the SPS.

- *Median openings per mile* was changed to *percentage of median openings with left turn lanes* because left turn lanes at crossovers are specifically referenced in VDOT's access management standards (VDOT, 2010a) and the percentage of median openings with left turn lanes is expected to increase.

- *Arterial level of service* was excluded for two reasons: (1) LOS can be affected by many factors outside an access management program such as the volume of traffic and the percentage of traffic composed of trucks, and (2) whereas the researchers had intended SPS to be used to obtain LOS, the project steering committee suggested that field visits would likely be required.

- *Percentage of signals with substandard spacing* was replaced with *percentage of signals with spacing at or above standard distance.* This change does not alter the information provided but allows the measure to be framed positively.

- The measure *signals per mile* was dropped. Other factors may influence this measure, and it is unlikely to improve over time.

- *Waivers granted to access management standards* was modified to *percentage of commercial entrance permits issued that meet access management spacing standards.* The phrase "commercial entrance permits" was adopted directly from the Exception Request Form: Access Management Regulation 24 VAC 30 -72. The word "issued" was used to exclude applications that are denied. The phrase "access management spacing standards" was incorporated to focus on only the spacing standards and not other standards (such as drainage). This change allows the measure to be framed positively without a loss of information.

Each recommended measure is defined in Appendix A.

DISCUSSION

The literature review, catalog of PMs, survey, test application, and development of recommendations provided the following observations:

- Not all goals have a direct PM.
- Access management PMs reflect three diverse areas.
- VDOT customers desire PMs in three diverse areas.
- Complexity influences computational cost more than data collection.
- Other agencies may have reason to choose additional PMs.
- For some PMs, future land development makes it unlikely they will improve.

Not All Goals Have a Direct Performance Measure

An effort was made to relate each recommended PM to at least one of the five goals of VDOT's access management program stated in the *Code of Virginia* (§ 33.1-198.1). The first goal, reduced traffic congestion, is the only one that does not relate to a recommended PM. The difficulty in finding such a measure is due to the multiple factors affecting traffic congestion. For example, although congestion may increase because of additional access points, it may also increase because of factors unrelated to access management such as increased truck traffic, poor signal timing, and poor roadway alignment.

Access Management Performance Measures Reflect Three Diverse Areas

Despite a catalog of 42 PMs, no universal measure was identified. This is because a successful access management program involves success in three interrelated areas: outcomes (e.g., the crash rate is reduced); design (e.g., access points are constructed to accepted standards); and administration (e.g., the appropriate authority reviews requests for entrances to the highway network). Assessing the entire program with a single measure is not possible because no single measure addresses all three areas. Although it may be tempting to discard administration and design PMs in favor of outcome PMs, such outcome PMs are influenced by factors other than access management. Thus, metrics covering all three areas remain essential.

A similar perspective is obtained from examining the responses for Question 13, which asked for additional comments. Multiple respondents suggested that outreach to local and business leaders is necessary to communicate the reasoning behind managing access, which is an administrative function. Further, respondents also suggested specific geometric elements, such as interparcel connectors and turn lane warrants—which is a design function. Further, although respondents noted that uniform standards are necessary for the successful implementation of access management, they also suggested that access management is not necessary in all parts of Virginia.

Stakeholders Desire Performance Measures in Three Diverse Areas

The survey results suggest that all three types of PMs are important to stakeholders, i.e., localities, consulting firms, MPOs/PDCs, and VDOT engineering staff. An initial review of the survey results suggested that only outcome or design measures are useful, since when asked to identify the most useful, few respondents named administrative area. However, when respondents were asked to indicate the importance of specific measure on a scale from 1 to 4 (with 4 being the most important) as shown in Table 7, the average rating for administrative measures (3.30) was nominally *higher* than that of outcome measures (3.20) or design measures (3.08). Thus, although the literature (Cambridge Systematics, 2006) suggested that outcomes are preferred relative to outputs or inputs, the survey responses indicated (based on these tests) that specific administrative and design measures are as important as outcome measures.

The survey responses provided numerous insights into how access management is perceived by transportation professionals. One important result from the survey that was incorporated into the recommendations was the responses to Question 7 where respondents were asked to identify additional performance measures that could be helpful. Several responses related to the consistent application of access management standards. The PM *percentage of commercial entrance permits issued that meet access management spacing standards* is closely related to this objective. This measure was not among the four administrative procedures measures originally included in the survey, and it was not included in the original drafts of the catalog of PMs. However, when the importance of uniform application of access standards was highlighted in the survey results, the usefulness of this became more apparent.

Complexity Influences Computational Cost More than Data Collection

Table 10 indicates that computational cost is not driven by the type of data source (e.g., databases, agency contacts, and aerial photographs.) Rather, except when site visits are required, computational cost is influenced by the measure's complexity and hence the amount of data analysis required.

Table 10. Number of Performance Measures Sorted by Computational Cost and Type of Data Source[a]

Type of Data Source	Computational Cost				
	Hard	Hard/Medium	Medium	Medium/Easy	Easy
Existing Databases	--	--	1	1	1
Aerial Photographs	1	2	3	--	4
Modifications to Existing Databases	1	--	1	--	--
Agency Contacts	--	--	1	--	--

[a] Seven performance measures shown in Table 8 are excluded, i.e., the five measures that always require a site visit and the two measures for which computation may require a site visit depending on the quality of the data in the database.

Other Agencies May Have Reason to Choose Additional PMs

The PMs recommended in this report were tailored for implementation by VDOT. For example, the five criteria used to evaluate the candidate PMs omitted one characteristic suggested by the literature (Cambridge Systematics, 2006; Meyer and Miller, 2001): in how many situations is this measure useful? Cambridge Systematics (2006) further stated that a measure should have "vertical alignment," such as being applicable to both a single street and an entire corridor, and "horizontal alignment," such as being applicable to multiple modes. Although these characteristics are useful, they were omitted to limit the number of criteria used. Further, horizontal alignment is less critical because access management refers exclusively to arterial highways rather than to other surface transportation modes.

It is possible that other agencies (such as other state DOTs or cities that manage their own roadway systems) might choose some different, or additional, PMs relative to those recommended for VDOT. For example, suppose an agency wanted to compare the ability of access management to reduce congestion relative to other programs that reduce congestion, and further suppose that agency was only interested in congestion reduction. Many of the measures listed in the catalog of performance measures in Tables 3 and 4 may provide the basis for this task such as *travel time*, vehicle density, or level of service. As another example, suppose an agency was responsible for a much smaller roadway system and suppose that agency could focus exclusively on a single corridor in a single jurisdiction. In that instance, the agency might consider measures derived from a computer simulation of traffic conditions in the specific corridor, which although is more time consuming than those recommended for VDOT, might be feasible if a smaller number of facilities was the agency's focus.

For Some PMs, Future Land Development Makes it Unlikely They Will Improve

To some extent, the value of certain PMs that are driven by land development, such as the number of traffic signals and the number of unsignalized driveways, would not be expected to be reduced with a new access management program. Instead, a new program would be expected either to slow their rate of increase or not to change them. For example, if new commercial land is developed adjacent to an arterial facility, the number of new unsignalized commercial driveways will be either zero (perhaps achieved through greater sharing of existing commercial driveways) or a positive number, but it is unlikely to be negative (unless some type of reconstruction is undertaken as described by Plazak and Preston [2005]). As a consequence, even a perfect access management program will not show such an indicator to improve over time. Thus, an alternative approach to using such an indicator is to recognize land development may occur and to select an indicator that reflects how that development is accommodated, such as the measure chosen herein (*percentage of commercial entrance permits issued that meet access management spacing standards*). Thus a consideration in selecting measures is to select those for which actions taken by the agency are able to improve the measure relative to an existing baseline value, even if new land development were to occur.

CONCLUSIONS

- *Many PMs are available as candidates for evaluating access management programs.* Forty-two PMs to evaluate an access management program were developed in this study. If a PM for an access management program is desired, there is an ample supply of measures from which to choose.

- *The process of implementing an access management program results in three disparate, yet complementary areas where performance can be assessed.* These areas are outcomes (e.g., crash rates and delay); design (e.g., the spacing and geometry of access points); and administration (e.g., communications among the state, local governments, and developers).

- *No single perfect PM exists.* Primarily, this is because each PM assesses performance in only one of the three areas. Further, no single PM meets all five criteria established in this study for determining the best PM (i.e., VDOT controls the measure; improvement is likely; measure is an outcome rather than an output or input; survey shows support for the measure; necessary data are relatively easy to collect). For example, although *crash rate* was highly rated in terms of usefulness by survey respondents and is one outcome sought by an access management program, *crash rate* is imperfect because it is not within VDOT's direct control. Although the measure *miles of highway with an access plan* appears attractive, the measure is imperfect because it does not directly assess an outcome of an access management program.

- *Survey respondents view PMs in all three areas (outcomes, design, and administration) as very important.* When asked which set of measures was most useful, more survey respondents indicated outcomes than *administration*, and the difference was statistically significant ($p < 0.01$). However, when given specific PMs in all three areas, survey respondents' average ratings of the importance of these measures did not differ by area. For example, on a scale of 1 to 4 with 4 being the most important, the average rating for administrative measures (3.30) was slightly higher than that for outcome measures (3.20).

RECOMMENDATION

1. VDOT should use the following five PMs to evaluate access management performance:

   - crashes per million vehicle miles traveled

   - percentage of signals with spacing at or above standard distance

   - percentage of commercial entrance permits issued that meet access management spacing standards

   - percentage of median openings with left turn lanes

   - percentage of localities with a corridor access management plan.

Details of how to obtain the data and compute the values for these measures are given in Appendix A. For the measure *percentage of median openings with left turn lanes*, two versions are provided in Appendix A: a short-term option that may be implemented immediately and a longer term option that may be implemented in the future.

SUGGESTION FOR FURTHER RESEARCH

A congestion-related PM similar to *level of service* should be developed. This measure should be easier to tabulate than level of service and be more closely related to the effect of access management on congestion.

COSTS AND BENEFITS ASSESSMENT

Benefits

Implementing the recommendations of this study would assist VDOT in the following areas: improving VDOT's access management program, providing transparency to the public, and communicating the impacts of access management initiatives effectively.

Improving VDOT's Access Management Program

Each recommended PM can be used to identify areas where the program can be improved. The measures *crashes per million vehicle miles traveled*, *percentage of signals with spacing at or above standard distance*, and *percentage of median openings with left turn lanes* can be used to identify areas in the highway network where improvements are needed. The measure *percentage of commercial entrance permits issued that meet access management standards* can be used to identify that standards are being waived most frequently. The measure *percentage of localities with a corridor access management plan* identifies if certain sections of the state are adopting access management more willingly than others; thus more attention can be devoted to regions where few localities have adopted access management plans.

Providing Transparency to the Public

Because access management decisions may concern property rights of a landowner with abutting property, such decisions have the potential to be controversial. Therefore, it is important that the reasoning behind these decisions be easily understood. These PMs have the potential to convey the rationale for controversial decisions in a transparent manner, as explained in the following hypothetical example that uses four of the recommended PMs.

Example:

A property owner desires a traffic signal to connect a parcel to the adjacent principal arterial highway and questions VDOT's denial of the traffic signal.

Solution:

1. *Crashes per million vehicle miles traveled* is 2.00 in the corridor, but crashes may rise by 40% to 250% if the signal density is increased to 4 per mile from 2 per mile as it is now (Gluck et al., 1999).

2. *Percentage of signals with spacing at or above standard distance* is 80% along the adjacent highway corridor. This is because eight of the existing signals are spaced at ½-mi intervals and only two are spaced at a substandard distance of 1/3 mi (e.g., 8/10 signals meet the standard). The proposed signal would be placed ¼ mi from each of two existing signals, increasing by three the number of signals with substandard spacing, thereby lowering this measure to 54% (e.g., 6/11 signals meet the standard).

3. Statewide, the *percentage of commercial entrance permits issued that meet access management standards* is 95%, suggesting that granting of exceptions is a rare occurrence.

4. The locality has adopted a *corridor access management plan* that does not call for this signal.

The efficacy of the solution shown here depends on the value of the PMs overall. If, for example, the *percentage of commercial entrance permits issued that meet access management standard* was really 40%, then access management PMs would have less utility in providing transparency regarding the decision to deny access.

Communicating the Impacts of Access Management Initiatives Effectively

The recommended PMs are designed to be easily understood. This will help VDOT communicate more effectively to the public. This may be useful for explaining and promoting access management improvements. A four-lane divided principal arterial as described by the PMs in Table 11 may be used as an example. An expensive method of improving this highway would be to add more lanes. These PMs identify corridors, such as those shown in Table 11, where access management retrofit may provide the greatest benefit. A project that eliminates signals, improves median openings, and develops a plan for future development along the corridor may be more cost-effective than a widening project.

Table 11. Example Performance Measure Values

Performance Measure	Value
Crashes per million vehicle miles traveled	4.25
Percentage of signals with spacing at or above standard distance	10%
Percentage of approved site plans meeting access standards	40%
Percentage of median openings with left turn lanes	60%
Percentage of localities with regulations or plans supporting access management	No plan for this corridor

Costs

The "costs" of obtaining performance measure values arise entirely, or almost entirely, from salaries paid for the labor required to extract these data and compute the measures. Because salaries are believed to be highly variable, the "costs" are presented in units of time and "costs" refers to the amount of time required to do this work..

To reduce data collection costs, the recommended PMs may be estimated by sampling necessary data at specific locations as described in Appendix A. These costs are based on the following assumptions:

- The person computing the measure is familiar with the procedures in Appendix A.
- Each district planner has identified three sites where sampling will be productive.
- A statewide value is computed from the 27 district sites.
- The PMs are updated annually.

The data collection costs are shown in minutes for a single highway segment and hours for 27 samples. These are intended as a guide for estimating the effort required to implement these measures. Actual implementation costs will vary depending on the entity collecting the data.

Initial Costs

Table 12 shows the time required to initially collect data for each PM based on the procedures tested in the course of this study. Because these times were found for only a single test application, they are only estimates and may be higher or lower than the actual values. In addition, these values may differ based on the condition of the highway being sampled. For example, although 40 minutes is the average data collection time for *percentage of signals with spacing at or above standard distance*, the time may increase for corridors with a large number of signals or corridors with signals that meet or fail the standards by a small margin.

Table 12. Cost Estimates of Implementing Performance Measures

Performance Measure	Cost Estimate for Single Application	Cost Estimate for Statewide Application[b]
Crashes per million vehicle miles traveled	10 min[c]	5 hr
Percentage of signals with spacing at or above standard distance	40 min[c]	18 hr
Percentage of approved site plans meeting access standards	Unknown[d]	Unknown[d]
Percentage of median openings with left turn lanes	15 min[c]	7 hr
Percentage of localities with regulations or plans supporting access management	80 min[e]	36 hr

[a] "Cost" refers to the time required to perform this work, given that most or all of the cost will result from labor and that the salary to pay for this labor is believed to be highly variable.
[b] Assumes 27 applications total (3 per district, 9 districts in Virginia) and that the sites have already been selected. Calculations rounded to the nearest hour.
[c] Time estimate is based on applying the measure to a 5-mi arterial facility (Route 17 in Stafford County).
[d] Time will depend on two information systems: one has already been implemented (Land Use Permit System), and another one (based on the VDOT Exception Request Form) which at the time of this research had not. Assuming both systems are implemented and perform as intended, data collection costs should be minimal.
[e] Time estimate based on collection of data from localities served by VDOT's Saluda Residency.

Ongoing Costs

The costs to update the measures each year will be the same as those shown in Table 12 for *crashes per million vehicle miles traveled* (about 5 hr) and *percentage of approved site plans meeting access standards* (to be determined). In both cases, the PMs must be computed anew.

For the remaining three PMs, it is possible to reduce the update costs shown in Table 12 if the entity responsible for computing them can be notified each time the following occurs:

- A signal is added (or removed) from the highway network.
- A median opening is modified.
- A new corridor access plan is initiated or published.

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APPENDIX A

RECOMMENDED PERFORMANCE MEASUREMENT SYSTEM FOR EVALUATING ACCESS MANAGEMENT PERFORMANCE

Table A1 lists the recommended performance measures (PMs) for evaluating access management performance

Table A1. Recommended Performance Measures

Performance Measure	Test Application Value
Crashes per million vehicle miles traveled	3.4 (2003 Data); 2.6 (2007 Data)
Percentage of signals with spacing at or above standard distance	0%
Percentage of commercial entrance permits issued that meet access management spacing standards	Value Unavailable
Percentage of median openings with left turn lanes	35%
Percentage of localities with a corridor access management plan	25%

Crashes per Million Vehicle Miles Traveled

Relationship to Code of Virginia

This measure addresses the goal "to enhance public safety by decreasing traffic crash rates."

Advantages of This Measure

- Strong support from survey respondents.
- Direct measure of an end goal of the program.
- Fairly simple data collection.

Definition and Data Sources

$$\text{Performance measure} = \frac{(1{,}000{,}000)\ (\text{Number of Crashes})}{(\text{AADT})(\text{Length of Segment})(365)}$$

- Number of Crashes: VDOT Crash Report Query Page at http://crash or SPS.
- Length of Segment: Mileposts of starting and ending nodes used to find crash rates. Alternatively, VDOT's GIS Integrator or a commercial program such as Google Maps can be used.
- AADT (annual average daily traffic): TMS or SPS.

Sample Application

Endpoint Node 1: 732496 – 88-01942(R)/(MP-28.02)
Endpoint Node 2: 617391 – JB-111/WCL FREDERICKSBURG/(MP-31.57)

Step 1: Read the number of crashes from VDOT's Crash Report Database (see Figures A1 and A2) or SPS (Figures A6 and A7).

Number of Crashes = 252 crashes (from the Crash Report Database)

Step 2: Determine the length of the segment. In this example, the mileposts associated with the nodes of the endpoints are used.

Length of Segment = 31.57 - 28.02 = 3.55

Step 3: Determine the AADT (see Figures A3 through A5). In this example, the TMS was used. The highway segment for this example was made up of three segments from the TMS.. A weighted average of the three segments was found using the lengths of the segments to weight the AADT values. The AADT for the middle segment was unavailable for 2003; therefore, the 2004 value was used. SPS can also be used to find the AADT (see Figure A8).

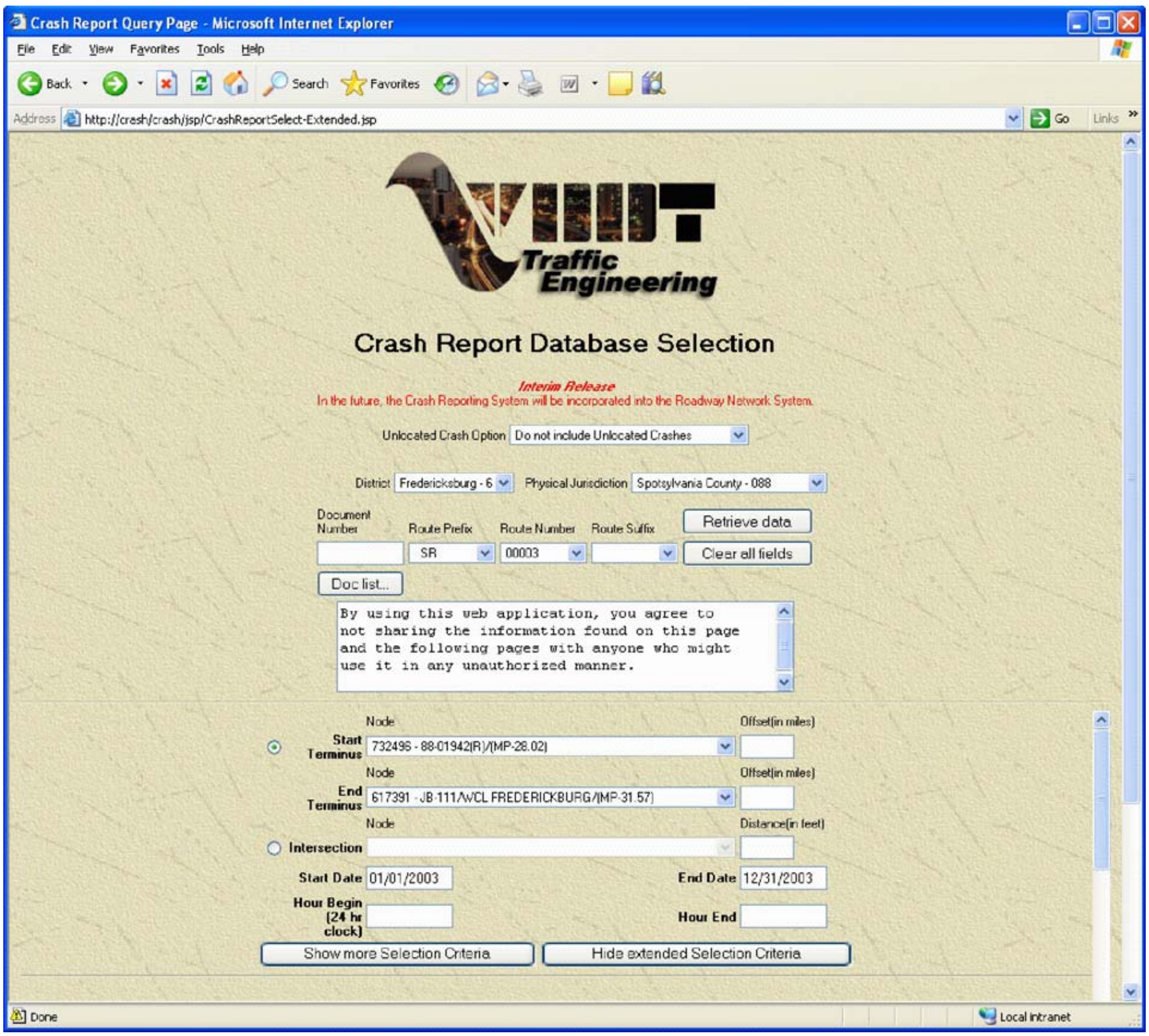
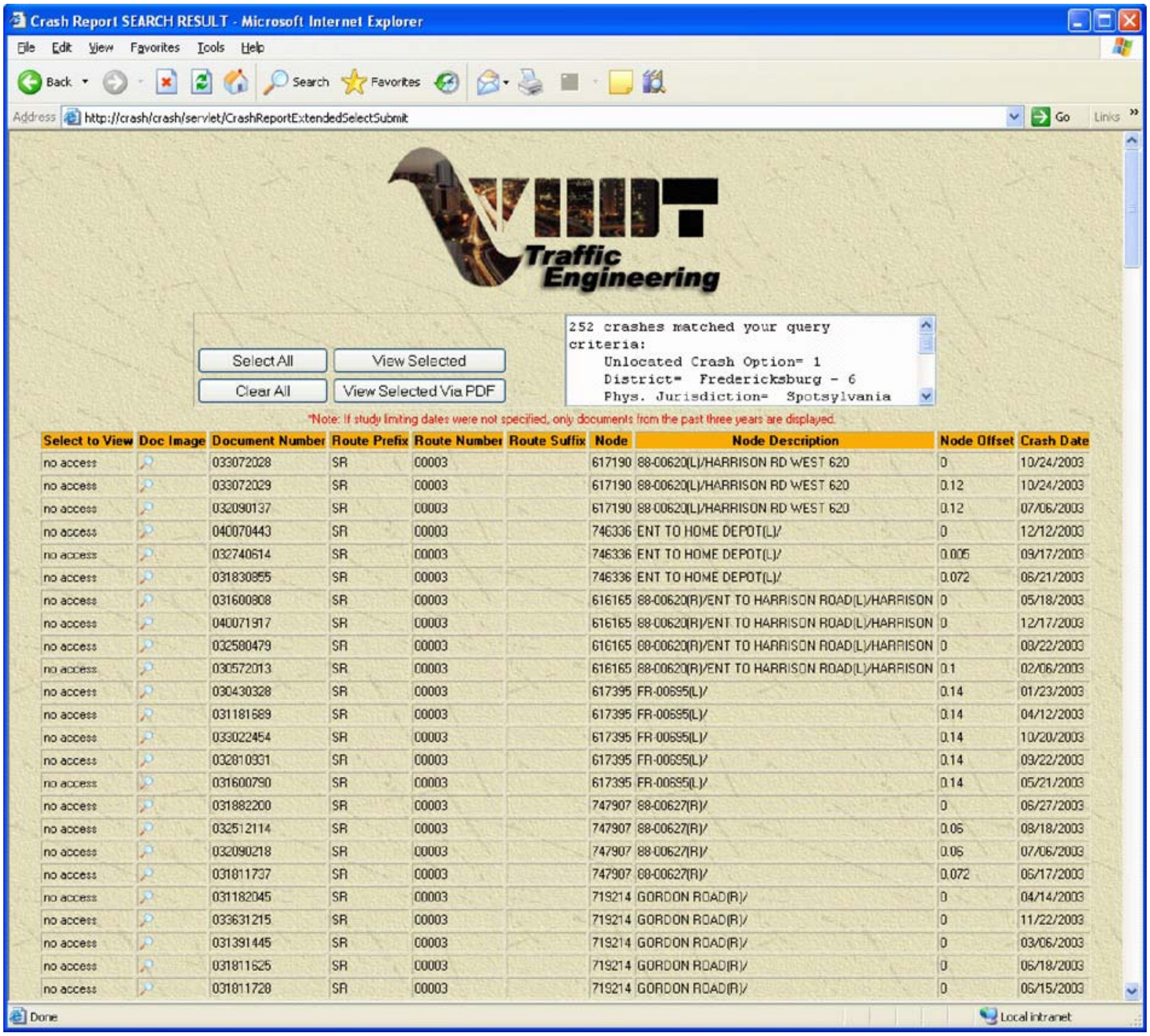


Figure A1. Example of Crash Report Database



Select to View	Doc Image	Document Number	Route Prefix	Route Number	Route Suffix	Node	Node Description	Node Offset	Crash Date
no access		033072028	SR	00003		617190	88-00620(L)/HARRISON RD WEST 620	0	10/24/2003
no access		033072029	SR	00003		617190	88-00620(L)/HARRISON RD WEST 620	0.12	10/24/2003
no access		032090137	SR	00003		617190	88-00620(L)/HARRISON RD WEST 620	0.12	07/06/2003
no access		040070443	SR	00003		746336	ENT TO HOME DEPOT(L)/	0	12/12/2003
no access		032740614	SR	00003		746336	ENT TO HOME DEPOT(L)/	0.005	09/17/2003
no access		031830855	SR	00003		746336	ENT TO HOME DEPOT(L)/	0.072	06/21/2003
no access		031600808	SR	00003		616165	88-00620(R)/ENT TO HARRISON ROAD(L)/HARRISON	0	05/18/2003
no access		040071917	SR	00003		616165	88-00620(R)/ENT TO HARRISON ROAD(L)/HARRISON	0	12/17/2003
no access		032580479	SR	00003		616165	88-00620(R)/ENT TO HARRISON ROAD(L)/HARRISON	0	08/22/2003
no access		030572013	SR	00003		616165	88-00620(R)/ENT TO HARRISON ROAD(L)/HARRISON	0.1	02/06/2003
no access		030430328	SR	00003		617395	FR-00695(L)/	0.14	01/23/2003
no access		031181689	SR	00003		617395	FR-00695(L)/	0.14	04/12/2003
no access		033022454	SR	00003		617395	FR-00695(L)/	0.14	10/20/2003
no access		032810931	SR	00003		617395	FR-00695(L)/	0.14	09/22/2003
no access		031600790	SR	00003		617395	FR-00695(L)/	0.14	05/21/2003
no access		031882200	SR	00003		747907	88-00627(R)/	0	06/27/2003
no access		032512114	SR	00003		747907	88-00627(R)/	0.06	08/18/2003
no access		032090218	SR	00003		747907	88-00627(R)/	0.06	07/06/2003
no access		031811737	SR	00003		747907	88-00627(R)/	0.072	06/17/2003
no access		031182045	SR	00003		719214	GORDON ROAD(R)/	0	04/14/2003
no access		033631215	SR	00003		719214	GORDON ROAD(R)/	0	11/22/2003
no access		031391445	SR	00003		719214	GORDON ROAD(R)/	0	03/06/2003
no access		031811625	SR	00003		719214	GORDON ROAD(R)/	0	06/18/2003
no access		031811728	SR	00003		719214	GORDON ROAD(R)/	0	06/15/2003

Figure A2. Output of the Crash Report Database

$$\text{AADT} = \frac{27{,}230 * 0.93\text{mi} + 67{,}447 * 1.53\text{mi} + 67{,}160 * 1.09\text{ mi}}{3.55\text{ mi}} = 56{,}823 \text{ vehicles}$$

Step 4: Calculate performance measure.

$$\frac{1{,}000{,}000 * 252 \text{ crashes}}{56{,}823 \text{ vehicles/day} * 3.55 \text{ mi} * 365 \text{ days}} = 3.4 \text{ crashes/million VMT}$$

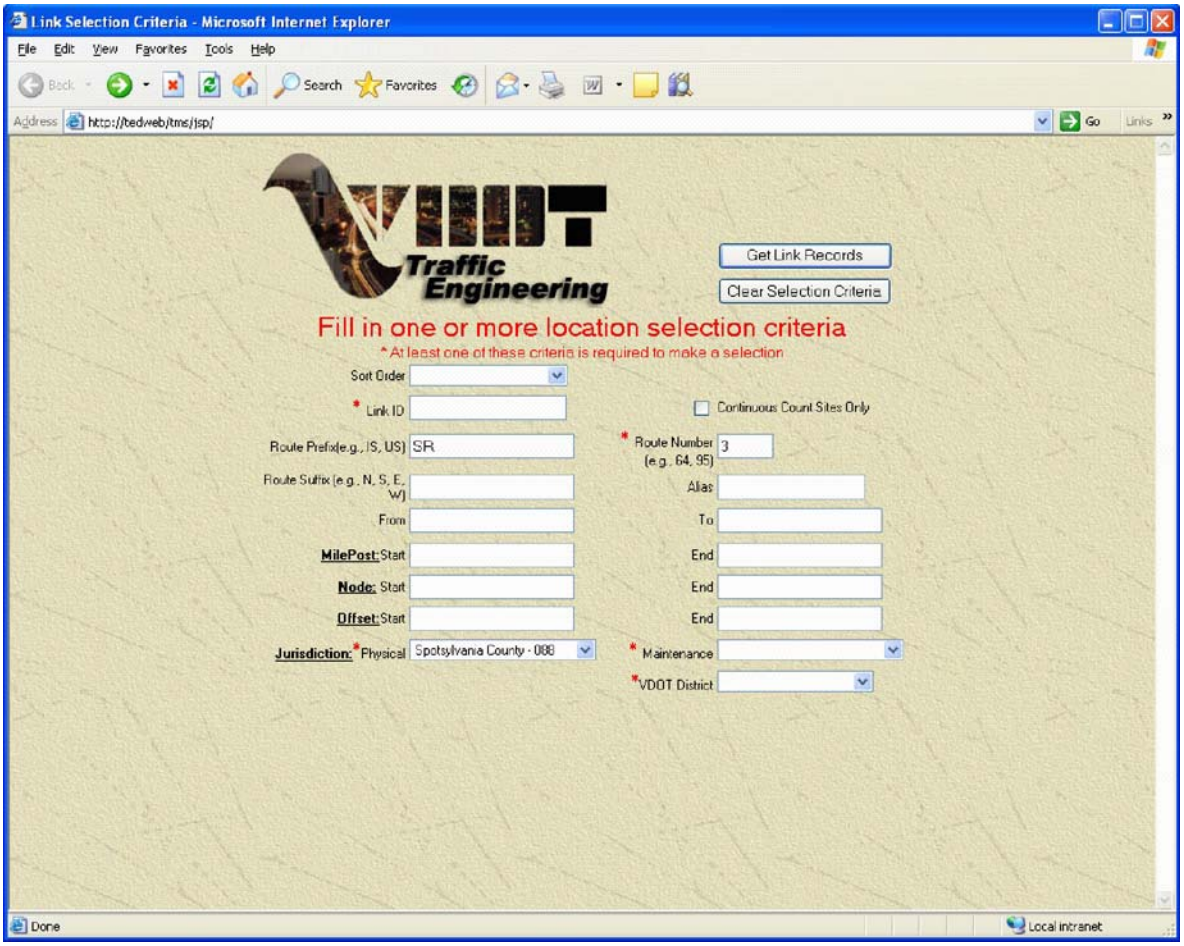
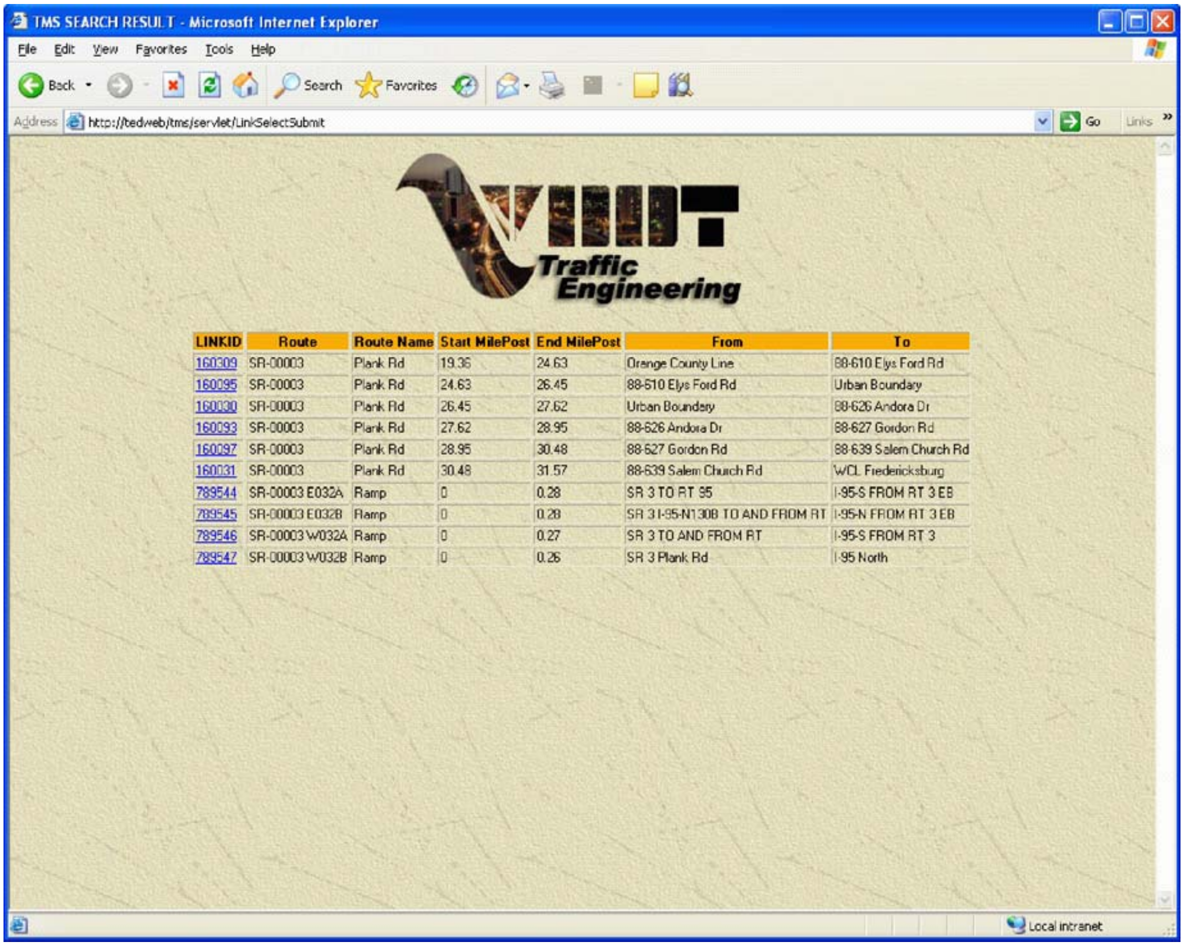


Figure A3. TMS Input Form



LINKID	Route	Route Name	Start MilePost	End MilePost	From	To
160309	SR-00003	Plank Rd	19.36	24.63	Orange County Line	88-610 Elys Ford Rd
160095	SR-00003	Plank Rd	24.63	26.45	88-610 Elys Ford Rd	Urban Boundary
160030	SR-00003	Plank Rd	26.45	27.62	Urban Boundary	88-626 Andora Dr
160093	SR-00003	Plank Rd	27.62	28.95	88-626 Andora Dr	88-627 Gordon Rd
160097	SR-00003	Plank Rd	28.95	30.48	88-627 Gordon Rd	88-639 Salem Church Rd
160031	SR-00003	Plank Rd	30.48	31.57	88-639 Salem Church Rd	WCL Fredericksburg
789544	SR-00003 E032A	Ramp	0	0.28	SR 3 TO RT 95	I-95-S FROM RT 3 EB
789545	SR-00003 E032B	Ramp	0	0.28	SR 3 I-95-N130B TO AND FROM RT	I-95-N FROM RT 3 EB
789546	SR-00003 W032A	Ramp	0	0.27	SR 3 TO AND FROM RT	I-95-S FROM RT 3
789547	SR-00003 W032B	Ramp	0	0.26	SR 3 Plank Rd	I-95 North

Figure A4. TMS Output Showing Links for Which Traffic Counts Are Available

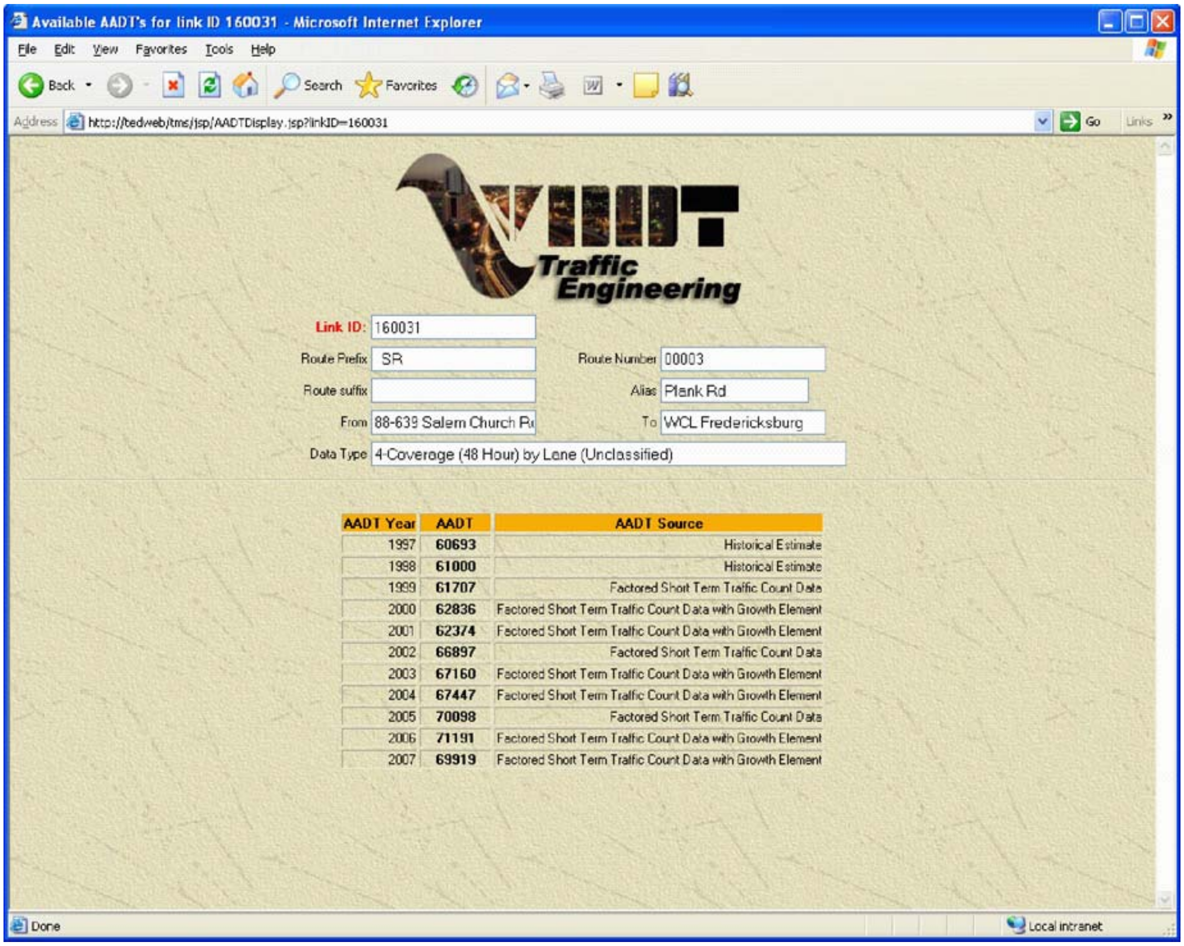


Figure A5. Output of TMS Database Showing 2003 AADT of 67,160 for Segment of Route 3 Between Salem Church Road and WCL [West City Line, e.g., jurisdictional boundary of] Fredericksburg

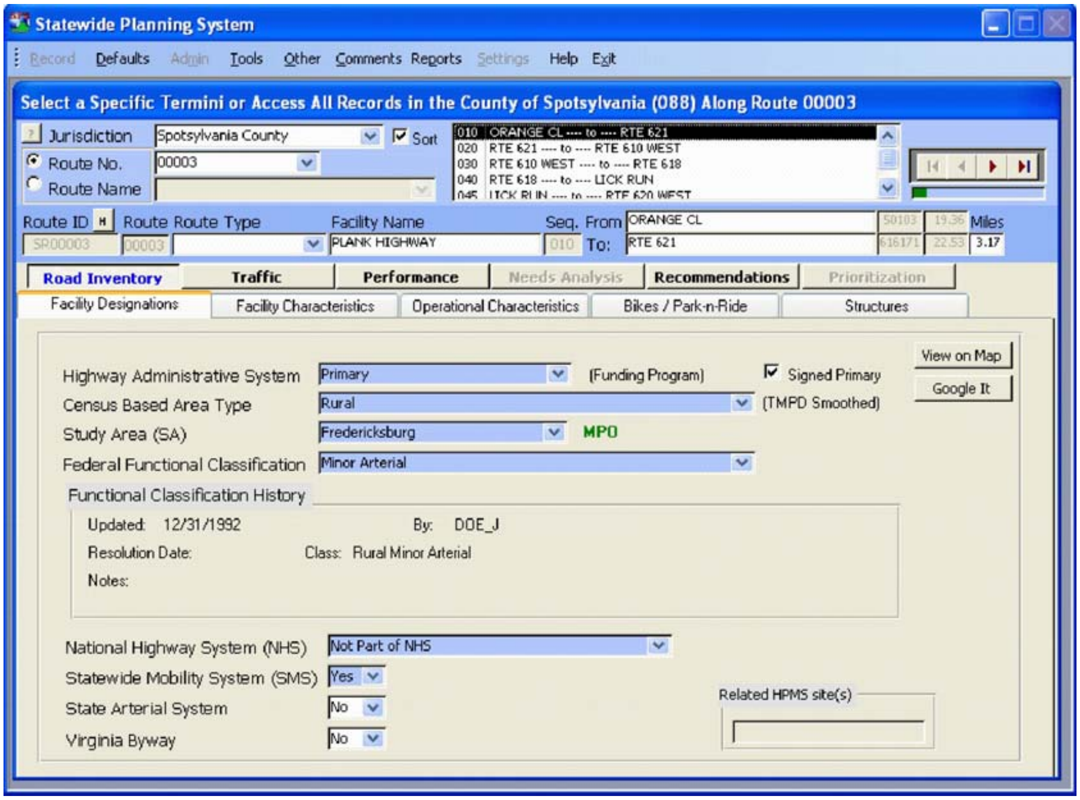


Figure A6. SPS Input Screen. To find crash data (Figure A7), the "Quick Crash Analysis" is chosen from the tool's dropdown menu.

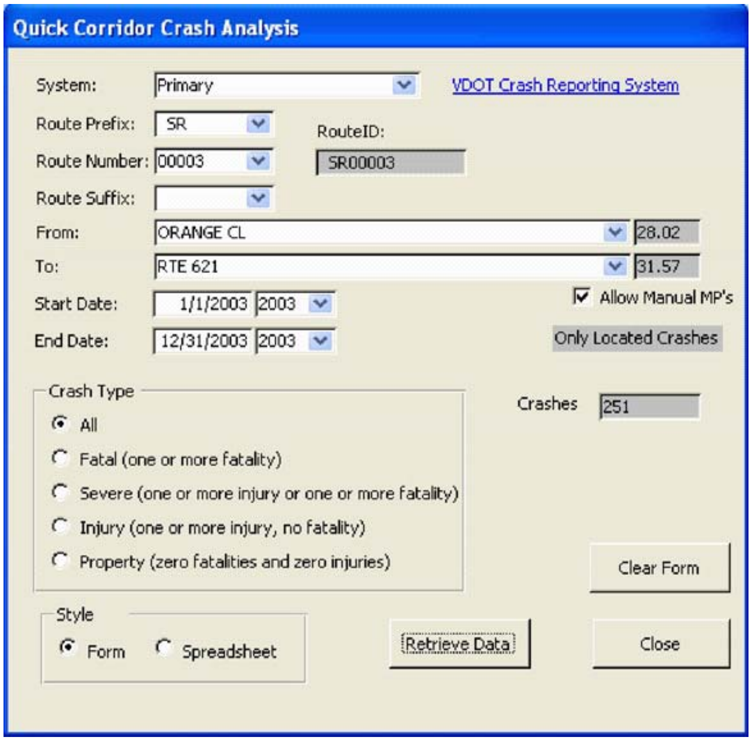


Figure A7. Quick Crash Analysis Input Menu. The "Allow Manual MP's" feature is chosen, and the other necessary data are input. As can be seen, the output is 251 crashes.

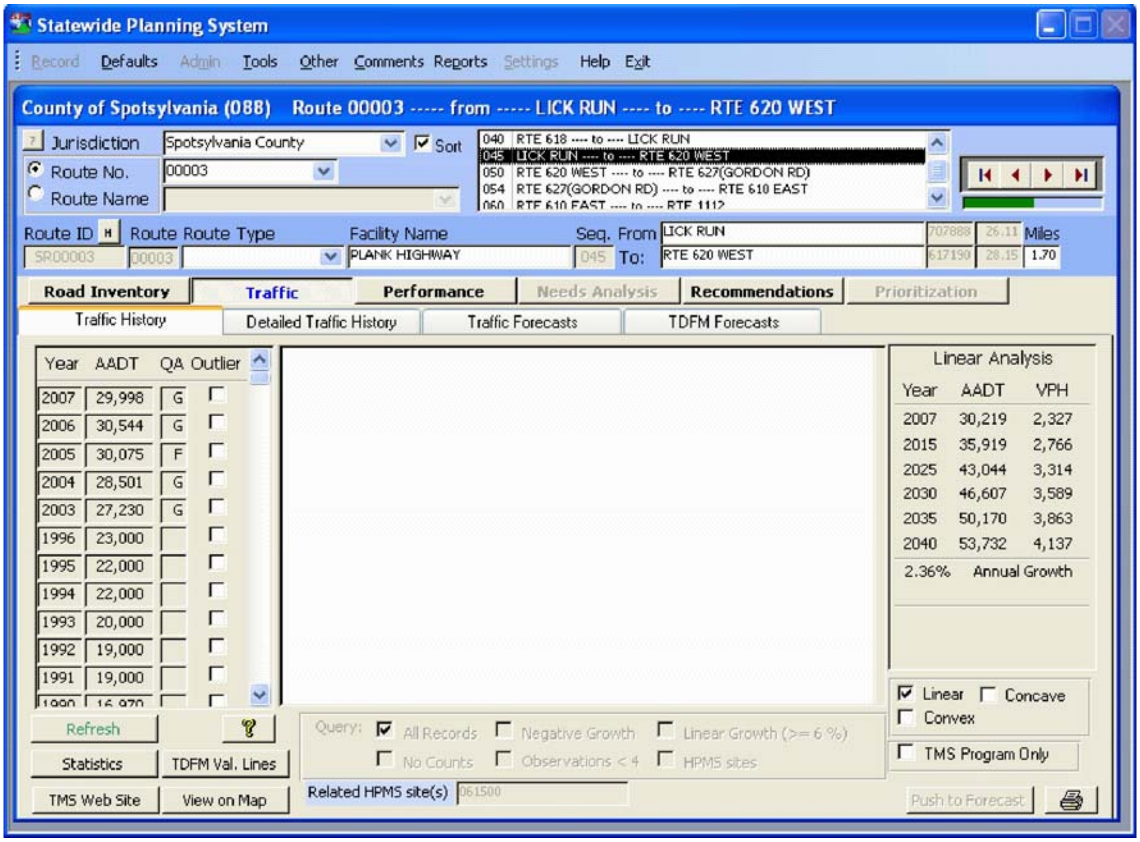


Figure A8. SPS Traffic Data Input and Output Form. SPS and the VDOT Crash Report Database give similar, but not identical, values of 252 and 251 crashes, respectively.

Percentage of Signals with Spacing at or Above Standard Distance

Relationship to Code of Virginia

This measure addresses two goals: "to support economic development in the Commonwealth by promoting the efficient movement of people and goods," and "to preserve public investment in new highways by maximizing their performance."

Advantages of This Measure

- Under VDOT's control and expected to improve.

Definition and Data Sources

$$\text{Performance measure} = \frac{\text{Number of Signals along Corridor with Spacing at or Above Standard Distance}}{\text{Total Number of Signals along Corridor}}$$

- Number of Signals at Appropriate Spacing: GIS Integrator.
- Appropriate Signal Spacing: Table 2-2 in Appendix F of VDOT's *Road Design Manual*.

- Total Number of Signals: GIS Integrator.

Sample Application

Step 1: Identify highway segment to be analyzed and identify locations where there are signalized intersections. Figure A9 shows a highway segment with two signals.

Figure A9. GIS Integrator Aerial Photograph Showing Two Signals. The "Measure" tool was used to determine that the distance between the centerlines of the two signalized intersections is 0.23 mile.

Step 2: For each signalized intersection, measure the distance to the other nearest signalized intersections and compare this distance to the standard distance. As calculated by the GIS Integrator "Measure" tool, the distance between the two signals in Figure A9 is 0.23 mile. This is below the standard of 2,640 ft (0.50 mi) given in Table 2-2 as shown in Figure A10. Therefore, 0% of the two signals is at or above the standard distance.

Spacing Standards for Commercial Entrances, Intersections, and Crossovers				
Highway Functional Classification	Legal Speed Limit (mph)①	Centerline to Centerline Spacing in Feet		
		Signalized Intersections②	Unsignalized Intersections & Full Access Entrances③	Partial Access One or Two Way Entrance④
Urban ⑤ Principal Arterial	≤ 30 mph 35 to 45 mph ≥ 50 mph	1,760 2,640 2,640	1,050 1,320 1,320	270 325 510
Rural ⑥ Principal Arterial	≤ 30 mph 35 to 45 mph ≥ 50 mph	2,640 2,640 2,640	1,320 1,320 1,760	270 440 585

Figure A10. Table 2-2 in Appendix F of VDOT's *Road Design Manua*l

Other Notes

- Once measure has been calculated initially, it should be updated as new signals are added. This does not require analyzing every existing signal, only those affected by the new signal.

- For the segment of Route 3 between node 732496 and node 617391, 0% of the signals meet the spacing standards.

Percentage of Commercial Entrance Permits Issued That meet Access Management Spacing Standards

Relationship to Code of Virginia

This measure directly addresses the goal "to preserve public investment in new highways by maximizing their performance."

Advantages of This Measure

- VDOT has the power to control.
- Measure may help improve standards by identifying areas where exceptions are granted frequently.
- Measure supported by responses to Question 7 in the sense that some responses emphasized consistent application of access management standards.

Definition and Data Sources

$$\text{Performance measure} = \frac{\begin{pmatrix}\text{Number of Entrance Permits Issued} \\ \text{that do not Require an Exception}\end{pmatrix}}{\text{Total Number of Entrance Permits Issued}}$$

Step 1: Determine the number of entrance permits issued as reported from the Land Use Permit System (LUPS)

Step 2: Determine the number of exceptions granted and tabulate measure as shown in Table A2. This can be found by recording exceptions from the Exception Request Form: Access Management Regulation 24 V.A.C. 30 -72 (see Figure A11).

Sample Application

Using a hypothetical example for illustrative purposes, 35 entrance permits were issued, 4 of which were approved with an exception and 31 of which were approved without an exception. Therefore, the value of the PM is:

$$\text{Performance measure} = \frac{\begin{pmatrix}\text{31 Entrance Permits Issued that} \\ \text{do not Require an Exception}\end{pmatrix}}{\text{35 Entrance Permits Issued}} = 89\%$$

It is expected that the denominator (35 entrance permits issued) will be obtained from the LUPS.

It is expected the numerator (4 entrance permits approved) will be obtained from tracking the Exemption Request Forms. Table A2 shows how an information system might capture these exceptions, which may exist for the following reasons:

1. No shared entrance was provided because of physical constraints, and entrance spacing does not meet standards because of insufficient property frontage.

2. Entrance spacing does not meet spacing standards because a proffer was approved by the locality prior to July 1, 2008, for the site plan.

3. Signalized entrance spacing does not meet spacing standards, but a traffic engineering study documents that highway operation and safety will not be adversely impacted.

4. Vehicle access to the adjoining property is not provided, and the entrance is restricted to right-in/right-out only.

VDOT Virginia Department of Transportation

January 2009

EXCEPTION REQUEST FORM

ACCESS MANAGEMENT REGULATION 24 VAC 30-72

Submitted by:		**Date:**
Email Address:		**Phone:**
Address:		
VDOT District:		**County/City:**
Route No.:	**Principal Arterial: Rural** ☐ **Urban** ☐	**Legal Speed Limit: mph**
Name of Business, Subdivision:		
Description of Proposed Development:		

NOTES: (i). Most of the exceptions below are specified in the Regulation and can be quickly approved upon receipt of the required documentation. (ii). Several of the spacing standard exceptions require more detailed information to be submitted - a traffic engineering study. The decision on such requests will be based on VDOT engineering judgment. (iii). The LD-440 Design Exception Request form should be used for sight distance and the Road Design Manual Appendix F Principal Arterial Access Management Standards (except the spacing standards Tables 2-22 to 2-24).

TYPE OF EXCEPTION

☐ **Shared entrance.** (24 VAC 30-72-120 A 2)

Reason for exception:

☐ A. Shared entrance agreement could not be reached with adjoining property owner(s)

☐ Attached: Written evidence of inability to reach an agreement with adjacent property owner.

☐ B. Physical constraints to creating a shared entrance: topography, adjacent hazardous land use, environmentally sensitive area such as stream or wetland, other.

☐ Specify constraint ____________________

☐ Attached: Topography map, proof of hazardous use or other documentation.

☐ **Spacing standards for entrances & intersections.** (24 VAC 30-72-120 A. 3. & 5; Tables 2-2, 2-3, 2-4 in Appendix F, Road Design Manual)

Type of entrance/intersection: Signalized ☐ Full access ☐ Partial access ☐

Required spacing distance ____ ft

Proposed spacing distance ____ ft

Requested exception: Reduction in required spacing ____ ft

Reason for exception:

☐ A. Shown on a proffered plan of development, site plan, preliminary or final subdivision plat approved by the locality prior to July 1, 2008.

☐ Attached: Land development document.

January 2009

☐ B. To be located on an older, established urban business corridor where existing entrances and intersections did not meet the spacing standards prior to July 1, 2008.

☐ Attached: Aerial photo of corridor identifying entrance/intersection location.

☐ Attached: Information on the following.

(i) Can a shared entrance or vehicular connection to adjoining property be provided?

(ii) Will the entrance be restricted to right-in /right-out movements?

(iii) Will the corner clearance standard be met? (Figure 4-3, App. F, Rd Design Manual)

☐ C. To be located <u>within</u> a new town, mixed use development (see 24 VAC 30-72-120 A.3.b.)

☐ Intersection sight distance will be met. (Table 2-7, Appendix. F, Rd Design Manual)

☐ Attached: Information on proposed development.

☐ D. Insufficient property frontage to meet entrance/intersection spacing standard from existing, adjacent entrance/intersection

☐ Attached: A traffic engineering study that documents how highway operation and safety will not be adversely impacted by the requested exception (24 VAC 30-72-120 B).

Note: Can access be achieved by creating a shared entrance or vehicular connection with an adjoining property?

☐ E. Spacing between the proposed signalized commercial entrance and an adjacent signalized intersection does not meet the signalized intersection spacing standard.

☐ Entrance will be physically restricted to right-in/right-out movements

☐ <u>Or</u> an attached traffic engineering study documents how highway operation and safety will not be adversely impacted by the requested exception (24 VAC 30-72-120 B).

☐ F. Meets VDOT/locality approved access management corridor plan spacing standards.

☐ **Vehicular/pedestrian connection to adjoining undeveloped property.** (24 VAC 30-72-120 A 4)

Reason for exception:

☐ A. Physical constraints exist such as topography, stream, wetlands, or adjacent hazardous use.

☐ Specify constraint below and attach documentation.

____

☐ B. Entrance will be physically restricted to right-in /right-out movements.

Exception Request: Approved ☐ **Denied** ☐	**Date:**
District Administrator or Designee:	
Remarks:	

Email copy to: <u>Paul.Grasewicz@VDOT.Virginia.Gov</u>

Figure A11. Exception Request Form: Access Management Regulation 24 V.A.C. 30-72

Table A2. Tabulation of Performance Measure for Hypothetical Example

Exception	Reason indicated in Figure A11[b]	No. of Entrance Permits Requiring Exception	No. of Entrance Permits Issued	% Not Requiring Exception
Shared Entrance (24 V.A.C. 30-72-120 A2)	A	0	35	
	B	1		
Spacing Standards for Entrances and Intersections (24 V.A.C. 30-72-120 A 3 & 5; Tables 2-2, 2-3, 2-4 in Appendix F of VDOT's *Road Design Manual)*	A	1		
	B	0		
	C	0		
	D	1		
	E	1		
	F	0		
Vehicular/Pedestrian Connection to Adjoining Undeveloped Property (24 V.A.C. 30-72-120 A4)	A	0		
	B	1		
Total [a]		4		89

[a] "Total" is not the sum of the rows since a single project may have multiple exceptions.
[b] The definition of each reason is given in Figure A11. For example, Figure A11 indicates that reason "A" under "Shared Entrance" is "Shared entrance agreement could not be reached with adjoining property owner(s)."

Percentage of Median Openings with Left Turn Lanes

Relationship to Code of Virginia

This measure addresses two goals: "to enhance public safety by decreasing traffic crash rates" and "o reduce the need for new highways and road widening by improving the performance of the existing systems of state highways."

Advantages of This Measure

- VDOT can control.
- Very unlikely that value of measure will decline.
- Support in survey for the use of turn lanes.
- Easy data collection.

Definition and Data Sources

$$\text{Performance measure} = \frac{\text{Number of Crossovers with Left Turn Lanes}}{\text{Total Number of Crossovers}}$$

- Number of Unsignalized Crossovers with Turn Lanes: VDOT's GIS Integrator
- Total Number of Unsignalized Crossovers: VDOT's GIS Integrator.

Sample Application

Step 1: Identify highway segment to be analyzed and identify locations where there are median openings. Measure the length of the highway segment. As can be seen, there are three median openings in the highway segment shown in Figure A12.

Figure A12. GIS Integrator Aerial Photograph Showing Three Median Openings. The eastern two openings have turn lanes, but the western-most opening does not. The roadway photograph of the western median opening is shown in Figure A13.

Step 2: For each median opening, determine whether left turn lanes are provided. In Figure A12, 2 of the median openings have turn lanes and 1 does not. For calculation and tabulation purposes, the median openings at the end of the segment are counted as 0.50. Therefore, there are 2.0 total median openings; 1.5 with turn lanes; and 0.50 without turn lanes. These data can be tabulated as shown in Table A3. For some median openings, it is difficult to identify turn lanes from the aerial photographs, and the roadway photographs from the GIS Integrator program can be used as shown in Figure A13.

Table A3. Sample Values for Short Highway Segment[a]

Highway Number	Locality	Unsignalized Crossovers	Unsignalized Crossovers with Turn Lanes	% with Left Turn Lanes
SR 3	Spotsylvania County	2.0	1.5	75%

[a] The crossovers at the end of the segment were counted as 0.50.

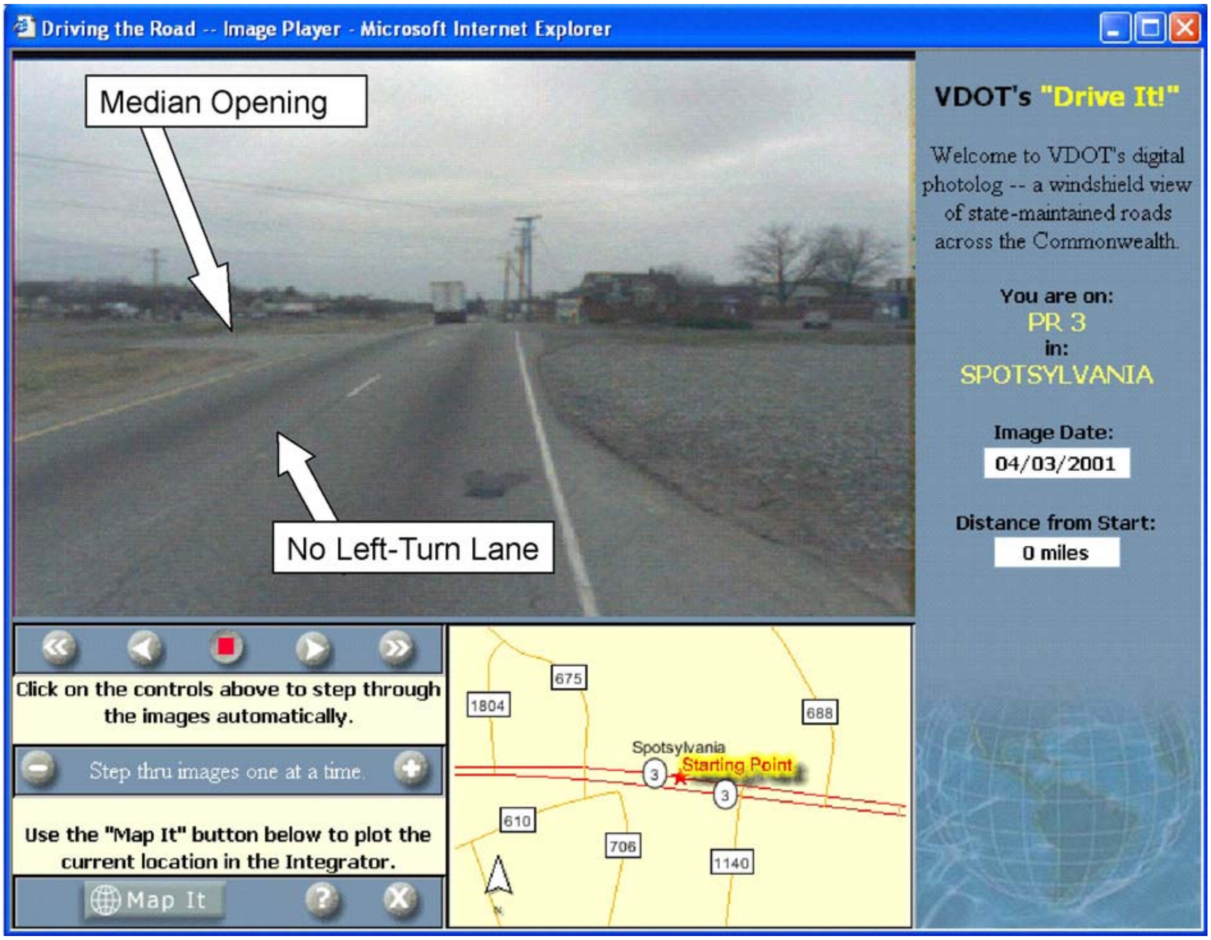


Figure A13. Roadway Photograph from GIS Integrator Program Showing Median Opening without Turn Lane. The photograph is oriented westbound.

Other Notes

- Once measure has been calculated initially, it should be updated as crossovers are modified without reexamining all existing crossovers.

- Only crossovers with left turn lanes in *both* directions should be included as having turn lanes unless all left and U-turns are restricted in the direction without a left turn lane.

- Table A4 provides the data for the segment of Route 3 between the nodes 732496 and 617391.

- In the future, when most unsignalized crossovers have left turn lanes, this PM can be changed to "percent of crossovers meeting all standards."

Table A4. Route 3 Data for Percentage of Median Openings with Left Turn Lanes

Highway Number	Locality	Unsignalized Crossovers	Unsignalized Crossovers with Turn Lanes	% with Left Turn Lanes
SR 3	Spotsylvania County	11.5	5.0	35%

Percentage of Localities with Corridor Access Management Plan

Relationship to Code of Virginia

This measure addresses the goal “to preserve public investment in new highways by maximizing their performance.”

Advantages of This Measure

- VDOT has the ability to control.
- Measure should improve over time.
- Received strongest support of the administrative measures listed on the survey.

Definition and Data Sources

$$\text{Performance measure} = \frac{\text{Number of Localities With a Corridor Access Management Plan}}{\text{Total Number of Localities}}$$

A corridor access management plan meets the following criteria:

1. Refers to a specific arterial.

2. Identifies existing access points such as driveways, median openings, intersections, or interchanges.

3. Recommends specific access management procedures either to preserve or improve highway operations or safety. Such procedures may include promoting land development at appropriate locations, breaking the median only where necessary, purchasing access rights, consolidating driveways, adding left turn lanes, or other access management actions.

4. Localities or residencies have verified that the corridor access management plan either has been adopted by the locality or has influenced recent corridor management decisions such as whether to grant a permit or how to design an access point.

5. VDOT staff have indicated that the corridor access management plan employs good access management principles (either explicitly through communicating their support of the plan or implicitly through their authorship or acceptance of the plan).

Sample Application

Step 1: Contact the appropriate counties or residencies and inquire about access management related plans.

Step 2: Based on the results of these communications, verify the existence of standards and plans and summarize how they support access management as shown in A5.

Table A5 shows that the PM is $\frac{\text{1 County With a Corridor Access Management Plan}}{\text{Total of 4 Localities}} = 25\%$.

Table A5. Sample Application for Saluda Residency

County	Specific Arterial	Identifies Existing Access Points	Specific Access Management Recommendations	Local Adoption	VDOT Acceptance
Gloucester (Gloucester County and VDOT, 2001)	Yes (Route 17)	Yes (41 access points are noted)	Yes (each of the 41 locations contains a specific recommendation such as adding a turn lane, closing a median opening, or leaving as is)	Yes (Ducey-Ortiz [2009] noted that the plan is "used to close existing cross-overs and channelize others. When new developments are proposed, we do refer to this document to make sure the crossover is proposed to remain.")	Yes (VDOT staff conducted the study; the document is maintained on the VDOT website [Parker, 2009].)
Matthews	A plan is not available (Shaw, 2009).[a]				
Middlesex	A plan is not available (M. Walker, personal communication, March 4, 2009).[b]				
King and Queen	A plan is not available (Parker, 2009).[c]				

[a] Shaw of Matthews County indicated that there are "no corridor access management plans for highways in Matthews County," but "access management will be reviewed and incorporated into . . . proposed overlay districts" (Shaw, 2009).
[b] Walker of Middlesex County indicated that the county is working on an overlay district for the Route 33 corridor, and this may include access management. Otherwise, there are no specific corridor plans for highways through the county (M. Walker, personal communication, March 4, 2009).
[c] Parker of VDOT indicated that she is not aware of any access management corridor plans for highways in King and Queen County (Parker, 2009).

Recommended Sampling Procedure

Although it may be desirable to apply these measures to every principal arterial highway and locality in Virginia, the limited resources available make this difficult. At a minimum, these measures should be implemented as follows. For the highway corridor measures—*crashes per million vehicle miles traveled, percentage of signals with spacing at or above standard distance,* and *percentage of median openings with left turn lanes*—at least three highway corridors in each VDOT district should be sampled. Sampling is not needed for the measure *percentage of commercial entrance permits issued that meet access management spacing standards* assuming the requisite information systems are in place to provide these data as discussed here. Preferably, the measure *percentage of localities with a corridor access management plan* should be implemented for at least three localities in each district. Contacting the VDOT residency in addition to localities may facilitate data collection.

Selection of Highway Corridors

At least three highway corridors in each district should be selected for implementation of these measures. These corridors should be selected at the district level, should be consistent in nature along their entire length, and may have the following attributes:

- commercial development has begun or it is probable that commercial development will begin or substantially increase in the near future
- current or potential heavy traffic volumes
- located in developing areas or on the outskirts of established developed centers
- exhibit the need for use of the seven design guidelines described in the literature review
- selected by a person familiar with the highway network and development patterns in the district
- selected in consultation with VDOT central office staff who agree that the selected highways represent a typical application of the access management regulations in the district.

Care should be taken to ensure that the selection is not based on personal bias or the desire to secure a preordained result.

Statewide Presentation of Measures

When aggregating the PMs for the state, appropriate adjustments should be made to avoid bias resulting from different sampling procedures in each district. For example, if only 3 sites were used in one district and 10 sites were used in another, a weighted average will ensure that each district has equal influence.

APPENDIX B

SURVEY INSTRUMENTS AND STATISTICAL TESTS

Survey Instruments

The final version of the survey as used in the Zoomerang survey program is shown in Figure B1.

What is believed by the researchers to be the final version of the survey as used in the McIntire School of Commerce survey program (see Figures B2 and B3) asked the same questions with the following exceptions:

1. Question 2 asked "Who do you work for?" rather than "What city, county, or town do you work for?"

2. Question 6 asked "Which set of measures is most useful" rather than "Which set of measures from Questions 3, 4, and 5 are most useful?"

3. In Questions 3, 4, and 5, the order of the alternatives varied between the two surveys.

4. Question 5 was written as desired whereas an extra "the" was unintentionally inserted in the Zoomerang survey program.

5. Question 9 used the word "design" twice (e.g., "The following are seven design elements of an access management program. Please rate the importance of each design element"), whereas the Zoomerang survey program used the word "design" only once.

6. Question 10 used the word "administrative" twice, whereas the Zoomerang survey program used the word "administrative" only once.

7. Question 10 was written as desired, whereas the Zoomerang version had an extra "to" in the sixth element (i.e., "Assisting to localities").

The visual appearance of the surveys was different. Finally, a review of the results showed that some Zoomerang survey respondents skipped a question. However, no McIntire School of Commerce respondent answered a later question but not an earlier question.

It is possible that these discrepancies may have affected the results of the two survey samples; there simply is no way to verify such a possibility without giving the two survey instruments to very similar populations and determining whether or not differences in responses exist. However, in the judgment of the researchers, the discrepancies appear relatively minor such that the survey results as reported herein are not materially affected.

1 What is your job title?

2 What city, county, or town do you work for?

3 A performance measure could be developed for each outcome listed below. Please rank the outcomes based on their usefulness (1 = least useful; 4 = most useful). Use each rank (1, 2, 3, 4) only **once**.

	1	2	3	4
Air Pollution (Example: Change in emissions attributed to access management)				
Crashes (Example: Change in crash rate attributed to access management)				
Property Values (Example: Change in value of property along a highway attributed to access management)				
Highway Performance (Example: Change in travel time attributed to access management)				

4 A performance measure could be developed for each design element listed below. Please rank the design elements based their usefulness (1 = least useful; 4 = most useful). Use each rank (1, 2, 3, 4) only **once**.

	1	2	3	4
Conflict points (Example: Number of conflict points along a highway)				
Traffic signals (Example: Number of signals per mile of highway)				
Driveways (Example: Number of commercial driveways per mile of highway)				
Supporting Streets (Example: Number of parallel roadways supporting a highway)				

5 A performance measures could be developed for each the administrative procedure listed below. Please rank the procedures based on their usefulness (1 = least useful; 4 = most useful). Use each rank (1, 2, 3, 4) only **once**.

	1	2	3	4
Cooperation (Example: Percentage of localities which promote access management)				
Observation of development (Example: Number of local planning meetings attended by VDOT employees)				
Planning by VDOT (Example: Percentage of highways in developing areas with an access management plan)				
Providing assistance (Example: Number of development plans reviewed by VDOT)				

6 Which ***set*** of measures from questions 3, 4, and 5 are most useful?

- Outcomes in Question 3
- Design elements in Question 4
- Administrative procedures in Question 5

7 What other measures would also help to describe the performance of Virginia's access management program?

8 The following are six goals of Virginia's access management program. Please rate the importance of each goal (1 = not important; 4 = very important).

	1 Not important	2 Somewhat important	3 Important	4 Very important
Reduced congestion	1	2	3	4
Reduced air pollution	1	2	3	4
Improved highway safety	1	2	3	4
Improved economy	1	2	3	4
Lowered need for new roadway construction	1	2	3	4
Preservation of the investment in the highway network	1	2	3	4

9 The following are seven design elements of an access management program. Please rate the importance of each element (1 = not important; 4 = very important).

	1 Not important	2 Somewhat important	3 Important	4 Very important
Designing highways with a minimum number of conflict points.	1	2	3	4
Spacing signals at long uniform distances.	1	2	3	4
Spacing unsignalized access points at long distances.	1	2	3	4
Using medians and two way left turn lanes.	1	2	3	4
Using dedicated turning lanes.	1	2	3	4
Restricting movements at median openings.	1	2	3	4
Constructing a supporting roadway network.	1	2	3	4

10 The following are seven administrative elements of an access management program. Please rate the importance of each element (1 = not important; 4 = very important).

	1 Not important	2 Somewhat important	3 Important	4 Very important
Developing agreements between the state DOT and local municipalities regarding the development of a highway corridor.	1	2	3	4
Promoting cooperation between the state DOT and local governments.	1	2	3	4
Developing an up-to-date land use plan at the local level.	1	2	3	4
Creating a plan for the development of a corridor in a rapidly growing area.	1	2	3	4
Providing up-to-date access management standards.	1	2	3	4
Assisting to localities.	1	2	3	4
Reviewing development plans to determine the current access management situation in the state.	1	2	3	4

11 In general, what percentage of your time is devoted to access management issues?

12 Please describe your activities in the area of access management.

13 What other comments do you have?

Figure B1. Zoomerang Version of Survey

Access Management Performance Measures in Virginia Localities

*What is your job title?

*Who do you work for?

*A performance measure could be developed for each outcome listed below.

	*Please rank the outcomes based on their usefulness. Use each rank (1,2,3,4) only once.			
	Least Useful 1	2	Useful 3	Most Useful 4
Crashes (Example: Change in crash rate attributed to access management)				
Property Values (Example: Change in value of property along a highway attributed to access management)				
Air Pollution (Example: Change in emissions attributed to access management)				
Highway Performance (Example: Change in travel time attributed to access management)				

*A performance measure could be developed for each design element listed below.

	*Please rank the design elements based their usefulness. Use each rank (1,2,3,4) only once.			
	Least Useful 1	2	Useful 3	Most Useful 4
Traffic signals (Example: Number of signals per mile of highway)				
Driveways (Example: Number of commercial driveways per mile of highway)				
Conflict points (Example: Number of conflict points along a highway)				
Supporting Streets (Example: Number of parallel roadways supporting a highway)				

*A performance measure could be developed for each administrative procedure listed below.

	*Please rank the procedures based on their usefulness. Use each rank (1,2,3,4) only once.			
	Least Useful 1	2	Useful 3	Most Useful 4
Observation of development (Example: Number of local planning meetings attended by VDOT employees)				
Planning by VDOT (Example: Percentage of highways in developing areas with an access management plan)				
Cooperation (Example: Percentage of localities which promote access management)				
Providing assistance (Example: Number of development plans reviewed by VDOT)				

*Which category of performance measures is most useful?

	*Which set of measures is most useful? Use each rank (1,2,3) only once.		
	Least Useful 1	Useful 2	Most Useful 3
Outcome performance measures			
Design element performance measures			
Administrative procedure perfomance measures			

Figure B2. McIntire School of Commerce Version of Survey (Questions 1-6)

What other measures would also help to describe the performance of Virginia's access management program?

test

*The following are six goals of Virginia's access management program.

	*Please rate the importance of each goal (1 = not important; 4 = very important).			
	Not important		Important	Very important
	1	2	3	4
Reduced congestion				
Reduced air pollution				
Improved highway safety				
Improved economy				
Lowered need for new roadway construction				
Preservation of the investment in the highway network				

*The following are seven design elements of an access management program.

	*Please rate the importance of each design element.			
	Not important		Important	Very important
	1	2	3	4
Designing highways with a minimum number of conflict points.				
Spacing signals at long uniform distances.				
Spacing unsignalized access points at long distances.				
Using medians and two way left turn lanes.				
Using dedicated turning lanes.				
Restricting movements at median openings.				
Constructing a supporting roadway network.				

*The following are seven administrative elements of an access management program.

	*Please rate the importance of each administrative element.			
	Not important		Important	Very important
	1	2	3	4
Developing agreements between the state DOT and local municipalities regarding the development of a highway corridor.				
Promoting cooperation between the state DOT and local governments.				
Developing an up-to-date land use plan at the local level.				
Creating a plan for the development of a corridor in a rapidly growing area.				
Providing up-to-date access management standards.				
Assisting localities.				
Reviewing development plans to determine the current access management situation in the state.				

In general, what percentage of your time is devoted to access management issues?

Please describe your activities in the area of access management.

What other comments do you have?

Back Finish

Figure B3. McIntire School of Commerce Version of Survey (Questions 7-13)

Statistical Tests

For Questions 3, 4, and 5, the percentage of people ranking the measure either 4 (most useful) or 3 (second most useful) was calculated. Then, it was determined whether this value was significantly higher than 50%. Fifty percent was chosen because if the respondents were indifferent about a measure, then it could be assumed that 50% of respondents would rank it 4 or 3 and 50% would rank it 2 or 1. If respondents viewed a measure as more important than the others, then the percentage of respondents ranking it 4 or 3 should be above 50%.

Equation B1 is used to calculate the test statistic Z_α (Freund and Wilson, 1997; Newbold, 1988).

$$Z_\alpha = \frac{\hat{p} - p_o}{\sqrt{p_o(1-p_o)/n}} \qquad \text{(Eq. B1)}$$

where

$\hat{p}$	=	Percentage of respondents ranking a PM 4 or 3
p_o	=	50%
Z_α	=	test statistic
n	=	number of respondents

For example, Table 5 showed that 79.8% of respondents (99 of 124) ranked *highway performance* either 4 or 3. Using Eq. B1, the test statistic was computed to be 6.64, as shown in Eq. B2.

$$\frac{99/124 - 0.500}{\sqrt{0.50(1-0.50)/124}} = 6.64 \qquad \text{(Eq. B2)}$$

The value *p* (known as the "*p* value" or "probability value" [Hogg and Ledolter, 1992]), is the probability that the test statistic Z_α in Eq. B2 will be greater than the observed value of this statistic when the null hypothesis is that $\hat{p} = p_o = 50\%$. Large values of Z_α correspond to smaller values of *p*. Eq. B3 shows that for a one-tailed test (appropriate when the question of interest is whether a number exceeds a certain value), Z_α values of 1.645, 1.96, and 3.09 correspond to *p* values of 0.05, 0.025, and 0.001. Smaller values of *p* suggest it is more likely that the null hypothesis ($\hat{p} = 50\%$) should be rejected; conventional practice is that *p* values less than 0.05 (or Z_α values greater than 1.96) indicate a significant difference.

$$p = \left(1 - \Phi(Z_\alpha)\right) \qquad \text{(Eq. B3)}$$

where

Z_α is the test statistic computed from Eq. 3
$\Phi(Z_\alpha)$ is the percentage of area at point Z for the standard normal distribution.

Eq. B2 shows that a test statistic of 6.64 easily exceeds 1.645, meaning there is a statistically significant difference between the percentage of respondents ranking a measure as 3 or 4 and the 50% value attributable to chance alone.

Note that p_o is used in the denominator (Freund and Wilson, 1997; Newbold, 1988) rather than $\hat{p}$ (Freund and Wilson, 1997). A rationale for this is inferred from Ross (2004) where the variance of the distribution in question is $np_o(1 - p_o)$ given that n is large and hence the normal approximation of the binomial is appropriate. When the variance in question is assumed to be $n\hat{p}(1-\hat{p})$, it is because there is no hypothesized value of p_o (Freund and Wilson, 1997).

For Question 6, the question was asked whether there is a statistical difference between the percentage of respondents who chose design element PMs as most useful (39.0%) and those who chose outcome PMs as most useful (50.4%). If the responses that chose administrative procedure PMs are eliminated, 71 of 126 chose outcomes and 55 of 126 chose design elements. As shown by Eq. B4, the z value when these proportions are compared to 50% is 1.425.

$$1.425 = \frac{\hat{p} - 0.50}{\sqrt{0.50(1-0.50)/126}} \qquad \text{(Eq. B4)}$$

where

$\hat{p}$ = 56% or 44%

The corresponding *p* value is 0.154 showing that these proportions are not significantly different than 50% at 95% confidence. (Note that this is a two-tailed test because the question is asked whether the proportion is significantly greater or lower than 50%.)

If a percentage of respondents who chose outcome PMs as most useful (50.4%) and those who chose administrative PMs as most useful (10.6%) are compared in the same way, the *p* value is less than 0.05, meaning there is a significant difference between these two proportions.