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Supplementary Notes

Abstract

Accurate data describing the status of the transportation network is the backbone of system operations management. Without accurate data, traffic engineers cannot optimize signal phasing and timing, effective incident management cannot be undertaken, decisions regarding managed lanes operations cannot be made effectively, and information cannot be shared with the traveling public. Traditionally, the data collected for all of these uses have been basic flow parameters, i.e., volume, speed, and occupancy. These data may be collected from continuous count stations, through special or project-related collection activities, or as part of an infrastructure-intensive traffic management system such as the Virginia Department of Transportation's (VDOT) Smart Traffic Centers (STCs). The biggest shortcomings of these data sources are that they tend to be limited in geographic scope or not continuous from a temporal perspective. In addition, the data are often considered for use by only the original "owner" or entity that collected them. The purpose of this project was to develop a comprehensive inventory of operations (traffic flow) data collection activities that occur within VDOT and to document the uses of the data collected.

The results of the study indicate that the majority of traffic flow data used in VDOT come from the Traffic Engineering Division's traffic monitoring system. All data collected are archived and accessible via the internal VDOT website. Data are also collected in VDOT's district offices and through the STCs deployed in Northern Virginia and Hampton Roads. Currently the STC data are rarely used outside the STC because of data quality issues.

To improve VDOT's traffic data collection practices, the following actions are recommended:

1. VDOT's Operations Management Division should initiate a data quality assessment program.
2. VDOT's Operations Management Division should identify and allocate dedicated funding for maintenance of all traffic data collection sites.
3. The Northern Virginia and Hampton Roads STCs should identify those detector stations in each region that provide critical data and discontinue maintenance of the remaining stations.
4. In Staunton, Salem, and Richmond, where STCs have been established but extensive deployment of sensors to obtain volume, occupancy, and speed has not yet occurred, deployment of such sensors should be limited to no more than one station between each interchange.
5. VDOT's Operations Management Division should proceed with obtaining travel time data for freeways and primary arterials.
6. VDOT's Operations Management Division in consultation with the Information Technology Applications Division should establish a common format for archiving data such that data can be shared across work units and applications. Where possible, data should be stored at the lowest level of aggregation possible so that they can be applied to the greatest number of uses.

FINAL REPORT

INVENTORY OF SYSTEM OPERATIONS DATA COLLECTION AND USE IN THE VIRGINIA DEPARTMENT OF TRANSPORTATION

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(A Cooperative Organization Sponsored Jointly by the
Virginia Department of Transportation and
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DISCLAIMER

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data such that data can be shared across work units and applications. Where possible, data should be stored at the lowest level of aggregation possible so that they can be applied to the greatest number of uses.

The cost of collecting and archiving traffic flow data for roadways VDOT owned and operated is significant. Although the uses of these data are different across agency work units, the data elements remain fairly consistent. Link volumes and speeds, turning movement counts, and vehicle classification are the primary elements employed. Some applications require data at a finer level of detail than do others. However, if the data can be collected and archived at the lowest level of detail required, tools can be developed to aggregate the data to any higher level. In this manner, additional data collection can be avoided.

According to TMS cost figures, by reducing the number of detector stations deployed as part of an STC, VDOT can save more than $1 million for each 100 roadway miles of coverage. Further savings could be realized by taking advantage of existing continuous count stations, as has been done in the Richmond STC. There is a cost associated with any new data collection, and VDOT will need to dedicate resources to obtaining data at locations not currently covered. Initially, deployment should focus on freeways in Richmond to provide the data required for traffic and incident management in the region. Travel time data should be obtained for at least one region in the state. The cost of deploying sensors in Richmond is estimated at approximately $500,000 based on the current costs of sensor stations in the TMS. The cost of procuring region-wide travel time is unknown at this time.

FINAL REPORT

INVENTORY OF SYSTEM OPERATIONS DATA COLLECTION AND USE IN THE VIRGINIA DEPARTMENT OF TRANSPORTATION

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INTRODUCTION

With the establishment of the system operations core function within the Virginia Department of Transportation (VDOT), new focus is being placed on ways to measure performance that are both meaningful to the public and useful for system management and planning purposes. Travel time is considered by many to be a critical measure that has the potential to serve many needs currently being met by other data elements with various levels of satisfaction. To explore the potential usefulness of travel time data to VDOT, an inventory of current data uses throughout VDOT is needed. To make a business case for the investment in travel time data, an inventory of current data collection practices (i.e., who collects what and for what purposes) is also needed.

Accurate data describing the status of the transportation network is the backbone of system operations management. Without accurate data, traffic engineers cannot optimize signal phasing and timing, effective incident management cannot be undertaken, decisions regarding managed lanes operations cannot be made effectively, and information cannot be shared with the traveling public. Traditionally, the data collected for these uses have been basic flow parameters, i.e., volume, speed, and occupancy. These data may be collected from continuous count stations, through special or project-related collection activities, or as part of an infrastructure-intensive traffic management system such as VDOT's Smart Traffic Centers (STCs). The biggest shortcoming of these data sources is that they tend to be limited in geographic scope or not continuous from a temporal perspective. In addition, the data are often considered for use by only the original "owner" or entity that collected them. It is likely that the data could be used for many more purposes if their existence were more widely known and they were more easily accessible to a wider audience.

This research effort is seen as the first in a series of research studies that will address the issues related to incorporating travel time into the day-to-day decision-making at VDOT. Without a clear understanding of VDOT's data needs, it is impossible to make decisions regarding future data types, collection/procurement practices, or archiving and retrieval systems.

PURPOSE AND SCOPE

The purpose of this project was to develop a comprehensive inventory of operations (traffic flow) data collection activities that occur within VDOT and to document the uses of the data that are collected.

The objectives of the project were as follows:

1. Determine the "who, what, where, why, and how" of data collection in VDOT, i.e., who (division, districts, consultants) is collecting data, what data they are collecting (aggregation, time period, geographic scope), where data are collected, why data are collected (how is it used once collected), and how data are collected (manual counts, automatic sensors, etc.).

2. Determine the current data applications that could now or in the near future be satisfied with the collection or procurement of travel time data on a wide-scale, continuous basis.

3. Identify opportunities for efficiency improvements for data collection and data sharing practices throughout VDOT.

The study was limited to an examination of operational data collection activities in VDOT, primarily traffic volume and speed data.

METHODOLOGY

The methodology consisted of four major tasks designed to achieve the study objectives.

1. *Identify data "uses" within VDOT.* Data play a critical role in many VDOT activities. Currently there is no comprehensive inventory of all the uses of the data being collected. In this effort, VDOT personnel from the central office and the districts were questioned to determine how data are regularly used in their work area and the characteristics of the data. Specific outputs from each application were identified such that current input data requirements could be separated from the desired or required output. This allowed for an identification of applications that could potentially benefit from new or enhanced data sources.

2. *Identify current data collection activities.* VDOT collects data daily for various purposes and in various formats. A complete inventory of the "why, when, where, and how" of data collection would provide the basis for a better understanding of VDOT's actual data needs. This task involved surveying representatives from VDOT's transportation and mobility planning, traffic engineering, and location and design divisions. In addition, personnel from each district were contacted to determine the data collection activities there. Data collected by consultants for specific VDOT projects were also included in this inventory. For the purposes of benefit/cost analysis of any potential alternate data collection strategies, costs of data collection were obtained.

3. *Develop a list of core data elements.* Based on the results of Tasks 1 and 2, a list of core data elements was developed. This list included data required to meet federal mandates as well as data routinely used within VDOT. Where the same data element was used in varying applications but at different levels of granularity, the impacts of collecting at a common level were determined.

4. *Develop recommendations for data collection and sharing across VDOT.* The availability of accurate, timely data is of huge importance to VDOT and represents a considerable investment of resources on an annual basis. Improvements in the manner in which data are collected, stored, and shared across the agency could potentially result in significant savings. Recommendations for enhancing the efficiency of data collection and management activities within VDOT were developed.

RESULTS

Traffic Data Collection Activities

Data collection activities in VDOT fall into two basic categories: data collected for primarily real-time purposes (such as in the STCs) and data collected for off-line purposes (such as for the traffic count program.) The data elements for these two categories are similar, but the methods of collection, use, and storage are quite different.

Real-Time Data

STC Data

VDOT has traditionally collected a tremendous amount of data through its STCs for use in real-time traffic management applications. STCs are currently deployed in the Northern Virginia (NOVA), Hampton Roads, Richmond, Staunton, and Salem districts. Each STC is somewhat different in how it operates and the level of field infrastructure deployed. NOVA and Hampton Roads have the highest level of field deployments and correspondingly the largest amount of data available for use. These data, consisting of volume, occupancy, and speed (VOS), come primarily from loop detectors imbedded in the pavement at approximately one-half-mile spacings on portions of the interstate networks in the regions. In general, these data are used within the STC for real-time operations but are seldom employed for any other applications. Road weather information system detectors have also been deployed at some locations that are capable of providing real-time information about visibility, pavement temperature, wind speed, etc. In some locations, these detectors can be configured to provide traffic count data as well. Given the significant investment associated with deploying and maintaining the detectors, identifying additional uses for STC-collected data could prove very beneficial.

For data to be useful beyond their real-time applications, they must be stored or archived in a manner that allows for easy retrieval. Data from STCs are currently archived at the Smart Travel Laboratory at the University of Virginia. The Smart Travel Lab is a facility managed cooperatively by the university and the Virginia Transportation Research Council (VTRC.)

Volume, speed, and lane occupancy data are archived for Hampton Roads and NOVA. In addition, incident data are archived from both regions to the extent that they are recorded in the STC; detector data from the Northern Virginia Smart Traffic Signal System are also archived.

In attempt to make these real-time data accessible to users from various segments of VDOT as well as to localities, an effort was undertaken under the sponsorship of a Federal Highway Administration (FHWA) Field Operational Test dubbed "ADMS Virginia." ADMS, short for *archived data management system,* provides easy access to flow and incident data from the NOVA and Hampton Roads STCs. Weather data, signal system data from the City of Norfolk, and data from VDOT's traffic monitoring system (TMS) continuous count stations are also available through a web-based interface. Specific tools for processing, aggregating, and presenting the data are available to a number of user "categories," including planners, environmental analysts, traffic engineers, special event planners, and incident management coordinators. For example, an incident management tool is available within ADMS that will take the characteristics of a current, active incident and search the database for similar, past events. Once a similar incident is located, the user can request to see the VOS data related to the similar incident in tabular or graphical form such that the impacts of the current incident can be estimated. Although these "real-time" tools have value in the STC, ADMS usage statistics to date have shown that planners are primary users of the data, employing them for off-line purposes.

Data collected in VDOT's STCs are also made available to private sector information providers who, in turn, offer value-added services and general information to motorists. Radio and TV stations, for example, will use CCTV images and data to produce the traffic reports aired during peak period broadcasts. In NOVA, private sector information providers have also deployed detection technology as a means of supplementing the data they obtain from VDOT. Data sharing agreements between the private sector provider and VDOT often make these data available to VDOT but may also include significant restrictions on how they can be used. In some cases, private sector data may not be archived for later use.

Currently, the largest roadblock to widening the use of STC data is a lack of consistent quality. The sheer number of detectors deployed in the Hampton Roads and NOVA regions combined with the fact that the majority of those detectors are imbedded loops makes maintenance a challenge. Given that the use of the data beyond the real-time applications within the STC was seen to be minimal and resources are always limited, a low priority was given to maintaining the field devices. Awareness of the value of the data at various levels in VDOT is changing this mindset, and more attention is being paid to the quality of the data collected. STC managers, staff within VDOT's Operations Management Division, and VTRC researchers have begun to debate the relative benefits of maintaining such a large number of loops versus abandoning some in favor of a more aggressive maintenance approach for the remaining loops. Concentrating on maintaining a core set of detectors at key locations, especially with the potential addition of travel time data to supplement current detector data, may be a good business decision for VDOT. This issue is discussed later.

Virginia Operational Information System (VOIS)

VOIS was developed to facilitate the sharing of real-time information on events that impact traffic flow. VOIS currently contains data on road conditions (clear, minor, moderate, severe, or closed [both the condition and cause are entered]); incidents (lane-blocking incidents that are predicted to last 15 minutes or more or result in a queue of 1 mile or more); work zones (including lanes closed); and maintenance requests (work orders for potholes, dead animals, etc.). As a real-time data application, VOIS provides the foundation for 511, Virginia's traveler information service, and the current version of the VDOT Operations Dashboard.

Unlike the STCs that have deployed field hardware to collect the data they use and archive, VOIS relies on data collected by other systems and entities, including STCs, the Virginia State Police's computer-aided dispatch systems, and calls to VDOT's Highway Helpline. Currently, all VOIS data must be entered manually at the local (source) level. Within an STC, this means that operators managing an active incident are responsible for entering data in the native STC software system and VOIS. This repetitive entry takes time and often results in incomplete or missing entries in VOIS. Efforts are underway to automate the data entry process, particularly within STCs. Outside the urban areas served by STCs, data entry occurs typically occurs at the residency level although responsibility for data entry varies from district to district. Although some are quite good at entering information, others are less consistent. If VOIS is to serve as the foundation for performance measurement, these inconsistencies will need to be addressed.

Off-Line Data

The largest source of traffic data for off-line applications is the TMS managed by VDOT's Traffic Engineering Division (TED) in VDOT's Central Office. This program oversees more than 300 continuous count stations, approximately 5,000 48-hour counts per year on every state-maintained roadway classified above a local road (16,500 links total), and 24-hour counts on approximately 13,500 local road segments on a 3-, 6-, or 12-year cycle (80,000 segments total). The continuous count stations provide volume, vehicle classification, and speed at 15-minute intervals. The annual budget for continuous count stations is approximately $3.2 million and includes operating and maintenance costs.

The short-term (48-hour) counts are conducted on each link every 3 years. The data collected are a mix of links with vehicle classification and speed and links with total axle counts. Volume data are collected by direction, by lane, and in 15-minute intervals. Local road counts provide only a 24-hour count; no interval data are collected. In addition, only total volume is provided; no speed or vehicle classification data are collected. The annual budget for short-term counts is approximately $2 million dollars. Of this amount, approximately $1.3 million is committed to contracted data collection services and $700,000 is allocated to state forces collecting data.

In addition to the data collected as part of the annual counts program, the TED is often asked to conduct additional counts for specific projects. These services are used by other central office divisions as well as the district offices when traffic count data are needed. In 2004, 142 direction turning movement counts, 215 vehicle classification counts, 54 vehicle occupancy class counts, and 1 pedestrian count were conducted by the TMS. The costs of these counts, $127,000 in 2004, are paid by the requestor from local project funds.

Data from the TMS are archived in an Oracle database and are available to all VDOT personnel through an internal web application.

The Richmond and Staunton STCs are taking advantage of the continuous count stations in their regions as a means of obtaining near-real-time VOS data. They are employing the "Stopwatch" program, which provides continuous polling of selected count stations. Each station is polled on a 5-minute interval to obtain the latest data available. So, in this case, infrastructure that is already deployed is being used for an additional purpose and filling a need. Although currently there are not enough count stations in either region to provide a complete picture of conditions, some data are better than none. Stopwatch data are archived with other STC data and not within the traffic count program database.

District Data Collection Activities

Notwithstanding the STC data discussed previously, district staffs collect or contract for the collection of traffic data both regularly and for project specific purposes. Some district offices have formal counting programs with dedicated staff to conduct counting activities, whereas others rely almost completely on data available from the central office TMS. Data collected by district staff range from intersection turning movement counts, to link counts, to speed data. The storage of these data varies by district, with some districts keeping only paper records of the counts they conduct locally and other districts maintaining very detailed databases.

The NOVA District is probably the most advanced with respect to the amount of data collection that occurs locally as well as the storage and use of the data beyond their original purpose. The traffic engineering group in the NOVA District maintains three or four teams of hourly employees who collect turning movement counts 3 days per week. When the teams are fully staffed, they collect approximately 20 turning movement counts per week. The data resulting from these counts are stored in an Access database that is searchable by route number or name. The database currently contains approximately 5 to 6 years of data, aggregated to 15 minutes. A link to the database is provided on the district's internal website such that anyone who needs data for a particular application can check the database to see what is available. Other district units are aware of the database and will check this resource first before undertaking additional data collection. Often the traffic engineering count teams are called upon to collect data for other units such as the district transportation planning unit, which do not maintain its own data collection resources. Data are also shared with Fairfax County traffic engineering and permits offices.

In addition to the turning-movement data, the NOVA database includes the output from various other data collection activities including ramp counts, link volume counts, and speed studies. Approximately 20 to 30 of these activities are undertaken each month. Data collected by consultants as part of submitted studies, such as traffic impact studies, are not submitted in electronic form and are, therefore, not included in the database. Data quality concerns have also prevented inclusion of "outside" data in the database. Without knowledge, and perhaps oversight, of how the data are collected, data administrators are reluctant to combine outside data with internally collected data. A potential solution to this challenge is to include metadata (data about the data) that indicate the original source and therefore an implied indication of quality. The NOVA traffic database does not currently incorporate data from intersections within the Northern Virginia Smart Traffic Signal System. This is because these intersections are managed within the Management Information System for Traffic (MIST) System, which includes its own database. MIST data are currently archived only within the Smart Travel Lab.

Another unique database maintained in the NOVA District is one that was dubbed MOBIS, short for MOBility Improvement Study. MOBIS is designed to identify small-scale projects to improve regional mobility based on transportation data. By overlaying accident, volume, and speed data on a common map, locations with the greatest potential for improvement can be more easily identified.

Data derived from Safety Service Patrol stops and assists are also provided in a spatial layer. Information on all traffic signals, on-line, planned (in design), and under construction, is also provided spatially. Although no detector data (speed or counts) are provided in this database, it is very useful for other purposes. For example, the Fairfax County permit officials use the database as they consider whether or not to issue individual lane closure permits. The database also includes lane closures associated with permits. Given that in Fairfax County alone there can be as many as 5,000 active permits at any one time, the ability to share these data in real time is critical. In addition to all the data mentioned above, the NOVA District also maintains spatial databases that contain the following data:

- pavement schedules
- ITS asset inventory
- roadway inventory
- Global Positioning System (GPS) cell-phone data.

There are currently approximately 260 GPS-enabled cell-phones in maintenance vehicles throughout the NOVA District that are primarily used to notify maintenance managers of interstate lane closures. The database contains information for every phone in use that includes the time, location, person to whom the phone is assigned, and speed once per minute. Ninety percent of these records can be mapped to a roadway. Lane closures are also called to the STC where operators can see the location of the cell phone on a map. The technology has also been employed in snow removal activities to help maintain real-time status of road conditions. The potential for these "probes" to provide real-time travel time data is intriguing.

The Richmond District is another location where a significant amount of data collection occurs locally. The Richmond District maintains one two-person counting team with one other person dedicated to the secondary roads count program. This team typically collects directional turning movement counts aggregated to half-hour intervals during the peak period and hour intervals during off-peak periods. Data from these counts are maintained in "hard copy" in a binder in the district's traffic Engineering group. The district also has the ability to develop count data from traffic signal controllers based on green times, although counts cannot be directly obtained. The data that are submitted with consultant reports are typically maintained only within the report although district staffs know where to find them and will occasionally refer to them when data are needed.

District personnel believe there would be a benefit to having additional data available. The district traffic engineer would like to have an additional one or two technicians dedicated to collecting count data. Additional data would allow the staff not only to do more of the kinds of studies they do now but also to collect data to support bicycle and pedestrian studies. Travel time data are seen as an important data element for traveler information.

Other districts tend to rely more on the data available from the central office TMS. Turning movement counts are often still collected locally for the purposes of traffic signal warrant analyses, but these counts are sporadic. Although the data are sometimes sent to the central office for incorporation in the count program database, there is often no formal means of archiving them locally. Speed data are also collected on a random basis and the data are stored only within the study report for which they were collected. In some locations, data can also be retrieved from cameras used as signal system detectors on an as-needed basis.

Current Uses of Traffic Data

As noted earlier, there are real-time and off-line uses for the traffic flow data currently collected within various VDOT work units. The uses identified to date are discussed here.

Real-time traffic management. Within STCs, VOS data are used to identify locations of potential incidents or recurring congestion. Once identified, steps are taken such as posting messages on changeable message signs to alert motorists to conditions ahead, deploying incident management resources, and providing information to private sector information providers. Although VDOT does not currently provide travel time information, several private information providers do estimate travel times based on VDOT data and information from other sources.

Emergency and event management. A subset of real-time traffic management, emergency and event management benefits greatly from accurate, timely data. Hurricane evacuation, for example, has been garnering a great deal of attention both nationally and in Virginia. Detailed evaluations of hurricane response plans are being conducted, and a common finding is that more real-time data on evacuation routes would provide a basis for managing demand throughout the impacted region.

Operations planning. Beyond the real-time use of data in STCs, the data collected there are also used for trend analysis. The impacts of holiday travel and incidents are investigated to improve future operations. In addition, volume conditions are evaluated to determine appropriate times for lane closures and other work zone activities.

Traffic signal studies. Within the districts, the biggest use of traffic data appears to be traffic signal studies. These include warrant analyses to determine the need for new signal location and re-timing studies to update the phasing and timing at an existing signal. Intersection turning movement counts are the primary data required for these studies.

Speed studies. A common citizen request at the local level involves the alteration of speed limits on roadways. Speed and sometimes volume data are used to determine the merit of the request.

Performance measurement and reporting. Reporting on the performance of the transportation system is a function that relies completely on data. Once the measures are defined, data to support them must be collected and stored such that both current and trend data are available for use. Although performance measures for a transportation agency will be wide-ranging to cover the variety of functions an agency undertakes, those related to traffic data include measures of congestion, system reliability, and safety. Commonly used performance measures include travel time, incident duration, delay, average speed, and number of crashes. Internal agency performance measures will likely include data quality, device reliability, and incident response time.

Long-range planning studies. An important functional responsibility of VDOT is planning for future transportation needs. Current traffic count data are used to develop forecasts of future conditions that can then provide the basis for design decisions. Historical databases of traffic conditions are also useful in the development of forecasts as they provide past trend information that can be combined with current and planned land uses in a region as input to the forecasting process.

Environmental studies. Traffic volume and speed are important elements of environmental studies estimating the noise and air pollution impacts of roadway projects.

Federal reporting requirements. All state departments of transportation are required to report traffic volume information to the Highway Performance Monitoring System (HPMS) on an annual basis. The HPMS is a national level highway information system that includes data on the extent, condition, performance, use, and operating characteristics of the nation's highways.[1] Annual average daily traffic estimates for all roadway links are provided to HPMS and are used in the federal apportionment process, directly impacting the level of federal transportation funding all states receive. Data collected within the TMS are fed into VDOT's Highway Traffic Records and Inventory System (HTRIS), where volume data are combined with the other data required by HPMS and submitted to FHWA.

Safety studies. The safety of VDOT's transportation network is a top priority. Studies of the safety of individual intersections, roadways, or corridors are undertaken at both the district and central office level. Speed and volume data along with accident histories are used in safety studies.

Table 1 summarizes the primary traffic data users, applications, and data sources within VDOT.

Table 1. VDOT Data, Users, Uses, and Sources

Data User	Application	Data Type	Current Source	Comments
Traffic Engineering	Speed studies Traffic signal studies	Link volume and speed Turning movement counts	TMS, local collection Local collection	 More data collected on regular basis would improve analysis results
Planning	Corridor studies/small urban studies Traffic forecasts	Link (tube) counts Turning movement counts Link counts, turning movement counts	TMS TMS/VDOT contractor TMS/VDOT contractor	More data would improve accuracy of study results
Environmental	Air quality conformity assessments Air and noise studies	Average speed Hourly volume Hourly volume, percent ADT and estimated operation speed, % trucks with 2 axles and 6 tires, % trucks with 3 or more axles, directional distribution, saturation capacity (v/hr) (air studies only)	TMS, planning models (forecasts) TMS, planning models (forecasts)	Use output from planning model for AADT and then convert to hourly volume using TMS data
Location and Design	Planning/design of new/improved facilities	Hourly volume (ramp/mainline), % trucks, turning movement counts	TMS, planning models (forecasts)	
STC Operators/Managers	Traffic management Incident management Trend analysis (operations planning)	Real-time VOS Real-time VOS, incident characteristic and status Archived VOS	STC field equipment STC field equipment, SSP, VSP CAD ADMS VA, TMS	Data quality is an issue Source data quality is an issue
Program Managers	Performance measurement	Archived VOS, incident history, travel time	ADMS, TMS, VOIS	Travel time not currently available but desired

Note: TMS = traffic monitoring system; ADT = average daily traffic; AADT = average annual daily traffic; VOS = volume, occupancy, and speed; SSP = safety service patrol; VSP = Virginia State Police; CAD = computer-aided dispatch.

Within each category in the table, what appear to be the same data elements may not be identical. For example, VOS data for STC operators will likely involve data for individual roadway segments at 1- to 5-minute increments although volume data for planners may be daily traffic volumes or hourly volumes. These differences do not mean that data cannot be shared across users and applications, they simply illustrate the need to determine the lowest level of detail required and collect and store data at that level. Once this is done, processes can be developed to aggregate the original data to other levels. For example, 5-minute volumes can be easily summed to create daily volumes, and several links can be combined to represent a longer roadway segment. The same is true for data quality. If data are intended to be shared across applications, the application with the most stringent quality standards must determine the overall requirements.

Data Quality

As noted previously, data quality, or the sometimes lack of it, is a primary concern. VDOT is not the only agency to struggle with data quality. In fact, a number of national workshops have been held on the topic. In a report prepared for FHWA as a result of one of these workshops, a method for determining traffic data quality was developed and presented.[2] The study put forth six fundamental measures of data quality:

1. *accuracy:* the degree of agreement between a data value(s) and a source assumed to be correct

2. *completeness:* the measure of how much data are available compared to how much data should be available

3. *validity:* the degree to which data values fall within the respective domain of acceptable values

4. *timeliness:* the degree to which data values are provided within an acceptable time frame

5. *coverage:* the degree to which the data values accurately represent the spatial or temporal space

6. *accessibility:* the relative ease with which data can be retrieved and manipulated by users.

Some of these measures are relatively easy to quantify, namely completeness, coverage, and accessibility, although others, such as validity and accuracy, are more complicated. Within ADMS Virginia, validity checks are used to determine the "reasonableness" of data. Although absolute quality cannot be determined without ground truth data, values that are theoretically impossible (positive volume with zero speed) can be flagged. ADMS VA also provides a completeness value to indicate the number of data records available compared to the number that should have been available.

A comprehensive data quality assurance program would facilitate the sharing of data by allowing all users to know that the data are current and accurate. Such a program cannot be implemented without significant resources, however. The aforementioned FHWA report provides estimates of the level of effort required to establish the elements of a traffic data quality assessment program. For the accuracy component, the study report estimates 8 hours per site to design and collect sample baseline data initially (and then periodically as needed) plus 1 hour and 15 minutes per site to download and check data against the baseline.[2] Given these resource requirements, it is advisable to develop a sampling plan for accuracy that ensures a statistically valid sample yet reduces the resource burden of collecting ground truth data for every site. Validity could still be checked in an automated fashion with questionable values flagged. A proposed sampling plan for data quality with STCs was developed by Smith et al. as part of a recent VTRC project.[3]

Potential Future Data Needs and Current Data Gaps

Activities and Applications

Many activities and applications that are not currently widespread in VDOT could play a significant role in VDOT's approach to system operations in the near future. Several are discussed here.

Ramp metering. Although not widely deployed in VDOT now, ramp metering has been proven to be an effective freeway traffic management tool. Advance metering algorithms require accurate, real-time data including volume by lane, speed, and density upstream and downstream of the ramp as well as queue lengths on the ramps themselves. There is a potential that as travel time data become more pervasive, algorithms could be developed to use these data in lieu of the volume and speed data more commonly used now.

Value pricing. The concept of managing demand through pricing is gaining support worldwide. In Virginia, a number of proposals submitted under the state's Public Private Transportation Act involve high-occupancy toll (HOT) lanes, a form of value pricing. Since value pricing is predicated on the notion of providing a congestion free alternative to motorists willing to pay a fee, any implementation will require highly accurate data on current conditions. Under a dynamic pricing scheme, these data would be used to adjust the fee in real time in response to changing conditions. Travel times for priced lanes and the free alternatives will provide motorists with the information they need to make a decision as to the route they will choose.

Gaps in Data

Although VDOT does collect a tremendous amount of traffic-related data, gaps do remain. Some of the gaps discussed here relate to the quantity of data available, and others relate to additional data elements.

Travel time data. With respect to system operations performance measurement, travel time is considered the primary measure. In one study conducted for FHWA, eight principles were offered for congestion performance monitoring. The number one principle is: "Mobility performance measures must be based on the measurement of travel time."[4] As stated previously, VDOT does not currently have the ability to measure travel time directly and has not been successful in attempts to derive travel time from point detector speed data. Beyond performance monitoring, travel times would also enhance traveler information services and emergency management activities such as evacuations and could also feed into algorithms for ramp metering, value pricing, and incident detection.

Arterial performance data. Freeway data are available in Hampton Roads and Northern Virginia, but real-time data on the arterial roadways are not as easy to come by. System operations, by its nature, is a regional activity. Managing the freeways addresses only a small part of the overall challenge. Integrated arterial/freeway management requires real-time knowledge of conditions on both the freeway and the arterials. Beyond the everyday challenges of balancing demand across all available routes, incident and emergency management often requires diverting traffic from one roadway to another. Doing so blindly, without complete information, can result in sending diverted traffic into a situation worse than that which they left.

Regularly collected turning movement counts. Turning movement counts are the basis for determining the need for traffic signals and for timing those signals once they are in place. There currently exists no statewide or regional program for collecting these data. Although counts are reportedly collected on an "as-needed" basis, the majority of individuals surveyed reported a desire for more and more regularly collected turning movement data.

Freeway performance data. As discussed earlier, VOS data are available from densely spaced detectors in Northern Virginia and Hampton Roads. In other regions, the deployment of sensors has not been as aggressive. Although experience has shown that the half-mile spacing previously employed is more than necessary and difficult to maintain, some detection is needed to provide a base level of information. This is an area where travel time could be a tremendous asset. Having travel time would not eliminate the need for volume data, but the deployment of technology to collect VOS data would be reduced significantly. If reliable methods of estimated volume from whatever technology is used to obtain travel time can be developed, the current number of count stations may be sufficient. If this is not the case, additional count stations may be required, but certainly no more densely than between each interchange in urban areas.

FINDING AND CONCLUSIONS

- *The traffic monitoring system managed by VDOT's TED collects the majority of non-real-time data in VDOT.* Traffic volume and lane occupancy data are collected at approximately 300 continuous count stations located throughout the state. Many districts rely heavily on these data as a primary source for local analysis needs.

- *Data collection efforts within the districts vary with the "urban" or "rural" nature of the district.* In general, the more urban the district, the more data are collected at the local level.

- *Archiving of data varies by location.* All data collected under the auspices of the TMS are archived. Real-time data from the STCs are archived at the Smart Travel Lab. The NOVA

District maintains an extensive spatial database. Other districts maintain data only in paper logs or not at all.

- *Turning movement counts, link (tube) counts, and link speeds are the primary data elements used at the district level.*

- *STC data are currently used outside the traffic management functions of the STC in only a limited fashion.* The primary reason for this is poor data quality.

RECOMMENDATIONS

1. VDOT's Operations Management Division should initiate a data quality assessment program.

2. VDOT's Operations Management Division should identify and allocate dedicated funding for maintenance of all traffic data collection sites.

3. The Northern Virginia and Hampton Roads STCs should identify those detector stations in each region that provide critical data and discontinue maintenance of the remaining stations.

4. In Staunton, Salem, and Richmond, where STCs have been established but extensive deployment of sensors to obtain volume, occupancy, and speed has not yet occurred, deployment of such sensors should be limited to no more than one station between each interchange.

5. VDOT's Operations Management Division should proceed with obtaining travel time data for freeways and primary arterials.

6. VDOT's Operations Management Division in consultation with the Information Technology Applications Division should establish a common format for archiving data such that data can be shared across work units and applications. Where possible, data should be stored at the lowest level of aggregation possible so that they can be applied to the greatest number of uses. Based on the data uses identified in this study, the levels of aggregation provided in Table 2 are recommended.

Table 2. Recommended Aggregation Levels for Archived Data

Data Type	Spatial Aggregation	Temporal Aggregation	Update Rate
Turning movement counts	Intersection approach	15-minute peak period, 1-hour off-peak	Every 5 years at signalized intersections or as needed
Link counts	Freeway: between each interchange, by lane	15minute	Continuous
	Arterial: by lane, locations determined locally	15-minute	Continuous in select locations
Travel Time	Freeway: link defined as interchange to interchange	1-minute peak period, 10-minute off-peak	Continuous
	Arterial: link approximately 2 miles in length, using intersections with freeway or primary arterial where possible	5-minute peak period, 10-minute off-peak	Continuous

BENEFITS AND COSTS ASSESSMENT

The cost of collecting and archiving traffic flow data for roadways VDOT owned and operated is significant. Although the uses of these data are different across agency work units, the data elements remain fairly consistent. Link volumes and speeds, turning movement counts, and vehicle classification are the primary elements employed. Some applications require data at a finer level of detail than do others. However, if the data can be collected and archived at the lowest level of detail required, tools can be developed to aggregate the data to any higher level. In this manner, additional data collection can be avoided.

The TED's TMS program currently spends approximately $3.2 million per year for the 306 continuous count stations deployed. The stations are leased from a contractor who is responsible for maintaining the equipment and ensuring data quality. This cost breaks down to approximately $10,500 per site, per year. If detector spacing in urban (STC) areas is reduced from one station every one-half mile to one station between each interchange, the number of stations required will be reduced significantly. Even the conservative estimate of one interchange per mile results in 50 percent fewer detector stations. This results in a savings of more than $1 million for each 100 roadway miles of coverage, based on the TMS cost figures. Further savings could be realized by taking advantage of existing continuous count stations as has been done in the Richmond STC.

There is, of course, a cost associated with any new data collection, and VDOT will need to dedicate resources to obtaining data at locations not currently covered. Initially, deployment should focus on freeways in Richmond to provide the data required for traffic and incident management in the region. Travel time data should be obtained for at least one region in the state. The cost of deploying sensors in Richmond is estimated at approximately $500,000 based on the current costs of sensor stations in the TMS. The cost of procuring region-wide travel time is unknown at this time.

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