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Data Needs Assessment for Making Transportation Decisions in Virginia

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16. Abstract:

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Based on interviews with practitioners, a survey of 182 professionals, and a review of data management practices in the literature, the study finds that needs vary by organizational type: whereas only 41% of the Virginia Department of Transportation (VDOT) survey respondents have at least one unmet data need, this percentage climbs to 70% for metropolitan planning organization and local respondents. When all respondents were asked to name, out of 51 databases, those that were needed but not available, almost one-fifth of all respondents cited three databases relating to infrastructure, safety, and operations; in Virginia these databases are known as roadway network system (RNS), Highway Safety Improvement Program (HSIP), and data maintained by the Traffic Operations Center (TOC), respectively.

A primary obstacle to meeting data needs is data availability: some proprietary data owned by VDOT cannot legally be shared with external agencies, some datasets are restricted in how they can be shared due to security concerns, and some datasets can be shared but are not known to external partners. Other obstacles include data quality, time required to access datasets, and database diversity as the survey suggested that planners need access to a wider variety of databases than do other types of transportation professionals.

Potential solutions documented in the report are to increase user awareness through seminars or the creation of a transportation data map, improve ease of access for select users through the use of virtual private networks, improve ease of use through providing a single location as a starting point for acquiring some publicly available existing data, and integrate databases in instances where common data elements allow such integration. In the short term, two recommended courses of action appear feasible: (1) conduct a workshop to make external partners and VDOT staff aware of some of these diverse databases, and (2) conduct periodic meetings of planning, information technology, and research staff to identify ways to enhance data sharing.

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FINAL REPORT

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ABSTRACT

To better plan, operate, and maintain the transportation system in Virginia, this study identifies Virginia transportation professionals' planning-related data needs, obstacles to fulfilling those needs, and potential solutions for overcoming those obstacles.

Based on interviews with practitioners, a survey of 182 professionals, and a review of data management practices in the literature, the study finds that needs vary by organizational type: whereas only 41% of the Virginia Department of Transportation (VDOT) survey respondents have at least one unmet data need, this percentage climbs to 70% for metropolitan planning organization and local respondents. When all respondents were asked to name, out of 51 databases, those that were needed but not available, almost one-fifth of all respondents cited three databases relating to infrastructure, safety, and operations; in Virginia these databases are known as roadway network system (RNS), Highway Safety Improvement Program (HSIP), and data maintained by the Traffic Operations Center (TOC), respectively.

A primary obstacle to meeting data needs is data availability: some proprietary data owned by VDOT cannot legally be shared with external agencies, some data sets are restricted in how they can be shared due to security concerns, and some data sets can be shared but are not known to external partners. Other obstacles include data quality, time required to access data sets, and database diversity as the survey suggested that planners need access to a wider variety of databases than do other types of transportation professionals.

Potential solutions documented in the report are to increase user awareness through seminars or the creation of a transportation data map, improve ease of access for select users through the use of virtual private networks, improve ease of use through providing a single location as a starting point for acquiring some publicly available existing data, and integrate databases in instances where common data elements allow such integration. In the short term, two recommended courses of action appear feasible: (1) conduct a workshop to make external partners and VDOT staff aware of some of these diverse databases, and (2) conduct periodic meetings of planning, information technology, and research staff to identify ways to enhance data sharing.

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INTRODUCTION

The key objectives of the Virginia Department of Transportation (VDOT) are planning, operating and maintaining a safe and efficient transportation system. This requires making important resource allocation and investment decisions that are based on facts and good judgment. This study focuses on exploring how the VDOT mission can be supported by providing greater accessibility to high quality transportation data to transportation professionals that include employees of VDOT, transportation planning organizations, localities, other agencies, and private consultants in Virginia.

Transportation involves intensive use of quantitative data. With cheaper data storage, higher speeds of data processing, and faster communication of information, transportation agencies have the opportunity to increase their effectiveness, providing greater safety and mobility. Notably, VDOT, planning agencies, and other professionals are increasingly using available and new data sources to monitor the performance of the transportation system and plan

for the future. With increasing ability to access large amounts of transportation-related data and the availability of new tools that transform the data into useful information, transportation agency personnel are able to make more informed and fact-based decisions. Cheaper data storage, higher speeds of data processing, and faster communication of information enable the planning, design, construction, operation and maintenance functions to be performed better.

Transportation performance measures increasingly capture a wide spectrum of transportation indicators, including incident and recurrent traffic congestion, safety, environment, as well as alternative mode use (pedestrian and bicycle), freight movement, jobs-housing balance, infrastructure maintenance, and financial system performance measures, i.e., allocations, obligations, and expenditures. Intrinsic differences in such a wide spectrum of data classes present a challenge for effective and efficient utilization of the data.

A substantial portion of transportation performance data is spatial in nature and is interdependent. The value of such data can be uncovered by providing access to the data in a usable and timely manner. However, some of the data on regional performance measures are available only to VDOT users because a firewall prevents non-VDOT users from getting access to these data. Thus, external users, such as staff of metropolitan planning organizations (MPOs), cannot get immediate access to these data. Furthermore, the enhancement of available data by improving visual appearance and ease of use and providing support services can result in substantial improvements in organizational efficiency and effectiveness. This study seeks to identify the unmet data needs of transportation professionals in Virginia and to identify potential unmet data needs.

PURPOSE AND SCOPE

The purpose of this study is threefold: (1) to characterize Virginia transportation professionals' planning-related data needs; (2) to document obstacles to fulfilling those needs; and (3) to identify potential solutions for overcoming those obstacles.

The scope of this study is bounded in five ways:

1. Potential solutions are restricted to those permissible by the Virginia Information Technology Agency (VITA). VITA oversees all information technology applications in state government and its policies restrict how data may be accessed through firewalls, encryption, and policies designed to enhance security and confidentiality.

2. Potential solutions must be coordinated with the VDOT Information Technology Division (ITD), which generally maintains VDOT's databases and is concerned with the data needs of all VDOT staff, not just those in transportation planning.

3. Individual databases are not studied in detail, rather, the study examines integration, processing, and acquisition of databases in a general sense.

4. The study considers both VDOT and non-VDOT data sources, and in the literature review only, considers national sources.

5. Transportation professionals are defined as VDOT division and district staff, Virginia MPO / planning district commission (PDC) staff, local staff, and private consultants. The perceptions of the public are not within the scope of this study.

While transportation planners are the core audience for this research, during the course of the project the technical review panel (TRP) suggested that data needs of other transportation professionals also be considered. Thus, the scope of the survey and related tasks were expanded to include data needs of a variety of transportation professionals rather than just planners.

METHODS

Five tasks defined the research approach:

1. Develop a conceptual framework relating data to transportation planning decisions.

2. Conduct a literature review of planning data needs and solutions.

3. Document Virginia databases in terms of type, users, and title.

4. Design, implement, and analyze the results of a survey of transportation professionals.

5. Assess potential short-term solutions to fulfil unmet data needs.

Conceptual Framework

A conceptual framework was developed to determine types of data used for transportation-related decisions. The framework helped identify data access concerns of two groups of stakeholders: data owners and data users.

Generally, data owners may be reluctant to provide access to data because:

- Making data accessible has not been identified as a need.
- Confidentiality, security, or integrity concerns restrict the sharing of data.
- Data are either proprietary or too valuable to distribute freely.
- Time and cost of sharing data are large.

Data users may be hampered from obtaining data because:

- Obtaining permission to access the data is time-intensive.
- Users may lack the technical or computing capacity to analyze large data sets.
- Users may be unaware of the data that can be useful to them.

Literature Review

The literature review was conducted by searching for relevant literature through various scholarly databases that include Scopus, Google Scholar, and National Transportation Library. Literature on planning data needs and potential solutions was identified and synthesized. The literature review also included an Internet search of several state DOT websites. This search showed other states' practices in terms of data made available to the public, data management, and data dissemination.

Document Virginia Databases

Along with input from the TRP, interviews of transportation professionals were used to document Virginia databases. Interviewees included technical developers of travel demand models in VDOT, VDOT district planners, PDC/MPO travel demand model users, local planners, MPO staff responsible for transportation improvement projects, transportation consultants, and ITD staff. Databases were documented in terms of type (e.g., the source and format of the data), users (e.g., what types of persons need access to the data), and name (e.g., the specific name of the database).

Then the identified databases were placed into two categories based on control: (1) those that are fully created and controlled by VDOT staff (e.g., Project Cost Estimating System [PCES]), and (2) those that are partially created or controlled by VDOT staff (e.g., VDOT's internal crash records system, which is shared by the Department of Motor Vehicles, Virginia State Police, and VDOT). In both categories, access to these data may be restricted.

Survey of Transportation Professionals

A survey was conducted of Virginia transportation professionals drawn from the staff of VDOT, PDCs/MPOs, localities, and consultants. The survey sought to identify unmet data needs and existing data sources that can address these needs. The research team identified existing VDOT and non-VDOT databases that can meet the needs of professionals. This survey work had three main steps: survey design, survey implementation, and survey analysis.

Survey Design

The survey of transportation professionals' data needs focused on the topics of data awareness, data acquisition, and data use. The survey attempts (1) to understand practitioners' use of existing data to determine if transportation and related data have been leveraged to the maximum extent, and (2) to identify unmet short-term data needs of transportation professionals and understand their access and use of transportation databases. The survey contents consisted of a set of questions requiring single/multiple choice responses together with open-ended questions that gave respondents the opportunity to input more detail in their answers. The survey had the following sections:

- Job descriptions, including job title, main tasks performed by the division where the respondent worked, main work duties, and number of persons supervised.

- Personal information, including highest education level completed, professional licenses or certifications, and years of experience.

- A total of 52 databases. A list of VDOT databases that can satisfy professionals' data needs was obtained with the help of VDOT Transportation Mobility and Planning Division staff; additional publicly available databases used by transportation professionals in Virginia was also obtained based on the literature and knowledge of the research team. These databases cover land use, infrastructure, network flows, performance, freight, programming, and travel behavior. Questions regarding software and databases currently used or that are needed but currently unavailable were also posed.

- Data accessibility, including the reasons for why the data are restricted for certain users.

- Data quality and handling, including frequency of data use, purpose of data use, data sharing methods, constraints on accessing databases, awareness of how data were collected, whether the data satisfy intended use, and how the data might be improved.

- Lessons learned and experiences from past projects, including issues related to data accessibility, software availability, and funding.

After a draft survey was developed, it was shared with the project TRP for their review, comments, and approval. Their comments were incorporated in the final survey that was implemented. The final survey questionnaire is included in Appendix A.

Survey Implementation

Survey participants were initially identified by their organizational type and job categories. Then a broad list of transportation data was created, and interviews with a select group of five data users from the Hampton Roads PDC were conducted. Based on a limited

number of interviews and research team's experiences, a draft survey was prepared for review by a VDOT TRP. After obtaining comments from the review panel and modifying the draft survey, it was implemented professionally by the Social Science Research Center (SSRC) at ODU between February-April 2013. An email invitation with a link to the survey was sent to potential respondents.

A total of 936 emails were delivered to potential respondents; 182 individuals responded to the survey, yielding a 19.44% response rate. Reminder emails were sent 10 days after the first email invitation, encouraging potential respondents to complete the survey. The study is inclusive of transportation professionals; the users included technical developers of travel demand models in VDOT, and PDC/MPO travel demand model users, MPO staff responsible for transportation improvement projects as well as VDOT district planners, local planners, transportation consultants, and other key professionals in VDOT's construction, operations, maintenance, and IT divisions.

Survey Analysis

Descriptive statistics were used to summarize the survey data, which are given in Appendix B. Various types of regressions were considered for further analyzing the data. Given the focus of the study, two dependent variables were the number of needed but unavailable databases and number of databases used by respondents. The standard Poisson or negative binomial regression models were estimated initially. However, such models may underestimate the probability of zeroes (the data included a large number of zeroes for the dependent variables). A more appropriate model for such data is the zero-inflated Poisson (ZIP) or zero-inflated negative binomial (ZINB). These models can capture both the excess zero group and the nonzero group, by estimating two separate models and connecting them. A first-step binary logit model is estimated for the "certain zero" cases, predicting whether or not respondents have zero unmet data needs or zero databases used. (Coding of this variable is somewhat counterintuitive, as 0 in the original data is coded as 1 in the binary model and >1 is coded as 0.) Then, a second-step Poisson (or negative binomial) model is estimated for analyzing the extent of unmet data needs or the extent of databases used.

A statistical test showed whether the zero-inflated model predicts response variable better than the standard model. Formally, consider two-step equations for the ZIP model. The first step is a binary model for zero dependent variable:

$$P\,(Y=0) = \frac{exp(\gamma_0 + \gamma_1 X_7 + \gamma_2 X_8\,)}{1 + exp(\gamma_0 + \gamma_1 X_7 + \gamma_2 X_8)} \qquad \text{(Equation 1)}$$

Y = dependent variable-number of unavailable but needed databases or the number of databases used by the respondents.

γ = parameters in binary model

The second-step model is a Poisson regression model:

$$Y = exp(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_m X_m) \quad \text{(Equation 2)}$$

X_1 =1 if the major job duty is operations, 0 otherwise
X_2 =1 if the major job duty is administration & finance, 0 otherwise
X_3 =1 if the major job duty is design/construction/maintenance, 0 otherwise
X_4 =1 if the major job duty is environmental, 0 otherwise
X_5 =1 if the major job duty is information technology, 0 otherwise
X_6 =1 if the major job duty is other, 0 otherwise
X_7 =1 if the organization is MPO and localities, 0 otherwise
X_8 =1 if the organization is consulting and others, 0 otherwise
X_9 = years of work experience for respondent
β = estimated parameters in Poisson model.

Important statistical tests include the chi-squared test for statistical significance of the model, the Vuong test for comparing the zero-inflated model with an ordinary Poisson regression model, and t-tests for statistical significance of each variable. These tests are typically done at the 5% confidence level, or p-value below 0.05.

Assessment of Potential Short-Term Solutions

After identifying possible short-term solutions based on the survey results, two steps were taken to assess partially some of these short-term solutions.

1. *A telephone interview of VDOT's chief information officer (M. Rao, personal communication, 2014) was conducted regarding data resources, VDOT data initiatives, and VDOT/VITA policies regarding data access.* Twelve questions were posed in order to better understand if some of the solutions are feasible to implement given ITD and VITA's policies regarding sharing of sensitive and non-sensitive data; these provided information about ongoing VDOT initiatives as well. These questions are shown in Appendix C.

2. *A survey was given to the project TRP; nine surveys were distributed and three responses were received.* The survey asked respondents to group VDOT databases into categories: Category A (databases that are created and fully controlled by VDOT staff, and access may be restricted) and Category B (databases that are partially created and/or controlled by VDOT staff, and access may be restricted). Databases that were neither created nor controlled by VDOT were not presented in this second survey. For each database, the respondents were asked to rate potential solutions that included increasing quality, awareness, access or improving data sharing. Respondents could also provide specific suggestions about how the databases can be enhanced. The questions and results are shown in Appendix D.

RESULTS AND DISCUSSION

Conceptual Framework

Figure 1 provides the conceptual framework. Data contribute to planning, operations, and maintenance of the transportation system; however, such decisions are also influenced by communications among these professionals—e.g., planners, operators, managers, and decision makers. Clearly, reliable, accurate, and timely data regarding public infrastructure projects, and related performance data, are critical for effective decision-making—and by extension, wider access to data is beneficial for such decisions.

Figure 1 may also be considered from the perspective of both data users and data owners. For example, consider a highway investment that will be placed in the MPO's Transportation Improvement Program (TIP)—a process that requires coordination between the state and the MPO. To the extent that the state has information about the transportation network, VDOT is a data owner and the MPO is a data user. However, if the MPO then performs a scenario analysis based on this project which affects air quality conformity (which the state needs), the MPO becomes the data owner and VDOT becomes the data user. Thus, concerns of data users (e.g., time to access data) and data owners (e.g., cost of sharing data) may apply to both organizations.

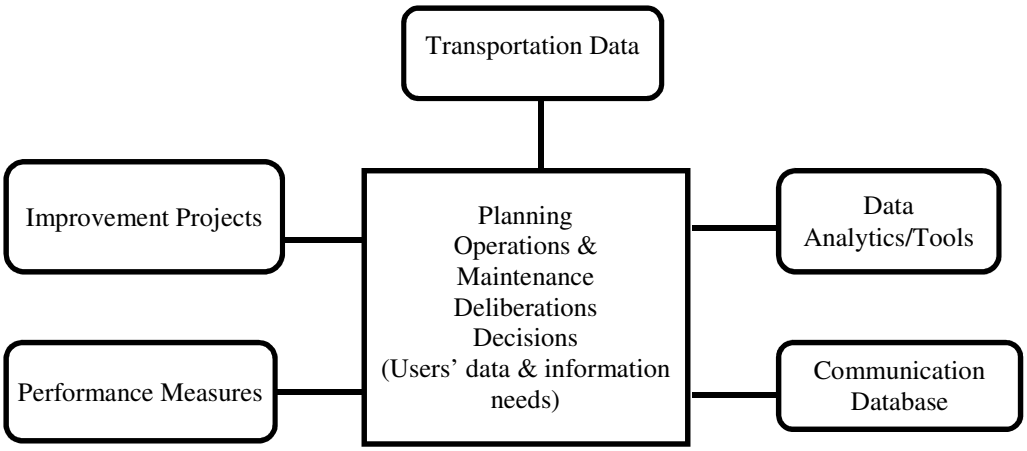


Figure 1. Conceptual Framework

Literature Review

The results of the literature review are presented in four categories:

1. transportation data collection and integration
2. ways to improve data access
3. state DOT data practices
4. synthesis of literature review.

Transportation Data Collection and Integration

Surveys have been conducted to investigate how public and private sectors deal with transportation data. A total of 56 transportation agencies from 33 states and the District of Columbia took part in a survey developed to query MPOs and DOTs regarding their policy for transportation data/model access and cost recovery (Ivey and Badoe, 2011). Questions on type of data requests received, mechanisms for handling requests, costs associated with requests, legal considerations and issues were asked in this survey. The data most frequently requested were travel demand model input/output files. Zimmerman et al. (2002) documented interviews about data sharing practices related to traveler information data and current state of the practice regarding how public and private sectors deal with data on travel conditions used in traveler information services. Public agencies (N=34) and private firms (N=7) were surveyed in this study. The data most frequently shared are highway-related data, especially real-time highway data. Miller and Balke (2001) documented a survey for examining the state of the practice of traveler information data sharing with the public and private sectors. Respondents from California, Minnesota, Texas, and Washington, representing the public and private sectors, completed the survey (N=36), showing that highway electronic/digital data were shared with both the private and public sectors to a greater degree compared with other data. Overall, surveys have identified a wide range of data needs related to public agencies and the private sector.

Numerous studies have offered valuable information about transportation data and its uses (Axhausen, 2000; Ivey and Badoe, 2011; Schofer et al., 2006, 2011). Data and data post-analysis products have become assets of transportation systems. They have played key roles in support of all steps of decision-making, from problem identification, design of options (Schofer et al., 2006), to critical policy choices and multimillion dollar investments (Committee on Strategies for Improved Passenger and Freight Travel Data, 2011). From another perspective, users' support is more likely to be secured when the transportation data provided can fulfill their roles in decision making. Easy access to archived data creates new opportunities for improving system performance (Liu et al., 2002). Additionally, the Committee on Strategies for Improved Passenger and Freight Travel Data (2011) suggests a national program for travel data and offers many useful practices regarding data sharing.

Table 1 shows details of studies dealing with data integration (combining data from various sources to extract valuable information), which is a key issue identified in the literature. Most of existing studies have focused on transportation data integration in specific fields.

Table 1. Selected Literature on Transportation Data Integration

Author	Study Objective	Data Collected	Major findings	Recommendations
Nakamya et al. (2007)	Investigate impact of combining data from different sources	Travel: Flemish Household Travel Survey (2000) & Time Use (1999), & Census (2001)	Integrated data were valuable in demand modeling & simulations	Using common IDs to connect databases.
Khan et al. (2010)	Collect road feature data from images & integrate them with GIS data	Road inventory: WisDOT Photolog data set; WisDOT GIS database.	Develop innovative and cost-effective application to collect and combine road inventory data	N/A
Liu et al. (2002)	Discuss ITS data mgmt. and archiving for Wisconsin	ITS: Review various data archiving systems around US	System requirements: reliable, effective archiving, manageable, affordable, presentation and maintenance	Identify potential uses of new ITS data; sharing of secure private information
Quiroga et al. (2006)	ITS data in Texas DOT. Review existing data management procedure in TX and other 4 states.	ITS: Preliminary & detailed surveys	Project-based hardcopy data archival and retention are well-defined. Electronic project documents are ad hoc & depend on district, office & project manager	Real-time GIS-based ITS data can support TMC operation; user-friendly, web-based interfaces; archive disaggregated operation data; guidelines to generate and maintain data
Hallenbeck et al. (2003)	Explore freight data collected from three ITS devices; Integrate data sets	Freight & ITS: In-vehicle GPS devices; In-vehicle transponders; loop-based freeway control and surveillance system	Bottlenecks and reliability of freight traffic; frequency and cost of nonrecurring events	Quality assurance required for digital map & accurate time stamps; integrating data should address differences in data collection methods
Gan et al. (2002)	Introduce a user-friendly system (INTDAS) to retrieve/analyze transit data	Transit: Integrated National Transit Database Analysis System (INTDAS); National Transit Database (NTD)	Users can set up new formulas to create new variables; visualize and analyze data with easy-to-use functions	Create pre-defined and user-defined reports; develop data analysis, data-mining, spatial analysis capabilities
Dutt et al. (2002)	Para-transit system software capabilities & scheduling functions.	Transit: Trapeze system (used in project). Mobile Data Terminals (MDTs)	MDTs/advanced software can reduce missed calls by 7%; Automatic Vehicle Location found useful	Develop internet-based software for receiving and storing information from MDTs
Pendyala (2003)	Identify data items/sources. Develop data integration mechanism to update databases	Travel, Inventory: FL Standard Urban Transp. Model Structure (FSUTMS) & FL Intrastate Hwy System (FIHS)	Suite of data integration tools & procedures to support statewide transportation modeling and planning	N/A
Arentze et al. (2000)	Data needs and quality requirements for activity-based models	Travel: Learning Based Transportation Oriented Simulation System; Trip diary data	Data needs include activities, location, time, mode; data quality measures -reliable, valid, consistent, complete, accessible	N/A

These studies include:

- How to combine survey data from different sources on travel behavior indicators to create reliable and quality database from household travel surveys (Nakamya et al., 2007). A related issue is data quality requirements of activity-based models (Arentze and Timmermans, 2000) and data quality issues in travel behavior surveys (Arentze and Timmermans, 2000; Heer and Moritz, 1997; Nakamya et al., 2007). These issues add complexity to data integration.

- Innovative cost-effective applications to collect GIS compatible data from image-based databases to develop a data collection and integration framework for road inventory data (Khan et al., 2010).

- Intelligent Transportation Systems (ITS) data management and archiving (Liu et al., 2002), applications in operations (Quiroga et al., 2006), and freight data from ITS devices (Hallenbeck et al., 2003).

- Integrated national transit data analysis system (Gan et al., 2002).

- Software solutions for public transit scheduling (Dutt et al., 2002).

- Procedures in support of statewide transportation modeling and planning processes (Pendyala, 2003). Data integration requires substantial effort and also involves efficiently providing quality data and keeping transportation databases up-to-date.

Ways to Improve Data Access

In addition to data integration, several solutions have been proposed and applied for improving data access in the existing literature (see Table 2). Data warehouses are typically used in large organizations and their functionality can be enhanced through the access control and audit model, which provides security and access to different users (Fernandez-Medina et al., 2006). Notably, state DOTs are sensitive to respect to privacy and security concerns. However, for non-confidential data, access can be improved by applying DAS or Data Access Services, to better handle data from several sources (Mayr et al., 2011). Large organizations (with 500 or more employees) typically rely on Unified Modeling Language or UML to run their core software programs. To improve data sharing and take advantage of the internet, Web Ontology Language (WOL) is used for structuring data (Zhang et al., 2008). Furthermore, solutions for transportation systems use advanced spatial technologies such as Multi-Dimensional Location Referencing System or MDLRS (Koncz and Adams, 2002). On-Line Analytic Processing (OLAP) can answer queries quickly and it is used to process data and present reports using data warehouse (Ahmad, 2006).

Table 2. Selected Solutions for Data Access Improvements

Author	Objective	Solutions	Major Finding/Contributions
Mayr et al. (2011)	Overcome gaps between data access services (DAS) and their implementation (e.g. data access objective (DAO)) when number of DAS grows	View-based, Model-Driven Data Access Architecture (VMDA)	VMDA can enhance software development productivity and maintainability; VMDA opens a wide range of applications (e.g. evaluate DAS usage for DAS performance optimization); VMDA can be applied in a large-scale case studies
Medina et al. (2006)	Propose model for Data Warehouses (DW) by specifying security rules in multi-dimensional (MD) modeling	Access Control and Audit (ACA) model	ACA can specify security information in MD; specify certain audit rules to analyze user behaviors; extend previous Unified Modeling Language (UML) with ACA
Zhang et al. (2008)	Introduce a new language (OWL) to improve data sharing, and develop an algorithm to automate data transformation processes	Web Ontology Language (OWL)	Establish a connection between UML and OWL; OWL allows data interoperability and facilitates information inference and reasoning; transformation algorithm provides an efficient method to develop OWL based on UML.
Koncz et al. (2002)	Develop a multi-dimensional model (1 to 4 dimensions) based on current Linear Referencing System (LRS)	Multi-Dimensional Linear Referencing System (MDLRS)	MDLRS is developed to integrate diverse dimensional reference systems; MDLRS provides temporal element beyond LRS data; permits inter-agency data sharing and helps manage transportation data more efficiently and effectively
Ahmad (2006)	Introduce a new (decision-making) database instead of traditional (transaction processing) database	Data Warehouse (DW)	DW requires end users to maximize usage & success; DW allows organizations to respond to market demand more quickly; provides right data to right people at the right time

Table 3 shows studies conducted to improve the availability of state DOT databases. Cherry et al. (2006) investigated the crash analysis system in Arizona, and recommended that Arizona DOT create a new GIS-based Accident Location Identification Surveillance System (ALISS). To improve data management and quality, Samuelson (2011) recommends establishing a traffic data working group, disseminating standard guidelines, and providing a Traffic Data Clearinghouse and Warehouse. Ahanotu and Mani (2008) discussed freight data improvements in Colorado, emphasizing the importance of truck O-D data collection. Caltrans (2011) mentioned data quality, data integration, and data access in sharing DOT databases, such as identifying business owners and data custodians, increasing accuracy and clarity of data and eliminating data silos and other barriers. Cevallos and Catala (2011) explored the needs of transit GIS data in Florida, suggesting that the Florida DOT (FDOT) establish a Transit GIS Data Clearinghouse (TGDC) and create transit GIS data standard, which was used statewide. Benac et al. (2011) conducted a traffic records assessment in Illinois, mentioning the importance of formalizing statewide tracking system and XML data format. A study conducted for the Kansas DOT by Intergraph Mapping and GeoSpatial Solutions (2005) focuses on Geospatial Enablement (GE), and emphasizes staff training and user participation as strategies for improving data use. The Kansas DOT also commissioned a statewide freight study to explore the freight data sharing issues (Cambridge Systematics Inc., 2009). Morris (2009) discussed the challenges and potential solutions in improving geospatial data sharing in North Carolina. Overall, studies have identified barriers to sharing of important data and strategies on how to overcome them.

Table 3. Relevant Studies About State DOT Database Improvement Recommendations

Author	DOT	Database Used	Solution
Cherry et al. (2006)	Arizona	Accident Location Identification Surveillance System (ALISS)	Utilize electronic, field-based data entry and data transfer; integrate new data into ALISS; give users direct access to crash data analysis and reports; grant internet-based, one-stop portal to users for crash data analysis; eliminate redundant data entry.
Samuelson (2011)	Arizona	Arizona DOT Freeway Management System	Establish traffic data working group; disseminate standard guidelines; create Traffic Data Clearinghouse and Warehouse
Ahanotu and Mani (2008)	Colorado	Global Insight TRANSEARCH	Collect roadside truck O-D data; enhance freight-focused vehicle classification data program
Caltrans (2011)	California	Caltrans Linear Referencing System (LRS) VMT, AADT	Identify Business owners and data custodians; increase accuracy and clarity of data; publish updated data; eliminate data silos and other barriers
Cevallos and Catala (2011)	Florida	Florida Transit Geographic Info. System (FTGIS). Transit Boarding Estimation and Simulation Tool (TBEST)	Develop Transit GIS Data Clearinghouse (TGDC); create transit GIS data standard; assist data sharing using Advanced Public Transportation System (APTS); promote use of GIS data
Benac et al. (2011)	Illinois	Illinois Roadway Information Report (IRIS); Statewide Injury Surveillance System (SWISS)	Evaluate data requirements and add them to Model Inventory of Roadway Elements (MIRE); make driver history data available for safety analysis; establish statewide tracking system and XML data standard; formalize Illinois Traffic Record Coordination Committees (IRTCC) meetings and activities; implement of electronic data collection
Intergraph Mapping and GeoSpatial Solutions (2005)	Kansas	GIS Strategic plan	Heighten awareness of and participation in geospatial enablement (GE); train staff on how to integrate GE; educate staff on geospatial, metadata and presentation standards; empower users at the operational database level in the GE endeavor; provide clearinghouse/central point of data to all users
Cambridge Systematics, Inc. (2009).	Kansas	Industry and Economic Data Freight System Data Commodity Flow Data	Use of TRANSEARCH will cover most of freight data needs but can be costly; use of FAF2 from FHWA is an option and rail freight data from the Surface Transportation Board, STB
Morris et al. (2009)	North Carolina	Digital geospatial data	Avoid formal agreements (between North Carolina State University and Library of Congress) that unnecessarily restrict free exchange of geospatial data; local, regional, state, and federal geospatial data will be made available through "NC OneMap" web access; secure sites enable free sharing of data.

State Departments of Transportation Data Practices

An Internet search of various state DOTs was conducted as part of this study to explore the content of publicly available data. Table 4 summarizes the findings, listing details of noteworthy state DOT practices.

Table 4. State DOT Practices Regarding Data

Source	System	Description	Features
California Department of Transportation (2015)	PeMS Perf. Measurement System	PeMS manages and analyzes traffic data that includes lane flow, lane occupancy, lane speed, images; provides processing capabilities	Accessible to public; friendly user interface; up-to-date and sustained data (March 2001~ June 2014); visualizes real-time performance
Arizona Department of Transportation Multimodal Planning (2015), and Illinois Department of Transportation (2015)	TDMS-Trans Data Mgt. System	TDMS provides web-based data for transportation users, e.g., traffic signal/sign management, traffic crash locations, pavement mgmt., travel times, project mgmt., pedestrian counts, work order tracking, & traffic video	Data mgmt. by professional company; geo-based traffic data; friendly search interface; up-to-date data (1990 – 2014); provides TDMS use instructions
Florida Department of Transportation (2015)	Florida Traffic Online, Real-Time Traffic Info	Florida Traffic Online is a web-based mapping application that provides traffic count site locations and historical traffic count data & real-time traffic information	Clear data classifications; provides relevant software; updated annually; real-time data; link other relevant data files (GIS shape files, traffic monitoring handbook, etc.)
University of Maryland CATT Lab (2015)	Central Data Warehouse	Central Data Warehouse is a "one-stop shop" for Florida's traffic data-archived & real-time traffic data (incidents and flows)	User account needed for access; based on Regional Integrated Transportation Information System (RITIS); Friendly interface
Pennsylvania Department of Transportation (2015)	iTMS-Internet Traffic Monitoring Sys.	The iTMS provides traffic volume data through interactive web application	Graphical display of traffic data; provides relevant reports & interactive user interface
Washington State Department of Transportation (2015)	Maps & Data	Provides link to maps & data on DOT home page. All maps and data clearly classified in categories (geospatial, collision, travel and roadway data)	Easy to find and access; clear data classifications; provides relevant applications & tools
Alaska Department of Transportation & Public Facilities Transportation Information Group (2011)	Transportation Information Group	Information group manages several programs about the data sharing	Clear data classification; intuitive user interface; links relevant data files
New York State Department of Transportation (2015)	Traffic Data Viewer	An interactive map program that displays traffic data graphically	Geospatial display of data; relevant reports attached on specific locations
Ohio Department of Transportation (undated)	Transp. Info. Mapping Sys.	A web-mapping portal; discover info about Ohio's transportation sys; create maps, and share info	Clear data classification; various data linked using GIS files (one-stop shop); easy to find and access
Oregon Department of Transportation (2015)	TransGIS	A powerful web mapping tool; diverse users can access data; presents many levels of complex data in interactive map format; multi-level views of Oregon´s transportation system	Easy to find and access data; geospatial data display; relevant application tools; link to other databases and data sharing systems
Texas Department of Transportation (undated)	Data Analysis Tool	Designed to give TxDOT personnel, MPO and other professionals easy way to access demographic info.	One-stop shop interface; presents integrated data; user can customize reports

State DOTs have developed various publicly available transportation databases. Noteworthy is the system developed by the Arizona DOT, which uses TDMS (Transportation Data Management System) to display traffic information. Nine other DOTs have contracted with ms2soft.com (Arizona DOT, 2015), which successfully manages their state traffic data including safety, congestion and pollution data. Midwestern Software Solutions has been used by state DOTs listed in Table 4 to provide data management, with GIS maps, and internal data validation. It can integrate traffic counts, crashes, traffic signal data, travel times, pavement conditions, pavement markings, and traffic videos.

The California DOT uses the freeway-based Performance Measurement System (PeMS) which extracts information from real time and historical data. The software is now marketed by Iteris, Inc., as iPeMS and it is being implemented by VDOT's Traffic Engineering Division to identify how traffic is changing over time, congestion hot spots, comparisons of travel times, and integrating data from new sources such as Bluetooth and GPS data.

The Pennsylvania DOT's Internet Traffic Monitoring System (iTMS) provides traffic volume data through an interactive web application. The Florida DOT and Washington DOT provide direct access to a substantial number of their databases through their home page through central data warehouses. The FDOT data are classified into several categories, enhancing user access. In addition, professional software is provided for analysis. Users get access to a Central Data Warehouse, which provides a "one-stop shop" data service. This data warehouse is managed by the Regional Integrated Transportation Information System (RITIS). Users including the planning and safety offices, as well as university and consulting firms, can request an account to use data through RITIS. Overall, state DOTs are increasingly involved in processing of data in order to make it useful and disseminate it widely.

Synthesis of Literature Review

Based on existing studies, major concerns identified for transportation data include: (1) a wide range of data needs (some met and others unmet) of diverse groups of transportation professionals; (2) barriers to sharing of important data, especially sensitivities with respect to privacy and security concerns; (3) ensuring data quality and efficiently keeping transportation databases up-to-date; and (4) processing of data in order to make it useful within and outside of the organization. Increasingly, there is emphasis on decision support (e.g., by predicting travel times) and accessibility/sharing of data more widely via the Internet, and use of reporting, data mining and visualization. Clearly, it is important to investigate the needs of different users in Virginia, and ask them about their data needs, concerns, quality of data available, and promising data solutions in a Virginia-specific context.

Previous studies and practices from other state DOTs or agencies can provide some guidance on improving data services. It is expected that different users, including internal DOT users, MPOs, private agencies and the general public, have different levels of data needs. While some data needs can be met by providing non-confidential data, other data requests that require sharing of confidential data may also involve costs of processing the data. Policies governing data sharing requests or recovery of expenses associated with responding to requests were identified as a barrier in studies such as Ivey and Badoe (2011).

In the Virginia context, VITA (2014) has a document on Information Technology Resource Management that provides Information Security Standards for Virginia state agencies (e.g., legislative, judicial, and executive branch) as well as Virginia colleges and universities. Adherence to the standards helps manage security risks and protects information systems and data. For effective risk management, well-documented data and model release policies and any differences that exist in data sharing practices for public versus private entities, can be clearly defined. It is also good practice that agency employees understand what data can be released and

the process to be followed for consistency of practices. An example of data sharing policy can be found in documents available from the Canada Transportation Act Review Panel (2001). The policy indicates four ways of sharing data based on user needs and data confidentiality: (1) confidential data cannot be released without permission from the data provider; (2) data can be more readily shared between government agencies; (3) only aggregated data should be released publicly, and (4) data must be protected through appropriate confidentially measures.

An example of sharing confidential data is how Transportation Secure Data Center under National Renewable Energy Laboratory (NREL) shares large-scale travel survey data with agencies and the public (NREL, 2015). Users must register to access to the database by accepting NREL data sharing agreements. Then they can authenticate and download the data for public use, including second-by-second driving records, vehicle type, driver demographics, and travel activities. However, the public use data available from NREL has limitations, since private information, such as geocodes of driving tracks, is removed in order to protect privacy. For accessing more detailed spatial data, special clearance is required (NREL, 2015). Such solutions can be considered by state agencies to share private data in order to meet the data needs of various authenticated users. In addition, the literature review identified a set of data solutions that that include PeMS (California DOT, 2015) and ms2soft.com (Arizona DOT, 2015).

Virginia Databases

Virginia databases may be characterized across four dimensions: (1) type (e.g., geospatial or relational), (2) users (e.g., individuals who may need access to the data and for what purpose), (3) name, and (4) with respect to VDOT, control, i.e., whether the database is fully or only partially controlled by VDOT,

Database Types

VDOT creates, maintains, and provides large amounts of data. VDOT is a large, multi-dimensional agency that is responsible for planning, designing, constructing, operating, and maintaining a large transportation system, with limited resources. It plays a critical role in moving people and goods and achieving social as well as economic goals. Virginia transportation agencies—VDOT, Department of Motor Vehicles, Virginia Department of Rail and Public Transit, Department of Aviation, Motor Vehicle Dealer Board , Office of Transportation Public-Private Partnerships, Virginia Commercial Space Flight Authority and Virginia Port Authority—collect and maintain data related to the following:

- *Movement of people by highways, transit, walking, and bicycling and movement of goods by truck, rail, and water.* A relevant database is RNS/HTRIS which includes crashes, traffic flow and control, roadway inventory, pavement condition, structures, and bridges. For truck movements, DMV databases are relevant. There are also new traffic data sources available to professionals, such as the INRIX data on segment travel time and speed, purchased by VDOT.

- *Travel information.* The website 511VA (VDOT, 2014b) provides a comprehensive real-time source of travel information to the public.

- *Behavioral data.* VDOT has invested in an add-on to the National Household Travel Survey, which is critical for updating and improving travel demand model performance.

- *Safety data.* Accidents and road inventory are accessible through RNS/HTRIS (Visiweb).

- *Financing of transportation improvement projects.* The VDOT project tracking database and the Six-Year Improvement Program (SYIP) database contains information about funding, allocations, expenditures, and cost forecasts of projects.

- *Environmental issues and concerns.* Examples are storm-water as well as storm-surge and evacuation information.

- *Land use and spatial data regarding population, employment, and type of land use* (e.g., residential, commercial, or industrial).

- *Past traffic impact analyses submitted to VDOT for development proposals.* These are available through LandTrack.

- *A Statewide "Geotechnical Database Management System"* (GDBMS) designed, developed, implemented and used in VDOT operations to retrieve, manage, archive, and analyze geotechnical data using a distributed GIS methodology (Yoon, 2006).

The VDOT website provides the SYIP, which is updated annually and is the means by which the Commonwealth Transportation Board (CTB) allocates funds to interstate, primary, secondary, and urban highway systems; public transit; ports and airports; and other programs. In the version available, information about the SYIP can be displayed by mapping projects in GIS format. However, the authors' assessment is that for a transportation user who is interested in readily visualizing the data geographically, the mapping functionality is not clearly provided on the SYIP webpage (VDOT, 2014a).

The VDOT Dashboard (VDOT, 2015b) provides performance reporting about highway performance on congestion, safety, road surface condition, and finance, project development, and public involvement.

Database Users

Transportation professionals in Virginia use a variety of data transforming it into useful information that guides their work and decisions. MPOs play a key role in transportation decisions. Specifically, regional planning organization staff is typically responsible for (1) project selection for the Long-Range Transportation Plan (LRTP), (2) allocation of Congestion

Management Air Quality (CMAQ) funds and Regional Surface Transportation Program (RSTP) dollars, (3) development of candidate LRTP projects, (4) a Transportation Improvement Program or TIP, and (5) supporting local decision making, e.g., when requests come from localities, or dealing with local issues such as spatial-mismatch or non-driver mobility. The type of data/information and applications decision makers need include:

- *Diagnosing current problems,* e.g., most congested critical corridors (Congestion Management Process), safety or environmental problems and anticipating future issues based on data and information about performance of the transportation system. Diagnosing problems may also require identification of interdependencies in user, spatial, and temporal contexts.

- *Analyzing and assessing the value and effectiveness of candidate transportation improvement projects that may enhance transportation system capability and performance and are economically feasible.* Development of effective candidate projects requires regional studies using travel demand models (e.g., CUBE software), and corridor or area studies. Meso- or microscopic modeling and simulation tools may be needed for corridor or area studies, e.g., application of VISSIM and Synchro, which require detailed traffic and roadway data.

- *Information about impacts,* i.e., what may happen to system performance if a particular course of action (e.g., improvement project) is selected.

- *Information about the status of the current transportation improvement projects* that can be related to roadway segments, interchanges, intermodal facilities, bridges, tunnels, public transit, bicycle, and pedestrian modes.

Database Names

Table 5 shows a structure of databases used by transportation professionals in Virginia. A wide spectrum of transportation databases are in this list including land use and development data; infrastructure, network flows, and performance data; freight data; programming data; traveler behavior data; and other transportation-related data.

Table 5. Transportation-Related Databases Used by VDOT

Data Needs list	Databases That Meet Data Need
Land use and land development	VDOT GIS files (e.g., Online Transportation Information Map) LandTrack (Land Development Tracking System) LUPS (Land Use Permit System)
Infrastructure, network flows, and performance data	VDOT-TOC (Traffic Operations Center-TransOps data) VDOT-RNS (Roadway Network System-includes structures, traffic, safety, maintenance) VDOT-TMS (Traffic Monitoring System) Real-time Incident Management Information System Archived Data Management System HSIP (Highway Safety Information Program) data FARS (Fatality Analysis Reporting System) data NHTSA (National Highway Safety Administration) data SPS (Statewide Planning System) Small Urban Transportation Plans database RUMS (Right of Way and Utilities Management System) BSA (Bridge Structure Analysis) 511 website, alerts, and voice recognition data INRIX (Speed/Travel time data purchased by VDOT) CEDAR (Comprehensive Environmental Data and Reporting System) AMS (Asset Management System)
Freight data	IHS Global Insight, Inc. (private freight data purchased by VDOT) PIERS (Port Import Export Reporting Service-private freight data purchased by VDOT) FAF (Freight Analysis Framework-FHWA database) CFS (Commodity Flow Survey) TREDIS (Transportation Economic Development Impact System)
Programming data	ABDS (Annual Budget Development System) CFS (Cash Forecasting System) FMS (Financial Management System) Trns*port (e.g., cost estimating, financial management, contractor claims) Integrated SYIP-Six-Year Program (funding, allocating, expenditures, cost forecast)
Travel and demographic data (including demand forecasting)	VA NHTS (Virginia National Household Travel Survey) data VA University Travel Survey VDOT tolling and congestion pricing surveys Census data (demographics, boundaries, commute patterns, Census Journey to Work data) ACS-American Community Survey CTPP (Census Transportation Planning Products) BTS - Bureau of Transportation Statistics (TransStats) data Weldon Cooper Center for Public Service data (State Demographics and Projections) Bureau of Labor Statistics data Bureau of Economic Analysis data
Other transportation-related data	Virginia Transportation Marketing Research Database PMS Data (Pavement Management System) GIS-GDBMS Data (Geotechnical Database Management System) CQIP (Construction Quality Improvement Program) LIS (Legislative Information System) FAA Air Travel Data (enplanements, airfares, destinations, cargo) VA DEQ Data (Water/Air Quality Data) DMV Data - Licensed Drivers, Registered Vehicles Port Data (VPA and AAPA) - total cargo, TEUs, exports/imports, commodities Rail Data (Amtrak) - Passenger Levels FTA NTD (National Transit Database)

Database Control

The collection, organization, storage, and ownership of data can make the task of meeting data needs of professionals rather complex. Furthermore, there is a need to understand the extent to which organizations share data they own, and the extent to which they seek to make potential users aware of the availability of other data resources (regardless of owner). For example, VDOT does not own or control the fatal accident database known as FARS (Fatality Analysis Reporting System). However, there are ways that VDOT can make FARS data available to professionals by increasing awareness of this source, e.g., by providing links from the VDOT website to the FARS website in the appropriate location. Additionally, increasing professionals' awareness of the FARS resource further could also be undertaken by NHTSA (National Highway Safety Traffic Administration) who maintain the data. This study categorized databases into the following:

- *Category A:* Databases that are created and fully controlled by VDOT staff, and access may be restricted due to security or confidentiality concerns, e.g., PCES or LUPS.

- *Category B:* Databases that are partially created and/or controlled by VDOT staff, and access may be restricted, e.g., some GIS shapefiles come from VGIN but then various VDOT divisions add roadway attribute information to them; or VDOT's internal crash records system shared between DMV, VSP, and VDOT.

There are additional publicly available or for purchase databases that are not created or truly controlled by VDOT, but they may be made available via VDOT information technology architecture, e.g., the National Transit Database, Census data, LIS (Legislative Information System) available at the Virginia General Assembly website, or Weldon Cooper Center data.

Table 6 shows the categorization of transportation-related databases and it is based on the research team's judgment as well as input from the VDOT TRP. Notably, databases that are neither created nor controlled by VDOT were excluded from the list.

Table 6. Categorization of Transportation-Related Databases

Databases Used	Category (A, B)
VDOT GIS files (e.g., Online Transportation Information Map)	A
LandTrack (Land Development Tracking System)	A
LUPS (Land Use Permit System)	A
VDOT-TOC (Traffic Operations Center-TransOps data)	A
VDOT-RNS (Roadway Network System-includes structures, traffic, safety, maintenance)	A
VDOT-TMS (Traffic Monitoring System)	A
Real-time Incident Management Information System	A
Archived Data Management System	A
HSIP (Highway Safety Information Program) data	A
SPS (Statewide Planning System)	A
Small Urban Transportation Plans database	B
RUMS (Right of Way and Utilities Management System)	A
BSA (Bridge Structure Analysis)	A
511 website, alerts, and voice recognition data	B
CEDAR (Comprehensive Environmental Data and Reporting System)	A
AMS (Asset Management System)	A
FAF (Freight Analysis Framework-FHWA database)	B
ABDS (Annual Budget Development System)	A
CFS (Cash Forecasting System)	A
FMS (Financial Management System)	A
Trns*port (e.g., cost estimating, financial management, contractor claims)	A
Integrated SYIP-Six-Year Program (funding, allocating, expenditures, cost forecast)	A
VA NHTS (Virginia National Household Travel Survey) data	B
VA University Travel Survey	B
VDOT survey related to congestion pricing	A
Virginia Transportation Marketing Research Database	B
PMS Data (Pavement Management System)	A
GIS-GDBMS Data (Geotechnical Database Management System)	B
CQIP (Construction Quality Improvement Program)	A
Port Data (VPA and AAPA) - total cargo, TEUs, exports/imports, commodities	B
TREDIS (Transportation Economic Development Impact System)	B
INRIX (Speed/Travel time data purchased by VDOT)	B
IHS Global Insight, Inc. (private freight data purchased by VDOT)	B
PIERS (Port Import Export Reporting Service-private freight data purchased by VDOT)	B

Category "A" databases that are created and fully controlled by VDOT staff, and access may be restricted due to data sensitivity concerns, e.g., PCES or LUPS. Category "B" databases that are partially created and/or controlled by VDOT staff, and access may be restricted, e.g., some GIS shapefiles come from VGIN but then various VDOT divisions add roadway attribute information to them; or VDOT's internal crash records system shared between DMV, VSP, and VDOT.

Survey of Transportation Professionals

The complete survey results are given in Appendix B; key findings from the survey may be considered in light of the following questions:

- To what extent are the survey results generalizable?
- What are the data needs?
- How do experience, profession, and agency influence data needs?

- How are data used?
- What is the perceived quality of data?
- What are obstacles to data access?
- What are obstacles to data use?

To What Extent Are the Survey Results Generalizable?

A total of 182 users completed the survey, which in some contexts may be considered a smaller sample. As shown in Figure 2, the sample was weighted more heavily toward the public sector (71% of respondents) than the private and nonprofit sector (29%) of respondents. To some extent, the sample was weighted more heavily toward a statewide rather than a local or regional perspective, given 82 VDOT respondents and 53 respondents from consulting firms, educational institutions, and other organizations compared to 47 respondents from MPOs/TPOs, and localities. The survey audience was also well educated and experienced: 45% of respondents have a bachelor's degree, and an additional 47% of the respondents hold a graduate degree; further, the average work experience for respondents was 22 years (with an average of 7 years in their current position). Given that the average respondent supervised 24 people, this would suggest that respondents tend to be fairly high in their work unit. To be clear, the survey results show considerable variability in the sample. For example, for the 82 VDOT respondents, the mean number of people supervised was 18, with the minimum number being 0 and the maximum value being 200. Given that the standard deviation (38) was larger than the mean (18), this suggests that the mean value may be affected by some high outliers, as confirmed by the median value which is 4 people supervised.

Certainly any survey that is distributed at single point in time will have some limitations: the results depend entirely on the accuracy of the respondents, it is possible that a survey conducted a few months later (or earlier) would show different results due to the passage of time, and because the survey was not mandatory, there will be some self-selection bias. That said, the results of the survey should be interpreted in light of the characteristics of the sample: the average respondent was well-educated, experienced, relatively high in the organization, and likely from the public sector.

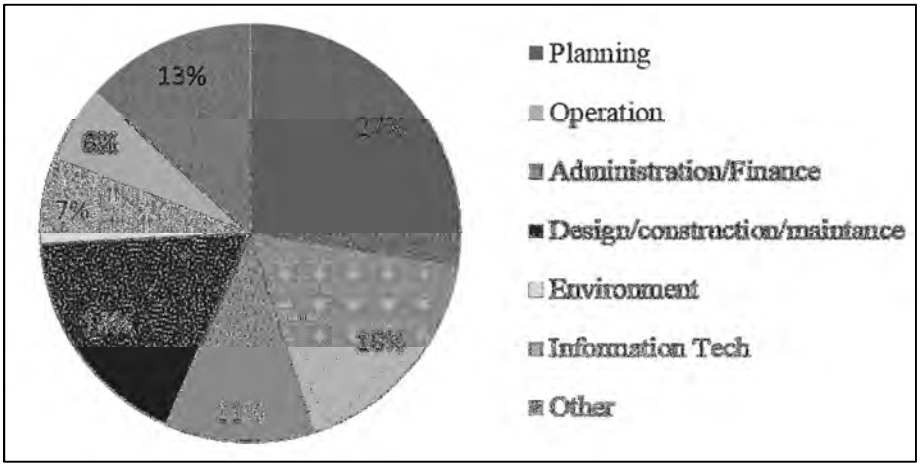


Figure 2. Respondents' Major Work Activities (N=182)

What Are the Data Needs?

Transportation professionals that participated in the survey were requested to provide information on whether the databases listed in Table 5 were currently used by them, or currently needed but were unavailable. Table 7 and Table 8 show the answers for most used and most needed but unavailable databases. The answers differ by organization with which respondents are affiliated. For VDOT employees, VDOT GIS data, Integrated SYIP data and VDOT-RNS data are the top three most used databases. These databases were used by nearly one-half of the VDOT respondents, followed by 511 website data (38%) and financial management data (34%). The results further indicate that users from different VDOT departments used various databases since these databases cover different data types--land use, programming, and infrastructure (including network flows, and performance). The unmet data needs identified by VDOT employees largely relate to infrastructure, network flows, and performance databases, listed in Table 7. Nearly 10% of VDOT respondents mentioned that Archived Data Management System, VDOT TOC, VDOT-RNS, and VDOT TMS databases were needed but unavailable to them to use. (While one might argue that most VDOT respondents either have these data or do not need them, another implication is that if one were to increase data access, these databases would be a productive place to begin for VDOT staff.)

Respondents from MPOs, TPOs, and local public agencies that deal with transportation have different uses and data needs. Respondents from Virginia MPOs reported mostly using travel data, including US census data (53%), ACS data (47%), Weldon Cooper State demographics data (40%) and Bureau of Labor Statistics data (36%). Integrated SYIP data are also commonly used by MPOs. Similar to respondents from VDOT, the data needed (but currently unavailable) was concentrated on infrastructure, network flows, and performance databases. Specifically, more than one third of users from MPOs and local agency respondents stated that they needed HSIP and RNS; nearly one-quarter of respondents mentioned VDOT GIS

Table 7. Commonly Used Transportation Data by Transportation Professionals (N=182)

Group	Most Used	Data Sources (Top 5)	%
VDOT (N=82)	Land use[a]	VDOT GIS files	59%
	Programming	Integrated SYIP-Six-Year Program	52%
	Infrastructure[a]	VDOT-RNS (Roadway Network System)	48%
	Infrastructure	511 website, alerts, and voice recognition data	38%
	Programming	FMS (Financial Management System)	34%
MPO/TPO, Locality (N=47)	Travel data	US Census data	53%
	Travel data	ACS (American Community Survey)	47%
	Travel data	Weldon Cooper (State Demographics)	40%
	Programming	Integrated SYIP-Six-Year Program	36%
	Travel data[a]	Bureau of Labor Statistics data	36%
Consulting company (N=53)	Land use	VDOT GIS files (e.g., Online Map)	30%
	Travel data	US Census data	30%
	Travel data	Bureau of Labor Statistics data	28%
	Travel data	BTS - Bureau of Transportation Statistics data	25%
	Travel data	Bureau of Economic Analysis data	25%

[a] Note that these categories overlap. For example, VDOT GIS files do include land use information (such as population) but they also include infrastructure information such as the roadway network.

Table 8. Unmet Transportation Data Needs (N=182)

Group	Need But (perceived to be) Unavailable	Data Sources (Top 5)	%
VDOT (N=82)	Infrastructure	Archived Data Management System	12%
	Infrastructure	**VDOT TOC** (Traffic Operations Center)	11%
	Infrastructure	**VDOT-RNS** (Roadway Network System)	11%
	Infrastructure	**VDOT TMS** (Traffic Monitoring Systems)	9%
MPO, TPO, Locality (N=47)	Infrastructure	HSIP (Highway Safety Information Program)	45%
	Infrastructure	**VDOT-RNS** (Roadway Network System)	36%
	GIS	**VDOT GIS files** (e.g., Online Transportation Information Map)	26%
	Infrastructure	**VDOT-TMS** (Traffic Monitoring System)	26%
Consulting company (N=53)	Infrastructure	**VDOT-RNS** (Roadway Network System)	25%
	Infrastructure	**VDOT TOC** (Traffic Operations Center)	21%
	Land use data	**VDOT GIS files** (e.g., Online Map)	19%
	Infrastructure	**VDOT-TMS** (Traffic Monitoring System)	19%
	Infrastructure	INRIX (Speed/Travel time data purchased by VDOT)	17%

files and VDOT-TMS data as their most needed data. (As shown in the survey in Appendix A, the term "GIS files" as used in this report refers to GIS files that support land use and development, as well as the Geotechnical Database Management System, the Online Transportation Information Map, and the Secondary Street Acceptance Requirements.) MPO and local agency respondents seemed concerned about safety databases-HSIP accounted for a large percent of their reported unmet database needs.

Transportation consulting company respondents working with VDOT use land use data (VDOT GIS files) and travel data (Census data and labor statistics data, transportation statistics data and economic analysis data) for their work. These users do not often directly deal with VDOT's raw historic/archived data but may use some VDOT databases for post-analysis. The VDOT GIS files are in the top needed but unavailable list—while this information is publicly available, consulting company respondents seem unaware of their availability or lacked information about how to access them. Other databases in the top list of needed but unavailable data include VDOT-RNS, VDOT TOC, VDOT-TMS, and INRIX databases (Speed/Travel time data purchased by VDOT). Note that because INRIX travel time data are purchased from a private company, there are restrictions on sharing it outside VDOT.

Among all data needs, VDOT-RNS, TOC, GIS files, and TMS databases are repeatedly reported as needed by respondents from different groups. These databases share certain common features that relate to Virginia's transportation information, including roadway, traffic operations, geographically referenced data, and traffic monitoring systems. (As shown in Figure 1, network and travel condition information are needed by all transportation professionals—inside and outside VDOT.) Note that there is an online approval system within the VDOT intranet called SARA (System Access Request Application) where VDOT supervisors can explicitly approve user access requests to a number of VDOT information systems and data brokers. About a fifth (21%) of all survey respondents reported in Question 11 that the Virginia Roadway Network System was one of the "databases that you need to use at work - but are currently unavailable to you." For VDOT, this percentage was 11%. A substantially higher number of respondents from MPOs and consulting companies reported not having access to

RNS; 36% and 25%, respectively. Furthermore, VDOT TOC databases were also needed but reported as unavailable by some of the respondents, especially those who were affiliated with VDOT and consulting companies. Specifically, 11% of respondents from VDOT and 21% of respondents from consulting companies reported that they needed Traffic Operations Center-TransOps databases but did not have access to them.

Besides the databases mentioned in the survey, VDOT respondents also referred to other databases that they were using, which may not be available outside VDOT and which include the Cardinal financial management system and VDOT PCES (Project Cost Estimating System).

How Do Experience, Profession, and Agency Influence Data Needs?

To understand how unmet data needs vary by agency, two statistical models were estimated. One model measures the number of databases that survey respondents need but cannot access, and the second model determines the number of databases used by respondents. Respondents were asked to identify which of 52 individual databases are (1) "currently need[ed] but unavailable" and (2) "currently use[d]." Explanatory variables include the respondents' main work duties, and whether they work for VDOT, MPOs, localities, or transportation consulting companies.

With respect to number of databases that were needed but unavailable, one-half of the respondents (91 out of 182) stated that they did not have any unmet data needs, i.e., there were no databases that they currently needed but were unavailable (see Table 9). Specifically, 59% of VDOT respondents and 55% of respondents from consulting companies and other sectors reported that they had no unmet data needs, while this percentage for respondents from MPOs and localities was substantially lower at 30% (the difference between 59% and 30% is statistically significant, as shown in the modeling results below). Also, 15% (27 out of 182) of respondents reported that they do not use any databases for their work (from the 52 databases presented). Further breakdown shows that 17% of MPO and locality respondents and 26% respondents from consulting companies and other sectors reported that they did not use any of the databases presented, while this percent for respondents from VDOT was much lower, at 6%.

Table 9 gives the model results and descriptive statistics. The Incident Rate Ratios (IRRs) help interpret the coefficients of the model. Both models are statistically significant (5% level). The Vuong tests suggest that the zero-inflated Poisson models are more suitable for the data compared with standard Poisson models. The binary model (first step) for the zero group (Model 1) shows that compared with respondents from VDOT, respondents from MPOs and localities, consulting companies and other institutions reported that they are significantly less likely to have their data needs met (from the 52 databases presented to them in Table 5). Users that are external to VDOT are also less likely to report using any of the databases presented to them (Model 2). In other words, external users are more likely to say that they do not use any of the databases presented to them compared with VDOT respondents.

Table 9. Zero-Inflated Poisson Regression Model for Unmet Data Needs and Databases Used (N=182)

	Unmet Data Needs (Model 1)			**Databases Used (Model 2)**			**Descriptive Statistics Mean (Min., Max., SD)**	
Dependent: Unmet Data Needs							**4.165 (0, 33, 6.813)**	
Dependent: Databases used							**6.709 (0, 31, 6.617)**	
	β	**IRR**	**p-Value**	**β**	**IRR**	**p-Value**	**Mean (Min, Max, SD)**	
Job duty (Base: Planning)							0.275 (0,1,0.448)	
Operations	.136	1.145	0.279	-0.587	0.556	0.000	0.176 (0, 1, 0.382)	
Administration & Finance	.376	1.456	0.001	-0.722	0.486	0.000	0.115 (0, 1, 0.320)	
Design/construction/maintenance	-.017	0.984	0.892	-0.909	0.403	0.000	0.176 (0, 1, 0.382)	
Environmental	.038	1.039	0.792	-1.035	0.355	0.000	0.066 (0, 1, 0.249)	
Information Technology	1.348	3.849	0.000	-0.319	0.727	0.014	0.060 (0, 1, 0.239)	
Other	-0.002	0.998	0.986	-0.402	0.669	0.000	0.132 (0, 1, 0.339)	
Organization (Base: VDOT)							0.451 (0,1, 0.499)	
MPO and Localities	0.628	1.875	0.000	-0.289	0.749	0.000	0.258 (0,1, 0.439)	
Consulting and others	0.692	1.999	0.000	0.023	1.023	0.772	0.291 (0,1, 0.456)	
Yeas of work experience	-0.008	0.992	0.029	0.004	1.004	0.194	22.038 (1.5, 50, 10.268)	
Constant	1.712	5.538	0.000	2.461	11.715	0.000		
	Binary model for no unmet needs (for databases presented)			Binary model for no reported use (of databases presented)			Zero unmet data needs	Zero databases used
Organization (Base: VDOT)							59%	6%
MPO and Localities	-1.192		0.002	1.100		0.074	30% *	17% *
Consulting and others	-1.145		0.684	1.707		0.002	55%	26% *
Constant	0.334		0.138	-2.740		0.000		
Summary Statistics Number of Obs.=182	Non-zero Obs.= 91 Log likelihood = -537.5253 Prob.>χ^2 =0.000 Vuong Test: P(Z >z) = 0.0000			Non-zero Obs.= 155 Log likelihood = -654.0137 Prob.>χ^2 = 0.000 Vuong Test: P(Z >z) = 0.0001				

In the unmet data needs model, Y=0 means that the respondent has no unmet data needs. Negative signs of coefficients in the zero-inflated binary model means respondents are less likely to have their data needs met. Negative signs for job duty in the Poisson model means respondents having a particular job description will have smaller unmet data needs. In the database use model, Y=0 means the respondent did not use any databases presented in Table 5. Negative signs of coefficients in the zero-inflated binary model means respondents are less likely to not use any of the databases presented. A negative sign for job duty in the Poisson model means respondents having such a job use fewer databases. *Significantly different (5% level) from VDOT respondents. IRR = "Incident Response Ratio."

The Poisson model for unmet data needs (Model 1) shows that longer work experience is correlated with fewer unmet data needs, implying that with knowledge coming from experience, individuals may have greater awareness of and access to data or their data needs may be lower than less experienced colleagues. After controlling for years of work experience, the respondents from MPOs and localities have 87% higher reported unmet data needs compared with respondents from VDOT. This number is even higher for people from consulting companies and other organizations, with unmet data needs about two times higher than reported by VDOT personnel. Respondents with more diverse job duties show different data needs—compared with respondents focused on planning fields, individuals involved in administration & finance, and ITD reported having higher unmet data needs. Respondents from other divisions including environmental, design, construction, and maintenance do not show statistically different unmet data needs compared with the base (those working in planning).

Different from the unmet data needs model, the Poisson model for databases used (Model 2) explains how many databases are used by respondents. The respondents from MPOs and localities reported 25% lower frequency for databases used compared with respondents from VDOT. While there are multiple possible reasons for this (e.g., perhaps local employees don't need access to these data), the possibility that is germane to this report is that there MPO/locality employees might have access to fewer databases. Furthermore, consulting and other professionals do not show statistically significant differences compared with VDOT respondents. It is notable that those working in planning use more databases compared with professionals who have other job descriptions. Databases used by respondents from the ITD are 27% less than those from planning fields; this percent is 44% lower for respondents involved in operations; 51% lower for respondents involved in administration & finance, 60% lower for respondents from design/ construction/maintenance fields, and 64% lower for respondents from the environmental field. Contrary to the case of the unmet data needs model (Model 1), the variable years of working experience is not statistically significantly related to how many databases are used by respondents (Model 2).

How Are Data Used?

Exploring the purpose for accessing primary use databases can help us better understand data needs. To explore the role of data in transportation projects, the respondents were asked to recall a recent project, program, or plan they have worked on in the past year that was successful and whether access to certain transportation database(s) played a substantial role in the success of the project, program, or plan. Figure 3 shows how the users characterized their primary databases used out of the six major categories.

The survey directly asked respondents about how frequently they have used the primary databases. About 37% of respondents characterized themselves as frequent users whose job involved using data continuously or daily. About 28% of respondents used data weekly and 14% of respondents used data monthly.

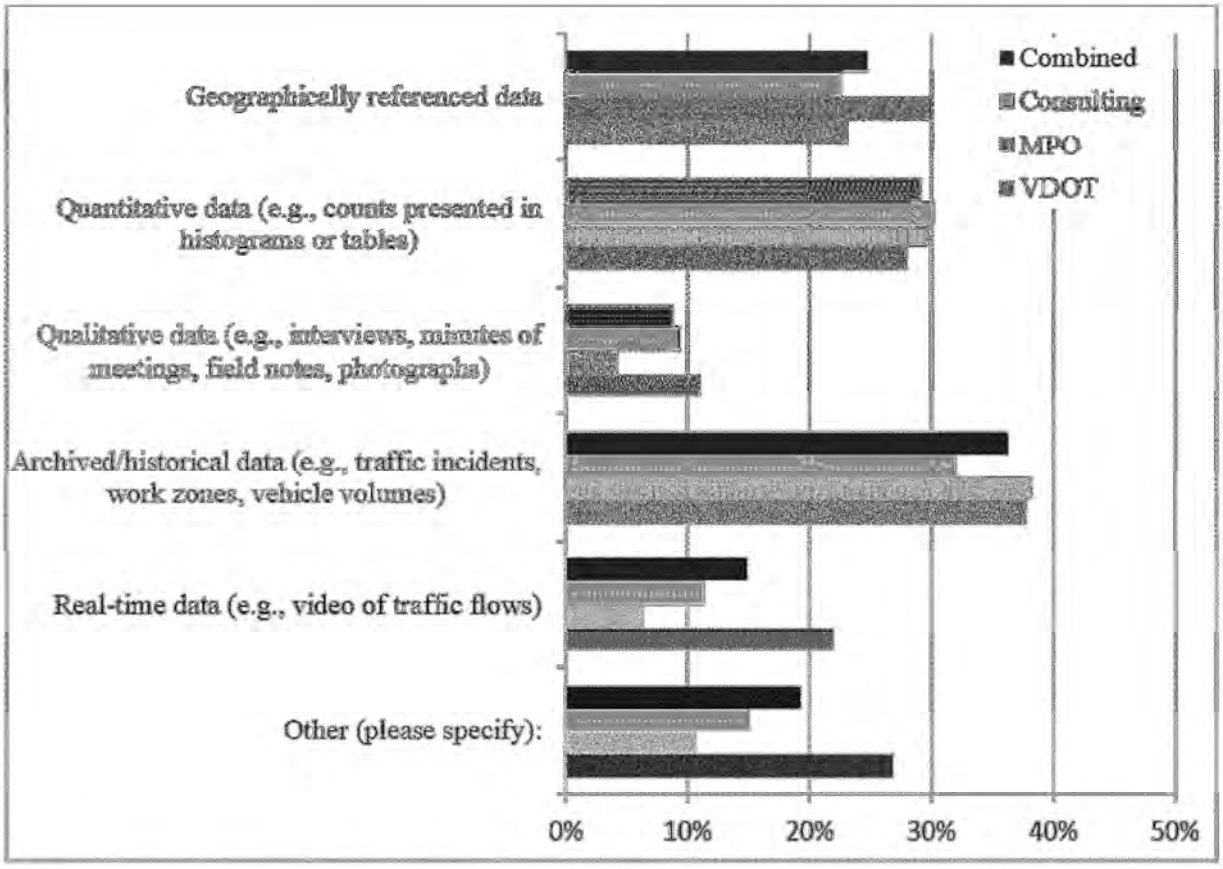


Figure 3. Characterizing Primary Databases Used by Survey Respondents (N=182)

Among the options provided to respondents for the purpose of using data, visualizing and displaying data was a key function, exercised by 40% of respondents from MPOs and localities. A typical use of visualized and displayed archived data relates to traffic incidents and traffic counts used to analyze historical trends. The data are also used for the purpose of analyzing, modeling, simulation, and land use analysis. Question 28 asked respondents to recall a recent project and then indicate whether this project "would have been successful without access to certain transportation databases." Almost a third of respondents (30%) indicated no—meaning that 30% of respondents indicated data were essential to the success of the project. A similar question was asked where the word "software" was substituted for "databases", and a higher percentage (43%) of respondents indicated no—meaning that for 43% of respondents, software was essential to the success of the project.

What Is the Perceived Quality of Data?

Responses to data quality of the primary uses databases are summarized in Figure 4. Positive opinions were expressed by a majority of respondents about data quality. Areas of potential improvements include whether the primary use database is well-documented, current, and timely. A large majority of the respondents had a positive view of data quality; only about 10% of respondents disagreed with the statement that their primary use data are well-

documented, current and timely and available in a user-friendly format. A higher percent of respondents (around 20%) were neutral on this issue, which indicates possible room for improvement in data documentation and timeliness. When asked how the primary use database can be improved, more than 35% respondents reported that it was important to increase user awareness and knowledge about the database; more than one-quarter of respondents stated that improvements can include providing better data access, increasing ease of data export/exchange, providing higher quality data, and more complete data.

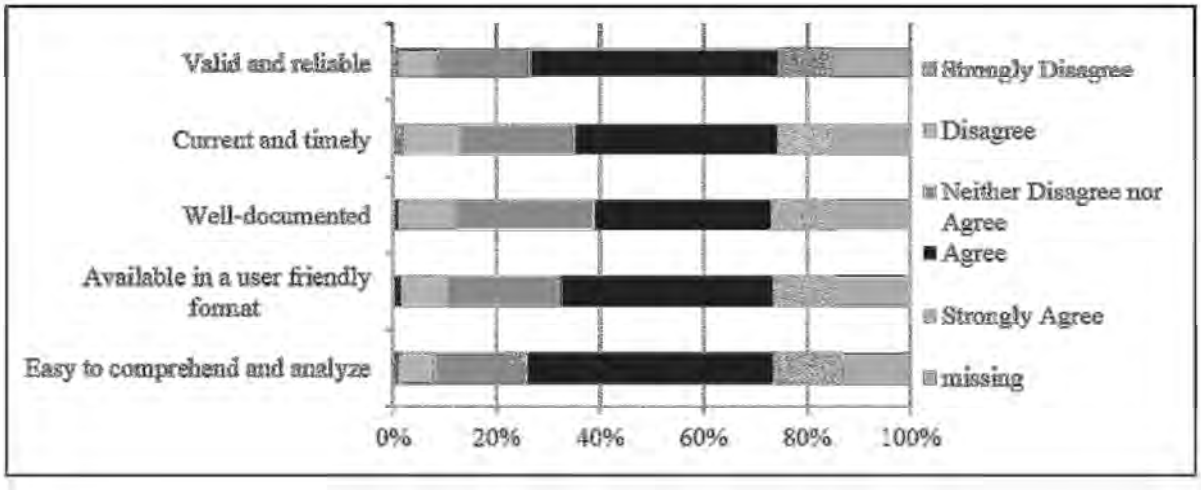


Figure 4. Data Quality Reported by Respondents (N=182)

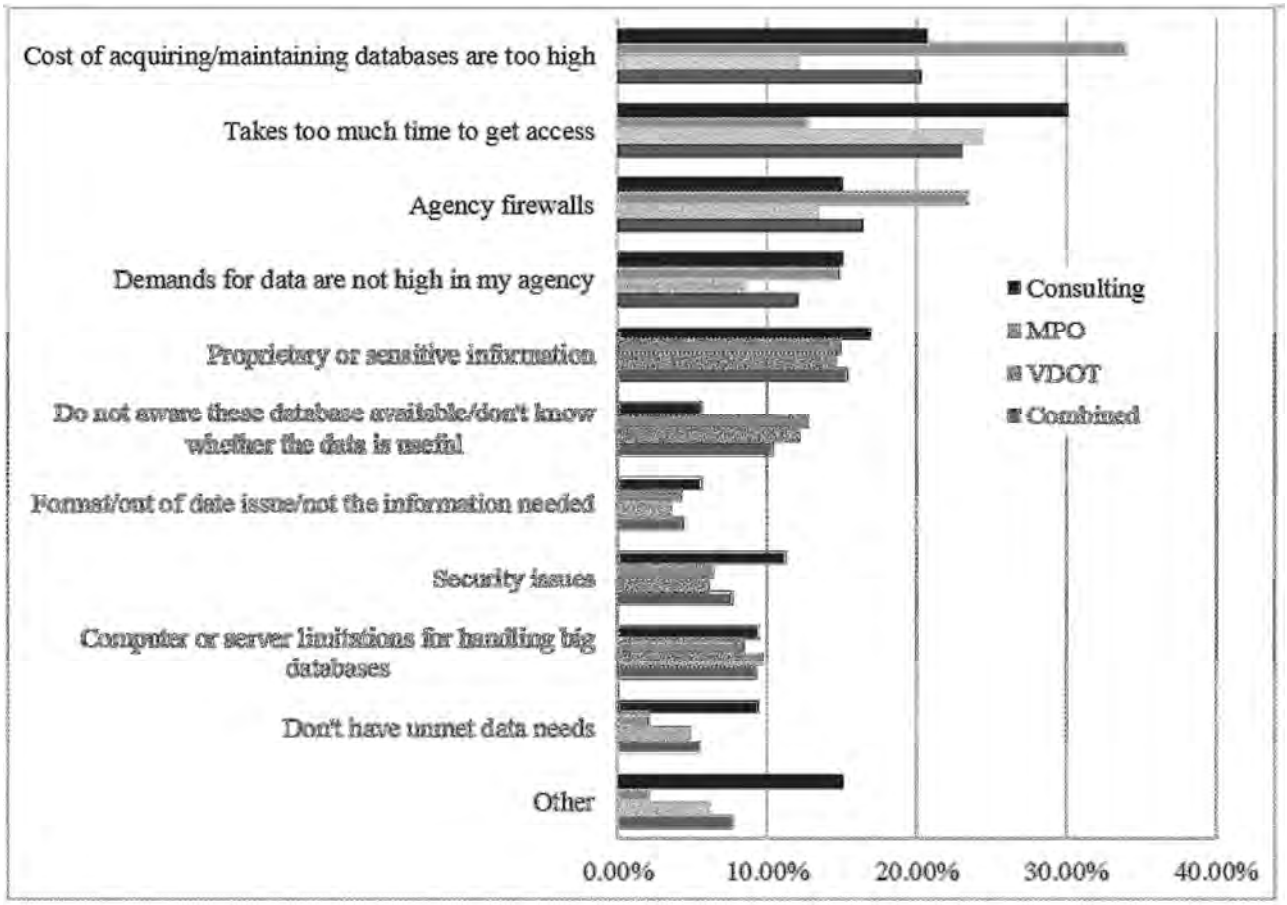
What Are Obstacles to Data Access?

The survey examined how users access databases and their major issues or concerns. For VDOT users, more than one-half accessed their data via the VDOT intranet direct link; fewer VDOT users reported accessing data via online/web internet. Non-VDOT users largely used the internet option to access databases since VDOT intranet is often not available to them on a routine basis. Specifically, 23% of MPO respondents and fewer than 10% of consulting company respondents accessed their primary use databases using the VDOT intranet. As mentioned previously, this is because the VDOT intranet is generally not available to external users (non-VDOT employees) for security reasons. There is an Outside VDOT resource that can provide non-employees access to some parts of data inside VDOT. However, VDOT permissions are required. Also, SARA is an online approval system for database access which VDOT supervisors can use to give access to VDOT employees.

Internet usage by MPOs and consulting companies is much higher than respondents from VDOT, as expected. Specifically, 45% of MPOs and localities, and 48% of consulting companies use the internet to access data; 72.5% of those who used the VDOT intranet mentioned that a password was required for them to access the database while this percent is only 46% for those who used the internet. This suggests that the internet and intranet users are likely not accessing the same databases. Respondents from VDOT did not use any other means to access databases other than internet and intranet, while 15% of users from MPOs and localities also used FTP servers. This number for consulting companies is less than 5%. Close to 10% of

users from MPOs and consulting companies transferred their data through computer hard-disk after their data access requests were approved by VDOT.

The respondents were asked questions to determine the reasons for why they were not able to access or use the databases that can benefit their work. shows the results only for the respondents who reported that they had unmet data needs. Only about 20% of all respondents stated that access to the databases cost too much or getting access was time-consuming. Databases that contain sensitive information could not be shared across agency firewalls--this is also an important issue, stated by 16% of the respondents. About 10% of the respondents mentioned that they had limitations regarding handling big databases due to computer or resource limitations. About 10% respondents said that they were not aware of some of the databases mentioned in the survey. Respondents also mentioned that they were hesitant to access VDOT databases since some were not what they needed or were in a format that they could not handle.



. Data Access Issues Reported by Survey Respondents (N=182 with multiple response permitted)

For VDOT respondents, a concern was that getting access to databases took much time, mentioned by about one-quarter of the respondents. This could be due to (lack of) user knowledge/experience, the approval process taking a long time, or the database itself being difficult to access. Nearly 15% users from VDOT stated that agency firewalls and the proprietary or sensitive nature of information (and required permissions) prevented them from accessing databases. Besides these reasons mentioned above, high cost of acquiring and maintaining the data, and computer or server limitations for handling large databases are also issues for VDOT respondents. About 12% of users from VDOT reported that they were unaware of several of the databases presented in the survey (Table 1) or were not sure the data are useful.

For users from MPOs and local public agencies, the high cost of acquiring and maintaining the databases and agency firewalls limit accessing VDOT databases. This is because some of the key databases have restricted access, available only within VDOT and not to outside users, i.e., users not working for VDOT typically do not have access to secure data. For example, a staff member at an MPO or locality cannot get past the VDOT firewalls and gain access to some of the VDOT databases. About 13% of users from MPOs and other public agencies stated that it was not clear to them how to find out which VDOT databases were available to them.

Regarding respondents' satisfaction with access and use of databases available at work, roughly 40% of the respondents were satisfied or very satisfied while a considerable amount of respondents (35%) were neutral. Among those who remained neutral, respondents from VDOT have the highest percent (41%), respondents from MPOs and localities have the lowest neutral rate (26%), and respondents from consulting companies are in between. Nearly 20% of respondents from MPOs and localities mentioned that they were not satisfied with access and use of databases available to them at work, while this percent for VDOT and consulting companies was substantially lower (10% and 6%, respectively). Overall, VDOT employees seem satisfied.

For users from consulting and other sectors, the time spent and costs are mentioned as reasons for their limited access to VDOT databases. Besides these two, firewalls and issues regarding sensitive information and security were also mentioned as impeding data access. In general, the demands for VDOT databases by VDOT users are relatively high, while users from consulting companies and MPOs and local public agencies seem unclear about availability of specific VDOT databases, though this is not a large group of respondents (see Figure 5).

What Are Obstacles to Data Use?

A critical data issue identified in this study is that of data awareness. In completing the survey, respondents appeared a bit surprised at the long list of databases (see Table 1), which indicates a gap in knowledge regarding currently available databases. While not all, or even most, databases will be relevant to individual job functions, improvements can still come from increasing knowledge about what the databases are available, how/where to obtain them, and possible applications of the databases. For example, several VDOT GIS files are publicly available (through the Environmental Systems Research Institute, ESRI). However, this fact is obscure and it may be helpful to highlight it via the VDOT website.

Besides the database awareness issue, there are substantial differences between VDOT and non-VDOT respondents when it comes to data needs. While non-VDOT professionals can sometimes request and get secure access to needed data through the VDOT intranet, non-VDOT respondents still show more unmet data needs for databases controlled and maintained by VDOT. Specifically, the databases used by MPOs mainly relate to historical/archived data, quantitative data presented in tables/graphs, and geographically referenced infrastructure data. To the extent that the responses from the 47 MPO and locality survey participants could be generalized to all MPOs and localities, their major purposes in using these databases are visualization, modeling and simulation, land use and transportation analysis. This highlights the challenges to effective transfer of data across agencies and maintaining them constantly up-to-date since these databases are generally large in size. Notably, VDOT follows a records retention policy where some records can be removed after 36 months and in other cases, records are retained in perpetuity (M. Rao, personal communication, 2014). Record storage costs are relatively high and this function is contracted out by VDOT. The difference in meeting the needs of external users and VDOT's sharing of data was confirmed by the results of the survey.

Users expressed a desire to have integrated information about the roadway network with operations and safety information. Given the size and complexity of transportation data within VDOT, a set of consistent, easy-to-use and flexible data integration procedures and tools that can combine roadway information with traffic operations and other geographically referenced data can be considered. For instance, to obtain traffic data, planners will be able to use the TMS, data collected for corridor studies, CLRP updates, and any rezoning requests. Notably, the VDOT central data warehouse and controlling it by granting different access permissions is a solution that VDOT is working on.

Privacy or security concerns can result in creation of firewalls, restricting incoming and outgoing information. However, in some cases, firewalls can also hinder data sharing and periodic reviews of firewalls can be conducted by VDOT ITD or VITA to ensure their continuing value. In the context of unmet data needs, this issue is somewhat complicated by sensitivities with respect to privacy concerns for the protection of proprietary data. Some users reported having access to data and models but did not have permission to use the software and/or data. Therefore, indicating how the data can be shared internal and external to VDOT would be helpful. Such indications might refer to how to obtain direct access or how to obtain permission to be granted access.

Assessment of Potential Short-Term Solutions

To assess potential short-term solutions to fulfill unmet data needs, the research team first developed potential solutions without explicitly considering the VDOT environment. Then, a telephone interview with VDOT's Chief Information Officer provided an understanding of ongoing initiatives in VDOT, and a second survey—solely of TRP members—provided additional information regarding the feasibility of some solutions.

Potential Short-Term Solutions

A short-term, conceptual data solutions framework is presented in Figure 6. The framework is based on the authors' synthesis of data management practices as reported in the earlier section titled "synthesis of literature review." The framework does not guarantee that the solutions can be implemented within the VITA or VDOT ITD policy framework but rather provides areas for exploration. VDOT data sources enter the figure from the bottom, and these data sources would ideally be integrated by the Information Technology Division and other divisions as appropriate. The data reside in a central VDOT-wide data warehouse, which is accessible to appropriate VDOT users through the intranet. In addition, external users can access a subset of the data that are unrestricted from a mirror image of the data warehouse, and some of these databases can be shared with all users. There are two ways to provide this information in a secure manner: authentication or a Demilitarized Zone (DMZ). If the latter concept is used, then only the mirror image of VDOT data in a DMZ is accessible to external users; the central data warehouse located in the VDOT intranet is not accessible to external users. Thus, users cannot modify the data in the central data warehouse, and the DMZ with firewalls can provide double protection to a central data warehouse such as VDOT's. While the DMZ will not address privacy issues, it will address security issues.

Professionals needing access to these data can be categorized as follows:

1. Professionals who are unaware of VDOT data.

2. Professionals who are aware of VDOT data, but who do not have the time or capacity to acquire the data. For example, users might not be able to transform data so for ready use within various analytical packages such as travel demand modeling software.

3. Professionals who are aware of VDOT data, and have the capacity to acquire it, but are unable to access it. Such potential users may include a TPO or locality who, without obtaining prior permission, cannot get access to data that is protected by the VDOT firewall. Rather, these external users must get permission to access firewalled VDOT information; for example, if consultants need electronic plans, which are stored in VDOT's Falcon database, they must complete and access and security agreement (VDOT, undated). Users who are unable to access databases or software may also include VDOT employees who do not have administrative privileges on their VDOT computers; such employees must obtain permission through SARA (if permission is needed) or have the software installed by VITA (if a software installation is needed).

4. Users who are aware, have the access to the data, and are able to use it effectively for making informed fact-based decisions.

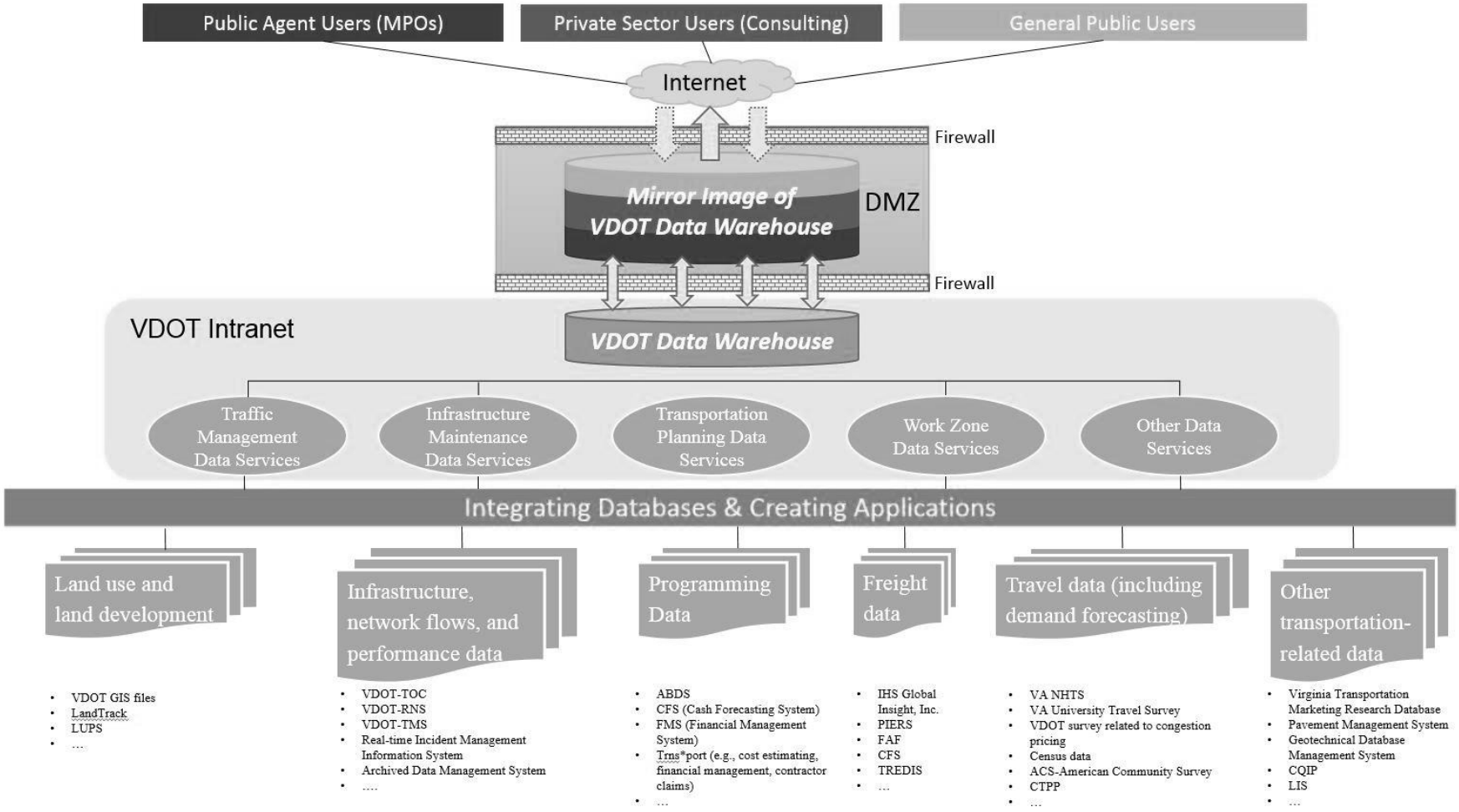


Figure 6. Conceptual Short-term Data Solutions Framework

Clearly professionals in the first three categories can benefit in different ways from the proposed solutions.

The potential solutions can be placed into six broad categories:

1. increasing awareness of data resources
2. improving data resources
3. integrating databases
4. increasing database use
5. disseminating data by providing access to databases
6. establishing organizational structure for governance.

Increasing Awareness of Data Resources

The reviewed literature and the survey results underline the importance of increasing awareness of VDOT databases. The survey results suggest that some respondents were not aware of the many VDOT databases; respondents appeared a bit surprised at the diversity of databases listed in the survey, despite the fact that only a subset of those databases would be relevant to each respondent (see Table 1). Several strategies could be considered by ITD and/or TMPD staff to increase awareness, including data-centered education/training programs, webinars, workshops, conferences/meeting sessions, websites, database update/performance reports, social media interactions, creation of a transportation data map that lists key VDOT databases, VDOT data portals, and on-line access to VDOT studies conducted by various divisions. The VDOT-wide online library (VCTIR, 2013) can facilitate dissemination of studies and reports about databases and also studies that will be conducted in the future.

The creation and distribution of a 'Transportation Data Map' can increase awareness (see Table 10). Such a map would disseminate information about databases such as database ownership, control of database, sensitivity, availability of database to different users, main uses, and contract person for database acquisition. VDOT could consider increasing awareness of databases that it does not fully own or control but can be of benefit to transportation professionals, including VDOT employees. For example, VDOT does not own FARS, but VDOT could increase awareness of FARS data by providing links to the National Highway Traffic Safety Administration (NHTSA) website. (When such links are provided, it is appropriate to indicate to visitors that they are being directed to a non-VDOT site.)

Ideally the transportation data map would indicate, for each database, the entity that owns the database, sensitivity concerns, the extent to which the data can be shared, and a website or other means of getting access to these data. An excerpt of the data map is shown in Table 10 and could be extended to other databases such as, but not limited to, the VDOT Traffic Monitoring System, the Real-time Incident Management Information System, the Highway Safety Information Program, and the Land Use Permit System.

Table 10. Sample Excerpt of Proposed VDOT 'Transportation Data Map'

Database Types	Databases That Meet Data Need	Ownership and Control	Sensitivity Concerns	Availability	Website
Land use and land development	VDOT GIS files (e.g., Online Transportation Information Map)	VDOT	Must respect copyright	Publicly available	(VDOT, 2015a)
	LandTrack (Land Development Tracking System)	VDOT TMPD	Not known	Publicly available	(VDOT, 2015c)
Safety	RNS	VDOT ITD	Must not include identifying information	Only VDOT staff	Internal
	Crash locations	VDOT and DMV		Publicly available	(DMV, 2015)

Improving Data Resources

For a data owner, a key solution is to enhance the "Data Warehouse" functionality by linking more databases and archiving select data collected by VDOT. There are potentially four elements of this solution, recognizing that the first is most specific and the latter three are more exploratory in nature.

1. VDOT has already developed a data warehouse that is a repository of data and feeds data to portals such as the Dashboard (VDOT, 2015b) and the "Virginia Roads" site (VDOT, 2015a). Thus, a first step could be to merge these two sites into one web address to provide a one-stop shop for VDOT data. Further, the connections of the portal with dynamic feeds can be strengthened so data displayed can be updated automatically and frequently.

2. The centralized VDOT-wide data warehouse with extracts that come from even more VDOT divisions can, in the opinion of the authors, provide consistency in data integration and sharing. This solution if feasible and desired by multiple users should be considered further.

3. Data quality can be ensured by finding anomalies or errors in source data and then correcting those errors.

4. Data archival and storage can be expanded, if VITA policies allow, as more data and capacity for storing those data become available. For example: at present, ITD's Traffic Data and Performance Management System (TDPMS) can be used to conduct offline traffic performance analysis. In the future, as storage technology advances, additional data that are not routinely archived can be considered for archival and easy access. Such data could pertain to land use, land development, infrastructure, network flows, performance, freight, planning, programming, and travel demand. Such an effort would involve partner agencies and would be considered within the constraints of existing ITD data retention policies and resource constraints.

Integrating Databases

Although the survey did not expressly ask respondents about data complexity, the large number of transportation databases suggests that there could be a benefit to providing flexible data integration procedures, such as tools that can combine roadway information with traffic operations and other geographically referenced data in a consistent way. Notably, the unmet data needs of VDOT respondents revolved around transportation infrastructure. In this regard, efforts could be undertaken to further integrate road network system data with traffic monitoring data, operations data, and safety data, however, additional information would be needed to determine the total cost of this integration in terms of labor and capital expenditures. Databases might be integrated using Application Programming Interfaces (APIs). They include the Roadway Network System (RNS), Traffic Monitoring Systems (TMS), Traffic Operations Centers (TOC), Highway Safety Improvement Program (HSIP) and traffic crash records.

The techniques for data integration typically include data standardization, data simplification (where needed), and data linking. In particular, data linking can allow a centralized approach that can prevent duplication and expedite data exchange with a large number of partners. However, a significant amount of work might be required to create linkages between different (disparate) databases, which themselves can consist of several inter-connected databases. In this context, standards and consistency in terms of data collection units, data format, and data linking would be valuable.

As an example, RNS data might be integrated with operations and safety information. A tool that facilitates data integration and use of applications (visualization, analysis, hot-spot identification, and forecasting) is PeMS. The software can display statewide transportation data in real-time on maps covering all major metropolitan areas. PeMS integrates a wide variety of information related to roadway inventory, vehicle volume data from traffic detectors, CCTV video images, speeds, incidents, lane closures, tolls, weigh-in-motion, traffic messages posted on electronic message signs, and weather and fog information. Importantly, PeMS functionality might be expanded to integrate additional databases, in particular focusing on improved monitoring of arterial routes (VDOT controls many arterial roadways) and integrating that information using PeMS.

Another possible example of potentially useful data integration, if feasible, is providing information on active construction projects, allowing authenticated users to spatially locate projects, and check financial information (amounts of allocations, obligations, and expenditures). This was stated as an important data need during contacts with regional transportation planners in MPOs and PDCs. Furthermore, MPOs reported that it is difficult to find out how much project money is unspent.

There are some existing data integration efforts underway. VDOT ITD continues to integrate various databases, e.g., crash records data will be integrated, after anonymizing them. Notably, the crash records are only available internally, and they can be queried by professionals familiar with SQL, allowing users to point critical crash locations that can help with identifying countermeasures. Another resource is Comprehensive Environmental Data and Reporting

System (CEDAR) that organizes environmental data (including specific project documents, forms, and images) in one location and it is currently accessible to VDOT staff only. The VDOT ITD work on updating segments in the Linear Referencing System (LRS) is also very valuable for data integration. Generally, the VDOT ITD data integration efforts have focused on integrating traffic operations and maintenance data through internal data exchange brokers. In addition, the PeMS tool is being implemented by VDOT's Traffic Engineering Division.

Increasing Database Use

To meet users' needs, data warehouses can provide them with enhanced data processing capabilities. Data processing refers to a broad range of tools that support the full use of data. The products can provide users with easy data retrieval, better data visualization, indexing and sorting large datasets, data mining, analytics, image manipulation, and modeling and simulation. If provided to professionals, these tools have the potential to extract key parts of information from large-scale databases and help better assess the impacts of transportation decisions.

Given the movement toward data rich environments, "Big Data" has been used to refer to large and sometimes disparate datasets. Tools and techniques that support capabilities to work with big data are becoming increasingly popular. The tools can identify key pieces of information and then relate and cluster them in order to provide insights. Applications of big data are becoming more common in transportation, and there are some interesting applications, e.g., using Twitter interactions and 911 calls to identify and verify transportation incidents, and using second-by-second GPS data to proactively identify hotspots where excessive hard braking or speeding may occur. Therefore, providing data users with big data solutions may be considered in the context of applications for an enhanced central VDOT-wide data warehouse.

Disseminating Data by Providing Access to Databases

With 25% of survey respondents in this study requesting better data access, a key consideration is sharing by ITD of non-sensitive VDOT data with external users. Currently, there are multiple classes of data users, e.g., private consultant or contractors, localities and other agencies (DMV, VSP, MPOs). By making permissions available to them, planning organization staff can get secure access to needed data. In this case, the modes and levels of data access will be managed by applicable VDOT and VITA domain control policies.

Periodic review of privileges and permissions provided to various data users may be conducted. While the VDOT ITD does not restrict data usage by VDOT staff, (e.g., VDOT employees can access databases such as TMS and GIS shapefiles), some existing practices can be restrictive. For example, although VDOT has a statewide GIS license, one cannot install GIS software without administrative privileges. Because VITA has granted administrative privileges to relatively few VDOT employees, GIS installation cannot be done by an individual. Rather, installation can require multiple steps such as submitting the initial request to ITD, coordinating a date and time for the installation with VITA after VITA responds to the ITD request, and if necessary, conducting further follow up to resolve any repairs needed for the installation. There may be situations where VDOT ITD and VITA could work together to review such restrictions

regarding administrative privileges, and where appropriate, reduce restrictions. That said, there are reasons for retaining the restrictions, such as concerns about what software employees would install and potential software license violations.

Individual VDOT units may have other restrictions on data access. For example, there are restrictions on who can access the FR300 crash report forms. This is because of the sensitivity of personal identifying information in specific crash records. Security of data is also a concern. For example, while the project cost estimating software is available within VDOT, access is sometimes limited because some of the information is used to assess the quality of bids.

To meet data needs of data users other than VDOT employees, techniques are available for making existing data sources more accessible. As an example, the VPN technique is an enabler technology for providing selected users (e.g., TPO staff) secure access to VDOT's data. Also, improving data access through more intuitive user friendly interfaces and detailed data documentation (data dictionaries) can be considered.

Establishing Organizational Structure for Governance

Data have become ubiquitous, vehicles are communicating with each other and with infrastructure, multi-modal transportation systems are being developed, and public-private partnerships are a reality. To improve effectiveness in dealing with emerging data issues in a complex and multi-dimensional context, organizational mechanisms may be useful. For example, by appointing a Chief Data Officer, an agency may be able to better deal with governance and institutional issues related to data. The officer can deal with prioritizing data issues, enhancing cooperation among current and potential data users, forming new data partnerships, better coordinating various databases that include planning, design, construction, operations and maintenance data and explore innovative solutions to handling large-scale transportation data (e.g., by implementing decision support tools) in a timely and effective way. Furthermore, an organization's Chief Data Officer may play a leadership role in developing policies for sharing data and improving communication between agencies, firms, or data users. In private sector organizations, the Chief Data Officer might develop policies regarding the sale of data, this, however, is not applicable to VDOT or this report. However, policies regarding when and how to share data in an effective manner are relevant to the public sector and state government. To advise the Chief Data Officer, a "Data Board" could be considered with broad representation from diverse categories of current and potential users.

An internal "data advisory committee" could be formed to coordinate potential data exchange opportunities with agencies and organizations in Virginia that are involved in some particular aspect of transportation planning, such as demand forecasting. The meetings of such a committee could be conducted as open forums to encourage public agency partners to work with each other and with private sector professionals. A data advisory committee could (1) periodically review data user restrictions and propose appropriate solutions, (2) consider creation of new data partnerships, and (3) coordinate data resources and data exchange opportunities from different organizational units (both internal and external to VDOT). The committee could make

institutional arrangements between agencies and professionals to bring together transportation planners and operations practitioners, to share data and information and to the mutual benefit of regional planning and operations.

The roles of those involved in the data advisory committee, and the organizational structure of this committee, would likely evolve as new issues related to data emerge. The creation of this committee would be intended to improve data awareness, data access, data use, partnerships between public and private entities, and the feasibility of joint ventures that address large-scale data.

Feasibility of Short-Term Solutions

Three of the aforementioned solutions—increasing awareness of databases, providing greater access to databases, and integrating data—were considered from two perspectives: current VDOT initiatives and the results of a second survey.

Current VDOT Initiatives

The authors of this report estimate that VDOT has some 200 databases that are maintained by VDOT's Information Technology Division. They can be accessed by various groups through Oracle and SQL Server Databases (M. Rao, personal communication, 2014). VDOT's ITD data integration efforts have focused on integrating operations, maintenance, and financial data through internal data exchange brokers, and providing data to external users through location-based external services. One example of publicly available information is the Virginiaroads.org website, which provides interactive maps showing active construction projects, pavement condition on Virginia roads, and 511 information across Virginia. To enable extraction from various sources, VDOT's ITD uses Extract, Transfer, and Load (ETL) for daily activities. This facilitates data integration as data comes in from various sources, is transformed and loaded. Data marts allow users to access data from the central data warehouse. Reporting is done through SAP crystal reports and SAP Tableau is used for data processing and analysis. Geo-spatial representation of data is based on GIS capability and the use of ESRI tools, with Google Maps or Bing used to display location based information on maps. Note also that safety data are being integrated which requires anonymizing the crash records.

Notably, data security issues and information related critical infrastructure are particularly challenging when it comes to sharing of data. VDOT's ITD has to maintain a balance between VITA's policy restrictions on data sharing within VDOT and professionals outside of VDOT (M. Rao, personal communication, 2014). The Virginia Information Technology Resource Management Information Security Standard (VITA, 2014) implements various requirements regarding the roles and responsibilities of data owners, data custodians, data sensitivity classification, IT security audits, and risk assessment, etc. For example, VITA has a requirement for Independent Verification and Validation on all major development projects. In compliance with this directive, VDOT's ITD engages IV&V services for all major projects, despite having limited budget and staff resources. Overall, ITD has several ongoing activities related to data access and use (M. Rao, personal communication, 2014).

Presently, the VDOT ITD is working on updating millions of segments in the Linear Referencing System (LRS), which forms the foundation of data integration efforts (M. Rao, personal communication, 2014). LRS can define position on the network, connectivity of assets, and changes over time. Also, data are available through 511 cameras (900 of them throughout Virginia), Variable Message Signs, Reach the Beach initiative, and VDOT fleets (e.g., snow plow tracking system). However, several critical VDOT-controlled databases that include RNS, Traffic Monitoring System (TMS), and HSIP were ranked high by MPOs and localities in terms of their unmet data needs. Given that some of these databases are a mixture of federal and state databases, VDOT may have reasons for restricting access to these databases. Individual VDOT divisions also have certain restrictions on data sharing for various reasons. For example, there are restrictions on who can access the Police Crash Report forms (FR300) raw data given the sensitivity of personally identifying information. Also project cost estimating software is available to all VDOT staff but it is restricted because the information is used to assess quality of bids. The question is how to provide these databases appropriately to agencies and the public, without compromising privacy or security.

Results of a Second Survey

To gather information on the potential feasibility the three solutions (increasing awareness of databases, providing greater access to databases, and integrating data) a second survey was distributed to the nine TRP members. With only three respondents, the main value of this exercise was to determine if there were additional suggestions that could be offered for how to implement the solutions. For each database, the respondents were asked to rate the solutions provided or provide specific suggestions about how the databases can be enhanced. Appendix D shows the results. The respondents strongly agreed that there is room for increasing the awareness of currently available databases among VDOT staff. Respondents also strongly agreed that VDOT should further facilitate distribution of data to external organizations, that providing more access to data needed by certain transportation planning data users can have a positive impact within VDOT, and that VDOT divisions that can potentially work together on data issues may include Maintenance, Traffic Engineering, Transportation and Mobility Planning, Programming, Environmental, Structure & Bridge, and Right of Way and Utilities.

Summary of Feasibility

One interpretation of these results from the interview with VDOT's Chief Information Office (M. Rao, personal communication, 2014) and the comments from respondents to the second survey, is that two solutions—increased awareness of data and increased access to data—may be feasible through two distinct initiatives—a series of communications between users and providers and periodic meetings between key divisions who represent data users and providers.

CONCLUSIONS

- *Unmet data needs are greater for MPOs and localities than for VDOT*. Whereas only 41% of VDOT survey respondents have at least one unmet data need, a statistically significant higher percentage (70%) of MPO and local respondents have at least one unmet data need. After controlling for years of work experience, respondents from MPOs and localities have 87% higher reported unmet data needs.

- *The two databases where respondents most frequently indicated they needed access but did not have access relate to infrastructure (RNS) and safety (HSIP).* When all 51 databases were considered by all users, the database with the largest percent of users indicating they needed it but the database was unavailable (21%) was the roadway network system (RNS), followed by the Highway Safety Information Program (HSIP) at 18%. For MPOs and localities, these percentages were higher at 36% and 45%, respectively. The database with the third highest percentage overall was traffic operations center data (TOC), where slightly less than 18% of all users indicated they needed it but did not have access to it; for MPOs/localities this percentage was 26%. For VDOT, the top 3 databases (in terms of needing but not having access) were RNS, TOC, and ADMS (Archived Data Management System), but the percentage of users who needed but did not have access was lower than those cited above, ranging between 11% and 12%.

- *Transportation planners appear to have more diverse data needs than other professionals*. The survey results showed that planning professionals use more databases than professionals in the areas of information technology, operations, administration and finance, design, and the environment. To the extent that the number of databases is a surrogate for diversity of data sources, this suggests that planning professionals may have a relatively large degree of diverse data needs compared to other disciplines.

- *VDOT respondents and MPO/local respondents differ in terms of which databases they access the most frequently.* The top three data sources used by VDOT staff—VDOT GIS files, the internal iSYIP database, and the roadway network system (RNS)—differ from the top three data sources used by MPO/PDC/local staff—U.S. Census data, American Community Survey data, and demographic data from the Weldon Cooper Center for Public Service.

- *There are multiple obstacles to making data available to non-VDOT staff*. First, some units within VDOT may add information to publicly available datasets such as GIS shapefiles from VGIN to which roadway information has been added. In this case, persons outside VDOT may not be aware of the enhanced data resource. Second, some data sources created by VDOT and are restricted due to security concerns; an example is the Land Use Permit System (LUPS). In this case, persons outside VDOT cannot obtain the data unless VDOT takes specific steps to grant access. Third, there are some data elements where VDOT cannot legally provide the dataset; for example, VDOT has purchased—not created—INRIX data and is not allowed to distribute such data to a third party. Fourth, there are some databases

that are simply not controlled by VDOT—such as FARS—such that VDOT is not the entity that can necessarily provide such data.

- *Even when data can be accessed, other obstacles to addressing data needs remain*. One obstacle is the time required to access certain datasets, which one-fourth of VDOT respondents cited as a concern. A second obstacle is the quality of the database: for example, when respondents were asked whether they agreed with the statement that data were well-documented, 12% indicated they disagreed or disagreed strongly and 27% neither agreed nor disagreed. The survey gave similar percentages for other elements of data quality such as "valid and reliable" (9% disagreed and 18% neutral), and available in a user-friendly format (11% disagreed and 22% neutral).

- *A review of the literature coupled with survey responses suggests four types of improvements that potentially can help satisfy planners' unmet data needs.*

    1. *Increase user awareness* of databases was a suggestion offered by 35% of respondents who indicated how the database they primarily use could be improved. One way to increase user awareness is through a seminar, another way is through enhancements to a transportation data map.

    2. *Improve ease of access* was suggested by one-fourth of survey respondents. For the subset of VDOT data that are not publicly available, one technique to provide access to external users is the use of virtual private networks (VPN) for selected users, such as MPO staff.

    3. *Improve ease of use* for the subset of VDOT data that are publicly available can be achieved by providing one location as a starting point for acquiring data. As an example, there is a website maintained by VDOT titled "Virginia Roads" (VDOT, 2015a) and there is a different website maintained by VDOT that displays the agency Dashboard (VDOT, 2015b). It may be possible to have the former site point to the latter.

    4. *Integrate existing databases* is a method where data from two or more databases may be connected. An existing example is PeMS (which relates incident and inventory information); a proposed example is a financial database that allows users to locate projects on a map and then obtain expenditure information.

RECOMMENDATIONS

1. *VDOT's TMPD, with the involvement of district planners, should co-sponsor a data sharing workshop with staff from Virginia's regional planning partners (MPOs and PDCs).* The goal of the workshop will be to connect planning data customers with persons who are knowledgeable about databases and data access methods. It is recommended that the first workshop be initiated with the appropriate VDOT divisions (e.g., ITD, TED, and TMPD)

being prepared to articulate what VDOT can provide. During that workshop, a session could also be devoted to asking planning partners what information they require (see Tables 7 and 8). Important topics for the workshop may include the following:

- *Types of planning-related data that can be provided by VDOT.* Examples include crashes, traffic counts, and roadway inventory information (see Table 5).

- *Key contacts within various VDOT divisions.* An example is that crash data might be accessed through VDOT TED rather than TMPD. A starting point is the "Systems at a glance" spreadsheet found under "Stuff You Need" on the main page of "InsideVDOT" (VDOT, 2013). While this spreadsheet is currently only available to VDOT staff, it could serve as a Virginia-specific transportation data map that would also be of interest to local and PDC/MPO planners.

- *Tools that VDOT has developed expressly for sharing data.* Examples might be the information made available on the extranet, crash data that in the past have been exported, and advances with the Linear Referencing System (LRS).

The following additional workshop topics may be included if time allows:

- *Legal restrictions for sharing these VDOT datasets.* An example is that some imagery data accessible through VDOT's internal GIS servers is not the property of VDOT. (See Table 6, Categories A and B.)

- *Third-party datasets available from non-VDOT sources.* One example is population projections that the VEC has contracted out to the Weldon Cooper Center for Public Service. Another example is the National Transit Database, accessible through "INTDAS," which originated from Florida's transit data clearinghouse (see Table 5).

- *Data formats for these third-party datasets.* Examples include GIS shapefiles, spreadsheets, and Access databases.

- *Technical requirements for querying these datasets.* An example is that some of the INRIX datasets require extensive cleansing and simplification; in other datasets, certain GIS skills may be required.

2. *VCTIR, VDOT's ITD, and VDOT's TMPD should plan to meet periodically to discuss ways to improve access to transportation data, starting with planning-oriented data.* Several of the initiatives mentioned in this report, as well as the responses in Appendix D, suggest that a periodic exchange of ideas between data providers and data users may, in some cases, make it easier to obtain data.

BENEFITS AND IMPLEMENTATION

VDOT's TMPD and VCTIR are working to schedule the workshop noted in Recommendation 1 and expect it to occur within 1 year (e.g., by December 2015). Opportunities include the annual Virginia Association of Planning District Commission (VAPDC) meetings, the Virginia Association of MPOs that holds quarterly meetings, and the Statewide Transportation and Land Use Planning Forum. It is possible that in addition to TMPD, this workshop could be co-sponsored by the Virginia Chapter of the American Planning Association. The meetings noted in Recommendation 2 will occur roughly twice a year and will be coordinated with the fall and spring Transportation Planning Research Advisory Committee [TPRAC] and/or the fall and spring Joint Planning Managers Meetings (which are presently coordinated with TPRAC). In the future, these meetings may be expanded to include other VDOT divisions in order to facilitate access to a broader set of transportation data.

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APPENDIX A

SURVEY OF TRANSPORTATION PROFESSIONALS

Cover Letter
VDOT Data Needs Survey
Dear Participant,

The Virginia Department of Transportation has sponsored a study of unmet transportation data needs. The Old Dominion University is conducting the study. The study evaluates how transportation and related databases are accessed and used within your division/agency. For this purpose, we are conducting a survey, which should not take more than 30 minutes of your time. Your responses will help us better understand access and use of databases and software related to the state's transportation system. Please be assured your participation is voluntary and your responses will be kept confidential.

Thank you in advance for your assistance.

If you have any general questions about the survey, please contact Dr. Tancy Vandecar-Burdin at 757-683-6701 or by email at tvandeca@odu.edu. If you have specific questions of a technical nature about the content of the survey, please contact Dr. Asad Khattak at akhattak@odu.edu.

Thank you.

Research Project Team

Survey Questions

1. Please identify the type of organization where you work:
   - ( ) Virginia Department of Transportation
   - ( ) Virginia Department of Rail and Public Transportation
   - ( ) Metropolitan Planning Organization
   - ( ) Consulting Company/Corporation (e.g., transportation, energy, environment)
   - ( ) Locality/City (please specify locality/city):
   - ( ) Other [ ]
2. What is your job title at your workplace?
3. Please specify your Department or Division within your agency/company.
4. Please list up to three main tasks performed by your Department/Division.
5. What kind of work do you do primarily? (check up to three (3) options)
   - ( ) Develop/manage projects (e.g., high-risk intersections, signal timing coordination)
   - ( ) Develop/manage a program (e.g., regional pedestrian/bicycle safety, wildflowers)
   - ( ) Develop/manage plans (e.g., transportation improvement program/regional plans)
   - ( ) Public Involvement (e.g., presentation of information to mitigate adverse impacts on stakeholder, Title VI/environmental justice)
   - ( ) Manage consultants
   - ( ) Transportation operations
   - ( ) Mobility/congestion monitoring/management
   - ( ) Safety/performance analysis
   - ( ) Security/emergency planning
   - ( ) Land use and transportation analysis
   - ( ) Financial planning/programming of projects
   - ( ) Conduct studies (e.g., travel demand forecasting or corridor improvement studies)
   - ( ) Get approvals for projects (e.g., develop environmental impact statements)
   - ( ) Freight transportation
   - ( ) Involved in project/program design, construction, or maintenance
   - ( ) Other [ ]
6. Provide the number of persons who are under your supervision:

7. What is the level of highest education you have completed?
( ) High school or less ( ) Some college
( ) Vocational or technical school ( ) Completed college (Bachelor's degree)
( ) Graduate degree (Masters or Ph.D. degree) ( ) Other [ ]
8. Do you have licenses or certifications? (check all that apply)
( ) EIT (Engineer in Training) ( ) PE (Professional Engineer)
( ) PTOE (Professional Traffic Operations Engineer) ( ) AICP (American Institute of Certified Planners)
( ) Other [ ]
9. How many years of experience do you have in your field?
10. How long have you held your current position?

Data needs, met and unmet
11. Please identify the databases you currently use or need to use at work.
Using the first column, check all the databases that you need to use at work - but are currently unavailable to you.
Using the second column, check all the databases you currently use. Leave blank if you are unaware

Transportation planning/operations data
Land use and development
VDOT GIS files (e.g., GIS OTIM/SSAR)
( ) Currently need but unavailable ( ) Currently use
LandTrack (Land Development Tracking System)
( ) Currently need but unavailable ( ) Currently use
LUPS (Land Use Permit System)
( ) Currently need but unavailable ( ) Currently use
Infrastructure, network flows, and performance data+ Safety and Incident data
VDOT TOC (VDOT Local Traffic Operation Centers)
( ) Currently need but unavailable ( ) Currently use
RNS-VGIN (Roadway Network System-Virginia Geographic Information Network)
( ) Currently need but unavailable ( ) Currently use
RNS-HPMS (Roadway Network System-Highway Performance Monitoring System)
( ) Currently need but unavailable ( ) Currently use
VDOT-TMS (Traffic Monitoring System – includes AADTs: Annual Average Daily Traffic)
( ) Currently need but unavailable ( ) Currently use
VDOT speed data from VDOT detectors
( ) Currently need but unavailable ( ) Currently use
SPS (Statewide Planning System)
( ) Currently need but unavailable ( ) Currently use
Small Urban Transportation Plans database (ongoing Transportation and Mobility Planning database)
( ) Currently need but unavailable ( ) Currently use
RUMS (Right of Way and Utilities Management System)
( ) Currently need but unavailable ( ) Currently use
BSA-PC Pier/Beam (Bridge Structure Analysis)
( ) Currently need but unavailable ( ) Currently use
511 & DMS (Dynamic Message Sign) data
( ) Currently need but unavailable ( ) Currently use
INRIX (Speed/Travel time private data)
( ) Currently need but unavailable ( ) Currently use
CEDAR (Comprehensive Environmental Data and Reporting System)
( ) Currently need but unavailable ( ) Currently use
AMS-Work Accomplishment (Asset Management System – Work Accomplishment)
( ) Currently need but unavailable ( ) Currently use
Operations Planning Division Budget Program (Operations planning)
( ) Currently need but unavailable ( ) Currently use
RNS-Crash (Roadway Network System – Crash Reporting System)
( ) Currently need but unavailable ( ) Currently use

RNS-TREDS (Roadway Network System - Traffic Record Electronic Data System)
( ) Currently need but unavailable ( ) Currently use
TransOps-VDSIS-RTIMIS (TransOps-VDSIS-Realtime Incidence Management Information System)
( ) Currently need but unavailable ( ) Currently use
FARS (Fatality Analysis Reporting System) data
( ) Currently need but unavailable ( ) Currently use
NHTSA (National Highway Traffic Safety Administration) data
( ) Currently need but unavailable ( ) Currently use
HSIP (Highway Safety Improvement Program) FHWA database
( ) Currently need but unavailable ( ) Currently use

Freight data

IHS Global Insight, Inc. (private freight data purchased by VDOT)
( ) Currently need but unavailable ( ) Currently use
PIERS (Port Import Export Reporting Service/private freight data purchased by VDOT)
( ) Currently need but unavailable ( ) Currently use
VDOT Vehicle Classification data
( ) Currently need but unavailable ( ) Currently use
Freight Analysis Framework (FAF) (FHWA freight database)
( ) Currently need but unavailable ( ) Currently use
Commodity Flow Survey (CFS)
( ) Currently need but unavailable ( ) Currently use
AADF/TREDIS (Annual Average Daily Flow/Transportation Economic Development Impact System) (Traffic Freight Flow Data)
( ) Currently need but unavailable ( ) Currently use

Programming data

Programming database (related to VDOT project pool, SYIPs and STIPs)
( ) Currently need but unavailable ( ) Currently use
Six-Year Maintenance and Operations Program
( ) Currently need but unavailable ( ) Currently use
ABDS (Annual Budget Development System) (Financial Planning)
( ) Currently need but unavailable ( ) Currently use
CFS (Cash Forecasting System) (Financial Planning)
( ) Currently need but unavailable ( ) Currently use

Travel data (including demand forecasting)

VA NHTS (Virginia National Household Travel Survey) data
( ) Currently need but unavailable ( ) Currently use
VA University NHTS
( ) Currently need but unavailable ( ) Currently use
VDOT survey (related to congestion pricing)
( ) Currently need but unavailable ( ) Currently use
Census data (demographics, boundaries, commute patterns, Census Journey to Work data)
( ) Currently need but unavailable ( ) Currently use
ACS-American Community Survey
( ) Currently need but unavailable ( ) Currently use
CTPP (Census Transportation Planning Products)
( ) Currently need but unavailable ( ) Currently use
BTS - Bureau of Transportation Statistics (TransStats) data
( ) Currently need but unavailable ( ) Currently use
Weldon Cooper (State Demographics and Projections)
( ) Currently need but unavailable ( ) Currently use
Bureau of Labor Statistics data
( ) Currently need but unavailable ( ) Currently use
Bureau of Economic Analysis data
( ) Currently need but unavailable ( ) Currently use

Other transportation-related data+ Construction data

GIS-GDBMS (Geographic Information System - Geotechnical Database Management System)
( ) Currently need but unavailable ( ) Currently use
GIS-OTIM (Geographic Information System – Online Transportation Information Map)
( ) Currently need but unavailable ( ) Currently use
GIS-SSAR (Geographic Information System – System-Secondary Street Acceptance Requirements) (Transportation and Mobility Planning)
( ) Currently need but unavailable ( ) Currently use
FAA Air Travel Data (enplanements, airfares, destinations, cargo)
( ) Currently need but unavailable ( ) Currently use
VA DEQ (Water/Air Quality Data)
( ) Currently need but unavailable ( ) Currently use
DMV Data - Licensed Drivers, Registered Vehicles
( ) Currently need but unavailable ( ) Currently use
PMS Data (Pavement Management System)
( ) Currently need but unavailable ( ) Currently use
Port Data (VPA and AAPA) - Total Cargo, TEUs, Exports/Imports, Commodities
( ) Currently need but unavailable ( ) Currently use
Rail Data (Amtrak) - Passenger Levels
( ) Currently need but unavailable ( ) Currently use
TTI Data (Texas Transportation Institute) - Total delay, congestion costs, wasted fuel
( ) Currently need but unavailable ( ) Currently use
Transit data (National Transit Database and Local agencies) on ridership, unlinked trips, & trips by route
( ) Currently need but unavailable ( ) Currently use

Maintenance data

RNS-UMIS (Roadway Network System-Urban Maintenance Inventory System)
( ) Currently need but unavailable ( ) Currently use
CQIP (Construction Quality Improvement Program)
( ) Currently need but unavailable ( ) Currently use
LIS (Legislative Information System)
( ) Currently need but unavailable ( ) Currently use

11a. Why are you not able to access/use databases that can be beneficial in your work? {Check all that apply}

( ) Cost of acquiring and maintaining the databases are too high
( ) Takes too much time to get access
( ) Demands for data are not high in my agency
( ) Agency firewalls
( ) Proprietary or sensitive information
( ) Security issues
( ) Computer or server limitations for handling big or complex databases
( ) Other [ ]

12. Please list additional databases you currently use (leave blank if not applicable):

[ ]

12a. Please list additional data or databases you need to use (but are not currently available to you) (please leave blank if not applicable):

[ ]

Data type, quality and handling

13. Please name the ONE "primary use" database that you use most frequently at work:

[ ] (database name)

14. How frequently do you use this database?

( ) Hourly/continuously ( ) Daily
( ) Weekly ( ) Monthly ( ) Other frequency (please specify): [ ]

15. For what purpose do you use this database? (check all that apply)

( ) Analyze, model, or simulate transportation systems to assess construction or operational improvement impacts (e.g., travel demand forecasting and traveler behavior)

( ) Planning and operations for public transit (bus, rail), pedestrian, and bicycle transportation
( ) Visualize and display data/GIS
( ) System management, operations, intelligent transportation systems, traffic signals, traveler information to the public
( ) Transportation conditions prediction/analysis of unreliability, e.g., incidents, weather, work zones
( ) Emergency planning and operations (including contingency/evacuation)
( ) Safety/performance analysis
( ) Security analysis
( ) Environmental (air quality) and energy analysis
( ) Financial Planning and Programming
( ) Freight Transportation
( ) Land use and transportation analysis (e.g., site or regional plans)
( ) Public Involvement
( ) Title VI/environmental justice
( ) Maintenance of infrastructure
( ) Other (please specify): [ ]

16. How do you characterize this primary use database? (check all that apply)
( ) Real-time data (e.g., video of traffic flows)
( ) Archived/historical data (e.g., traffic incidents, work zones, vehicle volumes)
( ) Qualitative data (e.g., interviews, minutes of meetings, field notes, photographs)
( ) Quantitative data (e.g., counts presented in histograms or tables)
( ) Geographically referenced data
( ) Other (please specify): [ ]

17. How do you access your primary use database? (check all that apply)
( ) Intranet (direct link) using computer, smart phone, tablet *
( ) Internet (on-line/web) using computer, smart phone, or tablet**
( ) FTP-File Transfer Protocol
( ) CD-Rom/DVD
( ) Hardcopy/paper
( ) Directly from computer hard-disk
( ) Other ways of accessing data (please list) [ ]

17a. *If you checked "INTRANET" above please indicate if it is password/passcode protected:
( ) Yes ( ) No

17b. **If you checked "INTERNET" above please indicate if it is password/passcode protected:
( ) Yes ( ) No

18. Please indicate if your primary use data are:
Easy to comprehend and analyze
( ) Strongly Disagree ( ) Disagree ( ) Neither Disagree nor Agree ( ) Agree ( ) Strongly Agree
Available in a user friendly format
( ) Strongly Disagree ( ) Disagree ( ) Neither Disagree nor Agree ( ) Agree ( ) Strongly Agree
Well-documented
( ) Strongly Disagree ( ) Disagree ( ) Neither Disagree nor Agree ( ) Agree ( ) Strongly Agree
Current and timely
( ) Strongly Disagree ( ) Disagree ( ) Neither Disagree nor Agree ( ) Agree ( ) Strongly Agree
Valid and reliable
( ) Strongly Disagree ( ) Disagree ( ) Neither Disagree nor Agree ( ) Agree ( ) Strongly Agree

19. How is your primary use data collected? (check all that apply)
( ) Manually, including hand-held devices ( ) Surveys (e.g., behavioral or windshield surveys)
( ) Automatically (e.g., inductive loop detectors, video detectors, acoustic detectors, AVL-Automatic Vehicle Identification, GPS-Global Positioning System)
( ) Don't know ( ) Other (please specify) [ ]

20. How do you process or analyze your primary use data? (check all that apply)
( ) No processing/analyses are done ( ) Data are aggregated (e.g., from minutes to hours)
( ) Data are visualized in graphical format (charts, histograms, frequencies/tabulations)
( ) Descriptive statistics (means, variances, min/max) ( ) Data are spatially analyzed (displayed on maps)

( ) Simulations ( ) Other (please specify): [ ]

21. How successful is this database in addressing its intended use? (e.g., helps one to understand transportation problems or provides insights regarding solutions)?

( ) Not at all successful ( ) Not very successful
( ) Successful ( ) Very successful ( ) Not sure/Not applicable

22. Considering the primary use database, can the following be improved?

( ) Increase awareness of databases in your agency (please specify):
( ) Improve data access in your agency (please specify):
( ) Increase ease of data export/exchange (please specify):
( ) Aid data storage/archiving (please specify):
( ) Improve data quality (please specify):
( ) Improve data completeness (please specify):
( ) Improve data security (please specify):
( ) Reduce liability associated with data use (please specify):
( ) Facilitate distribution of data to other agencies (please specify):
( ) Facilitate distribution of data to the public (please specify):
( ) Collect new data on certain (new) performance measures (please specify):
( ) Create new data partnerships (please specify):

Experience and satisfaction with all databases used at work

22a. In general, how satisfied are you with access and use of databases available at work?

( ) Very dissatisfied ( ) Dissatisfied
( ) Neither satisfied nor dissatisfied ( ) Satisfied
( ) Very satisfied ( ) Not sure/Not applicable

22b. Please explain:

[ ]

23. Do you have any substantial constraints on accessing databases you use regularly at work? (e.g., cannot access it from home/remote location)

( ) Yes (please explain) ( ) No

24. Are there any databases that you would rather not use because they are outdated, old or obsolete? (please list or indicate "none" if this does not apply to you)

[ ]

25. Do any of the databases you use have substantial quality problems, such as missing data, or incorrect data?

( ) Yes ( ) No

Please indicate the database(s) and the problem(s):

[ ]

Software Use

26. What software do you currently use or need to use at work?

Using the first column, check all software that you need to use at work - but are currently unavailable to you.
Using the second column, check all software you currently use. Leave blank if you are unaware

Database Software

Oracle Operating Systems (Linux/Solaris)
( ) Currently need but unavailable ( ) Currently use

Oracle-Java
( ) Currently need but unavailable ( ) Currently use

Microsoft Access
( ) Currently need but unavailable ( ) Currently use

Other database software (please specify):
[ ]

Transportation Planning/Operations Software

CUBE suite (Voyager & Avenue)
( ) Currently need but unavailable ( ) Currently use

TransCAD
( ) Currently need but unavailable ( ) Currently use

Emme/2

( ) Currently need but unavailable ( ) Currently use
VISUM
( ) Currently need but unavailable ( ) Currently use
HCS (Highway Capacity Software)
( ) Currently need but unavailable ( ) Currently use
Evacuation
PC DYNEV (Personal Computer Dynamic Evacuation)
( ) Currently need but unavailable ( ) Currently use
OREMS (Oak Ridge Evacuation Modeling System)
( ) Currently need but unavailable ( ) Currently use
Transportation Simulation
DYNASMART
( ) Currently need but unavailable ( ) Currently use
TRANSIMS
( ) Currently need but unavailable ( ) Currently use
CORSIM/TSIS
( ) Currently need but unavailable ( ) Currently use
INTEGRATION 2.0
( ) Currently need but unavailable ( ) Currently use
Paramics
( ) Currently need but unavailable ( ) Currently use
Synchro
( ) Currently need but unavailable ( ) Currently use
Sim traffic
( ) Currently need but unavailable ( ) Currently use
VISSIM
( ) Currently need but unavailable ( ) Currently use
CUBE Avenue or Dynasim
( ) Currently need but unavailable ( ) Currently use
TransCAD TransModeler
( ) Currently need but unavailable ( ) Currently use
AIMSUN
( ) Currently need but unavailable ( ) Currently use
Logistics
TransCore
( ) Currently need but unavailable ( ) Currently use
Trns*Port – PES/EST/CES (Proposal & Estimate System/Estimator/Cost Estimating System (AASHTO Software)
( ) Currently need but unavailable ( ) Currently use
Computer-aided Design
AutoCAD
( ) Currently need but unavailable ( ) Currently use
MicroStation
( ) Currently need but unavailable ( ) Currently use
ArchiCAD
( ) Currently need but unavailable ( ) Currently use
Microsoft Office
Microsoft Office (MS Word, Excel, Powerpoint)
( ) Currently need but unavailable ( ) Currently use
Adobe Acrobat
Adobe Acrobat (PDF Reader)
( ) Currently need but unavailable ( ) Currently use
Geographical Information System (Geodatabase)
ESRI-ArcGIS (Explorer)
( ) Currently need but unavailable ( ) Currently use

GIS-Integrator/Integrator II
( ) Currently need but unavailable ( ) Currently use
ArcGIS Business Analyst
( ) Currently need but unavailable ( ) Currently use
Computer Programming
Microsoft Visual Studio (Visual Basic)
( ) Currently need but unavailable ( ) Currently use
C or C++
( ) Currently need but unavailable ( ) Currently use
SQL (Structured Query Language)
( ) Currently need but unavailable ( ) Currently use
Public based tools (e.g. Google, Bing)
Earth (mainly for visualization)
( ) Currently need but unavailable ( ) Currently use
Maps
( ) Currently need but unavailable ( ) Currently use
Statistical software
SPSS
( ) Currently need but unavailable ( ) Currently use
SAS
( ) Currently need but unavailable ( ) Currently use
STATA
( ) Currently need but unavailable ( ) Currently use
Please list other software that you currently use: [ ]
Please list other software that you currently need but are unavailable: [ ]

27. Please name one transportation software (e.g., CUBE or Vissim) that you have used most frequently within the past 3 months. [ ] (name of software)

Level of success for a project, program, or plan

28. Think about a recent project, program, or plan you have worked on in the past year that was successful. Would the project, program, or plan have been successful without access to certain transportation database(s)?
( ) Yes ( ) No ( ) Not sure Please identify the database(s) and explain: [ ]

29. Think about this same project, program, or plan you have worked on in the past year. Would the success of this project, program, or plan have been possible without access to certain transportation software?
( ) Yes ( ) No ( ) Not sure Please identify the database(s) and explain: [ ]

30. Learning from project, program, or plan mistakes
Was there a recent project, program, or plan that you or your team worked on in the past year but did not complete on time?
( ) Yes ( ) No

31. Please indicate if the following were reasons why the project, program, or plan was unable to be completed or held in abeyance (lack of activity):
Relevant data was not available or was not of good quality/obsolete
( ) Yes ( ) No
Relevant software was not available
( ) Yes ( ) No
Could not meet intended goals
( ) Yes ( ) No
Key/necessary tasks could not be completed
( ) Yes ( ) No
Expected outcomes were not realistic
( ) Yes ( ) No
Project, program, or plan did not provide sufficient benefits to the public
( ) Yes ( ) No
Complex legal/liability issues
( ) Yes ( ) No

Project or program could not be completed on-time
( ) Yes ( ) No
Lack of funding for the project
( ) Yes ( ) No
Project or program could not be completed within a realistic budget (capital/operating costs too high)
( ) Yes ( ) No
A different project, program, or plan/plan was suggested/adopted
( ) Yes ( ) No
Project, program, or plan could not receive approval by federal/state/local officials
( ) Yes ( ) No
Expertise to conduct analysis was not available or not financially feasible
( ) Yes ( ) No
Lack of political support
( ) Yes ( ) No

32. As part of the research, we may be examining sample data. Can we obtain sample data from you?
( ) Yes ( ) No ( ) Not available

33. Please feel free to write any additional comments on any of the various aspects covered in this survey.
[ ]

Thank you for your participation. We greatly appreciate your collaboration and time expended on this survey. Please click "finish" to submit your responses.

APPENDIX B

DESCRIPTIVE STATISTICS FROM THE SURVEY OF TRANSPORTATION PROFESSIONALS

Distribution of survey respondents by organization (N=182)

Organization	N	%
VDOT	82	45
MPO/TPO/VDRPT/Locality/City	47	26
Consulting Company	53	29

What kind of work do you do primarily? (check up to 3 options) (N=182)

Variable	VDOT	MPO/Locality	Consulting	Total
Develop/manage projects	17 (20.73%)	11(23.40%)	18(33.96%)	46(25.27%)
Develop/manage a program	21 (25.61%)	10(21.28%)	2(3.77%)	33(18.13%)
Develop/manage plans	5 (6.10%)	0(0.00%)	8(15.09%)	13(7.14%)
Public Involvement	4 (4.88%)	12(25.53%)	8(15.09%)	24(13.19%)
Manage consultants	21 (25.61%)	11(23.40%)	8(15.09%)	40(21.98%)
Transportation operations	22 (26.83%)	5(10.64%)	10(18.87%)	37(20.33%)
Mobility/congestion monitoring/management	8 (9.76%)	6(12.77%)	0(0.00%)	14(7.69%)
Safety/performance analysis	6 (7.32%)	6(12.77%)	6(11.32%)	18(9.89%)
Security/emergency planning	4 (4.88%)	2(4.26%)	1(1.89%)	7(3.85%)
Land use and transportation analysis	9 (10.98%)	14(29.79%)	9(16.98%)	32(17.58%)
Financial planning/programming of projects	8 (9.76%)	12(25.53%)	2(3.77%)	22(12.09%)
Conduct studies	13 (15.85%)	13(27.66%)	12(22.64%)	38(20.88%)
Get approvals for projects	7 (8.54%)	2(4.26%)	9(16.98%)	18(9.89%)
Freight transportation	0 (0.00%)	2(4.26%)	2(3.77%)	4(2.20%)
Project/program design, construction, or maintenance	18 (21.95%)	9(19.15%)	6(11.32%)	33(18.13%)
Other	19 (23.17%)	0(0.00%)	8(15.09%)	27(14.84%)

Note: The percentages provided for VDOT, locality, and consulting are based on sample sizes for each group (82 for VDOT, 47 for MPO, 53 for consulting. The percentages provided in Total column are based on 182 responses.

Provide the number of persons who are under your supervision.

Organization	Sample size	Mean	Std. Dev.	Min	Max
VDOT	82	18.14	38.19	0	200
MPO/TPO/VDRPT/Locality/City	47	12.05	34.29	0	200
Consulting Company	53	45.26	103.14	0	500

What is the level of highest education you have completed? (N=182)

Variables	VDOT	MPO/Locality	Consulting	Total
High school or less	1 (1.22%)	0 (0%)	0 (0%)	1 (0.55%)
Some college	2 (2.44%)	2 (4.26%)	1 (1.89%)	5 (2.75%)
Vocational or technical school	1 (1.22%)	0 (0%)	0 (0%)	1 (0.55%)

Completed college (Bachelor's degree)	38 (46.34%)	18 (38.3%)	26 (49.06%)	82 (45.05%)
Graduate degree (Masters or Ph.D. degree)	36 (43.9%)	26 (55.32%)	24 (45.28%)	86 (47.25%)
Other	4 (4.88%)	1 (2.13%)	2 (3.77%)	7 (3.85%)
Total	82 (100%)	47 (100%)	53 (100%)	182 (100%)

Note: The percentages provided for VDOT, locality, and consulting are based on sample sizes for each group (82 for VDOT, 47 for MPO, 53 for consulting. The percentages provided in Total column are based on 182 responses.

Do you have licenses or certifications? (N=182)

	VDOT	MPO/Locality	Consulting	Total
EIT	6 (7.32%)	4 (8.51%)	5 (9.43%)	15 (8.24%)
PE	25 (30.49%)	11 (23.4%)	24 (45.28%)	60 (32.97%)
PTOE	8 (9.76%)	2 (4.26%)	7 (13.21%)	17 (9.34%)
AICP	5 (6.1%)	12 (25.53%)	2 (3.77%)	19 (10.44%)
Other	17 (20.73%)	5 (10.64%)	7 (13.21%)	29 (15.93%)

Note: 1) The percentages provided for VDOT, locality and consulting are based on sample sizes for each group (82 for VDOT, 47 for MPO, 53 for consulting); 2) The percentages provided in Total column are based on 182 responses; 3) Percentages do not add to 100% because multiple responses were permitted.

How many years of experience do you have in your field?

Organization	Sample size (N)	Mean	Std. Dev.	Min	Max
VDOT	82	22.84	8.84	6	40
MPO/TPO/VDRPT/Locality/City	47	17.82	11.03	1.5	41
Consulting Company	53	24.58	10.75	5	50

How long have you held your current position?

Organization	Sample size (N)	Mean	Std. Dev.	Min	Max
VDOT	82	6.93	5.40	0	25
MPO/TPO/VDRPT/Locality/City	47	6.52	6.66	0.25	37
Consulting Company	53	9.60	7.37	0.2	40

Currently used data (N=182)

Variable	VDOT	MPO/Locality	Consulting	Total
VDOT GIS files	48(58.54%)	13 (27.66%)	16(30.19%)	77(42.31%)
LandTrack	17(20.73%)	1 (2.13%)	4(7.55%)	22(12.09%)
LUPS	11(13.41%)	1 (2.13%)	3(5.66%)	15(8.24%)
VDOT-TOC	12(14.63%)	2 (4.26%)	4(7.55%)	18(9.89%)
VDOT-RNS	39(47.56%)	2 (4.26%)	4(7.55%)	45(24.73%)
VDOT-TMS	21(25.61%)	4 (8.51%)	11(20.75%)	36(19.78%)
Incident Management Info. Sys.	9(10.98%)	1 (2.13%)	2(3.77%)	12(6.59%)
Archived Data Mgmt. Sys.	8(9.76%)	3 (6.38%)	3(5.66%)	14(7.69%)
HSIP data	19(23.17%)	6 (12.77%)	4(7.55%)	29(15.93%)
FARS data	6(7.32%)	2 (4.26%)	5(9.43%)	13(7.14%)
NHTSA data	7(8.54%)	4 (8.51%)	5(9.43%)	16(8.79%)
SPS (Statewide Planning Sys.)	21(25.61%)	9 (19.15%)	9(16.98%)	39(21.43%)

Small Urban Transport. Plans	9(10.98%)	2 (4.26%)	3(5.66%)	14(7.69%)
RUMS	7(8.54%)	1 (2.13%)	4(7.55%)	12(6.59%)
BSA (Bridge Structure Analysis)	5(6.10%)	1 (2.13%)	4(7.55%)	10(5.49%)
511 website data	31(37.80%)	9 (19.15%)	5(9.43%)	45(24.73%)
INRIX	24(29.27%)	8 (17.02%)	4(7.55%)	36(19.78%)
CEDAR	27(32.93%)	0 (0.00%)	2(3.77%)	29(15.93%)
AMS	16(19.51%)	0 (0.00%)	4(7.55%)	20(10.99%)
IHS Global Insight, Inc.	5(6.10%)	8 (17.02%)	3(5.66%)	16(8.79%)
PIERS	0(0.00%)	0 (0.00%)	1(1.89%)	1(0.55%)
FAF	2(2.44%)	6 (12.77%)	7(13.21%)	15(8.24%)
CFS (Commodity Flow Survey)	2(2.44%)	6 (12.77%)	6(11.32%)	14(7.69%)
TREDIS	3(3.66%)	2 (4.26%)	2(3.77%)	7(3.85%)
ABDS	9(10.98%)	0 (0.00%)	0(0.00%)	9(4.95%)
CFS (Cash Forecasting Sys.)	3(3.66%)	0 (0.00%)	0(0.00%)	3(1.65%)
FMS (Financial Mgmt. Sys.)	28(34.15%)	0 (0.00%)	2(3.77%)	30(16.48%)
Trns*port	19(23.17%)	0 (0.00%)	8(15.09%)	27(14.84%)
SYIP-Six-Year Program	43(52.44%)	17 (36.17%)	10(18.87%)	70(38.46%)
VA NHTS data	10(12.20%)	8 (17.02%)	5(9.43%)	23(12.64%)
VA University Travel Survey	3(3.66%)	3 (6.38%)	2(3.77%)	8(4.40%)
Congestion pricing survey	4(4.88%)	0 (0.00%)	3(5.66%)	7(3.85%)
Census data	19(23.17%)	25 (53.19%)	16(30.19%)	60(32.97%)
ACS-American Community Survey	11(13.41%)	22 (46.81%)	9(16.98%)	42(23.08%)
CTPP	14(17.07%)	14 (29.79%)	8(15.09%)	36(19.78%)
BTS - (TransStats) data	11(13.41%)	9 (19.15%)	13(24.53%)	33(18.13%)
Weldon Cooper data	20(24.39%)	19 (40.43%)	6(11.32%)	45(24.73%)
Bureau of Labor Statistics data	10(12.20%)	17 (36.17%)	15(28.30%)	42(23.08%)
Bureau of Economic Analysis data	8(9.76%)	15 (31.91%)	13(24.53%)	36(19.78%)
VA Transport. Marketing Research	1(1.22%)	0 (0.00%)	2(3.77%)	3(1.65%)
PMS Data	11(13.41%)	2 (4.26%)	7(13.21%)	20(10.99%)
GIS-GDBMS Data	6(7.32%)	0 (0.00%)	2(3.77%)	8(4.40%)
CQIP	7(8.54%)	0 (0.00%)	3(5.66%)	10(5.49%)
LIS (Legislative Information System)	29(35.37%)	5 (10.64%)	10(18.87%)	44(24.18%)
FAA Air Travel Data	1(1.22%)	3 (6.38%)	4(7.55%)	8(4.40%)
VA DEQ Data	7(8.54%)	7 (14.89%)	8(15.09%)	22(12.09%)
DMV Data	8(9.76%)	11 (23.40%)	4(7.55%)	23(12.64%)
Port Data (VPA and AAPA)	1(1.22%)	3 (6.38%)	4(7.55%)	8(4.40%)
Rail Data (Amtrak) - Passenger	2(2.44%)	8 (17.02%)	5(9.43%)	15(8.24%)
TTI Data	9(10.98%)	9 (19.15%)	9(16.98%)	27(14.84%)
FTA NTD	4(4.88%)	10 (21.28%)	7(13.21%)	21(11.54%)

Note: 1) The percentages provided for VDOT, locality and consulting are based on sample sizes for each group (82 for VDOT, 47 for MPO, 53 for consulting); 2) The percentages provided in Total column are based on 182 responses; 3) Percentages do not add to 100% because multiple responses were permitted.

Data needed but currently unavailable (N=182)

Variable	VDOT	MPO/Locality	Consulting	Total
VDOT GIS files	5 (6.1%)	12 (25.53%)	10 (18.87%)	27 (14.84%)
LandTrack	3 (3.66%)	11 (23.4%)	7 (13.21%)	21 (11.54%)
LUPS	4 (4.88%)	11 (23.4%)	7 (13.21%)	22 (12.09%)
VDOT-TOC	9 (10.98%)	12 (25.53%)	11 (20.75%)	32 (17.58%)
VDOT-RNS	9 (10.98%)	17 (36.17%)	13 (24.53%)	39 (21.43%)
VDOT-TMS	7 (8.54%)	12 (25.53%)	10 (18.87%)	29 (15.93%)
Incident Management Info. Sys.	7 (8.54%)	12 (25.53%)	9 (16.98%)	28 (15.38%)
Archived Data Mgmt. Sys.	10 (12.2%)	7 (14.89%)	6 (11.32%)	23 (12.64%)
HSIP data	4 (4.88%)	21 (44.68%)	8 (15.09%)	33 (18.13%)
FARS data	7 (8.54%)	15 (31.91%)	8 (15.09%)	30 (16.48%)
NHTSA data	6 (7.32%)	11 (23.4%)	6 (11.32%)	23 (12.64%)
SPS (Statewide Planning Sys.)	5 (6.1%)	10 (21.28%)	7 (13.21%)	22 (12.09%)
Small Urban Transport. Plans	6 (7.32%)	11 (23.4%)	8 (15.09%)	25 (13.74%)
RUMS	6 (7.32%)	8 (17.02%)	6 (11.32%)	20 (10.99%)
BSA (Bridge Structure Analysis)	4 (4.88%)	5 (10.64%)	7 (13.21%)	16 (8.79%)
511 website data	2 (2.44%)	1 (2.13%)	2 (3.77%)	5 (2.75%)
INRIX	4 (4.88%)	8 (17.02%)	9 (16.98%)	21 (11.54%)
CEDAR	3 (3.66%)	6 (12.77%)	8 (15.09%)	17 (9.34%)
AMS	6 (7.32%)	4 (8.51%)	6 (11.32%)	16 (8.79%)
IHS Global Insight, Inc.	3 (3.66%)	6 (12.77%)	6 (11.32%)	15 (8.24%)
PIERS	3 (3.66%)	5 (10.64%)	5 (9.43%)	13 (7.14%)
FAF	4 (4.88%)	4 (8.51%)	3 (5.66%)	11 (6.04%)
CFS (Commodity Flow Survey)	4 (4.88%)	3 (6.38%)	3 (5.66%)	10 (5.49%)
TREDIS	2 (2.44%)	10 (21.28%)	5 (9.43%)	17 (9.34%)
ABDS	3 (3.66%)	4 (8.51%)	1 (1.89%)	8 (4.4%)
CFS (Cash Forecasting Sys.)	2 (2.44%)	2 (4.26%)	2 (3.77%)	6 (3.3%)
FMS (Financial Mgmt. Sys.)	2 (2.44%)	4 (8.51%)	3 (5.66%)	9 (4.95%)
Trns*port	2 (2.44%)	8 (17.02%)	3 (5.66%)	13 (7.14%)
SYIP-Six-Year Program	4 (4.88%)	9 (19.15%)	4 (7.55%)	17 (9.34%)
VA NHTS data	3 (3.66%)	8 (17.02%)	4 (7.55%)	15 (8.24%)
VA University Travel Survey	4 (4.88%)	5 (10.64%)	2 (3.77%)	11 (6.04%)
Congestion pricing survey	3 (3.66%)	9 (19.15%)	5 (9.43%)	17 (9.34%)
Census data	1 (1.22%)	1 (2.13%)	5 (9.43%)	7 (3.85%)
ACS-American Community Survey	0 (0%)	0 (0%)	3 (5.66%)	3 (1.65%)
CTPP	1 (1.22%)	5 (10.64%)	2 (3.77%)	8 (4.4%)
BTS - (TransStats) data	0 (0%)	7 (14.89%)	4 (7.55%)	11 (6.04%)

Weldon Cooper data	1 (1.22%)	1 (2.13%)	2 (3.77%)	4 (2.2%)
Bureau of Labor Statistics data	1 (1.22%)	2 (4.26%)	1 (1.89%)	4 (2.2%)
Bureau of Economic Analysis data	1 (1.22%)	2 (4.26%)	1 (1.89%)	4 (2.2%)
VA Transport. Marketing Research	3 (3.66%)	6 (12.77%)	4 (7.55%)	13 (7.14%)
PMS Data	4 (4.88%)	5 (10.64%)	1 (1.89%)	10 (5.49%)
GIS-GDBMS Data	2 (2.44%)	6 (12.77%)	3 (5.66%)	11 (6.04%)
CQIP	3 (3.66%)	1 (2.13%)	3 (5.66%)	7 (3.85%)
LIS (Legislative Information System)	0 (0%)	2 (4.26%)	0 (0%)	2 (1.1%)
FAA Air Travel Data	3 (3.66%)	1 (2.13%)	1 (1.89%)	5 (2.75%)
VA DEQ Data	4 (4.88%)	4 (8.51%)	2 (3.77%)	10 (5.49%)
DMV Data	6 (7.32%)	4 (8.51%)	3 (5.66%)	13 (7.14%)
Port Data (VPA and AAPA)	4 (4.88%)	3 (6.38%)	2 (3.77%)	9 (4.95%)
Rail Data (Amtrak) – Passenger	6 (7.32%)	6 (12.77%)	3 (5.66%)	15 (8.24%)
TTI Data	2 (2.44%)	1 (2.13%)	3 (5.66%)	6 (3.3%)
FTA NTD	2 (2.44%)	1 (2.13%)	2 (3.77%)	5 (2.75%)

Note: 1) The percentages provided for VDOT, locality and consulting are based on sample sizes for each group (82 for VDOT, 47 for MPO, 53 for consulting); 2) The percentages provided in Total column are based on 182 responses; 3) Percentages do not add to 100% because multiple responses were permitted.

Why are you not able to access/use databases that can be beneficial in your work? (N=182)

Variable	VDOT	MPO/Locality	Consulting	Total
Cost of acquiring and maintaining the databases are too high	10(12.20%)	16(34.04%)	11(20.75%)	37(20.33%)
Takes too much time to get access	20(24.39%)	6(12.77%)	16(30.19%)	42(23.08%)
Demands for data are not high in my agency	7(8.54%)	7(14.89%)	8(15.09%)	22(12.09%)
Agency firewalls	11(13.41%)	11(23.40%)	8(15.09%)	30(16.48%)
Proprietary or sensitive information	12(14.63%)	7(14.89%)	9(16.98%)	28(15.38%)
Security issues	5(6.10%)	3(6.38%)	6(11.32%)	14(7.69%)
Computer or server limitations for handling big or complex databases	8(9.76%)	4(8.51%)	5(9.43%)	17(9.34%)
Other	5(6.10%)	1(2.13%)	8(15.09%)	14(7.69%)

Note: 1) The percentages provided for VDOT, locality and consulting are based on sample sizes for each group (82 for VDOT, 47 for MPO, 53 for consulting); 2) The percentages provided in Total column are based on 182 responses; 3) Percentages do not add to 100% because multiple responses were permitted.

How frequently primary database is used? (N=182)

Variable	VDOT	MPO/Locality	Consulting	Total
Missing	7 (8.54%)	7 (14.89%)	13 (24.53%)	27 (14.84%)
Hourly/continuously	14 (17.07%)	1 (2.13%)	4 (7.55%)	19 (10.44%)
Daily	35 (42.68%)	10 (21.28%)	5 (9.43%)	50 (27.47%)
Weekly	15 (18.29%)	17 (36.17%)	18 (33.96%)	50 (27.47%)
Monthly	8 (9.76%)	9 (19.15%)	9 (16.98%)	26 (14.29%)
Other	3 (3.66%)	3 (6.38%)	4 (7.55%)	10 (5.49%)
Total	82 (100%)	47 (100%)	53 (100%)	182 (100%)

Note: The percentages provided for VDOT, locality, and consulting are based on sample sizes for each group (82 for VDOT, 47 for MPO, 53 for consulting. The percentages provided in Total column are based on 182 responses.

Purpose for using primary database (check all that apply) (N=182)

Variable	VDOT	MPO/Locality	Consulting	Total
Analyze, model, or simulate	14 (17.07%)	16 (34.04%)	16 (30.19%)	46 (25.27%)
Planning and operations for transit, ped, bike	8 (9.76%)	15 (31.91%)	6 (11.32%)	29 (15.93%)
Visualize and display data/GIS	21 (25.61%)	20 (42.55%)	11 (20.75%)	52 (28.57%)
System management, operations, signals, ITS	19 (23.17%)	6 (12.77%)	4 (7.55%)	29 (15.93%)
Transportation conditions prediction/ unreliability	7 (8.54%)	5 (10.64%)	6 (11.32%)	18 (9.89%)
Emergency planning and operations	9 (10.98%)	6 (12.77%)	2 (3.77%)	17 (9.34%)
Safety/performance analysis	16 (19.51%)	10 (21.28%)	10 (18.87%)	36 (19.78%)
Security analysis	4 (4.88%)	0 (0%)	2 (3.77%)	6 (3.3%)
Environmental (air quality) and energy analysis	6 (7.32%)	5 (10.64%)	8 (15.09%)	19 (10.44%)
Financial Planning and Programming	22 (26.83%)	11 (23.4%)	4 (7.55%)	37 (20.33%)
Freight Transportation	1 (1.22%)	3 (6.38%)	3 (5.66%)	7 (3.85%)
Land use and transportation analysis	15 (18.29%)	17 (36.17%)	10 (18.87%)	42 (23.08%)
Public Involvement	9 (10.98%)	12 (25.53%)	8 (15.09%)	29 (15.93%)
Title VI/environmental justice	3 (3.66%)	6 (12.77%)	1 (1.89%)	10 (5.49%)
Maintenance of infrastructure	13 (15.85%)	4 (8.51%)	4 (7.55%)	21 (11.54%)
Other	17 (20.73%)	4 (8.51%)	15 (28.3%)	36 (19.78%)

Note: 1) The percentages provided for VDOT, locality and consulting are based on sample sizes for each group (82 for VDOT, 47 for MPO, 53 for consulting); 2) The percentages provided in Total column are based on 182 responses; 3) Percentages do not add to 100% because multiple responses were permitted.

How do you characterize the primary use database? (check all that apply) (N=182)

Variable	VDOT	MPO/Locality	Consulting	Total
Real-time data	18 (21.95%)	3 (6.38%)	6 (11.32%)	27 (14.84%)
Archived/historical data	31 (37.8%)	18 (38.3%)	17 (32.08%)	66 (36.26%)
Qualitative data	9 (10.98%)	2 (4.26%)	5 (9.43%)	16 (8.79%)
Quantitative data	23 (28.05%)	14 (29.79%)	16 (30.19%)	53 (29.12%)
Geographically referenced data	19 (23.17%)	14 (29.79%)	12 (22.64%)	45 (24.73%)
Other	22 (26.83%)	5 (10.64%)	8 (15.09%)	35 (19.23%)

Note: 1) The percentages provided for VDOT, locality and consulting are based on sample sizes for each group (82 for VDOT, 47 for MPO, 53 for consulting); 2) The percentages provided in Total column are based on 182 responses; 3) Percentages do not add to 100% because multiple responses were permitted.

How do you access your primary use databases? (check all that apply) (N=182)

Variable	VDOT	MPO/Locality	Consulting	Total
Intranet	47 (57.32%)	11 (23.4%)	5 (9.43%)	63 (34.62%)
Internet	29 (35.37%)	21 (44.68%)	25 (47.17%)	75 (41.21%)
FTP-File Transfer Protocol	0 (0%)	7 (14.89%)	2 (3.77%)	9 (4.95%)
CD-Rom/DVD	0 (0%)	1 (2.13%)	4 (7.55%)	5 (2.75%)
Hardcopy/paper	0 (0%)	3 (6.38%)	2 (3.77%)	5 (2.75%)

Directly from computer hard-disk	6 (7.32%)	4 (8.51%)	5 (9.43%)	15 (8.24%)
Other	3 (3.66%)	0 (0%)	6 (11.32%)	9 (4.95%)

Note: 1) The percentages provided for VDOT, locality and consulting are based on sample sizes for each group (82 for VDOT, 47 for MPO, 53 for consulting); 2) The percentages provided in Total column are based on 182 responses; 3) Percentages do not add to 100% because multiple responses were permitted.

Data quality concerns? (N=182)

	missing	Strong Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strong Agree
Easy to comprehend and analyze	13%	1%	7%	18%	48%	13%
Available in a user friendly format	15%	2%	9%	22%	41%	12%
Well-documented	15%	1%	11%	27%	34%	12%
Current and timely	16%	2%	10%	23%	39%	10%
Valid and reliable	15%	1%	8%	18%	48%	10%

How the primary use data are collected? (Check all that apply). (N=182)

Variable	VDOT	MPO/Locality	Consulting	Total
Manually, including hand-held devices	29 (35.37%)	11 (23.4%)	13 (24.53%)	53 (29.12%)
Surveys	8 (9.76%)	7 (14.89%)	13 (24.53%)	28 (15.38%)
Automatically (e.g., detectors)	24 (29.27%)	10 (21.28%)	12 (22.64%)	46 (25.27%)
Don't know	15 (18.29%)	13 (27.66%)	8 (15.09%)	36 (19.78%)
Other	19 (23.17%)	6 (12.77%)	6 (11.32%)	31 (17.03%)

Note: 1) The percentages provided for VDOT, locality and consulting are based on sample sizes for each group (82 for VDOT, 47 for MPO, 53 for consulting); 2) The percentages provided in Total column are based on 182 responses; 3) Percentages do not add to 100% because multiple responses were permitted.

How do you process or analyze your primary use data? (check all that apply). (N=182)

Variable	VDOT	MPO/Locality	Consulting	Total
No processing/analyses are done	14 (17.07%)	6 (12.77%)	11 (20.75%)	31 (17.03%)
Data are aggregated	22 (26.83%)	4 (8.51%)	11 (20.75%)	37 (20.33%)
Data are visualized in graphical format	28 (34.15%)	11 (23.4%)	15 (28.3%)	54 (29.67%)
Descriptive statistics	14 (17.07%)	8 (17.02%)	14 (26.42%)	36 (19.78%)
Data are spatially analyzed	19 (23.17%)	21 (44.68%)	18 (33.96%)	58 (31.87%)
Simulations	4 (4.88%)	2 (4.26%)	3 (5.66%)	9 (4.95%)
Other	18 (21.95%)	7 (14.89%)	4 (7.55%)	29 (15.93%)

Note: 1) The percentages provided for VDOT, locality and consulting are based on sample sizes for each group (82 for VDOT, 47 for MPO, 53 for consulting); 2) The percentages provided in Total column are based on 182 responses; 3) Percentages do not add to 100% because multiple responses were permitted.

How successful is this database in addressing its intended use (e.g., helps one to understand transportation problems or provides insights regarding solutions)? (N=182)

Variable	VDOT	MPO/Locality	Consulting	Total
Not at all successful	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)
Not very successful	4 (4.88%)	4 (8.51%)	3 (5.66%)	11 (6.04%)
Successful	48 (58.54%)	25 (53.19%)	23 (43.40%)	96 (52.75%)

Very Successful	22 (26.83%)	6 (12.77%)	7 (13.21%)	35 (19.23%)
Not sure/Not applicable	5 (6.10%)	6 (12.77%)	9 (16.98%)	20 (10.99%)

Note: 1) The percentages provided for VDOT, locality and consulting are based on sample sizes for each group (82 for VDOT, 47 for MPO, 53 for consulting); 2) The percentages provided in Total column are based on 182 responses; 3) Percentages do not add to 100% because some responses were missing.

What are some of the suggested solutions? (N=182)

Means	VDOT	MPO/Locality	Consulting	Total
Increase awareness of databases in your agency	40(48.78%)	14 (29.79%)	10(18.87%)	64(35.16%)
Improve data access in your agency	27(32.93%)	18 (38.30%)	8(15.09%)	53(29.12%)
Increase ease of data export/exchange	28(34.15%)	11 (23.40%)	7(13.21%)	46(25.27%)
Aid data storage/archiving	15(18.29%)	4 (8.51%)	1(1.89%)	20(10.99%)
Improve data quality	29(35.37%)	11 (23.40%)	12(22.64%)	52(28.57%)
Improve data completeness	25(30.49%)	13 (27.66%)	10(18.87%)	48(26.37%)
Improve data security	3(3.66%)	1 (2.13%)	1(1.89%)	5(2.75%)
Reduce liability associated with data use	4(4.88%)	2 (4.26%)	4(7.55%)	10(5.49%)
Facilitate distribution of data to other agencies	11(13.41%)	5 (10.64%)	3(5.66%)	19(10.44%)
Facilitate distribution of data to the public	13(15.85%)	4 (8.51%)	4(7.55%)	21(11.54%)
Collect new data on certain (new) performance measures	17(20.73%)	5 (10.64%)	4(7.55%)	26(14.29%)
Create new data partnerships	16(19.51%)	4 (8.51%)	5(9.43%)	25(13.74%)

Note: 1) The percentages provided for VDOT, locality and consulting are based on sample sizes for each group (82 for VDOT, 47 for MPO, 53 for consulting); 2) The percentages provided in Total column are based on 182 responses; 3) Percentages do not add to 100% because some responses were missing.

In general, how satisfied are you with access and use of databases available at work? (N=182)

Variable	VDOT	MPO/Locality	Consulting	Total
Very dissatisfied	1 (1.22%)	0 (0.00%)	1 (1.89%)	2 (1.10%)
Dissatisfied	7 (8.54%)	9 (19.15%)	2 (3.77%)	18 (9.89%)
Neither satisfied nor dissatisfied	34 (41.46%)	12 (25.53%)	18 (33.96%)	64 (35.16%)
Satisfied	32 (39.02%)	18 (38.30%)	19 (35.85%)	69 (37.91%)
Very satisfied	4 (4.88%)	1 (2.13%)	1 (1.89%)	6 (3.30%)
Not sure/Not applicable	3 (3.66%)	2 (4.26%)	5 (9.43%)	10 (5.49%)

Note: 1) The percentages provided for VDOT, locality and consulting are based on sample sizes for each group (82 for VDOT, 47 for MPO, 53 for consulting); 2) The percentages provided in Total column are based on 182 responses; 3) Percentages do not add to 100% because some responses were missing.

Do you have any substantial constraints on accessing databases you use regularly at work? (e.g., cannot access it from home/remote location) (N=182)

Variable	VDOT	MPO/Locality	Consulting	Total
No	61 (74.39%)	31 (65.96%)	39 (73.58%)	131 (71.98%)
Yes	15 (18.29%)	8 (17.02%)	6 (11.32%)	29 (15.93%)

Note: 1) The percentages provided for VDOT, locality and consulting are based on sample sizes for each group (82 for VDOT, 47 for MPO, 53 for consulting); 2) The percentages provided in Total column are based on 182 responses; 3) Percentages do not add to 100% because some responses were missing.

Do any of the databases you use have substantial quality problems, such as missing data, or incorrect data? (N=182)

Variable	VDOT	MPO/Locality	Consulting	Total
No	51 (62.20%)	34 (72.34%)	38 (71.70%)	123 (67.58%)
Yes	31 (37.80%)	13 (27.66%)	15 (28.30%)	59 (32.42%)

Note: The percentages provided for VDOT, locality, and consulting are based on sample sizes for each group (82 for VDOT, 47 for MPO, 53 for consulting. The percentages provided in Total column are based on 182 responses.

Software used (N=182)

Variables	VDOT	MPO/Locality	Consulting	Total
Oracle Operating Systems (Linux/Solaris)	16 (19.51%)	1 (2.13%)	4 (7.55%)	21 (11.54%)
Oracle-Java	11 (13.41%)	7 (14.89%)	4 (7.55%)	22 (12.09%)
Microsoft Access	49 (59.76%)	32 (68.09%)	34 (64.15%)	115 (63.19%)
Other Database Software	11 (13.41%)	9 (19.15%)	5 (9.43%)	25 (13.74%)
CUBE suite (Voyager & Avenue)	10 (12.2%)	12 (25.53%)	9 (16.98%)	31 (17.03%)
TransCAD	0 (0%)	2 (4.26%)	7 (13.21%)	9 (4.95%)
VISUM	1 (1.22%)	1 (2.13%)	6 (11.32%)	8 (4.4%)
HCS (Highway Capacity Software)	25 (30.49%)	9 (19.15%)	17 (32.08%)	51 (28.02%)
HSM	7 (8.54%)	2 (4.26%)	8 (15.09%)	17 (9.34%)
TRANSIMS	1 (1.22%)	0 (0%)	2 (3.77%)	3 (1.65%)
CORSIM/TSIS	14 (17.07%)	4 (8.51%)	14 (26.42%)	32 (17.58%)
Paramics	1 (1.22%)	0 (0%)	2 (3.77%)	3 (1.65%)
Synchro	21 (25.61%)	9 (19.15%)	15 (28.3%)	45 (24.73%)
Sim traffic	15 (18.29%)	5 (10.64%)	13 (24.53%)	33 (18.13%)
VISSIM	9 (10.98%)	2 (4.26%)	12 (22.64%)	23 (12.64%)
Dynasim	2 (2.44%)	2 (4.26%)	2 (3.77%)	6 (3.3%)
TransModeler	0 (0%)	0 (0%)	2 (3.77%)	2 (1.1%)
AIMSUN	0 (0%)	0 (0%)	1 (1.89%)	1 (0.55%)
TransCore	1 (1.22%)	1 (2.13%)	1 (1.89%)	3 (1.65%)
AutoCAD	0 (0%)	10 (21.28%)	25 (47.17%)	35 (19.23%)
MicroStation	22 (26.83%)	0 (0%)	23 (43.4%)	45 (24.73%)
ArchiCAD	0 (0%)	0 (0%)	2 (3.77%)	2 (1.1%)
Microsoft Office	78 (95.12%)	45 (95.74%)	50 (94.34%)	173 (95.05%)
Adobe Acrobat	77 (93.9%)	44 (93.62%)	50 (94.34%)	171 (93.96%)
ESRI ArcGIS	31 (37.8%)	32 (68.09%)	26 (49.06%)	89 (48.9%)
GIS-Integrator	36 (43.9%)	4 (8.51%)	10 (18.87%)	50 (27.47%)
ArcGIS Business Analyst	6 (7.32%)	2 (4.26%)	6 (11.32%)	14 (7.69%)
Microsoft Visual Studio	9 (10.98%)	3 (6.38%)	11 (20.75%)	23 (12.64%)
C or C++	4 (4.88%)	1 (2.13%)	7 (13.21%)	12 (6.59%)
SQL	17 (20.73%)	4 (8.51%)	10 (18.87%)	31 (17.03%)
Google Earth	52 (63.41%)	36 (76.6%)	43 (81.13%)	131 (71.98%)
Maps	62 (75.61%)	43 (91.49%)	48 (90.57%)	153 (84.07%)
SPSS	4 (4.88%)	2 (4.26%)	9 (16.98%)	15 (8.24%)

SAS	2 (2.44%)	0 (0%)	5 (9.43%)	7 (3.85%)
STATA	0 (0%)	0 (0%)	3 (5.66%)	3 (1.65%)

Note: 1) The percentages provided for VDOT, locality and consulting are based on sample sizes for each group (82 for VDOT, 47 for MPO, 53 for consulting); 2) The percentages provided in Total column are based on 182 responses; 3) Percentages do not add to 100% because multiple responses were permitted.

Software needed but unavailable (N=182)

Variables	VDOT (%))	MPO/Locality	Consulting	Total
Oracle Operating Systems (Linux/Solaris)	0 (0.00%)	1 (2.13%)	1 (1.89%)	2 (1.10%)
Oracle-Java	0 (0.00%)	2 (4.26%)	1 (1.89%)	3 (1.65%)
Microsoft Access	0 (0.00%)	1 (2.13%)	2 (3.77%)	3 (1.65%)
Other Database Software	0 (0.00%)	0 (0.00%)	1 (1.89%)	1 (0.55%)
CUBE suite (Voyager & Avenue)	1 (1.22%)	2 (4.26%)	2 (3.77%)	5 (2.75%)
TransCAD	1 (1.22%)	2 (4.26%)	3 (5.66%)	6 (3.30%)
VISUM	1 (1.22%)	4 (8.51%)	1 (1.89%)	6 (3.30%)
HCS (Highway Capacity Software)	0 (0.00%)	3 (6.38%)	1 (1.89%)	4 (2.20%)
HSM	1 (1.22%)	6 (12.77%)	3 (5.66%)	10 (5.49%)
TRANSIMS	0 (0.00%)	3 (6.38%)	1 (1.89%)	4 (2.20%)
CORSIM/TSIS	1 (1.22%)	2 (4.26%)	1 (1.89%)	4 (2.20%)
Paramics	0 (0.00%)	2 (4.26%)	1 (1.89%)	3 (1.65%)
Synchro	4 (4.88%)	2 (4.26%)	1 (1.89%)	7 (3.85%)
Sim traffic	2 (2.44%)	3 (6.38%)	0 (0.00%)	5 (2.75%)
VISSIM	1 (1.22%)	4 (8.51%)	1 (1.89%)	6 (3.30%)
Dynasim	0 (0.00%)	4 (8.51%)	1 (1.89%)	5 (2.75%)
TransModeler	1 (1.22%)	1 (2.13%)	2 (3.77%)	4 (2.20%)
AIMSUN	0 (0.00%)	1 (2.13%)	1 (1.89%)	2 (1.10%)
TransCore	1 (1.22%)	2 (4.26%)	2 (3.77%)	5 (2.75%)
AutoCAD	2 (2.44%)	1 (2.13%)	1 (1.89%)	4 (2.20%)
MicroStation	5 (6.10%)	0 (0.00%)	0 (0.00%)	5 (2.75%)
ArchiCAD	0 (0.00%)	0 (0.00%)	1 (1.89%)	1 (0.55%)
Microsoft Office	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)
Adobe Acrobat	1 (1.22%)	0 (0.00%)	0 (0.00%)	1 (0.55%)
ESRI ArcGIS	3 (3.66%)	0 (0.00%)	0 (0.00%)	3 (1.65%)
GIS-Integrator	0 (0.00%)	2 (4.26%)	0 (0.00%)	2 (1.10%)
ArcGIS Business Analyst	3 (3.66%)	4 (8.51%)	0 (0.00%)	7 (3.85%)
Microsoft Visual Studio	0 (0.00%)	1 (2.13%)	0 (0.00%)	1 (0.55%)
C or C++	0 (0.00%)	0 (0.00%)	1 (1.89%)	1 (0.55%)
SQL	0 (0.00%)	1 (2.13%)	0 (0.00%)	1 (0.55%)
Google Earth	7 (8.54%)	0 (0.00%)	1 (1.89%)	8 (4.40%)
Maps	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)
SPSS	5 (6.10%)	2 (4.26%)	1 (1.89%)	8 (4.40%)
SAS	3 (3.66%)	1 (2.13%)	1 (1.89%)	5 (2.75%)
STATA	0 (0.00%)	0 (0.00%)	1 (1.89%)	1 (0.55%)

Note: 1) The percentages provided for VDOT, locality and consulting are based on sample sizes for each group (82 for VDOT, 47 for MPO, 53 for consulting); 2) The percentages provided in Total column are based on 182 responses; 3) Percentages do not add to 100% because multiple responses were permitted.

Think about a recent project, program, or plan you have worked on in the past year that was successful. Would the project, program, or plan have been successful without access to certain transportation database(s)? (N=182)

Variable	VDOT	MPO/Locality	Consulting	Total
No	20 (24.39%)	12 (25.53%)	22 (41.51%)	54 (29.67%)
Yes	38 (46.34%)	24 (51.06%)	22 (41.51%)	84 (46.15%)
Not sure	24 (29.27%)	11 (23.40%)	9 (16.98%)	44 (24.18%)

Note: The percentages provided for VDOT, locality, and consulting are based on sample sizes for each group (82 for VDOT, 47 for MPO, 53 for consulting. The percentages provided in Total column are based on 182 responses.

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Think about this same project, program, or plan you have worked on in the past year. Would the success of this project, program, or plan have been possible without access to certain transportation software? (N=182)

Variable	VDOT	MPO/Locality	Consulting	Total
No	34 (41.46%)	18 (38.30%)	26 (49.06%)	78 (42.86%)
Yes	28 (34.15%)	16 (34.04%)	15 (28.30%)	59 (32.42%)
Not sure	20 (24.39%)	13 (27.66%)	12 (22.64%)	45 (24.73%)

Note: The percentages provided for VDOT, locality, and consulting are based on sample sizes for each group (82 for VDOT, 47 for MPO, 53 for consulting. The percentages provided in Total column are based on 182 responses.

Was there a recent project, program, or plan that you or your team worked on in the past year but did not complete on time? (N=182)

Variable	VDOT	MPO/Locality	Consulting	Total
No	66 (80.49%	42 (89.36%	38 (71.70%	146 (80.22%
Yes	16 (19.51%	5 (10.64%	15 (28.30%	36 (19.78%

Note: The percentages provided for VDOT, locality, and consulting are based on sample sizes for each group (82 for VDOT, 47 for MPO, 53 for consulting. The percentages provided in Total column are based on 182 responses.

Please indicate if the following were reasons why the project, program, or plan was unable to be completed or held in abeyance (lack of activity): (N=182)

Reason	VDOT	MPO/Locality	Consulting	Total
Relevant data was not available or was not of good quality/obsolete	6(7.32%)	2 (4.26%)	7(13.21%)	15(8.24%)
Relevant software was not available	2(2.44%)	1 (2.13%)	1(1.89%)	4(2.20%)
Could not meet intended goals	3(3.66%)	1 (2.13%)	1(1.89%)	5(2.75%)
Key/necessary tasks could not be completed	7(8.54%)	1 (2.13%)	2(3.77%)	10(5.49%)
Expected outcomes were not realistic	6(7.32%)	0 (0.00%)	5(9.43%)	11(6.04%)
Project, program, or plan did not provide sufficient benefits to the public	1(1.22%)	0 (0.00%)	0(0.00%)	1(0.55%)
Complex legal/liability issues	1(1.22%)	0 (0.00%)	0(0.00%)	1(0.55%)
Project or program could not be completed on-time	5(6.10%)	3 (6.38%)	9(16.98%)	17(9.34%)
Lack of funding for the project	5(6.10%)	1 (2.13%)	3(5.66%)	9(4.95%)
Project or program could not be completed within a realistic budget (capital/operating costs too high)	4(4.88%)	1 (2.13%)	2(3.77%)	7(3.85%)
A different project, program, or plan/plan was suggested/adopted	1(1.22%)	0 (0.00%)	3(5.66%)	4(2.20%)
Project, program, or plan could not receive approval by federal/state/local officials	2(2.44%)	0 (0.00%)	1(1.89%)	3(1.65%)
Expertise to conduct analysis was not available or not financially feasible	1(1.22%)	2 (4.26%)	0(0.00%)	3(1.65%)
Lack of political support	0(0.00%)	1 (2.13%)	2(3.77%)	3(1.65%)

Note: 1) The percentages provided for VDOT, locality and consulting are based on sample sizes for each group (82 for VDOT, 47 for MPO, 53 for consulting); 2) The percentages provided in Total column are based on 182 responses; 3) Percentages do not add to 100% because some responses were empty.

As part of the research, we may be examining sample data. Can we obtain sample data from you? (N=182)

Variable	VDOT	MPO/Locality	Consulting	Total
No	28 (34.15%)	15(31.91%)	23 (43.40%)	66 (36.26%)
Yes	37 (45.12%)	17(36.17%)	9 (16.98%)	63 (34.62%)
Not available	17 (20.73%)	15(31.91%)	21 (39.62%)	53 (29.12%)

Note: The percentages provided for VDOT, locality, and consulting are based on sample sizes for each group (82 for VDOT, 47 for MPO, 53 for consulting. The percentages provided in Total column are based on 182 responses.

Selected comments by respondents to Survey of Professionals

Most comments from the survey respondents fall in predetermined categories such as:

- VDOT needs to expend more effort in improving the quality and timeliness of crash data.
- I've harped on the age of crash data several times in this survey.
- Better access to data and transportation software would help us tremendously.
- Secondary issue is consistency, quality and reliability of some of the data.
- Our biggest concern is getting direct access to data included in VDOT's internal databases.
- Need more time for training on current databases. Knowing what data sources are available is key.
- Many other programs are used by my staff that I may not have access to.

Additionally, there are several interesting comments as follows:

- Illinois DOT maintains a GIS application for their AADT data that displays the most recent AADT right on the screen so there is no clicking-through for the basic data. Drill-down is then available for more in-depth data. It would also be nice to be able to access RNS data by milepoint - currently able to search by MP, but unable to ascertain where the specific data is located without jumping through hoops on the GIS page for each piece.
- It would be interesting to conduct a survey of data providers (asking them what information they need from users). It may be the case that solutions lie in two-way conversations between providers and users.
- The survey didn't mention SharePoint. SharePoint provides a good platform for this, but we need the entire suite of tools to fully leverage this product and share information. SharePoint workflows will eliminate much of the "data entry" that goes on, since the systems will be able to glean much of the performance data from the workflow. Tools like SharePoint PerformancePoint and Dashboard Designer will enable us to take the workflow data and display it, and may eliminate the need for many standalone systems (like our current Dashboard).
- Having a data committee including members from different divisions to work together and to share knowledge and information to each other.
- We need the ability to geo-reference data. Most of VDOT's data can be tied to a location (Lat/Long) but that information is not available in most systems. Location information, combined with the right geo-analytical tools (ArcGIS, Tableau, RITIS, etc.) will open up a whole new world of data analyses. We also need the ability to share that information easily.
- It should be possible to "subscribe" to datasets, that is, to have new data pushed out to subscribers or to have a simple API that would allow users to query the newest observations as new data becomes available. For example, it just does not make sense that I can't simply download a historical series of lane-mile data by jurisdiction and then have it update as new data is made available. Or, query the TVT published data with the option of drilling down to the raw observations on which it is based.

APPENDIX C

TELEPHONE INTERVIEW QUESTIONS FOR VDOT'S CHIEF INFORMATION OFFICER

1. What are some of the important recently completed data initiatives that VDOT's Information Technology Division has undertaken? (please list)

2. What are other data initiatives that are on the drawing board?

3. Is there a particular user group or specific VDOT business needs that have been the focus of recent data initiatives?

4. VDOT has a Data Warehouse containing GIS-HPMS data; please tell us if other datasets (e.g., safety and emissions data) are also linked?

5. Is there any other business software that VDOT has used (e.g., Oracle, others) to facilitate data storage and data integration?

6. If a strategic plan for ITD exists, will you be willing to share it?

7. Please tell us VDOT ITD priorities for improving:
    a. Data storage? (high, medium, or low)
    b. Data access by staff? (high, medium, or low)
    c. Data sharing with external stakeholders? (high, medium, or low)

8. What are some of the key constraints that relate to data access and sharing? E.g., policy, organizational, technology, staffing, budget?

9. As increasing amounts of actionable data are being generated, how are you planning to handle large-scale (big) databases?

10. What are some of the major constraints in terms of VITA & VDOT policies that preclude some types of data from being shared i) within VDOT and ii) outside of VDOT (to other stakeholders such as MPOs).

11. Is there an existing VDOT data coordination committee that provides recommendations on collection, integration, and sharing various types of data?

12. Do you have any thoughts on the role of ITD that you would like to share?

APPENDIX D

FINDINGS FROM THE TECHNICAL REVIEW PANEL SURVEY REGARDING SOLUTION FEASIBILITY

1) Data Issues: Respondents indicated level of agreement with statements, on a 5-point scale ranging from strongly disagree (=1) to strongly agree (=5):

- On average, respondents strongly agreed (4.7) that there is room to increase awareness of currently available VDOT databases among VDOT staff.
- Respondents agreed (4.0) that barriers exist to sharing/accessing databases within VDOT, e.g., because of agency firewalls and proprietary or sensitive data.
- Respondents were neutral (3.0) that databases created by VDOT and used by VDOT staff are current and timely.
- Respondents were neutral (3.0) when asked: for handling big databases, VDOT staff has substantial limitations on their computer and server capabilities.
- Respondents agreed (4.3) that Overall, there is a need to improve data access.

2) Data solution strategies: Provided on a 5-point scale ranging from strongly disagree (=1) to strongly agree (=5):

- On average, respondents agreed (4.0) that VDOT should collect new data on certain transportation performance measures, e.g., network reliability.
- Respondents moderately agreed (3.3) that VDOT should create new data partnerships (similar to Inrix).
- Respondents strongly agreed (4.7) that VDOT should further facilitate distribution of data to other agencies/organizations (e.g., TPOs).
- Respondents agreed (4.0) that VDOT should further facilitate distribution of data to the public.
- One respondent gave additional thoughts on data solution strategies: VDOT divisions should create user groups that include MPO staffs and interested local governments involved in transportation planning. These groups should be led by VDOT technical staff and serve as a forum to advise MPO and local staffs as to use and applications of VDOT available data. VDOT should also provide technical assistance to MPOs to enable them to use VDOT generated or managed data (INRIX travel time data and accident data for use on the MPO's CMP-Congestion Management Process).

3) Specific data solutions: Assessment of the impact that suggested solutions can have within VDOT (1=Low Impact & 5=High Impact).

- Respondents believe that the solution of systematically linking and integrating disparate databases for various applications can have a significant impact (4.0) within VDOT.
- Respondents believe that the solution of increasing awareness of data resources can have a significant impact (4.0) within VDOT.
- Respondents believe the solution of providing more privileges/access to data needed by certain transportation planning data users can have a significant impact (4.3) within VDOT.
- Respondents believe the solution of facilitating and enhancing use of large datasets by providing analytics and data mining solutions can have a significant impact (4.0) within VDOT.
- One respondent commented on solutions concerning the data needs of VDOT staff and stakeholders: I would like to see VDOT do more from the Central Office level to reach out to MPO's and VDOT district staffs to let us know about resources and availability of data that we can use for meeting MPO planning requirements. My impression is that VDOT central office feels like it is not their job to help MPO's in addressing their data requirements and providing us with assistance is something they may work in when the have time or if we send them several requests and reminders.

4) Specific VDOT Divisions or offices who should work together on implementing data solutions?

- One respondent answered this question: Maintenance, Traffic Engineering, Transportation and Mobility Planning, Programming, Environmental, Structure & Bridge, RW & Utilities Divisions.

5) Respondents were asked to categorize the databases below (as A or B) based on to the following definitions:

- One respondent answered all questions and one respondent selectively gave suggestions for some databases. The responses are shown as below:

Databases	**Category**	**Solutions**	**Other suggestions**
VDOT GIS files (e.g., Online Transportation Information Map)	A	Improve sharing	Respondent 1: Increase training on use of ArcGIS; common site and naming convention to store shape
LandTrack (Land Development Tracking System)	A	Increase awareness	Respondent 1: Increase GIS linkage
LUPS (Land Use Permit System)	A	Improve data quality	Respondent 1: Make system more stable, add GIS functionality
VDOT-TOC (Traffic Operations Center-TransOps data)	A	Increase awareness	Respondent 1: Don't know what this is
VDOT-RNS (Roadway Network System-includes structures, traffic, safety, maintenance data)	A	Improve data quality	Respondent 1: Make more user-friendly, update data
VDOT-TMS (Traffic Monitoring System)	A	Increase awareness	Respondent 1: Make more user-friendly
Real-time Incident Management Information System	A	Increase awareness	Respondent 1: Don't know what data is there
Archived Data Management System	A	Increase awareness	Respondent 1: Not sure what this is
HSIP (Highway Safety Information Program) data	A	Increase awareness	Respondent 1: Don't know what data is there
SPS (Statewide Planning System)	A	Improve sharing	Respondent 1: Make availability more general across dept./external
Small Urban Transportation Plans database	B	Increase awareness	Respondent 1: Don't know what data is there
RUMS (Right of Way and Utilities Management System)	A	Improve access	Respondent 1: Don't know what data is there
BSA (Bridge Structure Analysis)	A	Increase awareness	Respondent 1: Don't know what data is there
511 website, alerts, and voice recognition data	B	Improve data quality	Respondent 1: Info frequently not current
CEDAR (Comprehensive Environmental Data and Reporting System)	A	Improve sharing	Respondent 1: Don't know what data is there
AMS (Asset Management System)	A	Improve access	Respondent 1: Don't know what data is there
FAF (Freight Analysis Framework-FHWA database)	B	Increase awareness	Respondent 1: Don't know what data is there
ABDS (Annual Budget Development System)	A	Increase awareness	Respondent 1: Limited need for this one
CFS (Cash Forecasting System)	A	Increase awareness	Respondent 1: Limited need for this one

Databases	Category	Solutions	Other suggestions
FMS (Financial Management System)	A	Increase awareness	Respondent 1: Current or old one? Respondent 2: VDOT Richmond District in process of implementing the Financial Analysis Tool (FAT) to manage TIP, PCES, SYIP, and other systems. From what I've seen, it looks like a good system EXCEPT, VDOT will not grant MPO's read only access (which means we need to always work with VDOT district staff to get answers).
Trns*port (e.g., cost estimating, financial management, contractor claims)	A	Increase awareness	Respondent 1: Cost estimate information may be helpful for other uses
Integrated SYIP-Six-Year Program (funding, allocating, expenditures, cost forecast)	A	Improve access	Respondent 2: VDOT Richmond District in process of implementing the Financial Analysis Tool (FAT) to manage TIP, PCES, SYIP, and other systems. From what I've seen, it looks like a good system EXCEPT, VDOT will not grant MPO's read only access (which means we need to always work with VDOT district staff to get answers).
VA NHTS (Virginia National Household Travel Survey) data	B	Increase awareness	[Comments]
VA University Travel Survey	B	Increase awareness	[Comments]
VDOT survey related to congestion pricing	A	Increase awareness	[Comments]
Virginia Transportation Marketing Research Database	B	Increase awareness	Respondent 1: Don't know what data is there
PMS Data (Pavement Management System)	A	Improve sharing	[Comments]
GIS-GDBMS Data (Geotechnical Database Management System)	B	Increase awareness	Respondent 1: Don't know what data is there
CQIP (Construction Quality Improvement Program)	A	Increase awareness	Respondent 1: Limited need for this one
LIS (Legislative Information System)	B	Improve sharing	Respondent 1: Limited need for this one
Port Data (VPA and AAPA) - total cargo, TEUs, exports/imports, commodities	B	Increase awareness	Respondent 1: Don't know what data is there
TREDIS (Transportation Economic Development Impact System)	B	Increase awareness	Respondent 1: Limited need for this one—but would help justify (or not) projects, so making info generally available would be a good thing
INRIX (Speed/Travel time data purchased by VDOT)	B	Increase awareness	Respondent 2: VDOT needs to provide assistance to MPO staff in developing our CMP analysis using archived travel time data.
IHS Global Insight, Inc. (private freight data purchased by VDOT)	B	Increase awareness	Respondent 1: Don't know what data is there Respondent 2: VDOT purchased this data in 2004 and it was very useful. We wish that VDOT would purchase updated data and make it available to MPOs again.

Databases	Category	Solutions	Other suggestions
PIERS (Port Import Export Reporting Service-private freight data purchased by VDOT)	B	Increase awareness	Respondent 1: Don't know what data is there