Virginia Center *for* Transportation INNOVATION & RESEARCH

Determinants of Variability in Preliminary Engineering Funding

http://www.virginiadot.org/vtrc/main/online_reports/pdf/14-r2.pdf

JOHN S. MILLER, Ph.D., P.E.
Principal Research Scientist

BETHANY L. TURNER, EIT
Graduate Research Assistant

Final Report VCTIR 14-R2

VIRGINIA CENTER FOR TRANSPORTATION INNOVATION AND RESEARCH
530 Edgemont Road, Charlottesville, VA 22903-2454

www.VTRC.net

Standard Title Page - Report on Federally Funded Project

1. Report No.: FHWA/VCTIR 14-R2	2. Government Accession No.:	3. Recipient's Catalog No.:
4. Title and Subtitle: Determinants of Variability in Preliminary Engineering Funding		5. Report Date: June 2014
		6. Performing Organization Code:
7. Author(s): John S. Miller, Ph.D., P.E., and Bethany L. Turner, EIT		8. Performing Organization Report No.: VCTIR 14-R2
9. Performing Organization and Address: Virginia Center for Transportation Innovation and Research 530 Edgemont Road Charlottesville, VA 22903		10. Work Unit No. (TRAIS):
		11. Contract or Grant No.: 103640
12. Sponsoring Agencies' Name and Address: Virginia Department of Transportation 1401 E. Broad Street Richmond, VA 23219	Federal Highway Administration 400 North 8th Street, Room 750 Richmond, VA 23219-4825	13. Type of Report and Period Covered: Final
		14. Sponsoring Agency Code:
15. Supplementary Notes:		

16. Abstract:

For the Virginia Department of Transportation (VDOT), preliminary engineering (PE) is a phase in the project development process whose expenditures are differentiated from the right of way (RW) and construction (CN) phases. PE funds support tasks such as planning studies, preliminary and final design, public involvement, and environmental processes. At the program level—that is, the aggregate funds from all projects that are to be allocated to PE as opposed to RW or CN—PE expenditures must be large enough to prepare future projects for construction yet small enough to build existing projects. The initial interest in this study resulted from the fact that, assuming a fixed program amount, higher PE spending will be associated with lower CN spending, and construction spending is logically of interest to VDOT's stakeholders. At the project level—that is, the PE funds available for a specific project—forecast PE expenditures provide project managers with a guideline regarding what resources will be needed to prepare a specific project for construction. This report analyzes the extent and causes of this variability in PE expenditures at the program and project levels.

At the program level, the mean statewide PE pooled percentage was 14.7% based on data reflecting FY 2004-2012. The mean annual district PE percentage for the same period ranged from 11.3% to 21.3%, and much of this variation (89%) was explained by three statistically significant variables: the percent of expenditures spent on minimum-plan or no-plan jobs (as opposed to complete plan jobs); the percent of projects in the development phase (e.g., projects for which PE or RW but not CN funds were spent); and the percent of expenditures spent each year on large projects (defined as universal project codes [UPCs] in the 99th percentile for a given district and year). At the project level, variations in PE expenditures were explained by statistically significant variables such as the estimated construction cost, the project's duration, whether it is administered by VDOT or some other entity, the length of the project in miles, and whether the project has a categorical exclusion. Based on a testing set of data that were not used to build the project-level forecasting models, the results suggested that the forecasting error—that is, the difference between forecast PE expenditures and actual PE expenditures for a given project—can be reduced from a mean value of about $195,000 (when one considers construction expenditures only as is currently the case) to about $109,000 (when one considers these other variables in a recalibrated model).

The study recommends that the project-specific model developed herein be further piloted to determine if it continues to offer improved accuracy relative to an existing approach that relies only on the construction cost estimate. The study also recommends that the experiences one district has had of providing historical PE percentages to stakeholders in the planning and programming process be shared with other VDOT districts. Because the study showed that interviews of district staff were essential for understanding how to interpret PE expenditures, the two recommendations offered were applied at the district level.

17 Key Words: programming, resource allocation, preliminary engineering, forecasting, planning	18. Distribution Statement: No restrictions. This document is available to the public through NTIS, Springfield, VA 22161.		
19. Security Classif. (of this report): Unclassified	20. Security Classif. (of this page): Unclassified	21. No. of Pages: 182	22. Price:

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

FINAL REPORT

DETERMINANTS OF VARIABILITY IN PRELIMINARY ENGINEERING FUNDING

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

Bethany L. Turner, EIT
Graduate Research Assistant

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

Virginia Center for Transportation Innovation and Research
(A partnership of the Virginia Department of Transportation
and the University of Virginia since 1948)

Charlottesville, Virginia

June 2014
VCTIR 14-R2

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Virginia Department of Transportation, the Commonwealth Transportation Board, or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation. Any inclusion of manufacturer names, trade names, or trademarks is for identification purposes only and is not to be considered an endorsement.

Copyright 2014 by the Commonwealth of Virginia.
All rights reserved.

EXECUTIVE SUMMARY

Introduction

For the Virginia Department of Transportation (VDOT), preliminary engineering (PE) is a component in the project development and delivery process. The sequence of steps that VDOT follows to develop a project—that is, to prepare it for construction—has been referred to as a *single phase* titled the "Preliminary Engineering and Right-of-Way Acquisition Phase" (Kerley, 2011b). The sequence of steps to prepare a project for construction has also been referred to as a "Project Development Process," which in turn contains *five separate phases* (Kerley, 2011a), one of which refers to right of way and four of which do not refer explicitly to right of way. The sequence of steps to prepare a project for construction has also been referred to as *two phases*, one of which is preliminary engineering and one of which is right of way (VDOT, 2011d). Expenditures associated with developing and delivering a project are generally categorized within VDOT's accounting systems as one of three types: (1) right of way (RW), which is the purchase of land as well as related labor such as appraisals; (2) preliminary engineering (PE), which includes other aspects of project development such as design and public involvement; and (3) construction (CN). Thus, PE expenditures are differentiated from those that refer to right of way (RW) and construction (CN). As is discussed in this report, although expenditures may be discretely categorized as PE, RW, or CN, the dates when PE work and RW work are conducted—that is, what this report calls the PE phase and the RW phase—can overlap.

As discussed in this report, VDOT's definition of *preliminary engineering* is considerably broader than many of those used by others. As practiced by VDOT, PE is a recursive process that includes preliminary design, final design, public involvement, and other activities both at the beginning of a project (such as conducting a study) and after construction is underway (such as answering a contractor's question about establishment of traffic control). VDOT's PE activities are relatively diverse. For example, it is in the PE phase that a project's scope may fundamentally change.

This study analyzed variability in VDOT's PE expenditures at the program and project levels. The study was motivated by a research need evaluated by the Transportation Planning Research Advisory Committee (2010) of the Virginia Center for Transportation Innovation and Research. A description of the research need noted: "Even though—for the average project—PE and RW is estimated to consume less than 20% of a project's total cost, in one recent year more than half of the SYIP dollars for one district was spent on PE and RW, leaving less than half of the dollars for construction." ("SYIP" refers to VDOT's Six-Year Improvement Program.) The concern was as follows: "Is it possible to spend close to 80% of SYIP dollars on construction year after year and still prepare enough projects for future construction (i.e., by spending close to 20% of SYIP dollars on PE and RW)?" This question led to the study's program-level component. At the program level, the amount of PE funds allocated in a given fiscal year reflects two potentially conflicting goals: (1) ensure enough money is spent on PE in the current year to prepare projects for construction in future years (multi-year projects are the norm), and (2) ensure enough money is spent on CN in the current year to prepare projects for use by the public (Transportation Planning Research Advisory Committee, 2010).

At the project level, the amount of expenditures that will be required for PE is forecast prior to the initiation of the PE phase. These forecast PE expenditures provide project managers with a guideline regarding the resources that will be needed to prepare a specific project for construction. As the study progressed, VDOT staff in the Fredericksburg District suggested to the researchers that there was a need to determine which variables other than CN cost influence PE costs for a specific project. Such variables could then presumably be used to develop a forecast of the PE expenditures for a specific project, which would be of interest to project managers. This was the reason for the project-level component of the study.

Purpose and Scope

The purpose of this study was to analyze the extent and causes of variability in VDOT's PE expenditures at the program and project levels within the constraints of available VDOT data. The scope of the study was defined as answering five questions.

1. What is *preliminary engineering* both as defined in the literature and as practiced by VDOT?

2. Are the data available to determine the percentage of funds spent on PE by VDOT district, project, and year, and are these data reviewed by VDOT staff?

3. At the program level, based on a review of the practices of other states, what percentage (or range of percentages) of funds is appropriate to spend on PE relative to RW and CN, and how does this percentage compare to Virginia's?

4. At the program level, which characteristics explain the variation spent on PE by district and then by fiscal year?

5. At the project level, which project characteristics have a statistically significant impact on PE costs?

The scope of the study was limited to information that could be extracted from four data sets: (1) information obtained from interviews of project managers and other staff in each of VDOT's nine districts and VDOT's central office; (2) expenditures extracted from Financial Management System II (FMSII) and Cardinal, two of VDOT's financial management systems; (3) project-specific characteristics found mainly in a suite of VDOT's linked internal databases (including the Project Pool and the Integrated Project Manager [iPM]); and (4) the preliminary and construction engineering (PCE) expenditures of other states. Accordingly, because of data availability, the scope for Question 3 was limited to years 1990-2010 inclusive and the scope for Question 4 was limited to 2004-2012 inclusive.

Question 3 uses the word *appropriate,* which was based on its use in the work plan for this study. The word was used to signify a suitable or reasonable range of PE expenditures and was used in the interview questions. However, it was later pointed out that the word could imply a value judgment, which would vary by individual. Although this remains the case, in the context of Question 3, *appropriate* may be defined as not deviating substantially from normal practice where such deviations may be identified either quantitatively or qualitatively.

Description of the Four Data Sets

The four data sets may be described as follows.

1. *Information obtained from interviews of project managers and other staff in each of VDOT's nine districts and staff from VDOT's Programming Division and Fiscal Division.* The interview questions and the interview notes taken by the researchers and verified by the interviewees are provided in Appendix A. These notes served to define *preliminary engineering,* alert the researchers to critical caveats with regard to how to interpret the data, and advise the researchers with regard to how to analyze variability given the data sets. These interviews were conducted between September 2012 and May 2013.

2. *Expenditures extracted from FMSII and Cardinal, two of VDOT's financial management systems.* FMSII was operational through November 2012, and VDOT's current database, Cardinal, became operational after November 2012. This data set included all universal project codes (UPCs) listed in the SYIP for which expenditure data were reported in VDOT's financial systems, which to the best of the researchers' knowledge, reflect all projects except those with a UPC beginning with the letter "T" (Carver, 2012a). Later reviews by the researchers suggested that such projects were usually public transportation projects. These data are believed to be complete for fiscal years 2004 through 2012 (hereinafter 2004-2012). Further, they include expenditures prior to FY 2004 for projects that were underway at any point during the period 2004-2012.

3. *Project-specific characteristics mainly in VDOT's Project Pool and associated linked databases.* Although some of these characteristics (such as project description) were available from the SYIP, many were extracted from the Project Pool and associated linked databases. Characteristics included the amount of design required (e.g., a minimum-plan construction project); the level of environmental review required (e.g., EA); and other characteristics that better described the project such as length (in distance, e.g., a 4-mile project), estimated construction cost, and duration (in time, e.g., a 7-year project). This data set also included project characteristics provided by some of the district interviewees, such as whether the project, despite its appearance in the SYIP, was really a maintenance or operations project funded with a construction allocation.

4. *PCE expenditures of other states for the period 1990-2010.* These expenditures were obtained from the Federal Highway Administration's (FHWA) annual *Highway Statistics* volume for each year from 1990 through 2010 (FHWA, 1990-2010) and refer to disbursements for "state administered highways." PCE data and PE data are not identical; however, they are similar in that they both include elements of PE and design. For the period 2004-2010 (when the two data sets overlap), the mean PE percentage for Virginia was 14.6% and the mean PCE percentage was 16.8%; by year, these values had an average difference of less than 5%.

Findings

Finding 1. VDOT preliminary engineering is an expansive, recursive process.

Preliminary engineering as practiced by VDOT is expansive. VDOT's PE phase prepares projects for construction, spanning activities that occur from the time a project charge number is made available until the date the project is awarded for construction. PE activities are diverse and, especially for smaller projects, may include developing a fundamental engineering definition of the project (e.g., raising the entire road bed versus designing a new drainage system). Thus, *preliminary engineering* as defined by VDOT may span more activities than is the case for other organizations. In terms of funding, the five phases of PE as described in the VDOT Project Development Process (VDOT, 2012a) align with the funding categories in the SYIP. However, scheduling is not consistent between the two because in practice the RW phase may overlap with the PE and CN phases whereas in the SYIP these phases are sequential.

Preliminary engineering as practiced by VDOT is recursive. VDOT's PE phase is divided into five major phases: scoping, preliminary design, detailed design, final design and RW acquisition, and advertise plans (VDOT, 2012a). Despite the seeming linearity of these phases, PE can be a looped process. For example, as noted in some of the interviews, 30% to 40% of the design could be accomplished before the realization that a change in the final product was needed. Reasons for needing to revisit earlier PE work could include unforeseen geotechnical challenges; responses to public involvement that necessitated detailed design changes; changes in land development; staff turnover (including a shift from an in-house design to a design-build process); changes in design standards; changes in available funding; and revisions to the project's purpose and scope. The probability of needing to revisit earlier PE phases increases as the duration of the project development process increases: for example, if the RW phase is not begun within 3 years of holding public meetings, any new design standards must be followed.

Finding 2. PE expenditure data are available, but their interpretation is subject to caveats. Further, the data are reviewed at the project level but not the program level.

Based on fiscal years 2004-2012 inclusive, the data are available to determine the percentage of funds spent on PE by VDOT district and fiscal year at the program level. Further, the data are available to determine PE expenditures at the project level. There are, however, critical caveats that affect how these data are interpreted.

- *PE expenditures may be made outside the PE phase of a given UPC.* In some cases, a single UPC represents a single project, and that UPC has a PE, RW, and CN phase. However, it may be the case that multiple projects share a single UPC or that a given project is defined by multiple UPCs. In addition, the availability of a district-wide pre-scoping UPC means that some PE will not be associated with a specific project. These cases would not affect a program-level PE analysis but would affect a project-specific PE analysis in that the project's PE expenditures would be reduced to the extent work on that project was done under a district-wide UPC. Interviewees also noted that there were other ways to perform PE projects without directly charging to

PE. For instance, some staff who had an administrative function might accomplish PE work without charging to PE for a specific project. The project scope will also affect PE charges; for example, in the case of two projects that will use existing wetlands, if Project A used wetland banking, the additional costs would be placed in PE whereas if Project B constructed a new wetland, the additional costs would be placed in CN.

- *Project characteristic data may not always be available.* VDOT's Project Pool and associated linked databases are a rich source of project characteristics such as functional classification, environmental work required, whether the project is locally administered (or administered by an entity other than VDOT), and whether the project is a minimum-plan project. Although these characteristics are routinely available, other types of details, such as types of agreements in place, are not necessarily applicable or always available for a given project. Interviewees clarified that the availability of such data will depend in part on the practices of the project manager; however, they also noted that VDOT's Project Pool is not intended to be an archive for every conceivable piece of project data. For example, for locally administered projects, a scoping document is not required.

Interviewees noted that at the district level, a program-level review of PE expenditures typically does not occur. Further, no interviewees provided a single target for a PE percentage given the variety of factors that influence PE, such as a long project duration during which funding levels may change. However, at the project level, PE expenditures are reviewed to ensure a specific project is kept on budget. Interviewees noted again that a variety of factors will influence the PE percentage; one interviewee noted that PE percentages had ranged from 13% to 58% in a previous review of projects. There was consensus, though, that PE percentages will tend to drop as construction costs increase since larger scale projects tend to be better defined than smaller ones.

Finding 3. Virginia has PCE expenditures that are higher than the national average but not higher than those of other states that maintain their county roads.

FHWA (2000) identified three types of expenditures made by states in its capital outlay program (based on information provided by states for transportation construction): PCE, RW (e.g., purchase of land, relocation of property owners, and RW administration), and CN. FHWA reports these capital outlay expenditures for each of the 50 states by year in the Highway Statistics Series. PCE is not identical to PE; for example, the FHWA capital outlay program does not include any maintenance projects. By contrast, such projects may be in the SYIP. Thus the definitions of *PCE* and *PE* are not identical and the percentages are also different; for example, whereas the pooled PE percentage for Virginia for the years 2004-2010 ranged from 11.2% to 17.8%, the statewide PCE percentage for the same period ranged from 10.6% to 24.0% (FHWA, 1990-2010).

Other than Virginia, four states maintain their county roads (Alaska, Delaware, North Carolina, and West Virginia). The average of these states' PCE ratios (i.e., ratio of PCE to total costs) for 1990-2010 was about 3.5 percentage points higher than the average of the other states (excluding Virginia). That is, for this period, on average, PCE expenditures accounted for 17.6% of the capital outlay for Alaska, Delaware, North Carolina, and West Virginia, whereas such expenditures accounted for only 14.1% of the capital outlay for the other 45 states (excluding Virginia). (For each of the two groups of states, two steps are taken to yield these averages: first, compute the average PCE ratio for each year [e.g., 1990, 1991…2010], and second, compute the average of these annual averages.) For Virginia, the average PCE ratio was 16.5% for the period 1990-2010. Virginia's PCE ratio was significantly higher than the national average ($p = 0.03$) but was not significantly different from the average of the four states ($p = 0.23$). The inclusion of Texas (which was suggested as being comparable to Virginia in that Texas also has a large state system) in the group represented by the four states did not materially change these results. The differences in PCE ratios between those states that maintained the equivalent of a secondary system and those that did not suggested that later examination of variation within Virginia districts should consider whether the type of facility on which projects occurred (e.g., secondary, urban, primary, or interstate) affected PE costs. As discussed in the body of the report, there may be factors other than secondary facilities that explain the differences among state PCE ratios.

Finding 4. Characteristics that explain variation in PE percentage by district or year include minimum-plan and no-plan projects, projects in the development phase, large projects, study-only projects, and the presence of non-typical projects.

Table ES1 shows the percentage of expenditures spent on PE (as opposed to RW or CN) for each VDOT district and fiscal year and the mean percentage for each district for the period 2004-2012. For example, for the Bristol District, the mean of 25.6% (in 2004), 17.3% (in 2005), and so forth yielded a district mean of 18.3%. The statewide pooled percentage for each fiscal year is also shown, which is the total amount spent statewide on PE divided by the total amount spent on PE, RW, and CN.

Table ES1. Percentage (%) of Expenditures Spent on Preliminary Engineering by Fiscal Year and by VDOT District, 1-Year Average[a]

VDOT District	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	District Mean %
Bristol	25.6	17.3	13.4	7.7	14.8	25.7	31.2	13.0	15.7	18.3
Culpeper	22.9	18.0	20.8	11.7	20.4	22.1	17.4	26.0	32.0	21.3
Fredericksburg	14.6	5.2	3.1	3.4	24.4	45.5	15.5	11.5	32.9	17.4
Hampton Roads	13.3	14.6	11.2	11.7	10.5	11.9	14.3	14.2	15.3	13.0
Lynchburg	3.6	2.7	4.3	15.5	18.2	24.0	18.4	4.2	13.0	11.6
Northern Virginia	22.1	15.0	15.6	12.5	14.3	17.4	18.0	11.9	24.5	16.8
Richmond	7.3	10.9	14.0	7.6	9.6	15.8	22.2	9.4	9.9	11.9
Salem	16.7	19.6	18.7	28.6	16.7	15.9	17.2	9.0	13.8	17.3
Staunton	10.2	11.2	9.5	9.5	15.9	12.8	11.6	7.9	12.9	11.3
Statewide Pooled %	15.7	13.3	12.5	11.2	14.2	17.3	17.8	11.5	18.8	14.7

VDOT = Virginia Department of Transportation; statewide pooled % = statewide pooled percentage for each fiscal year, which is the total amount spent stateside on preliminary engineering divided by the total amount spent statewide on preliminary engineering, right of way, and construction; district mean % = mean percentage from years 2004-2012 for each district.
[a]A more detailed version of Table ES1 appears as Table 6 in the body of the report.

Initially, 29 independent variables were defined and used to predict the mean district PE percentage for the period 2004-2012 inclusive such that there were nine values for this dependent variable, i.e., one for each VDOT district. Stepwise linear regression was used to determine if any of the 29 independent variables explained the variation among districts in this PE percentage to a statistically significant degree; the details of the assumptions in the four models developed are provided in Appendix B. Equation ES1 (program-level Model 3) explained 89% of this variation based on three statistically significant variables ($p < 0.05$): (1) percent of expenditures spent on minimum-plan or no-plan projects, (2) percent of projects in the development phase, and (3) percent of expenditures spent each year on large projects.

$$\text{Mean} = 0.055 - 0.652(\text{Minimumplan}) + 0.476(\text{Develop}) - 0.278(\text{Large}) \qquad \text{[Eq. ES1]}$$

where

Mean = mean district PE percentage for 2004-2012
Minimum plan = percent of expenditures spent on minimum-plan or no-plan projects
Develop = percent of projects in the development phase
Large = percent of expenditures spent each year on large projects.

Model 3 suggests that a 10% reduction in percent of projects in the development phase (e.g., where PE and RW are underway but CN has not begun) will reduce the PE percentage by 4.76%. Since the district percent of projects in the development phase ranged from 56.1% to 73.2%, Model 3 suggests that the maximum reduction in PE percentage that could be obtained at the program level would be (73.2% – 56.1% = 17.1%)(0.476), or about 8.1%. The coefficients in Model 3 are reasonable in that as expenditures for minimum-plan, no-plan, or large projects increase, the percentage of PE expenditures will decrease.

When the annual variation in PE percentages (i.e., the percentages by district and by year) was considered, there were 81 rows of data, given 9 years and nine districts. There was substantial random variation such that if the district and year were not included in the model, the best model could explain only about 52% of this variation. After autocorrelation (i.e., errors that are correlated by year [Newbold, 1988]) was controlled for, five independent variables were statistically significant: (1) percent of expenditures spent each year on large projects as used in Equation ES1 (i.e., Model 3); (2) average cost of UPCs; (3) percent of expenditures for study-only projects; (4) percent of expenditures for projects under the American Recovery and Reinvestment Act of 2009 (ARRA); and (5) percent of expenditures on non-typical projects. The percentage of projects in the development phase was not significant unless the constant was omitted, in which case it had a statistically significant coefficient of 0.479, which is similar to that shown in Equation ES1. Although its terms were statistically significant, the ability of Model 3 to explain variation by year and district was limited. For example, if the variable for expenditures for study-only projects is considered, the variable influenced the PE percentage by 3% or less for 90% of the year-district combinations shown in Table ES1.

A word must be said about non-typical projects. *Non-typical projects* refers to projects considered by interviewees to have an anomalous characteristic, such as minimum-plan or no-plan jobs' locally administered projects or projects administered by an entity other than VDOT;

enhancements; district-wide projects; study-only projects; ARRA projects; or projects suggested for exclusion for some other reason by district staff, such as maintenance/operations projects that use CN funds. The common characteristic of such projects is a non-typical PE phase compared to that of a "typical" construction project; for example, a study-only project would have only PE expenditures; a minimum-plan project would have unusually low PE expenditures. To be clear, these projects were included in the analysis. However, depending on the district and the year, they ranged from 14.8% to 98.3% of the expenditures in the data set. Overall, of the 4,345 UPCs identified in the SYIPs and for which expenditures were available for 2004-2012, only about 881 UPCs (roughly one fifth) or between 29% and 42% of the expenditures (depending on the year) were not non-typical. In sum, the majority of projects in the SYIP were not typical construction projects per se. Removal of such non-typical projects from the data set would reduce the mean pooled PE percentage from 14.7% in Table ES1 to 11.4%. Further, with nine construction districts, there are a total of 36 possible pairwise comparisons between districts. For 2004-2012 inclusive, when all projects were considered, there were 11 statistically significant differences among the districts in terms of this PE percentage. Removal of the non-typical projects reduced this to just 3.

Finding 5. In addition to the scoping construction estimate, characteristics that affect project-level PE costs include length, duration, level of required environmental review, whether the project is administered by VDOT, and whether a project requires RW.

Currently, VDOT's project-level PE forecast is a percentage of the CN estimate. VDOT develops this estimate using the Project Cost Estimation System (PCES), in which three equations are used such that as the construction estimate rises, the PE percentage (not necessarily the PE cost) decreases. Project managers may use engineering judgment to add or remove costs based on their knowledge of the project. The CN estimate is the only variable used to forecast PE costs.

This study developed a new approach to forecast project-level PE costs. First, a sample set of projects was gathered from the SYIP. Second, projects were removed from the list that did not meet any of three requirements: (1) the project was not an enhancement, district-wide, study-only, ARRA, minimum-plan, or no-plan project or a project that district interviewees thought should be excluded; (2) an estimate of the forecast construction cost was available; and (3) the CN phase was underway or completed.

The approach for forecasting PE costs developed in this study used characteristics in addition to the construction estimate. Three steps identified project-level characteristics that might affect the PE estimate: (1) interviews with VDOT staff in project management, programming, planning, and construction; (2) an analysis of a sample set of projects; and (2) a review of the literature. The method for collecting these additional characteristics for each project is detailed in Appendix C. A model (Model 7) was developed based on the initial scoping construction estimate and other variables available at that time, such as expected duration, length, whether VDOT or another entity such as a locality was to administer the project, and level of environmental review required (see Eq. ES2). The model was calibrated based on 97 projects and is applicable for projects that have a construction cost under $5M. Based on an additional 27 projects used to test the accuracy of the model, the average error between forecast PE costs and actual PE costs was approximately $109,000. This error is about one-half the error ($195,000) that resulted from applying VDOT's current (PCES) approach. The difference in accuracy is statistically significant (p = 0.02).

$$PE=2.2285*CN\ Estimate^{0.73010}*Duration^{0.32275}*2.8634^{VDOT}*0.64695^{Length}*1.70796^{CE} \quad \text{[Eq. ES2]}$$

where

PE = forecast preliminary engineering cost in dollars

CN estimate = forecast construction cost in dollars

Duration = expected duration of the project in years

VDOT = 1 if project is administered by VDOT, 0 otherwise

Length = project length in miles

CE = categorical exclusion under the National Environmental Policy Act of 1969 [NEPA]) = 1 if categorical exclusion, 0 otherwise.

For example, the model shows that a 10% increase in the expected duration of a project would be expected to increase forecast PE costs by 3%. Changing the administration of a project from VDOT to a non-VDOT entity (hence changing the VDOT variable from 1 to 0) would decrease the forecast PE cost by 65%. Similarly, changing a project from having a CE to not having a CE (i.e., changing the CE variable from 1 to 0) would decrease the cost by 40%.

Including Equation ES2 (project-level Model 7), seven project-level models for forecasting PE costs were developed (i.e., Models 5-11). One of these, Model 6, is the same model form as Model 5, the PCES approach currently used by VDOT, but recalibrated with new parameters. Such recalibration may be beneficial. Model 6 yielded an average absolute error of approximately $154,000, which is nominally lower than that of the current PCES approach ($195,000), and the non-significant difference appears to be attributable to the small data set. The p-value was 0.07 and as shown in the body of the report, the relatively high probability of a Type 2 error suggests that the difference may be found to be significant with a larger data set.

Conclusions

1. *PE expenditure data are available, but their interpretation is subject to caveats noted by interviewees.* These include the facts that a single project may use multiple UPCs, other cost centers for accomplishing PE work may exist, and some project activities may be placed in different phases (e.g., wetland banking is a PE cost but wetland replacement is a CN cost).

2. *Virginia has a significantly higher PCE percentage (16.5%) than the national average (14.4%), but there is not a significant difference in the PCE percentages of Virginia and other states that maintain the equivalent of a secondary system* (i.e., Alaska, Delaware, North Carolina, and West Virginia, which have a mean annual PCE percentage of 17.6%). This conclusion refers to national data for the period 1990-2010.

3. *Typical construction projects account for a minority of construction projects in the SYIP*. For the period 2004-2012, projects that interviewees considered to be non-typical (e.g., enhancement, study-only, and ARRA-funded projects; a maintenance project funded with construction allocations; minimum-plan and no-plan projects; and so forth) accounted for four-fifths of the UPCs in the original data set.

4. *Restricting the data set to typical projects as per Conclusion 3 reduces VDOT's mean annual statewide program-level PE percentage from 14.7% to 11.4%.*

5. *There is substantial variation in the PE percentage by year, by district, and by district-year combination*. For 2004-2012, the statewide PE pooled percentage ranged from 11.2% in 2007 to 18.8% in 2012. The mean district PE percentage ranged from 11.3% (Staunton District) to 21.3% (Culpeper District). By individual district and year, variation ranged from 2.7% (Lynchburg District in 2005) to 45.5% (Fredericksburg District in 2009).

6. *Simple linear models suggest that without accounting for annual variation (during 2004-2012), three independent variables appear to explain 89% of the variation in the PE percentage at the program level: percent of expenditures for minimum-plan or no-plan projects; percent of annual expenditures on large projects; and percent of projects in the development phase.*

7. *Less variation in the program-level PE percentages is explained when annual PE percentages are included*. A simple linear model based on five independent variables—average project cost, percent of expenditures spent each year on large projects, percent of expenditures for ARRA projects, percent of expenditures for study-only projects, and percent of expenditures for non-typical projects—explained about 52% of the variation in the data set for the period 2004-2012.

8. *The use of variables in addition to construction cost to forecast PE costs at the project level improved forecast accuracy in the testing data set*. When calibrated based on a training data set of 97 projects, a model based on forecast construction cost, length, duration, level of required environmental review, and whether the project was administered by VDOT reduced the mean absolute error from about $195,000 to $109,000 in a testing data set of 27 projects.

Potential Action Items

The study provides two recommendations.

1. *Apply Model 7 (Equation ES2) on a pilot basis in one VDOT district and compare its forecast accuracy with the current approach over a 24-month period.* Should such results continue to be promising as observed with the small testing data set noted in this study, it may be appropriate to include this equation as an option within the PCES. One potential benefit of this recommendation is potentially more accurate PE forecasts. Because the recommendation is to compare forecasts with observed values, a second benefit is knowledge of how accurate these forecasts are. Because no forecast is completely accurate but will have an error, forecasts may thus be provided as a range rather than solely as a point estimate.

2. *Consider providing the historical annual percentage spent on PE at the program level, similar to what was reported in Table ES1, to stakeholders during the planning or programming process.* Although it is not necessarily productive to respond to year-by-year changes in the PE percentage because of annual variation, decision makers may consider tracking the PE percentage at the program level. For example, historical data suggest that the PE percentage has been about 14.7% when all projects are considered. If this percentage rises more than 2 standard deviations about the historical levels (which would be about 20.3% in a given year), Equation ES1 suggests how reducing the percentage of projects in the development phase could bring the PE expenditures back to historic levels (unless a large influx of funds was expected in which case a higher PE percentage would likely be justified).

The "Benefits and Implementation Prospects" section of the report outlines additional steps that can help implement these recommendations. These involve developing additional models to revise the PE estimate once PE is underway and clarifying the estimate and expenditure data in the Project Pool. These steps would require efforts beyond the scope of this study.

FINAL REPORT

DETERMINANTS OF VARIABILITY IN PRELIMINARY ENGINEERING FUNDING

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

Bethany L. Turner, EIT
Graduate Research Assistant

INTRODUCTION

Preliminary engineering (PE) is loosely described as detailed physical planning and design conducted during project development, after which a project's scope, cost estimate, and financial plan should not be changed (Federal Transit Administration [FTA], 2007; Smith, 1999). In the Virginia Department of Transportation (VDOT), PE is also a phase in the project development process that is differentiated from the right of way (RW) and construction (CN) phases in terms of expenditures. The need to examine variability in PE expenditures has been noted at both the program level (Transportation Planning Research Advisory Committee [TPRAC], 2010) and the project level (A. Hammadi, personal communication, 2012).

A program-level analysis is one that analyzes the expenditures for a transportation program for a specific time period (e.g., all PE expenditures by VDOT for a 3-year period). A project-level analysis is one that analyzes the expenditures for a specific project (e.g., all PE expenditures for a specific lane widening project in a given district). Thus, a program-level analysis refers to a specific time period but is unconstrained in the number of projects contained therein, and a project level analysis refers to a specific project but is unconstrained in the number of years contained therein. For example, Figure 1 shows the duration of seven hypothetical projects. As may be seen, a program-level analysis for years 1996-2001 would include some expenditures from Projects 3 through 7, even though Project 6 was never completed. A project-level analysis based on projects completed prior to year 1996 would include all expenditures from Projects 1 and 2.

Program-Level Versus Project-Level Analyses

At the *program level,* e.g., for VDOT's Six-Year Improvement Program (SYIP), the allocation of PE funds in a given fiscal year to a particular set of projects serves two goals: (1) ensure sufficient funds are spent on PE in the current year in order to prepare enough projects for CN spending in future years, and (2) constrain total spending on PE in the current year in order to ensure that enough monies are spent on CN in the current year. These goals may conflict because increasing PE expenditures will help achieve the first goal whereas reducing PE expenditures will help achieve the second goal. The reason for a program-level analysis is to address these two goals.

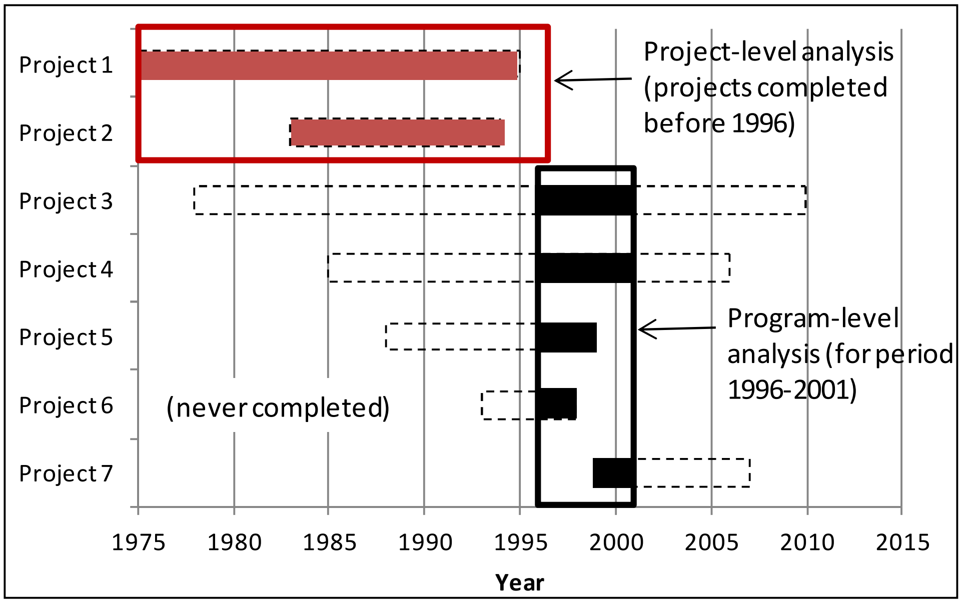


Figure 1. Duration of Seven Hypothetical Projects. The dashed lines indicate the duration. The 2 lighter shaded (red) projects comprise a project-level analysis (for projects completed before 1996). The five darker shaded (black) items comprise a program-level analysis (for the period 1996-2001).

For example, the research need that was the genesis of this study noted that in one recent year more than one-half of SYIP dollars for one construction district was spent on PE and RW, leaving less than one-half of the funds available for construction (TPRAC, 2010). Based on that anecdote, a concern is whether the second goal was met, given that PE costs would be expected to be smaller—on the order of 20% depending on the features of the projects. At the program level, the research need also questioned whether it was reasonable to compare the proportion of funds Virginia spends on PE with the proportion of funds other states spend on PE. Answers to these questions could help decision makers in VDOT or metropolitan planning organizations (MPOs) manage their programs such that they could be assured the two goals are reached.

With one exception, no literature discussing the relative amounts of funds that should be or are spent on PE at the program level was found. The exception was the VDOT FY 2013- FY 2014 Business Plan (2011a), which identifies action item 1.1.1 as being to allocate between 10% and 15% of the annual construction program for new PE work annually. The VDOT FY 2014-FY 2015 Business Plan (2013a) contains a different action item: ensure that the SYIP has a minimum of $130M to $150M for new PE annually, which, assuming a $1.44B construction budget that was reported for FY 2014 (VDOT, 2013b), would be between 9% and 10% of the program.

Liu et al. (2011) reported that the state auditor reviewed PE, RW, and CN expenditures for 292 North Carolina Department of Transportation (NCDOT) highway projects whose construction was completed between April 1, 2004, and March 31, 2007, and who were let between 2001 and 2009. With PE, RW, and CN expenditures of $117M, $149M, and $1.020M, respectively, for these projects, PE accounted for approximately 9% of the total project costs. This was not a program-level analysis, however, because it did not appear to cover a specific time frame and it did not cover all NCDOT spending (e.g., presumably the 292 projects did not include abandoned projects).

At the *project level,* i.e., for a single project, staff from one VDOT construction district suggested that the forecast of PE costs helps balance two goals: (1) making each aspect of the project (e.g., drainage, structures, and so forth) as good as it can be, and (2) completing the design as quickly and as cheaply as possible. VDOT staff currently use the Project Cost Estimation System (PCES) to forecast PE costs relative to CN costs. CN costs do not explain all the variation in PE costs, however, which necessitates that individuals who are estimating costs must use their experience to adjust the PE estimate (G. Holley, personal communication, 2012). For such a project-level analysis, VDOT district staff questioned how various project characteristics, such as wetland mitigation required, project delivery method, type of drainage, and other factors, influence overall PE costs. An answer to this question could help project managers develop a better forecast of PE costs for a given project and might help such managers strike the balance between achieving the best design and achieving a relatively quick and/or inexpensive design. A potential ancillary benefit would be that other stakeholders, such as localities or advocacy groups, who wished to influence the planning or project development process might better understand the project development cycle.

Although both the program-level and project-level analyses entail an assessment of PE expenditures, the audience for each type of analysis differs. At the program level, the audience ultimately reflects those charged with making investment decisions, such as MPO or VDOT staff supporting decision makers who decide on the emphasis of a transportation program. Accordingly, these staff are interested in allocations—that is, allotments of funds to future projects. At the project level, the audience is likely project managers, who are charged with delivering specific projects from inception to construction. Accordingly, these staff are interested in forecasting expenditures—i.e., the monies spent on specific projects.

Complicating Factors in Analyzing VDOT's PE Expenditures

There are at least five potential complicating factors in analyzing VDOT's PE expenditures.

1. *The term "preliminary engineering" may not be defined in the same manner for all projects*. Differences in the definition result because of different perspectives on project management and the diverse nature of construction projects. For example, the ability to forecast reliably the cost estimate for buried utility relocation would differ depending on whether the project was a major highway investment (which would require substantial earthwork); an intelligent transportation systems (ITS) investment (which might require some foundation work); or a transit investment (which, if it focused on rolling stock only, could arguably not require any foundation work unless the surface needed to be strengthened to accommodate heavy vehicles).

2. *The categorizations of costs may not be uniform throughout agency databases.* For example, there is a variety of ways PE costs can be handled depending on whether the project is classified as maintenance or construction. Because the distinction between maintenance and construction may not always be clear (e.g., a bridge deck reconstruction), the cost categorizations may affect some types of projects more than

others. Saunders (2012) noted that more than 70% of projects that are advertised do not have any PE funding; thus, a portion of PE-related labor expenditures may be under an administrative category rather than a PE funding category.

3. *Programming practices evolve in response to specific conditions*. For example, for the period 2009-2011, a drop in revenues and an emphasis on "shovel-ready" projects led to a focus on funding projects that were underway or scheduled to be underway soon to ensure that all federal funds were obligated, including those based on the American Recovery and Reinvestment Act of 2009 (ARRA) (also known as "stimulus" funds).

4. *Programming practices may vary by region*. An older version of the research need for this effort suggested that in Northern Virginia, for many years more than one-half of SYIP dollars had been spent on RW (TPRAC, 2012) because RW (in urban areas) was expensive. Further, any comparisons of Virginia practices to those of other states may not be useful unless (1) the other states have transportation responsibilities comparable to those of Virginia, or (2) the data are controlled such that comparable projects are compared. Virginia also has specific requirements: for example, Cherry, Bekaert & Holland (2010) noted that approval from the Federal Highway Administration (FHWA) is required before each phase (named in that report as "preliminary engineering, right of way, construction") is initiated and that VDOT has a policy of not authorizing PE for a project until funding for the CN phase is available. However, this policy does not preclude the existence of PE-only projects in the SYIP.

5. *Long, multi-year horizons are associated with construction projects*. As an illustration, the FY 2012 SYIP for the Hampton Roads District (VDOT, 2008) contained 303 universal project codes (UPCs) for which expenditures were shown. Table 1 indicates whether monies were spent on the same UPCs in previous fiscal years. For example, 248 of these UPCs had some type of expenditure in FY 2011 and 39 had some type of expenditure as early as 2000. Hammadi (2012) noted in particular that delays can cause the PE portion of total costs to be higher than would otherwise be the case for three reasons: (1) geometric design standards change during the intervening years (necessitating a more expensive design); (2) the project scope changes such that PE must be performed anew for what is really a fundamentally different project but with the same UPC; or (3) extensive studies such as interchange justification reports or other environmental documents may be required and thus increase the cost.

Because of these complications, prior to analyzing the determinants of variability in PE expenditures, the researchers sought to define *preliminary engineering* as used in VDOT construction districts and to determine the extent to which expenditure and project characteristic data were available.

Table 1. Previous Years' Expenditures for Projects From FY 2012 SYIP for Hampton Roads District

Fiscal Year	Total Amount	No. of Projects With Expenditures > $0
2011	$206,003,948	248
2010	$127,405,950	164
2009	$101,014,170	127
2008	$90,626,126	106
2007	$52,676,949	89
2006	$29,745,949	71
2005	$29,830,681	56
2000	$13,071,368	39
1995	$888,258	14
1990	$361,906	4
1985	$4,317	1
1981	$720	1

SYIP = Six-Year Improvement Program.
Source: The source of the data in this table was tabulations of expenditures by the researchers obtained from a review of VDOT (2008) and Carver (2012b).

PURPOSE AND SCOPE

The purpose of this study was to analyze the extent and causes of variability in VDOT's PE expenditures at the program and project levels within the constraints of available VDOT data. The scope of the study was defined as answering five questions.

1. What is *preliminary engineering* both as defined in the literature and as practiced by VDOT?

2. Are the data available to determine the percentage of funds spent on PE by VDOT district, project, and year, and are these data reviewed by VDOT staff?

3. At the program level, based on a review of the practices of other states, what percentage (or range of percentages) of funds is appropriate to spend on PE relative to RW and CN and how does this percentage compare to Virginia's?

4. At the program level, which characteristics explain the variation spent on PE by district and then by fiscal year?

5. At the project level, which project characteristics have a statistically significant impact on PE costs?

The scope of the study was further limited to information that could be extracted from four data sets: (1) information obtained from interviews of project managers and other staff in each of VDOT's nine districts and VDOT's central office; (2) expenditures extracted from Financial Management System II (FMSII) and Cardinal, two of VDOT's financial management systems; (3) project-specific characteristics found mainly in VDOT's Project Pool and associated suite of internal linked databases (hereinafter Project Pool); and (4) the preliminary and construction engineering (PCE) expenditures of other states. Accordingly, because of data availability, the scope for Question 3 was limited to years 1990-2010 inclusive and the scope for Question 4 was limited to 2004-2012 inclusive.

Question 3 uses the word *appropriate* based on its use in the work plan for this study. The word was used to signify a suitable or reasonable range of PE expenditures and was used in the interview questions. However, it was later pointed out that the word could imply a value judgment, which would vary by individual. Although this remains the case, in the context of Question 3, *appropriate* may be defined as not deviating substantially from normal practice where such deviations may be identified either quantitatively or qualitatively.

METHODS

Five tasks were conducted to achieve the study objectives.

1. Define preliminary engineering based on a review of the literature and interviews with VDOT district and central office staff.

2. Determine the types of available VDOT PE expenditure data.

3. Compare the Virginia statewide preliminary and construction engineering (PCE) percentages to those of other states for the period 1990-2010.

4. At the program level, determine and interpret the percent of funds spent on PE as opposed to RW and CN for each VDOT district and each fiscal year for the period 2004-2012.

5. At the project level, develop an approach for forecasting PE expenditure as a function of project characteristics identifiable when the project is scoped.

Task 1: Define Preliminary Engineering

In this task, *preliminary engineering* was defined based on a review of the literature and interviews with VDOT district and central office staff. A literature search was conducted using the TRID database and the Google Internet search engine. Three types of literature were sought: descriptions of the activities that are included in preliminary engineering, literature citing the percentage of funds spent on preliminary engineering at the program level, and quantitative approaches for forecasting PE expenditures at the project level. In addition, project managers and/or planning and investment managers (PIMs) were interviewed from the nine VDOT construction districts and VDOT's central office as indicated in Table 2.

Table 2. Schedule for Interviews of VDOT Staff

District	Interview Label[a]	VDOT Staff (Expertise Represented)	Interview Date
Fredericksburg	FR1	Abdul Hammadi (PM), Kevin Northridge (PM), and Jason Williams (PM)	Sept. 25, 2012
Bristol	BR2	Chase Buchanan (PM) (interview conducted by telephone)	Nov. 2, 2012
Culpeper	CU3	John Giometti (PM), Brent Sprinkel (PIM), and Wendy Thomas (PIM)	Jan. 4, 2013
Salem	SA4	Tommy DiGiulian (PIM), Jane-Ellen Hess (PM), and Alex Price (PM)	Jan. 28, 2013
Central Office	CO5	Bob Carver (FD), Margit Ray (PD), and Rob Walters (PD)	Jan. 30, 2013
Lynchburg	LY6	Jay Brown (PD), Brian Casto (PM), Jeff Kessler (Area Land Use Engineer), Randy Hamilton (ACE), and Zack Weddle (ACE)	March 5, 2013
Hampton Roads	HR7	Bruce Duvall (PM) and Steve Rowan (PIM)	March 29, 2013
Staunton	ST8	Mike Fulcher (PIM), Matt Dana (PM), and Terry Short (District Planner)	May 9, 2013
Northern Virginia	NV9	Dic Burke (PM), Claudia Llana (PM), Bud Siegel (PM), Kanti Srikanth (PIM), and Jim Zeller (PM)	June 17, 2013
Richmond	RI10	Rob Crandol (PIM), Sam Hayes (PM), and Mark Riblett (PIM)	May 29, 2013

VDOT = Virginia Department of Transportation; PM = Project Manager; PIM = Planning and Investment Manager; ACE = Area Construction Engineer, FD = Fiscal Division, PD = Programming Division

[a] Each interview was assigned an identifying label signifying the VDOT district or office (e.g., FR for the Fredericksburg District, CO for the Central Office) and the order in which the interview was conducted (e.g., "1" for the first interview.

Further, as seen in Table 2, each interview was assigned an identifying label signifying the VDOT district or office (e.g., "FR" for the Fredericksburg District, "BR" for the Bristol District, "CO" for the central office) and the order in which the interview was conducted (e.g., "1" for the first interview conducted). Throughout this report, to signify an interview as the source of the information being discussed, the identifying label is provided in parentheses (e.g., Interview FR1, Interview BR2, etc.).

For interviews in the Culpeper, Fredericksburg, Lynchburg, and Salem districts, the researchers relied on the appropriate members of the technical review panel (TRP) to help identify interviewees knowledgeable about PE from the project management and/or programming perspective. For the Staunton, Hampton Roads, Richmond, and Northern Virginia districts, as there was not a TRP member who represented these districts, the researchers contacted the district transportation planner who could help identify these individuals; in Bristol, the researchers knew an individual in the PE field who was a good candidate for the interview.

The researchers emailed each known interviewee the questions ahead of the interview and also brought copies to the interview, which was helpful in case additional staff had been invited by other interviewees. The researchers sought to interview all interviewees in the same room at the same time; however, in one district (Culpeper), one member of the group could not be present at the same time as the other members of the group; thus, two interviews were conducted. The number of people at each interview ranged from 1 to 5. With the one exception of a videoconference used for the Bristol District interview, the researchers conducted the interviews in person at the offices of the interviewees and took notes of each interview. After each interview, the interviewees were given an opportunity to review the notes and make changes to increase the accuracy of the notes. (Generally, the researchers sent the interview notes to all members of the group to review; any corrections offered were accepted; if no one responded to the request for verification, the researchers followed up until a member of the group responded.) The verified (and revised) notes are provided in Appendix A.

Several interview questions concerned the VDOT Project Development Process (Kerley, 2011a) such as the tasks included in PE, the extent to which a project's design changes throughout the PE process, examples of projects that illustrate the role of PE, and how to obtain project information. The first district interview, i.e., the interview with the Fredericksburg District, also served to clarify which interview questions were most critical. Following the interview, revisions to the interview questions were made and then similar questions, with one additional question concerning characteristics that might explain variation in project level PE costs, were posed in the remaining district interviews. The interview questions are provided in Appendix A.

Task 2: Determine the Types of VDOT PE Expenditure Data Available

From the SYIPs for the period FY 2004 through FY 2012 (hereinafter 2004-2012), every UPC within each of the nine VDOT districts was identified (VDOT, 2008). Then, the amount of funds spent for each project on PE, RW, and CN by district and fiscal year was obtained from staff of VDOT's Fiscal Division. VDOT district staff were also asked whether certain projects should be excluded from the analysis because of anomalies associated with these projects. An example would be a study-only project. In order to interpret these expenditure data better, the second half of the interview questions addressed how PE expenditure data were tracked. Interview questions asked about the availability of expenditure data at the district level, the extent to which district staff monitor these data at the program and project levels, and limitations of the data set. These questions are provided in Appendix A. One suggestion from the interviews was that the researchers should consult with VDOT central office staff regarding the identification of projects for which financial information was unlikely to change (meaning the project was essentially finished or terminated) versus projects that may represent ongoing work. Thus an interview was conducted with staff of VDOT's Programming Division and Fiscal Division concerning the identification of those projects. The interview also provided an opportunity to learn caveats from central office staff in analyzing such data, such as the possibility that a few large projects could skew the analysis, the fact that a long project development cycle means that one may need to examine PE percentage over a longer, rather than a shorter, period of time, and the impact of unexpected changes in forecast future revenues. These interview questions and responses are provided in Appendix A.

Task 3: Compare Virginia Statewide PCE Percentages to Those of Other States

In its Highway Statistics Series, FHWA provides the percentage of funds spent on preliminary and construction engineering (PCE) by state and year. These data were obtained for each year for the period 1990-2010 (FHWA, 1990-2010) from a table containing disbursements for “state administered highways.” Although *PCE percentage* does not have the same definition as *VDOT PE percentage,* the FHWA data do provide some ability to compare Virginia to other states with the use of a common data set. The comparisons were made with all other states and then only those states that maintained the rough equivalent of Virginia’s secondary system: Alaska, Delaware, North Carolina, and West Virginia (O’Leary, 1998; Oman, 2006). When reporting these PCE results (e.g., the results of Task 3), this report uses the state names (e.g., “Virginia”), which is consistent with how the data are reported by FHWA (1990-2010).

The paired *t*-test (Eq. 1) was used to determine whether these percentages were significantly different

$$T = \frac{D}{S_D / \sqrt{n}} \qquad \text{[Eq. 1]}$$

where

D = the average difference among pairs of samples

S_D = the standard deviation of these differences

n = the number of pairs

T = the Student’s *t*-distribution from which compute the corresponding *p*-value associated with n-1 degrees of freedom can be computed.

For example, for year 1990, the paired difference between Virginia’s PCE percentage and the mean PCE percentage for the remaining 49 states can be computed. Repeating this calculation for n = 21 years of data (e.g., 1990, 1991…2010) yields n = 21 paired differences, with mean D = 2.09%, standard deviation S_D = 4.19%, and hence T = 2.28, such that the corresponding *p*-value with n – 1 = 20 degrees of freedom is 0.03. Generally, *p*-values, also known as significance levels, of 0.05 or less are considered significant, meaning that there is at most a 5% chance that the observed difference is due to chance.

Task 4: At the Program Level, Determine and Interpret the Percentage of Funds Spent on PE As Opposed to RW and CN for Each VDOT District and Each Fiscal Year

The percentage of funds spent on PE versus RW and CN was calculated for each VDOT district and the state as a whole and for each fiscal year for the period 2004-2012 inclusive. A state fiscal year begins July 1 and ends June 30; for example, FY 2012 begins July 1, 2011, and ends June 30, 2012. The percentages were calculated using all projects for which expenditure data were available, i.e., those projects with a UPC that did not begin with the letter “T.” The majority of such projects appeared to be public transportation projects; for example, in 2012, 79% of projects in the 2012 SYIP (VDOT, 2008) were public transportation projects whereas 2%

of projects that did not begin with the letter "T" were public transportation projects. These results are reported as "VDOT" PE percentages since they refer to VDOT-specific data.

To understand these percentages, variables that explained differences in VDOT PE percentages by district, and by district and year, were identified. The TRP and the district interviewees suggested that it was possible that some independent variables might explain variation in district-level percentages. Examples of such variables were the percentage of low-cost projects, since PE as a percentage tends to be larger for such projects; the percentage of expenditures for secondary roads, since such PE percentages would be expected to be higher to the extent they are lower-cost projects; and the percentage of expenditures spent on minimum-plan or no-plan projects. Minimum-plan or no-plan projects do not require detailed surveys or construction plans (VDOT, 2005) and thus would be expected to have lower PE percentages. A total of 29 independent variables were identified, and the ability of these variables to explain variations in PE percentage by district and by district and year was examined through the use of stepwise linear regression, and a general linear model, respectively, in SPSS to determine the statistical significance of the variables. The TRP was generally supportive of this analysis because it made use of the full data set. Model 1 uses a single variable (percent of expenditures spent on minimum-plan or no-plan projects); Model 2 adds to this another variable (the percent of projects in the development phase); and Model 3 adds a third variable (percent of expenditures spent each year on large projects). Model 4 modifies the dependent variable to be the pooled PE percentage rather than the mean PE percentage.

In both cases, when results were examined by district or by district and year, the statistical significance of the independent variables and one measure of goodness of fit—the adjusted R^2, which is the percentage of variation explained by the independent variables in the model and ranges from 0 to 1—was reported by the software used (i.e., SPSS). Critical assumptions that were specific to each of these data sets were also considered, as documented in Appendix B. For the data set without annual variation, the smallness of the data set caused the researchers to assess normality, based on a procedure outlined by Johnson and Wichern (2002), and constant variance of the residuals, based on a procedure outlined by Newbold (1988). For the data set with annual variation, the possibility of autocorrelation necessitated an adjustment suggested by Newbold (1988) to remove this autocorrelation.

Then, the researchers examined how the PE percentage changed after excluding from the data set any projects that district interviewees recommended be excluded. Examples of such non-typical projects were enhancement projects; district-wide projects; study-only projects; projects funded with ARRA monies; minimum-plan projects; no-plan projects, locally administered projects or projects administered by an entity other than VDOT; and projects that interviewees recommended be excluded for some other reason, such as railroad crossing projects. The rationale for this analysis was that in Interview Questions 4 and 5 (see Appendix A), district staff identified projects that were not conventional VDOT construction projects; thus, in the researchers' view, a more robust comparison across districts could be made once the data set was restricted to construction-only projects. The TRP cautioned, however, that such an analysis would lose value because it would not capture all projects. Although it provided a more rigorous comparison, it changed the research focus from that of a program-level analysis.

Task 5: At the Project Level, Develop an Approach for Forecasting PE Expenditures As a Function of Project Characteristics Identifiable When the Project Is Scoped

A review of the literature that identified methods for forecasting PE costs at the project level and further examination of projects recommended by district interviewees suggested types of project characteristics that could be useful for forecasting PE costs. Further examination of the availability of these characteristics by project in six VDOT districts enabled the researchers to determine which characteristics were usually or always available. The process for collecting these data and making this determination is given in Appendix C. Generally, these projects had a forecast PE expenditure and an actual PE expenditure. In addition, they had a forecast CN expenditure generated at the scoping phase, as shown in the PCES database. For example, Figure 2 indicates that for UPC 57044, the CN estimate at the scoping phase was $10,186,389. A total of 156 projects were identified. Figure 2 also shows that the PCES database is linked to the Project Pool and the Integrated Project Manager (iPM); the latter is a database of details regarding how a project is developed, and the former is the first database encountered after one enters the iSYP. In short, with a given UPC, the Project Pool and its linked databases enable one to find information about a given project such as its functional class.

Of the 156 projects, 124 were under $5M; these smaller projects were then split into a set of training data (97 projects) that was used to develop models and a set of testing data (27 projects) that was used to evaluate model performance. Seven project-level models were identified: the existing model for forecasting PE costs used in VDOT's PCES (Model 5), a second model that had the same functional form as the first but was recalibrated with the new training data (Model 6), and five alternative models based on project characteristics in addition to the CN estimate (Models 7-11). In short, training data were used to calibrate the models and testing data were used to validate the models.

The six new models (Models 6-11) were evaluated with respect to four sets of criteria:

1. their ability to explain variation in the PE costs in the training data set (e.g., the adjusted R^2)

2. their ability to improve forecasting accuracy relative to the first model (the existing approach based on PCES) with the testing data set

3. their use of variables that were statistically significant in the training data set

4. the extent to which they met seven statistical assumptions in model development as reported in Appendix B: linearity, independence of errors, homogeneity of variance, normality, reasonableness of the coefficients, feasibility of forecasting independent variables, and interpretation of Type 2 error.

A prerequisite for a variable being included in model development was the use of data that are available (or at least can be forecast) when the project is scoped.

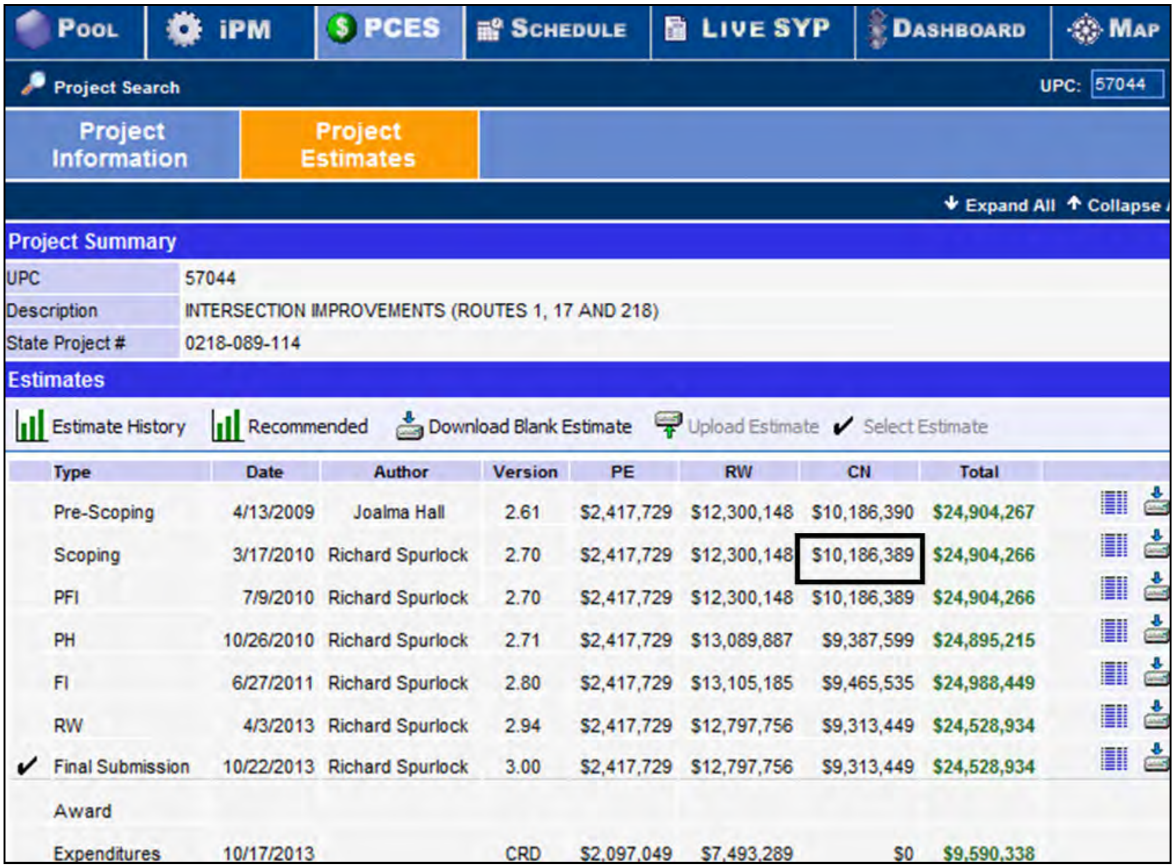


Figure 2. Construction Estimate UPC 57044 Derived From the Project Cost Estimating System (PCES) Database, Which Is Linked to the iPM (Integrated Project Manager) and the Project Pool

RESULTS AND DISCUSSION

The results are organized into five objectives as defined by the five questions in the "Purpose and Scope" section:

1. Define *preliminary engineering* based on a review of the literature and interviews with VDOT district and central office staff.

2. Determine the availability and staff review of VDOT PE data.

3. Compare the percentage of funds spent by Virginia and other states on preliminary and construction engineering (PCE): 1990-2010.

4. Explain variation in VDOT's program-level PE percentages: 2004-2012.

5. Develop a model to forecast VDOT's PE expenditures at the project level.

Objective 1. Define Preliminary Engineering

Definitions of *Preliminary Engineering* in the Literature

Five different definitions of *preliminary engineering* were found in the literature. These definitions, discussed here, ranged from the precise to the general.

Definition of Preliminary Engineering by VDOT

VDOT's Project Development Process defines *preliminary engineering* as five steps: scoping, preliminary design, detailed design, final design and RW acquisition, and advertise plans. An interactive flow chart (VDOT, 2012a) provides additional information for each step as follows:

1. *Scoping* establishes the cost estimate, schedule, management policy, and project team and confirms the "project purpose and need" (VDOT, 2012a). The project development approach is determined by a scoping kickoff team meeting that allows the project team to document all significant information (e.g., environmental data; traffic analyses; sources of risk; and evaluations of stakeholder involvement, including coordination with the lead design engineer). The PCES is used to estimate costs across three phases: PE, RW, and CN. Developing the project schedule requires the team members to identify project tasks and assign duration estimates. The schedule is closely monitored and can be changed if circumstances change. The project management policy is the overall structure and organization showing how tasks will be completed and who is responsible for each stage of the project.

2. *Preliminary design* includes the "design of roadway, structures and bridges, traffic control devices/intelligent transportation systems, and landscaping" (VDOT, 2012a). Each design is then "reviewed by all stakeholders in the project, such as affected property owners and local governments" (VDOT, 2012b). Stakeholders may share their opinions at one or more public information hearings, after which a decision is made regarding "the location of the roadway and details such as right-of way width, type of intersections and interchanges, and materials needed" (VDOT, 2012a). Before any major design work or RW acquisition is undertaken, approval of the Commonwealth Transportation Board is required.

3. *Detailed design* includes RW acquisition, which is done early to minimize delays later in the project development process; field inspections; control of erosion; and "performing constructability and work zone reviews" (VDOT, 2012a). Field inspections also address "issues such as constructability, plan clarity and maintenance aspects as well the project related questions and comments included with the plans" (VDOT, 2011b). If questions arise that need further review, the project manager can seek clarification from the district project development engineer.

4. *Final design and RW acquisition* results in a pre-advertisement conference where any plan refinements prior to advertisement are made. This phase consists of a "thorough review of the plans including the proposed sequence of construction and maintenance of traffic, as well as the contract documents, by the entire project team prior to advertisement of the project" (Kerley, 2011a). Preparing for the conference is critical as all project details are finalized, making the plans ready for bidding.

5. *Advertise plans* results in project advertisement and award. Permits, environmental certificates, plans, specifications, and estimates must all be complete and approved before the bidability review. Projects must also meet the contract time determination guidelines.

In sum, VDOT's definition of *preliminary engineering,* as reflected in the VDOT Project Development Process, is expansive. Theoretically, all of the responsibilities stated in the five steps except for RW acquisition and associated labor are charged to the PE phase of a project.

Definition of Preliminary Engineering by the Federal Transit Administration

FTA (2007) noted the use of varying definitions, such as the engineering necessary to complete the environmental requirements in the National Environmental Policy Act of 1969 (NEPA) or 30% of final design. This "Federal environmental review process," described in this report as a NEPA review, determines the "environmental, transportation, cultural, and social impacts" for a given project after which steps are developed to mitigate these impacts (FTA, 2007). Final products of the PE phase include a final scope, an accurate cost estimate, a project management plan, and a financial plan with funding committed to the project. The final scope includes the overall project objectives and clear definitions of what is expected at the end of the project. A guiding principle behind PE is "[c]ompletion of all cost estimating to the level of confidence necessary for the project sponsor to implement its financing strategy."

New Starts (i.e., federal transit capital investments) entails a three-phase project development process (FTA, n.d.). Phase 1 (Alternatives Analysis) evaluates mode choice for a given corridor and includes "costs, benefits and impacts of transportation options so that the community can identify a preference." The phase once an alternative has been selected and adopted into the MPO's long-range plan. Phase 2 (Preliminary Engineering) entails consideration of alternative designs and terminates when the NEPA review is completed. Throughout this phase, leaders "finalize management plans, demonstrate their technical capabilities to develop the project, and commit local funding sources." Phase 3 (Final Design) also entails development of construction plans and details for the bid documents. FTA (2007) indicated that during PE, the design must comprise "all major or critical project elements to the level that no significant unknown impacts relative to their costs or schedule will result." In sum, FTA's (n.d.) definition of *preliminary engineering* does not include final design, in contrast with VDOT.

Definition of Preliminary Engineering by the North Carolina DOT

In reference to NCDOT, Liu et al. (2011) defined *preliminary engineering* as "the efforts required to plan and design a highway project for construction."

> PE begins when a specific highway project first receives funding authorization for planning and/or design activities. The delivery of the construction documents for project letting marks the end of PE.

This definition is aligned with VDOT's definition in that it includes a broad range of activities.

Definition of Preliminary Engineering by Dowling and Elias in a Study of the Extent and Highway Capacity Manual Is Used in Planning

In their study, Dowling and Elias (2012) defined *preliminary engineering* narrowly. They present a graphic dividing a general planning and preliminary engineering phase into four stages: pre-project planning, project need, project initiation, and project clearance. The project clearance stage is where the "planning analyses start to intersect and overlap with engineering analyses" and is defined therein as preliminary engineering. In this PE phase, the "project details have still not been finalized . . . but the outcome of this stage will produce the final project details before actual design begins." Although this PE definition, is narrow, its "pre-project planning" stage, which Dowling and Elias (2007) also described as a "pre-project development" stage, overlaps with what VDOT would define as the earlier planning process, where travel demand models are created to help develop system performance measures, such as passenger hours traveled (PHT), passenger miles traveled (PMT), vehicle hours traveled (VHT), and vehicle miles traveled (VMT). (Later, during the "project clearance" stage, such system measures can be used in "air quality analyses, including sustainability, climate change, and greenhouse gas emission analyses" [Dowling and Elias, 2007].)

Definition of Preliminary Engineering by AECOM et al. in a Study to Estimate Soft Costs for Major Public Transportation Fixed Guideway Projects

In their study, AECOM et al. (2010) provided a high-level analysis of how "soft costs" affect transportation projects. In contrast with hard costs (e.g., "construction such as steel, concrete, rail cars and buses, or construction labor"), soft costs generally refer to professional services and include "designing the project, obtaining permits, and managing the construction project." A relatively narrow subset of the soft costs category is preliminary engineering, which AECOM et al. (2010) defined as "the costs of early design, negotiations for operations and/or maintenance, developing financial plans, and ridership studies." To be clear, this definition of *preliminary engineering* excludes certain VDOT typical soft costs (e.g., final design, surveys, and environmental permits) such that although soft costs are estimated as 30% of construction costs, PE is estimated as 2% of construction costs. AECOM et al. (2010) reported a variety of factors that influence soft costs (e.g., project delivery method) and that can hinder accurate forecasting of a project's soft costs.

Summary of Definitions of Preliminary Engineering in the Literature

Table 3 summarizes the five disparate definitions of *preliminary engineering* in the literature, listing them from the broadest to the most limited.

Table 3. Summary of Definitions of *Preliminary Engineering* in the Literature

Source	Audience	Activities Included in Definition	Breadth of Definition[a]
VDOT (2012a)	VDOT	Scoping, Preliminary Design, Detailed Design, Final Design and RW Acquisition, Advertise Plans	Expansive (all activities prior to CN except RW acquisition included)
Liu et al. (2011)	NCDOT	Everything between PE funding authorization through delivery of construction documents	
FTA (2007, n.d.)	FTA, transit agencies	30% of design, NEPA review	Moderate, excludes final design
AECOM et al. (2010)	Transit agencies	Draft Environmental Impact Statement (DEIS), Early Design, Negotiations for Operations and/or Maintenance, Developing Financial Plans, and Ridership Studies	
Dowling and Elias (2012)	Users of the HCM	Final project details before actual design begins, TDM to determine performance measures (PMT, VMT, PHT, and VHT)	Restricted, also overlaps with planning

PE = preliminary engineering; VDOT = Virginia Department of Transportation; CN = construction; RW = right of way; NCDOT = North Carolina Department of Transportation; FTA = Federal Transit Administration; NEPA = National Environmental Policy Act; TDM = travel demand model; PMT = passenger miles traveled; VMT = vehicle miles traveled; PHT = passenger hours traveled; VHT = vehicle hours traveled; HCM = Highway Capacity Manual.
[a] Definitions are listed in order from the broadest to the most limited.

Definition of *Preliminary Engineering* Based on VDOT Interviews

Interview Questions 1 through 4 (see Appendix A) helped define *preliminary engineering* as practiced by VDOT. These interview questions concerned the alignment between the VDOT project development process and the SYIP (Interview Questions 1 and 2); the extent to which PE is a linear or recursive process (Interview Question 3); and the availability of UPCs that help describe the PE process (Interview Question 4). As will be seen, the VDOT interviews showed that the PE function varies by project.

Alignment Between VDOT Project Development Process and SYIP (Interview Questions 1 and 2)

The VDOT Project Development Process Flow Chart (VDOT, 2012a) shows five phases for PE: scoping, preliminary design, detailed design, final design and RW acquisition, and advertise plans. These align with the SYIP in terms of funding. However, scheduling is not consistent between the two. In practice, the RW phase may overlap with the PE and CN phases. For a hypothetical project, Table 4 shows that the start dates for PE are identical with regard to SYIP; however, the PE, RW, and CN phases may overlap in the project development process but are strictly sequential in the SYIP. The PE and RW phases may overlap and the RW and CN phases may overlap in reality; the only rule, at least for some districts, is that the PE phase ends when the CN phase begins (Interviews FR1, CU3, and HR7). However, for some districts, PE may continue after CN has begun (Interview NV9). Of the five definitions of *preliminary engineering* noted in Table 3, VDOT's definition aligns most closely with that used by NCDOT as noted by Liu et al. (2011).

Table 4. Alignment of VDOT Project Development Process and SYIP for a Hypothetical VDOT Project

VDOT Project Development Process		Six-Year Improvement Program	
Phase	**Hypothetical Schedule**	**Phase**	**Hypothetical Schedule**
Scoping	Begin Jan. 2013 End Dec. 2015	Preliminary Engineering	Begin Jan. 2013 End Dec. 2013
Preliminary Design			
Detailed Design			
Final Design and RW Acquisition			
Advertise Plans			
RW phase is not shown but may begin while PE is underway.	Begin Jan. 2014 End July 2014	RW	Begin Jan. 2014 End Dec. 2014
CN phase is not shown but occurs after advertisement.	Begin Jan. 2016 End Dec. 2016	Construction	Begin Jan. 2015 End Dec. 2016

VDOT = Virginia Department of Transportation; SYIP = Six-Year Improvement Program; RW = right of way; PE = preliminary engineering; CN = construction.

Tables 3 and 4 show that VDOT's definition of *preliminary engineering* is broad. VDOT's PE spans activities that occur from the time a charge number for a project is made available until the project is awarded (not just advertised) for construction.

Extent to Which PE Is a Linear or Recursive Process (Interview Question 3)

Interview Question 3 asked how the end products of three subphases in the PE phase—preliminary design, detailed design, and final design and RW acquisition—typically changed throughout the PE process. The results revealed some typical benchmarks, such as preliminary design being completed when approximately 30% of PE funds have been spent and RW / detailed design being completed when 65% of PE funds have been spent (Interviews BR2 and HR7). However, interviewees also pointed out that these benchmarks were not definitive for every project, with one set of interviewees noting that the end products may change "very little, substantially, or somewhere in between" (Interview SA4). Perhaps not surprisingly, the scale of the project influences this level of change—one example given was the contrast between paving an unpaved road and constructing a bypass around a metropolitan area, with the latter having more changes relative to the former.

An unanticipated finding was the observation by interviewees that PE can be a recursive (i.e., a looped) process. For instance, one set of interviewees noted one might accomplish 30% to 40% of design before realizing a change in the final product was needed because of changes in land development, unforeseen geotechnical challenges, or public involvement (Interview HR7).

Five factors tend to increase the likelihood that the PE process will be recursive.

1. *Duration.* As time passes, four key types of events become more likely: design standards or regulations change (especially if there is a long gap between PE initiation and construction advertisement) since failure to begin the RW phase within 3 years of the public meeting means new design standards must be adhered to); the scope changes (perhaps in response to public involvement); funding availability changes; or land development occurs (Interview NV9). In the last instance, it can be the case that new property owners are not satisfied with the conditions agreed to by previous property owners. One example of how a change in funding levels increased

the percentage of costs was when the planned addition of a turn lane was replaced with the installation of flashing lights (Interview LY6). If a given UPC has PE for a turn lane but the construction costs reflect only the lights, the PE/CN ratio will be quite high.

2. *Staff turnover*. Such turnover can increase costs (Interview RI10) because some tasks may need to repeated, especially if late in the PE phase the project moves from an in-house design to a design-build process. Appendix A suggests that the likelihood of such turnover is increased by a longer PE process.

3. *Size*. Although they involve numerous design decisions, larger projects (e.g., an interchange) may have some stability in that the project involves a well-defined solution (e.g., an interchange, a bypass, etc.). By contrast, the purpose and need for a smaller project may be such that numerous designs must be considered (e.g., elevate the roadway or build a drainage system given that the purpose is to eliminate flooding) (Interview FR1). Further, larger projects may also build momentum as the PE process unfolds such that stakeholders do not want to sacrifice the investment made in earlier design steps.

4. *Responsiveness to public opinion*. The visibility of the project and the public involvement process may lead to detailed design changes throughout the process including design treatments that were not previously anticipated. This responsiveness influences costs (Interviews CU3, SA4, LY6, HR7, and NV9).

5. *Location in an urban area*. One interviewee noted that the risk of geotechnical challenges increases in an urban area (whether attributable to buried utilities, rock, results of structural integrity tests based on the California Bearing Ratio, or other design variables) (Interview HR7). Such risks, if they result in higher-than-anticipated costs, could necessitate a revision in the design.

When a PE process is recursive and requires repetition of previously performed work, its duration—and hence cost—can increase. Although all five of these factors were cited by at least one interviewee as influencing PE costs, the narratives in Appendix A suggest that duration may be one of the largest influences. As an illustration, a 5-mile project cited by the Culpeper District had approximately $4M in PE costs. The 17-year duration appears to have contributed to other actions that increased PE costs such as survey updates, additional location hearings, a change from state to federal funding (which increases environmental requirements), and turnover in internal and external staff (Interview CU3).

Availability of UPCs That Help Describe the PE Process (Interview Question 4)

Interview Question 4 asked interviewees to recommend a sample of UPCs that would help foster a better understanding of the role of PE and how PE tasks are funded. Interviewees provided projects that illustrated various dimensions of the project development process. For example, interviewees from the Hampton Roads District (Interview HR7) noted the higher PE costs on a percentage of total cost basis associated with smaller scale Highway Safety

Improvement Projects (typically under $1M); the Bristol District interview *(*Interview BR2) yielded five UPCs that showed Tier 1 versus Tier 2 projects and variables that influence cost, such as wetland mitigation. Other factors that influenced PE costs included whether the project was locally administered, as some localities may not have to charge all of their PE staff time to an actual PE phase; whether the project was design-build; and whether the construction project was a "Complete Plan" project as opposed to a minimum-plan or no-plan project, which would have lower or no PE costs (Interview SA4).

Interviewees also gave instances where the project development process did proceed as expected. An example (where the project development process appears to have been sequential rather than iterative) is Route 639 in Caroline County, which was described as a best case scenario because of stakeholders' agreement on the project scope (FR1). The Lynchburg District noted a passing zone project on Route 501 where first a budget was established and then a design was selected that fit within the constraints of the budget (Interview LY6).

However, the interviews also showed at least five types of scope changes where the work performed in some portion of the PE phase might not ultimately be used in the construction of the project. These five types are shown in Table 5. As examples, PE may be performed for a 4-mile section of roadway but only a 2-mile section is constructed. For smaller projects, a problem rather than a project might be presented (e.g., a problem might be that "a road is flooding").

Table 5. Types of Scope Changes in the Preliminary Engineering Phase in VDOT Districts

No.	Type of Scope Change	Example Projects
1	PE may be done for a larger section than what is built.	For Route 687 in Pulaski County, the PE reflected a 1.5-mile section, but the CN reflected only 2 spot improvements (Interview SA4).[a]
2	The scope may change because the project is not fully defined or may require the evaluation of multiple designs. This is especially the case for small projects.	For Route 634 in King & Queen County, the initial purpose and need were to raise the roadbed (to eliminate flooding); later the design was changed to build a better drainage system. This required multiple pre-scoping efforts to define a relatively small project (Interview FR1).
		For Route 58 in Scott County, a relatively small project had multiple designs considered at the preliminary field inspection stage (where a preliminary set of plans are reviewed) (Interview BR2).
3	The scope of the project may grow as a result of the public involvement process.	A project on Route 668 in the Salem District illustrated the role of elected officials who can write letters of support (Interview SA4).
4	The scope of the project may shrink as a result of changes in funding.	A series of widening and intersection improvements was planned for Route 15 in the Lynchburg District; however, because of insufficient funds, the project was scaled back to more modest improvements (Interview LY6).
5	PE may include tasks that are not strictly PE.	For an interchange project on I-95 in Stafford County, PE included the cost of preparing the required interchange justification report (IJR). Other interviewees noted that the VDOT accounting systems record very specific tasks in the CN phase but not in the PE phase (Interview FR1).

VDOT = Virginia Department of Transportation; PE = preliminary engineering; CN = construction.
[a] Parentheses indicate interview source as shown in Appendix B; for example, "(SA4)" indicates the information came from the interview with the Salem District.

Thus, PE will include consideration of diverse alternatives, such as, in this case, building a bypass drainage system or elevating the roadway. By extension, such projects illustrate the importance of PE—in this example, the cost of the different alternatives varied by almost an order of magnitude, from a midpoint estimate of $700,000 for the lowest-cost alternative to $5 million for the higher cost alternative. Not surprisingly, the percentage of costs attributable to PE drops, according to VDOT's PCES tool, as the construction cost rises; one district noted that the percentage of PE costs ranged from 8% to 35% depending on the project (Interview BR2). Further, a drop in CN funding can cause PE work not to be used in project construction.

Two special cases of projects were noted in some interviews:

1. *Design-build projects.* One interview noted that for design-build projects, PE activities are charged to construction, although at the program level, it was suggested that design-build projects were a lesser concern as there are relatively few of them (on the order of 5 to 10 per year statewide) (Interview CO5). That said, one interview noted that certain PE tasks may be repeated (with such repetition increasing costs) if there is a shift from in-house work to consultants (or vice-versa) or a change from a traditional project delivery process to design-build part way through the PE process (Interview CU3).

2. *Travel demand management/rideshare programs, including some elements of park and ride programs* (Interview NV9).

Objective 2. Determine Availability and Staff Review of VDOT PE Data

The extent to which PE expenditure data are available to and reviewed by VDOT staff was covered in Interview Questions 5 through 9. The interviews showed that although expenditure data are accessible, data limitations influence the types of analyses that are undertaken. District staff review PE percentages for specific projects but not for the entire program. Some interviewees gave a range of appropriate project-level PE percentages but cautioned that they are influenced by several factors. Such factors prevented most interviewees from citing a single program-level PE percentage. Accordingly, this section considers (1) the availability and quality of PE financial data; (2) the availability and quality of project characteristic data; and (3) the extent to which these data are presently used or could be used by staff.

Availability and Quality of PE Financial Data

Availability of Data

A requirement for investigating PE expenditures is the availability of financial data. For information about estimates, and to a limited extent, expenditures, the Integrated Six-Year Plan (iSYP) is a gateway to a suite of project-specific applications such as funding sources, the project cost estimating system, and an internal version of the Six Year Improvement Program; the iSYP can only be accessed internally within VDOT. For this report, the main role of the iSYP was to access VDOT's Project Pool, which in turn provides access to a suite of internal agency databases containing financial and engineering characteristics for individual projects. One of these databases is the Project Pool itself, other databases are the iPM and the PCES; these databases are linked to each other but, after one enters the iSYP, the first database one encounters is the Project Pool which is why the Project Pool is generally the term used in this report to describe how to access these project-specific data.) The Project Pool has a "Schedule / Estimates" section that provides estimates and [cumulative] expenditures for PE, RW, and CN. This information is routinely available, and expenditures are updated in the Project Pool every 2 weeks (Interview BR2). Although other databases, with different focus areas, contain project estimates and expenditures, the Project Pool is most likely to have current expenditures (Interview NV9). At the beginning of a project, the Project Pool has an approved estimate for each phase. However, after activities are charged to the project, the estimates are changed to reflect current project expenditures.

Estimates that do not change once a project has begun are located in the "PCES" database linked to the Project Pool. As was shown in Figure 2, estimates may be shown in up to eight sections depending on how far a project has progressed. From earliest to latest, these sections are pre-scoping, scoping, PFI (preliminary field inspection), PH (preliminary hearing), FI (field inspection), RW (right of way), final submission, award, and expenditures. Although these estimates are located in the PCES section, estimates can originate from at least two estimating tools: PCES, used earlier in the process, and TRNS*PORT, which is used for the Final Submission estimate. Interviewees suggested that the "tolerance" is ±25% for PCES and ±5% for TRNS*PORT. The researchers interpreted this to mean that PCES estimates would be within 25% of the correct answer and TRNS*PORT estimates would be within 5% of the correct answer. Neither tool includes items such as sidewalks and trails (Interview FR1).

The financial data are available to compute the percentage of expenditures spent on PE as opposed to RW or CN. However, financial data accessibility is complicated by the need for three different information systems: Cardinal (for expenditures after November 2012); FMSII (for expenditures for roughly the period January 2003 through November 2012); and Financial Management System I (FMSI) for projects prior to FMSII (Interview SA4).

That said, expenditure data from FMSI, which were ported into FMSII from earlier periods, are believed to be accurate. Further, if a UPC appears in FMSII, the data therein should be complete, although it is acknowledged that some information may be lost generally as financial systems change (Interview CO5). For current projects (e.g., expenditures since 2012), the Business Objects (BOXI) portal into Cardinal provides financial information by phase, and a direct query of Cardinal provides information by activity, account, and entity charging to each project (Interviews BR2 and CO5).

Interviewees noted that there can be confusion about allocations, estimates, and expenditures. The SYIP, with planned resources for each project, contains allocations of funds to specific UPCs (Interview SA4). There is a difference between funds that have been set aside for a specific project to be used at a point forward in time (i.e., an allocation) and funds that have already been spent on a specific project (i.e., an expenditure). Expenditures are reported by phase. However, although the SYIP shows estimated amounts by phase, the SYIP formally allocates amounts to a specific UPC—e.g., when a SYIP shows a given amount for a particular project, that amount could, in theory, be intended for any of the three phases. That said, one can draw inferences by comparing the estimate and the allocation (Interview SA4). For instance, a project with an estimated PE cost of $1M, an estimated RW cost of $2M, and an estimated CN cost of $3M that shows a SYIP allocation of $6M would be inferred to be fully funded.

Quality of Data

Interviewees noted nine reasons the financial data should be treated with caution. The districts generally agreed that tracking projects by phase and activity will not yield the entire amount VDOT spends on PE for two reasons: (1) the availability of a pre-scoping UPC means some PE is not attributed to a specific project, and (2) the manner in which maintenance projects are funded means some PE is not attributed to a specific project. In addition, some districts noted other reasons as to why the financial data should be treated with caution, such as the lack of a PE phase for secondary roads prior to the existence of FMSII (Interview CU3).

There are nine reasons it is possible that reported PE expenditures may not fully represent the PE work required to complete the PE phase for a particular project; however, tracking PE for a program as a whole should be feasible provided Reasons 3 and 5 can be addressed.

1. *The availability of a pre-scoping UPC means some PE is not attributed to a specific project.* Some PE work may be accounted for in charges made to district-wide project numbers for pre-scoping, and such charges will not be recorded as part of the PE phase (Interviews BR2 and CU3) for a specific project. For example, UPC 99570 refers to pre-scoping for the Fredericksburg District; these expenditures are counted as PE but are not attributed to a specific project. This can occur when it is difficult to obtain authorization to perform PE work on a project; such district-wide numbers will yield a lower [project-specific] PE expenditure since some initial work was charged to a different UPC (Interview CU3). Pre-scoping funds are also helpful because a project can begin while waiting for federal funding or getting into the SYIP. High-profile projects that begin in the pre-scoping phase may have a lower PE because some of the early tasks can be taken care of in the pre-scoping phase (Interviews ST8 and NV9).

Some of these activities in the pre-scoping phase include PE-related charges such as planning costs and administrative costs (Interview LY6). However, one district described such exceptions as minor if one is concerned about the relationship of PE to CN, since these items (e.g., administration) would also affect the RW and CN phases (Interview LY6). The amount of pre-scoping funds varies by year: for each district it was $750,000 (Year 1) and $1,000,000 (Year 2 at the time of the interview); such variation determines the extent to which pre-scoping funds influence the PE percentage (Interview SA4).

2. *The manner in which maintenance projects are funded means some PE is not attributed to a specific project.* The number of maintenance projects heavily influences how tracking expenditures by phase and activity yield the entire amount VDOT spends on PE. For maintenance projects, all PE may be charged to a single UPC, such as in the Salem District where there are 28 paving projects whose PE is handled by a single UPC (Interview SA4). This use of a single charge number makes it difficult to delineate specific PE tasks from one project to

another. However, if maintenance projects are excluded from the analysis, the limitations may not be significant. A sensitivity analysis could be conducted to determine the importance of such limitations (Interview CU3).

3. *The existence of other sources for accomplishing PE work.* Some districts noted that PE tasks can be charged to other sources. In the past, PE work for some projects was done by residencies, and such work might not have been captured as PE expenditures but rather as expenditures for some other cost center (Interview SA4). Presently, staff who charge a significant amount of their time to administration may charge some time to administration that could be charged instead to a particular UPC (Interview RI10). Some planning staff who are 100% funded by VDOT's Transportation and Mobility Planning Division (TMPD) may put some time into PE (Interview RI10). Further, related RW costs (although not RW acquisition) may be charged to PE if RW tasks must be performed when the RW phase is not yet open to charges (Interview LY6). Finally, the termini for two projects may intersect such that the environmental portion of one must be done prior to completing PE on the other. In that case, some of the PE for one project may be linked to the other project (Interview ST8). Although a best practice is to ensure PE costs are charged to the appropriate UPC, in some cases one UPC has PE for more than one project (Interview RI10).

4. *The use of multiple UPCs.* There is not necessarily one UPC per project (Interview SA4). PE from multiple projects may be bundled into a single UPC; for instance, in the City of Richmond, there is one UPC that contains all PE for 10 separate CN-only UPCs (Interview RI10). Some projects have two UPCs: one for PE/RW (or PE-only) and one for CN (Interviews BR2 and HR7). In such an instance, use of only one UPC to calculate the PE percentage can skew the results toward a higher or lower PE percentage. The interviews did not discuss why there might not be a one-to-one relationship between UPCs and projects.

5. *Difficulty in delineating PE activities from CN activities.* Details that separate the PE, RW, and CN phases may not be immediately apparent. A project that will take existing wetlands may be used as an example. If the mitigation is to purchase wetland credits, that cost is charged to PE, but if the mitigation is to construct a new wetland, that cost is charged to CN. Accordingly, it is difficult to compare VDOT PE with that of other states (Interview FR1).

The use of consultants and the method of project delivery influence interpretation of PE costs. For instance, the loaded rate for consultants is higher than that of in-house staff, but electricity and office space are not included in overhead for the latter (Interview FR1). The project delivery type can also influence how PE expenditures are reported in databases. If the project delivery method is "design-build," the PE activities are charged to the CN phase (Interview CU3). This category adds a layer of complexity because in theory, when the project passes from VDOT to the firm doing the design-build work, the project is already at 30% of design but in practice the project is not necessarily at that point (Interview SA4).

The duration of the PE phase can affect how PE activities were defined. Prior to 2001 or 2002, when FMSII was relatively new, at least some secondary system projects did not have a PE phase but rather had all PE work charged to CN. For this and other reasons, it is possible that not all PE tasks will show expenditures within the PE phase (Interview CU3).

6. *The need for additional details.* The PE budget can change during the scoping phase, where scoping tasks are not tracked to the same degree that as RW and CN tasks, such that valuable information can be omitted (Interview FR1). The inability to track the PE budget at a level of detail useable to managers was noted as a concern by interviewees (Interview FR1). Details such as the amount individual disciplines (e.g., environmental versus hydraulics) are charging are not well documented. Although activity codes provide a substantive portion of a project's costs, information about the specific components of an activity are not available.

Information about a project may not be available to the VDOT designer in the sense that most other states leave local road design to localities, in which case more information about the project's need will be available to the local designer than is the case in Virginia. Accordingly, interviewees noted that some districts create their own databases to track PE (Interview FR1).

7. *Abandoned projects.* In some cases PE is authorized and a portion of the PE work is completed, but the project is not built. It is difficult to determine how often this occurs, but in an interviewee's experience, this happened with 3 of 20 recent projects (Interview BR2). This also can skew the analysis to report a higher PE percentage since there is no CN expenditure information reported. Accordingly, Interview Question 8 raised the subject regarding whether there was a credible way for each district to identify a list of projects (including "dead" projects) that would enable them to determine the portion of total project cost spent on PE. All district interviewees responded in the affirmative. The iPM has a function to export a spreadsheet of all projects and their defining characteristics by district or for the entire state (Interview BR2). A list of projects can also be queried in the SYIP (Interview CU3). However, complications may arise. For example, in the iPM, some projects will have a letter stating that the project is abandoned and others will not. An alternative to using the iPM to identify abandoned projects is to contact Programming Division staff regarding whether a project has been closed out (Interview CU3).

8. *The presence of anomalies.* Some projects are atypical such that they have a characteristic that would cause them to have lower-than-typical PE costs. These include (1) maintenance projects; (2) design-build projects, in PE activities are charged to the CN phase) (Interview CU3); and (3) "Min" or "No" Plan projects (Interview HR7). Although some ARRA projects may be atypical, some are not. Initially, the researchers planned to remove all ARRA projects and other projects without expenditure data in all three phases from the analysis. However, they found out that some ARRA projects have normal project development processes and that the urban Northern Virginia District has a significant number of projects that do not have a RW phase but that are nonetheless [typical] "construction projects" (Interview NV9).

Accordingly, instead of removing projects with anomalies from the analysis, the researchers decided that more accurate results would be obtained if all projects in a district were included in the analysis (Interview RI10). One district is developing a utility that will automatically produce a report that will answer the types of questions raised in the interview based on the various financial systems and the various project characteristics such as abandoned projects. At the time of the interview, the utility was being tested for deployment. The more important aspect of the utility is not "what does the report contain" but rather "what do we do with the information?" Thus the report will likely be used to help determine, for instance, which types of funds have not been spent, as different funding sources have different restrictions, and whether additional resources are needed to deliver the program (Interview RI10).

9. *Some PE expenditures may occur after CN has begun.* Two of the nine districts noted that some PE expenditures may occur after CN has begun (Interviews BR2 and NV9). The interviews of the Bristol and Northern Virginia districts offered examples of PE expenditures occurring after CN has begun, which allows for contingencies. Some districts charge additional PE activities to the CN phase once CN has begun. The Northern Virginia District, however, keeps the PE phase open until the end of the project (Interview NV9). For example, a VDOT district may use PE funds in order to answer a question for a contractor about traffic control restrictions and revise the plan accordingly (Interview BR2). In this instance, when PE activities are occurring after construction has begun, PE is being defined as a specific set of activities (one of which is planning for traffic control) rather than as a temporal phase that must always precede construction (as it does in the Six Year Improvement Program, where one always expects to see the PE phase prior to the CN phase).

Availability and Quality of Project Characteristic Information

Similar to the financial information, the Project Pool also has a "General" section that has project characteristics such as the type of environmental work, functional class, facility type, project length, work flow status, and number of bridges required. This information is routinely available except for some projects where, within the Project Pool, fields indicating environmental work and functional classification are blank.

The Project Pool and the iPM, two linked databases within the iSYP, contain detailed information on project characteristics. If it was uploaded to the iPM, a complete scoping document (also known as a scoping report), found within the "project documents subsection of the iPM, will contain characteristics such as, but not limited to, bicycle/pedestrian accommodation, bio retention (water quality) basin, memorandum of agreements including railroad involvement, recoverable slope study, value engineering study, transportation management plan type, design services provider, businesses and homes to be taken, utility relocation (also called utility conflicts), and alternate delivery method. If applicable, documents other than the scoping document may show characteristics such as (1) whether wetlands are affected, (2) the need for hazardous materials (HazMat) evaluations, and (3) National Historic Preservation Study Evaluations. Generally, project documents are uploaded into the iPM about every 3 months or more frequently if approaching milestones are closer than 3 months.

Interviewees collectively suggested four key limitations of the project characteristic data that in the researchers' judgment could potentially affect the analysis for this study:

1. *Not all details are in the Project Pool.* The details that are available in the iPM database, which is linked to the Project Pool, largely depend on (1) the habits of the project manager, and (2) when the project was started. For projects initiated before the existence of the iPM, in 2007 or 2008, some managers may have retroactively updated details in the iPM and others may not have (Interview SA4). For earlier projects, information on PE could possibly be in a file folder for the specific UPC at the district office (Interview SA4) or the project manager

may be contacted directly for the information (Interviews HR7 and SA4). Years ago, one district used project folders (e.g., right of way, environmental, and so on) with a consistent naming convention; such folders did help organize the material for each project (Interview RI10).

A scoping document is not required by VDOT for locally administered projects or paving projects (Interview RI10). Although the iPM provides excellent information, it was not designed to contain every record for a project but rather is expected to have the critical documents and decisions for agency managers (Interview HR7). Several interviewees noted that they encourage project managers to include material in the iPM such as critical files (Interview HR7) and appropriate documents (Interview ST8) or material that although not required may still be helpful such as the scoping document for locally administered projects (Interview RI10).

2. *Multiple UPCs are used.* PE information may also be limited in the Project Pool if the project UPCs are "co-mingled" where the PE phase and the CN phase are given separate UPCs yet reflect the same project (Interview SA4). This does not occur very often; however, larger projects with multiple construction phases may have co-mingled UPCs. Generally, if the project UPCs are co-mingled, there will be a note in the "Notes" section of the Project Pool. However, if there is no such note, finding the UPCs will be nearly impossible without contacting the project manager. As noted previously, some projects can be divided so that the PE reflects a given section of a project (e.g., Mileposts 0 to 4) but the CN reflects only a portion of the project (e.g., construction between Mileposts 2 and 4) (Interview SA4). Thus, in the Project Pool, PE may have a longer physical length and time duration than what would be appropriate for the project that was actually constructed.

3. *Interpretation of blank fields requires judgment*. After reviewing a set of projects for one district, the researchers categorized the project characteristics as "usually available" (where the only reason a characteristic was missing was a data entry error or some unexplained event); "sometimes available" (where the characteristics were usually available provided the scoping document was uploaded); and "rarely available" (where characteristics were found less frequently even when extensive documentation was uploaded to the iPM).

The interpretation of blank fields in the Project Pool required judgment by the researchers because it was not always clear that missing characteristic data did not constitute an error. Data could be missing because the project did not require that particular data element. By contrast, if a project was missing general information, this would likely constitute an omission of a data element. It was also suggested that when the PE duration had 0 days, the data element was likely in error because all projects have a PE start and end date (J. Brown, personal communication, 2013). However, projects that are in sequential UPC order and have the same duration are not uncommon and are likely accurate (J. Brown, personal communication, 2013).

4. *Archived projects are used rather than closed-out projects*. Project level data are chiefly available from the Project Pool. Some districts suggested that only those UPCs that had been "closed out" should be used. A staff member of VDOT's Fiscal Division familiar with FMSII noted that although a field exists in FMS II to indicate whether a project has been closed out, this field is not typically updated (R. Carver, personal communication, 2012). However, VDOT programming staff noted that the projects that have been "archived" can be used for the

purpose of determining projects whose financial information is unlikely to change (Interview CO5).

Extent to Which PE Expenditure Data Are Used and Could Be Used by VDOT Staff

Staff Review of PE Percentages

At the project level, district staff track expenditures across all three phases (PE, RW, and CN) to keep the project on budget (Interviews SA4, LY6, and HR7). Such tracking also helps managers ensure projects are receiving accurate charges and that FHWA is receiving allowable project charges (Interview HR7). In short, PE expenditures are reviewed by managers for their specific projects, and interviewees cited examples of project-specific PE percentages.

With regard to whether anyone reviews PE percentages at the district level on a program-level basis (e.g., how much the district spent on PE versus CN for an entire fiscal year with respect to all projects), no interviewees noted that such program-level reviews occur. District staff do not review PE percentages at the program level for two reasons: the data have limitations, and it is not clear how such an analysis would be used. Review of such percentages, if performed, would most likely occur within VDOT's Programming Division (Interview SA4). A credible approach to reviewing such percentages would be to create a data set of projects listed in the SYIP but ensure that maintenance projects were not included since maintenance-related projects do not have an explicit PE phase, although they may have PE-related tasks (Interview CU3). Such a data set would not be perfect because of other limitations (e.g., the fact that some PE work may be done before a UPC is available), but the problem of mixing construction and maintenance projects would be avoided (Interview CU3). To be clear, review of PE percentages at the program level would be within the purview of the project investment managers rather than solely that of the project managers.

Appropriate PE Percentages

One use of PE percentages envisioned by the researchers was using a particular PE percentage as a desired target. Accordingly, in Interview Question 6, interviewees were asked: "What is a range of appropriate percentages to be spent on PE relative to other project phases?"

At the project level, interviewees cited a wide range of percentages. The highest and lowest PE percentages for specific projects were around 35% and 8%, respectively (Interview BR2). A rough estimate for a specific project might assume the ratio of PE to CN is 0.15 to 0.20 for projects between $5M and $10 M. This percentage may decrease to 10% as the projects costs exceed $20M and may increase to 50% in some cases for a $1M project (Interviews CU3 and SA4). However, not all projects will fit into the typical project "mold." A recent review of selected projects showed that the percentage of funds spent on PE ranged from 13% to 58% (Interview LY6).

Most interviewees (an exception being Interview SA4) did not give an appropriate PE percentage for the program level but noted factors that influence this percentage. One factor is the portfolio of projects. For example, a significant number of smaller projects make up the program for the Hampton Roads District—especially Highway Safety Improvement Program investments that have a relatively high ratio of PE to CN. These are typically in the $500,000 to $750,000 range (Interview HR7). Similarly, one would expect that the Northern Virginia District would spend a lower percentage on PE than the Culpeper District in part because the former tends to pursue a greater proportion of large-scale projects than the latter (Interview CU3). A second factor is district-specific costs: RW costs in the Northern Virginia District are higher than in the Culpeper District, which would logically increase the latter's PE percentage (Interview CU3). A third factor is changing agency priorities such that a single percentage may not be appropriate (Interview CO5). For example, in the past VDOT almost "ran out of work" because too little money was spent on PE, owing to the large portion of funds dedicated to construction and debt service; more recently, the portion of funds focused on PE has been relatively low because of the emphasis on ARRA projects.

One interviewee noted that an appropriate PE percentage for an entire program might be 15% (Interview NV9). However, consistent with the other interviewees (e.g., Interviews CU3, CO5, and HR7), the interviewee noted other factors that influence such a percentage. One factor is the "non-predictability of funding," where the amount of funds available for investments changes over time. Such changes may occur quicker than the project development process itself; for example, for some projects in the SYIP, the PE phase alone may take 8 years. A second factor is politics: state or local officials may influence the time and cost for the PE phase of specific projects. A third factor is project age, especially for older unfinished projects (Interview SA4).

Objective 3. Compare Percentage of Funds Spent by Virginia and Other States on Preliminary and Construction Engineering

Virginia follows a practice that if PE is funded but RW and CN are not, PE will be undertaken such that the project is "shelf ready" when additional funding is available. For this reason, it was desirable to compare Virginia's PE percentages to those of other states. A surrogate for PE is what FHWA (2000) refers to as "preliminary and construction engineering." There are differences between PCE as reported by FHWA and the PE percentages available from the Virginia data such that PCE is not identical to PE. However, a comparison of PCE for Virginia and other states is relevant for two reasons: it helps determine (1) whether Virginia's secondary system makes Virginia fundamentally different from most other states, and (2) whether the changes in the PE percentage over time in Virginia are replicated in other states.

Within the capital outlay program, FHWA (2000) identified three types of expenditures made by state and local highway agencies: (1) "preliminary and construction engineering," defined as containing expenditures for "field engineering and inspections; surveys, material testing, and borings; preparation of plans, specifications and estimates (PS & E); and traffic and related studies"; (2) "acquisition of right of way"; and (3) "highway construction and system preservation." FHWA (2000) clarified that this capital outlay program does not include maintenance by listing a separate "physical maintenance" program and three additional programs entitled "highway and traffic services," "administration and research," and "highway law enforcement and safety." FHWA (2000) noted that although physical maintenance should include "all expenditures for routine roadway surface, shoulder, roadside and drainage operations," such maintenance should not include "improvements, additions and betterments, or resurfacing, restoration, rehabilitation, and reconstruction expenditures (3R/4R)," which should instead be placed in the capital outlay program.

As noted previously, FHWA reports these capital outlay expenditures for each of the 50 states in its Highway Statistics Series. Thus, for the period 1990-2010 inclusive, it was possible to compare what Virginia spent on PCE as opposed to RW and CN with that spent by other states (FHWA, 1990-2010). As previously discussed, PCE includes not only PE but possibly some tasks that are not strictly PE. Thus to be clear, the PCE percentages available from FHWA are not the same as the PE percentages that can be obtained from an extraction of expenditure data in Virginia's financial management systems. For example, whereas the pooled PE percentage for Virginia for the years 2004-2010 ranged from 11.2% (in 2007) to 17.8% (in 2010), the statewide percentage spent on PCE for the same period ranged from 10.6% (in 2009) to 24.0% (in 2008). That said, FHWA's terminology of "preliminary and construction engineering" is not completely unrelated to VDOT's definition of *preliminary engineering* based on at least one previously described anecdote reported in the Bristol District: if a contractor reviewing a plan has a question about a traffic control pattern, staff would use PE funds to answer the question for the contractor and revise the plan accordingly.

A concern when comparing other states to Virginia is that most other states do not have a secondary system but rather have county roads that are not the responsibility of the state to build or maintain. Indeed, the four other states that maintain their county roads (Alaska, Delaware, North Carolina, and West Virginia) have a ratio of PCE-to-total costs that is about 3.5 percentage points higher than that of the remaining states (excluding Virginia): from 1990-2010 inclusive, PCE expenditures, when averaged first by year and then for the 1990-2010 period as a whole, accounted for 17.6% of the capital outlay for Alaska, Delaware, North Carolina, and West Virginia, whereas such expenditures accounted for only 14.1% of the capital outlay for the remaining 45 (non-Virginia) states. When comparing results by year between these two groups (i.e., the aforementioned four states versus the remaining 45 states with Virginia omitted), the difference is statistically significant ($p < 0.01$). When RW costs are excluded, a similar pattern emerges: for Alaska, Delaware, North Carolina, and West Virginia, the ratio of PCE-to-total costs (excluding RW), is 19.3% compared to 15.3% if one computes the averages for the remaining states (excluding Virginia); again, these differences are significant ($p < 0.01$).

Figure 3 shows the ratio of PCE to total expenditures for Virginia; the nation; and the four states of Alaska, Delaware, North Carolina, and West Virginia. *Total expenditures* is the sum of PCE; RW (e.g., purchase of land, relocation of property owners, and RW administration); and construction. When comparing Virginia to the national average for the years 1990-2010, Virginia's PCE ratio is significantly higher than the national average ($p = 0.03$) but is not significantly different from the average of the four states of Alaska, Delaware, North Carolina, and West Virginia ($p = 0.23$). The suggestion was made that the analysis be redone after adding Texas to this group of four states because Texas possibly had a large portion of the equivalent of secondary roads. A comparison of Virginia's PCE percentage to the average percentage of the five states of Alaska, Delaware, North Carolina, Texas, and West Virginia did not show a significant difference ($p = 0.88$).

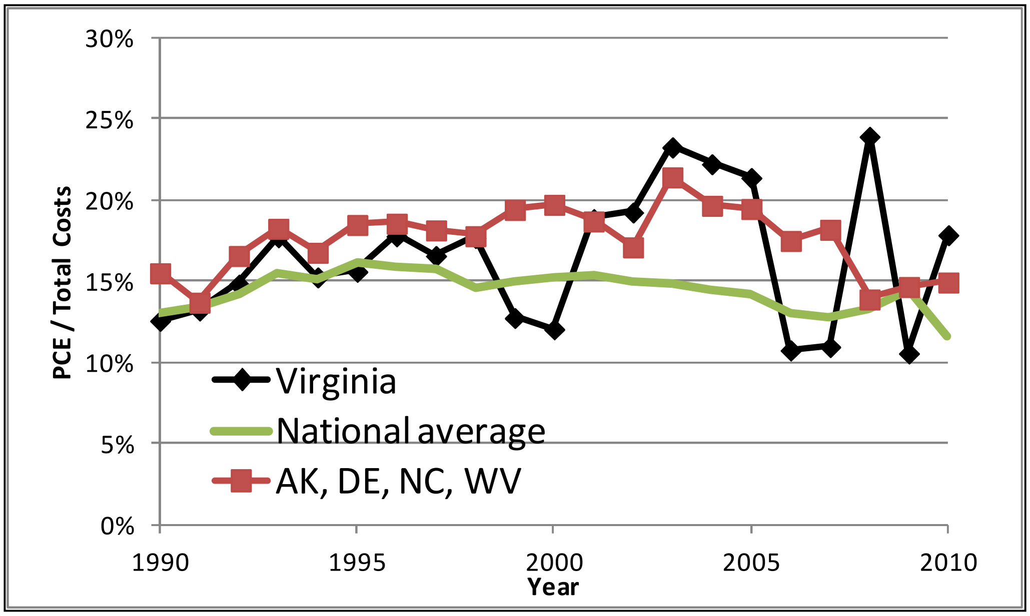


Figure 3. Ratio of Preliminary and Construction Engineering (PCE) Expenditures to Total Costs: Virginia; National Average; and the Average of Alaska (AK), Delaware (DE), North Carolina (NC), and West Virginia (WV). Like Virginia, the latter four states maintain what Virginia calls secondary roads.

The large variation shown in Figure 3 for Virginia is not usual for other states; the coefficient of variation for the PCE percentages for Virginia for the period 1990-2010 inclusive was 0.25, which was below the national average of 0.32. Of the 50 states, Virginia had the 30th highest coefficient of variation.

Within the context of the district interviews, Figure 3 shows two possible areas of exploration.

1. *The impact of the type of project.* Figure 3 suggests that at the national level, states that maintain the equivalent of county roads have higher PCE percentages that states that do not. To the extent that projects on such roads have smaller total costs than projects on other road systems and to the extent that PCE is similar to PE, one would expect PCE percentages to be larger for such projects. Generally, PE percentages are higher for lower-cost projects than for higher-cost projects. For example, Figure 4 shows Virginia's current approach for forecasting the percentage of construction costs where for a $20M project the PE percentage would be 8% but for a $1M project would be 19%. Further, Virginia data from 2004-2012 showed PE percentages on secondary facilities to be higher than those for projects on other types of facilities.

That said, the data do not enable one to determine fully whether the percentage spent on the secondary system explains the higher PCE for Virginia relative to other states. Based on the data set used to generate Table 6 for the years 2004-2010, Virginia spent an average of 8.2% per year on projects on the secondary system. For 2004-2010, the PE percentage for secondary projects (23.2%) was 1.65 times as high as the PE percentage for interstate, primary, and urban projects (14.0%). If it were the case that a higher percentage for PE (attributable to secondary system projects) translated into the same higher percentage for PCE, a simplistic assumption

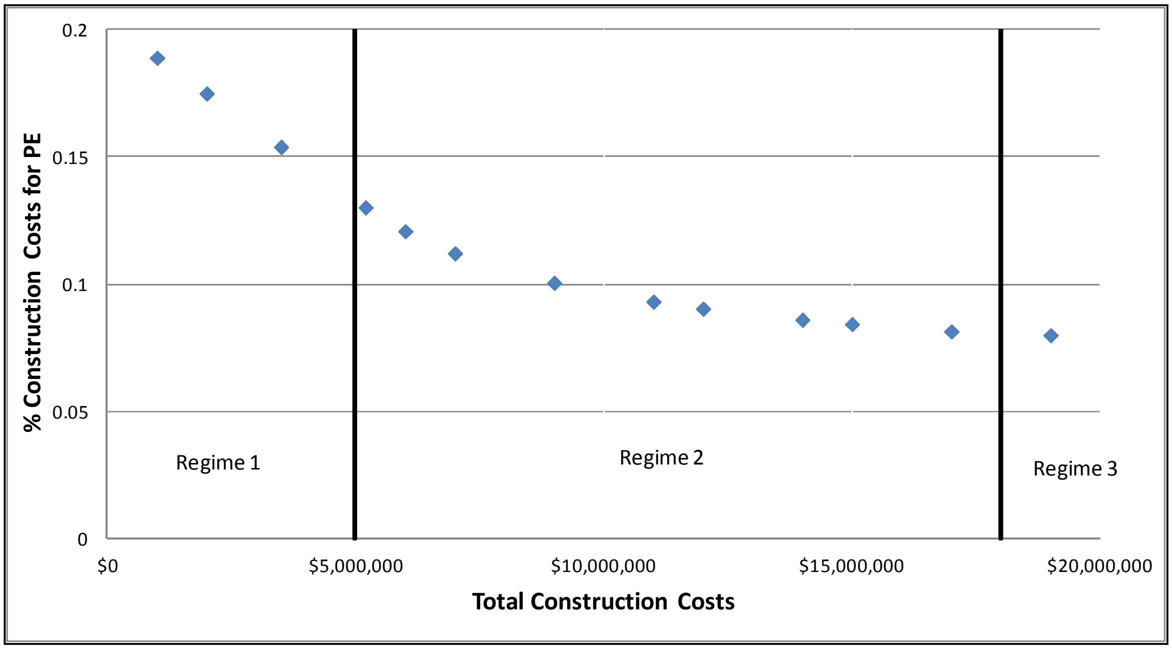


Figure 4. Percentage of Construction Costs Given to Preliminary Engineering (PE) As a Function of Total Construction Costs. The percentage varies by regime, where Regime 1 refers to construction costs under $5M, Regime 2 refers to construction costs between $5M and $18M, and Regime 3 refers to construction costs in excess of $18M. Formulas were obtained from Bourne (2012a-c) in reference to PCES.

would be that Virginia's PCE percentage was 1.05 times larger than the PCE percentage for states with no "secondary" roads based on the expression 1 + (65%)(8.2%). With the PCE percentage for the states without secondary roads (i.e., states other than Alaska, Delaware, North Carolina, Virginia, and West Virginia) being 13.0% for 2004-2010, one would have expected Virginia's PCE percentage to be about (13.0)(1.05) = 13.7%, rather than 16.8%, for 2004-2010. This simplistic expectation is tempered by the facts that PE and PCE are not identical and that differences exist in calendar years, federal fiscal years, and state fiscal years (FHWA, 1990-2010).

In short, it is not necessarily the case that the percentage spent on the secondary system explains the higher PCE for Virginia. Rather, there may be other factors that explain this higher PCE percentage. For example, it may be the case that other variables, such as the quantity of minimum-plan projects, affect the PE percentage to a greater degree than the facility type. Such possibilities suggest that program-level model development should explicitly consider related variables, such as the role of secondary facilities and the amount spent on minimum-plan or no-plan projects.

This echoes a suggestion that although Virginia maintains secondary facilities, Virginia is not constructing secondary roads to the degree it had in the past such that it would be appropriate to consider the role of secondary road construction in the forecast of PCE costs. Accordingly, this would suggest that one should explicitly model the impact of the percentage of funds (PE, RW, or CN) spent on secondary roads as opposed to interstate or primary facilities. It is also conceivable that other factors, such as amount of funding available for construction, could also play a role and thus other such factors should be included in the modeling.

2. *The passage of time for interpreting the PE percentage.* Until 2001, Virginia's PCE proportion was never higher than that of Alaska, Delaware, North Carolina, and West Virginia. For the period 2001-2010, Virginia's PCE ratio was nominally higher for 7 of those 10 years. A similar trend is noted when one excludes RW, which should vary by state: the ratio of PCE to total costs (excluding RW) was nominally higher for Virginia than for the other four states for 7 of the 10 years for the period 2001-2010 inclusive (see Figure 5). These differences were not statistically significant ($p = 0.84$ for comparing Virginia to the other four states based on PCE/total costs for 2001-2010 and $p = 0.54$ for a similar comparison where RW is excluded from total costs.) However, the differences also suggest that other factors should be considered. For example, O'Leary (2013) pointed out that during a portion of this study period—roughly 2005-2010—the funding for available construction in Virginia dropped sharply; further, in Virginia, maintenance needs are funded first and then remaining funds can be used for construction. This suggests it may be appropriate to extract funding-related information from the SYIP to see if such information explains variation in PE percentages in Virginia.

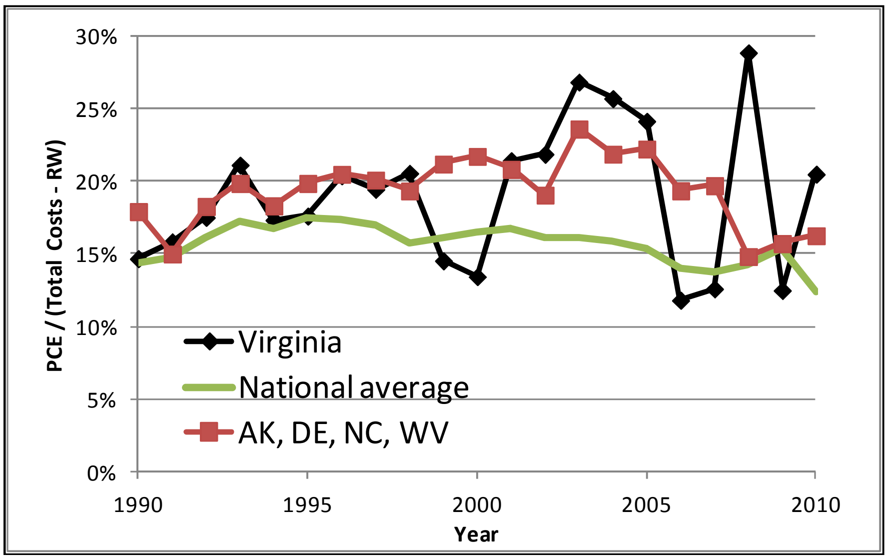


Figure 5. Ratio of PCE Expenditures to (Total Costs Minus Right of Way Costs [RW]: Virginia; National Average; and the Average of Alaska (AK), Delaware (DE), North Carolina (NC), and West Virginia (WV). Like Virginia, the latter four states maintain what Virginia calls secondary roads.

Objective 4. Explain Variation in VDOT's Program-Level PE Percentages

Interview Question 4 (see Appendix A) asked which characteristics explain the variation in PE by VDOT district and/or by fiscal year at the program level. Table 6 shows the percentage of funds spent on PE by district and year for the period 2004-2012. The data were examined in two ways.

First, the extent to which district-specific variables, such as the average amount spent per UPC, can explain the variation in the district values was quantified. This directly addressed the question of greatest interest to the TRP: What factors explain the variation by district?

Second, the extent to which PE percentages change when certain non-typical projects are removed was quantified. This analysis was of interest given some interviewees' emphasis on examining how PE percentages might vary once one considered only comparable construction projects; however, because it removes non-typical projects, it differs from a program-level analysis that looks at all available expenditures regardless of project type.

Percentage of Funds Spent on PE by VDOT District and by Year

For each district, Table 6 presents two PE percentages.

1. A *pooled percentage computed as a single ratio, defined as the total amount of PE spent from 2004-2012 inclusive divided by the total amount spent on PE, RW, and CN for the same period, and presented as a percentage.* For example, for the Bristol District, if one summed all PE expenditures for the period 2004-2012 inclusive and divided them by all PE, RW, and CN expenditures for the same period, the pooled percentage would be 18.1% spent on PE. The pooled PE percentage weights all nominal dollars equally, and the row containing statewide pooled percentages is highlighted in Table 6. For VDOT, the practical advantage of the pooled percentage rests with the highlighted row of statewide values in Table 6: these statewide pooled percentages are unaffected by the disparate size of the construction program in each district.

2. *A mean percentage computed by averaging the annual PE percentages for the same period.* For the Bristol District, the average of the annual percentages shown (e.g., 25.6% from 2004, 17.3% from 2005, and so forth) yielded a mean percentage of 18.3%. The rightmost column of Table 6 shows the standard deviation for these year-by-year percentages. The mean PE percentage weights all years equally, and the column containing district mean percentages is highlighted in Table 6. For VDOT, the practical advantage of the mean percentage rests with the highlighted column of district values in Table 6: these district mean percentages are unaffected by the fact that $1 in 2012 and $1 in 2004 had unequal purchasing power.

Each percentage has an opposite advantage. As noted by one reviewer, the pooled PE percentage loses no information from the data set; each dollar contributes equally to the pooled percentage. In the opinion of the researchers, this is advantageous for the statewide percentage and hence the corresponding row is highlighted in Table 6. For districts, however, the mean percentage is robust to the fact that total expenditures vary by year. For example, although 2012 expenditures were 27% higher than 2004 expenditures, the use of the mean percentage results in higher-expenditure years influencing PE percentages to the same extent as lower-expenditure years. The mean percentage is also not affected by changes in the real value of nominal dollars from 2004-2012 (e.g., inflation does not affect the mean percentage). In the opinion of the researchers, this is advantageous for the district percentages, and hence the corresponding column is highlighted in Table 6.

Table 6. Percentage (%) of Funds Spent on Preliminary Engineering by Fiscal Year and by VDOT District, 1-Year Average[a]

VDOT District	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	Pooled %	Mean %	Standard Deviation
Bristol	25.6	17.3	13.4	7.7	14.8	25.7	31.2	13.0	15.7	18.1	18.3	7.6
Culpeper	22.9	18.0	20.8	11.7	20.4	22.1	17.4	26.0	32.0	21.3	21.3	5.7
Fredericksburg	14.6	5.2	3.1	3.4	24.4	45.5	15.5	11.5	32.9	14.4	17.4	14.5
Hampton Roads	13.3	14.6	11.2	11.7	10.5	11.9	14.3	14.2	15.3	13.1	13.0	1.7
Lynchburg	3.6	2.7	4.3	15.5	18.2	24.0	18.4	4.2	13.0	8.3	11.6	8.0
Northern Virginia	22.1	15.0	15.6	12.5	14.3	17.4	18.0	11.9	24.5	16.7	16.8	4.2
Richmond	7.3	10.9	14.0	7.6	9.6	15.8	22.2	9.4	9.9	11.0	11.9	4.8
Salem	16.7	19.6	18.7	28.6	16.7	15.9	17.2	9.0	13.8	15.6	17.3	5.2
Staunton	10.2	11.2	9.5	9.5	15.9	12.8	11.6	7.9	12.9	11.1	11.3	2.4
Pooled %[b]	15.7	13.3	12.5	11.2	14.2	17.3	17.8	11.5	18.8	14.8	14.7	2.8
Mean %[b]	15.1	12.7	12.3	12.0	16.1	21.2	18.4	11.9	18.9			
Standard Deviation	7.4	5.8	6.0	7.1	4.6	10.3	5.6	6.1	8.7			

The highlighting signifies the summary statistics that the authors believe readers would find most useful. FY = fiscal year.

[a]Total funds are those spent on PE, RW, or CN in the SYIP but excludes those spent on the category of "other" or incidental," which represented 0.1% to 0.2% of statewide funds. For 5 of the 9 individual districts, the percentage of "other" or "incidental" funds for 2004-2012 was 0.1% to 0.3%; it was higher in the Staunton (1.1%) and Fredericksburg (0.4%) districts and lower in the Hampton Roads (0.01%) and Northern Virginia (0.01%) districts.

[b]The pooled percentage weights dollars equally regardless of year; the mean percentage weights years equally regardless of dollars. For example, for the entire 2004-2012 period, when dollars spent on PE are divided by dollars spent on PE, RW, and CN, the pooled percent spent on PE is 14.8%. If the average for each year is computed (e.g., 15.1% for 2004, 12.7% for 2005, and so forth), the mean percentage is 14.7%. (The "b" notation refers to the "Pooled %") shown in the left column of the table, third line up from the bottom.

For 2004-2012, the PE percentage for projects on secondary facilities is significantly higher than the PE percentage for projects on three other categories of facility: interstate/primary, secondary, and urban. Table 6 showed that the average of the statewide pooled PE percentage for all facility types was 14.7%. For interstate/primary projects only, the mean statewide pooled PE percentage was 14.3%; for urban projects was 14.1%, and for secondary projects was 21.8%. Although the differences between urban and interstate/primary PE percentages were not significant ($p = 0.87$), they were significant for secondary versus urban and secondary versus interstate/primary ($p = 0.03$ in both cases). Examination of district-specific results showed that the PE percentage for secondary projects was higher than the PE percentage for interstate/primary projects in all nine districts, with an average difference by district of 16.3%. Further, the PE percentage for secondary projects exceeded the PE percentage for urban projects in seven of the nine districts, with the two exceptions being the Bristol and Culpeper districts, with an average difference of 5.7%.

Statistical Explanation of Variation in PE Percentages by District and Year

Because Table 6 showed variation by district and year, an analysis was conducted to determine which, if any, characteristics explained this variation. Once 29 independent variables were identified, the bivariate correlation of each variable with the district PE percentage was assessed in the hope that a single variable would explain most of the variation in PE percentage. When no strong correlations were identified, a series of linear regression models were developed to explain variation in each district's mean PE percentage. As reported in Appendix B, six additional models (Models B1 through B6) were developed to explain annual variation, but these results did not generally yield findings that were more practical than the simple district-based models (i.e., Models 1-4).

Identification of Independent Variables

Initially, 13 factors that might explain variation in PE percentages by districts were identified, based on remarks from the interviewees and the TRP. Because some of these factors could be defined in different ways, they became 29 independent variables.

For example, one factor was suggested by the Culpeper District (Interview CU3): the build-out amount. The district noted that it was impractical to describe a set of closed-out UPCs because of the concern that very limited resources are spread over many projects, leading to a large set of projects where PE could be completed but construction might not be completed. The district noted that this process had occurred in the past with county-driven secondary system allocations, where the county would aim to program every project requested—even if complete funding was not available. An implication is that for a given fiscal year, how one interprets the district's PE percentage should be influenced by whether those projects are eventually built or are abandoned. Accordingly, the district strongly suggested that one consider what it would cost to finish building all projects in the program completely, otherwise known as the build-out amount. Conceptually, this single factor appeared to be a single variable.

Yet a complication was that for a few projects, a component of the build-out amount was negative, which would imply that the sum of funds available exceeded project costs. Thus, three different variables were identified as candidates for representing the build-out amount: the total balance (as originally intended), the 5-year balance (which was generally positive but that did not include the out years), or the out-year balance (which for some projects was negative).

The 29 independent variables were defined as follows.

1. Presence of larger projects in the program:

    a. *Average expenditure per active UPC*. The numerator includes expenditures in the category of PE, RW, CN, and Other. The denominator reflects all UPCs with $1 or more in expenditures.

    b. *Number of UPCs exceeding $18M in expenditures for the 9-year analysis*. The value of $18M was chosen because this threshold is used in the PCES to define the largest tier of projects.

    c. *Percent of expenditures spent each year on large projects*. Large projects are defined as those UPCs where for a given year and district the amount spent on the UPC was in the 99th percentile for all UPCs for that district and year. For example, in 2004, in the Bristol District, 1% of all UPCs had an expenditure greater than $6.5M. A total of $37.6 M was spent on these UPCs, whereas the district spent a total of $62.0M on all UPCs that year. Thus the percentage of funds spent on large projects was $37.6/$62.0 = 61%. For the years 2004-2012 inclusive, the average 99th percentile for annual expenditures for the state as a whole was $5,032,664 per UPC.

2. Percent of expenditures spent on projects with potentially reduced PE. These are defined as:

    a. *Percent of expenditures spent on UPCs that have minimum-plan or no-plan jobs*. This was one type of anomaly noted by interviewees. (The term "job" refers to a particular component of the project that helped determine whether the project was a minimum or no-plan project in which case it was included herein.)

    b. *Percent of expenditures spent on UPCs that do not have a construction job*. Although this includes the expenditures shown in Variable 2a, it also includes other types of jobs such as flashing signals. (As shown in Appendix A, Interview LY6, Question 6, there can be multiple jobs for a given project.)

    c. *Percent of expenditures spent on VDOT-administered projects*. Non–VDOT administered projects was one type of anomaly noted by interviewees.

3. *Percent of expenditures for enhancement projects*. This was one type of anomaly noted by interviewees.

4. *Percent of expenditures for district-wide UPCs*. This was one type of anomaly noted by interviewees.

5. *Percent of expenditures for study-only projects*. This was one type of anomaly noted by interviewees.

6. *Percent of expenditures for ARRA projects*. This was one type of anomaly noted by interviewees.

7. Percent of expenditures recommended for exclusion by district staff.

    a. *Percent of expenditures on UPCs recommended for exclusion by district staff that were otherwise typical construction projects*. This variable represents UPCs that interviewees recommended for exclusion yet that were construction jobs, administered by VDOT, not an enhancement, not district wide, not study-only, and not ARRA. Thus Variable 7a could capture the projects that were typical construction projects based on information provided from Variables 2 through 6 but were nonetheless recommended for exclusion by district staff, such as maintenance/operations projects that use construction funds.

    b. *Percent of expenditures on UPCs that are non-typical for any reason: they were either recommended for exclusion by district staff or were non-typical based on any of the Variables 2 through 6*. This variable represents UPCs that met any one of these criteria: not a construction job, not administered by VDOT, an enhancement, district wide, study-only, ARRA, or recommended for exclusion by staff. The content of the interviews suggested to the researchers excluding projects based on the information in variables 2 through 6; the researchers then asked district staff to exclude additional projects. Thus, when district staff were asked to exclude projects, they were told to exclude projects beyond those in variables 2 through 6.

8. Percent of expenditures by functional class. Four definitions were considered:

    a. Percent of expenditures spent on interstate projects.

    b. Percent of expenditures spent on primary projects.

    c. Percent of expenditures spent on secondary projects.

    d. Percent of expenditures spent on urban projects.

9. The build-out amount, defined as:

a. The total balance for "non-T" projects in the SYIP, i.e., projects whose UPC did not begin with a "T." (Expenditure data were not available for projects that began with a T.)

b. The 5-year balance for non-T projects in the SYIP.

c. The out-year balance for non-T projects in the SYIP.

10. Percent increase in the total SYIP budget from the previous year. This was defined in five ways:

    a. *The ratio of the total balance for the current SYIP to the total balance for the previous SYIP for non-T projects*. For example, for the FY 2004 SYIP, the Bristol District needed $81.2M to complete its projects from FY 2005 onward, and for the FY 2005 SYIP, the district needed $89.8M to complete its projects from FY 2006 onward. Thus this ratio was $89.8/$81.2 = 1.11. Data were not available for 2004.

    b. *The ratio of the 5-year balance for the current SYIP to the 5-year balance for the previous SYIP for non-T projects*. Data were not available for 2004.

    c. *The ratio of the out-year balance for the current SYIP to the out-year balance for the previous SYIP for non-T projects*. Data were not available for 2004.

    d. *The ratio of the expenditures for the current year of the SYIP to the ratio of expenditures for the previous year of the SYIP*. This was done for all projects. For example, for the FY 2003 SYIP, the total allocation was $94.4M for the Bristol District. For the FY 2004 SYIP, the total allocation was $170.7M. Thus the ratio was $170.7/$94.4 = 1.81.

    e. *The ratio of the expenditures for the current year of the SYIP to the ratio of expenditures for the previous year of the SYIP*. This was done only for the non-T projects and thus excludes 2004.

11. *2010 Population percentage of each construction district*. This variable was used only for the analysis of mean district PE percentages (Tables 7 and 8) and was not used in the subsequent analysis that included annual variation (Appendix B, Tables B1 and B2). This was the construction district's percentage of total state population in 2010.

12. Number of projects in some type of development, which may be defined as:

    a. *Number of projects with at least $1 in expenditures in a given fiscal year.*

b. *Number of projects in the development phase* (i.e., PE and RW but not CN). This is defined as projects that have PE or RW expenditures but no CN expenditures in a given year.

c. *Percent of projects in the development phase*. This was defined as the number of projects in the development phase (i.e., PE and RW but not CN defined in Variable 12b) divided by the number of projects with at least $1 in expenditures (defined in Variable 12a). This normalizes Variable 12b.

13. *Percent of PE-Only UPCs*. This is defined as the number of UPCs each fiscal year labeled "PE Only" as described in the SYIP with at least $1 in expenditures divided by the number of UPCs with at least $1 in expenditures.

Each variable potentially has a limitation. For example, the existence of some projects with more than one UPC will affect the utility of variables that are based on the number of UPCs. The question is whether these variables, with this limitation, can nonetheless explain a statistically significant amount of the variation in PE percentages by district or year.

Correlation of Independent Variables With Each District's PE Percentage

The mean value for each of the independent variables for each district was computed. For example, Variable 1a, the average expenditure per UPC, may be considered. For the Bristol District, average expenditures were $737,853 in 2004, $776,114 in 2005, and so forth. The mean of these values for the years 2004-2012 inclusive for the Bristol District was $553,952. A mean value was similarly computed for the other districts for Variable 1a.

The bivariate correlation of each of these independent variables with the pooled PE percentage and the mean PE percentage for each district was computed. For example, because there are nine districts, the nine mean values for average expenditure per UPC (for Variable 1a) were correlated with the nine district pooled PE percentages and the nine district mean PE percentages. Generally, the use of the pooled PE percentage or the mean PE percentage affected the correlation by an average of 0.11, as shown in Table 7.

Most independent variables showed little correlation with either PE percentage. Of the 29 independent variables, only 2 showed correlations having an absolute value above 0.50 with a PE percentage: the percentage of expenditures spent on minimum-plan or no-plan projects (Variable 2a) and the percentage of expenditures spent on enhancement projects (Variable 3).

To determine if these variables could be used to explain the variation in PE percentage by district, two types of analyses were performed: (1) an analysis based on the PE percentage for each district that did not account for year-to-year variation, and (2) an analysis that examined variation by district and year. Then, a sensitivity analysis examined how modifications in the computations of these variables affected the results.

Table 7. Correlation of Program-Level Variables with District Pooled Percentages and Mean Percentages

No.	Variable Description	Correlation With District Pooled %	Correlation With District Mean %
1a	Average expenditure per active UPC	0.05	0.01
1b	Number of UPCs exceeding $18M in expenditures for all 9 years	0.12	0.01
1c	Percent of expenditures spent each year on large projects	-0.23	-0.40
2a	Percent of expenditures spent on minimum-plan or no-plan projects	-0.74	-0.73
2b	Percent of expenditures spent on UPCs that do not have a construction job	-0.15	-0.24
2c	Percent of expenditures spent on VDOT-administered projects	0.16	0.29
3	Percent of expenditures for enhancement projects	0.68	0.65
4	Percent of expenditures for district-wide UPCs	-0.01	0.09
5	Percent of expenditures for study-only projects	0.15	0.30
6	Percent of expenditures for ARRA projects	-0.39	-0.14
7a	Percent of expenditures for UPCs recommended for exclusion by district staff that were otherwise typical construction projects based on Variables 2a-6	0.49	0.44
7b	Percent of expenditures for UPCs that were (1) recommended for exclusion by district staff and/or (2) were not typical construction projects based on Variables 2a-6	0.10	0.04
8a	Percent of expenditures for interstate projects	-0.07	-0.22
8b	Percent of expenditures for primary projects	0.27	0.45
8c	Percent of expenditures for secondary projects	0.37	0.46
8d	Percent of expenditures for urban projects	-0.39	-0.45
9a	Total build out balance in the SYIP for non-T projects	-0.08	-0.23
9b	5-year balance in the SYIP for non-T projects.	0.11	-0.06
9c	Out-year balance in the SYIP for non-T projects.	-0.12	-0.25
10a	Ratio of the total balance for the current SYIP to the total balance for the previous SYIP for non-T projects.	0.12	0.05
10b	Ratio of the 5-year balance for the current SYIP to the 5-year balance for the previous SYIP for non-T projects	0.29	0.45
10c	Ratio of the out-year balance for the current SYIP to the out-year balance for the previous SYIP for non-T projects	-0.34	-0.29
10d	Ratio of the expenditures for the current year of the SYIP to the ratio of expenditures for the previous year of the SYIP for all projects.	0.23	0.36
10e	Ratio of the expenditures for the current year of the SYIP to the ratio of expenditures for the previous year of the SYIP. This is done for non-T projects and excludes 2004.	0.32	0.42
11	Population percentage of each construction district	-0.03	-0.18
12a	Number of projects with at least $1 in expenditures in a given FY	-0.05	-0.23
12b	Number of projects in the development phase (e.g., PE and RW but not CN).	-0.05	-0.23
12c	Number of projects in the development phase (e.g., PE and RW but not CN defined in Variable 12b) divided by the number of projects with at least $1 in expenditures (defined in Variable 12a)	0.37	0.28
13	Number of UPCs each FY labeled "PE Only" as described in the SYIP divided by the number of UPCs with expenditures	0.45	0.35

UPC = universal project code; ARRA = American Recovery and Reinvestment Act; SYIP = Six Year Improvement Program; FY = fiscal year; PE = preliminary engineering; ROW = right of way; CN = construction

Analysis of District PE Percentages

The mean PE percentage for each district was determined for the period 2004-2012 inclusive such that there were nine values for this dependent variable—one for each district. Then, stepwise linear regression was used to determine if any of the variables in Table 7 offered explanatory power for this mean PE percentage. Stepwise linear regression was also used to determine if these same independent variables explained variation in the pooled PE percentage.

A model (Model 1) based on a single variable—percent of expenditures spent on minimum-plan or no-plan projects (Variable 2a)—explained 47.2% of the variation in the mean PE percentage. A second model (Model 2), which combined this variable with the percentage of projects in the development phase (Variable 12c), explained 75.2% of the variation. The addition of a third variable—percent of expenditures for each year on large projects—explained 89.3% of the variation in the mean PE percentage (Model 3). All three variables were statistically significant ($p \leq 0.03$). A fourth model (Model 4), which used the pooled PE percentage as the dependent variable, yielded results that were comparable to those of Model 2. These four models are shown in Table 8.

With only nine values for the dependent variable, a concern was overfitting: in an effort to obtain independent variables that are statistically significant and that have high explanatory power, one might violate key assumptions in linear regression and develop a model with variables that were not applicable beyond this particular data set. Accordingly, three types of tests were performed—an analysis of the practical meaning of the parameters, examination of the variance reflected by the residuals, and an assessment of whether the residuals are normally distributed. The results of these tests are reported in Appendix B, and they show that the key assumptions of normality and heteroscedasticity were not violated for any of the four program-level models.

However, a concern with Model 4 is the relatively large intercept; although this is not a fatal flaw, it suggests that Models 1 through 3 may be preferable. The fact that the signs of the

Table 8. Program-Level Models for Explaining Variation in District Mean PE Percentages, FY 2004-FY 2012

Model No.	Adjusted R^2	Constant	Percent of Expenditures Spent on Minimum-Plan or No-Plan Projects (Variable 2a)	Percent of Projects in Development Phase (Variable 12c)	Percent of Expenditures Spent Each Year on Large Projects (Variable 1c)
1	0.472	0.212 ($p < 0.01$)	-0.609 ($p = 0.03$)		
2	0.752	-0.025 ($p = 0.77$)	-0.745 ($p < 0.01$)	0.378 ($p = 0.03$)	
3	0.893	0.055 ($p = 0.40$)	-0.652 ($p < 0.01$)	0.476 ($p < 0.01$)	-0.278 ($p = 0.03$)
4[a]	0.899	-0.101 ($p = 0.13$)	-0.869 ($p < 0.01$)	0.497 ($p < 0.01$)	
Minimum and maximum values for each independent variable			4.4% (Bristol District) to 14.5% (Staunton District)	56.1% (Lynchburg District) to 73.2% (Salem District)	47.2% (Lynchburg District) to 63.6% (Richmond District)

[a] This model used the pooled PE percentage rather than the mean PE percentage as the dependent variable.

independent variables did not change is consistent with expectations: the percentage of expenditures spent on large projects (Variable 1c) and the percent of expenditures spent on minimum-plan and no-plan projects (Variable 2a) should reduce the amount spent on PE (and thus be negative), and the percentage of projects in the development phase (Variable 12c) should increase the amount spent on PE and thus should be positive.

Although it is tempting to select Model 3 over Model 2 as the best model given the former's higher explanatory power (89% of the variation rather than 75% of the variation), the practical significance of these models is similar in that the only variable that reflects discretion on behalf of the scheduling practices in each district and that is statistically significant is the percent of projects in the development phase (Variable 12c). The other two variables—percent of expenditures on minimum-plan or no-plan projects and percent of expenditures on large projects—reflect characteristics that logically are not influenced by when projects are placed in the program (e.g., an individual district cannot necessarily choose to have large-scale projects or projects that can be built from minimum plans; however, decision makers can influence the percent of projects in the development phase through when funding is allocated). In this regard, a 10% reduction in the percentage of projects in the development phase (e.g., where PE and RW are underway but construction monies have not been spent) will reduce the PE percentage by 4.76% on average (according to Model 3) or 4.97% on average (according to Model 4). Considering that the percentage of projects in the development phase ranged from 56.1% to 73.2%, Model 3 suggests that the maximum reduction in PE percentage one could obtain at the program level would be (73.2% – 56.1% = 17.1%)(0.476) or about 8.1%. For Model 4, the maximum value would be slightly higher (73.2% – 56.1% =17.1%) (0.497) = 8.5%—a relatively similar reduction in the PE percentage that might be obtained.

Using Model 3 as a basis, the other two variables, based on multiplying the parameter in Model 3 by the range from the lowest value of the independent variable to the highest value of the independent variable, could influence the PE percentage to a lesser extent than 8.1%: 6.6% (Variable 2a, percent of expenditures on minimum-plan or no-plan projects) or 4.6% (Variable 1c, percent of expenditures spent on large projects). The use of standardized coefficients (which for Variables 2a, 12c, and 1c were -0.785, 0.693, and -0.403, respectively) would have given a slightly different answer in that Variable 2a would be considered more powerful because of its larger standardized coefficient. However, a regression model is valid only over the range of data that formed the basis of the model, and factually the range of observed values for Variable 2a was less than two-thirds the range of observed values for Variable 12c.

In short, a case can be made that Models 3 and Model 4 explain a larger portion of the variation than do Models 1 and 2, but a key observation is that all models beyond Model 1 show that increasing the percent of projects in the development phase increases the PE percentage; the amount of this increase is similar for Models 2, 3, and 4.

Summary of Variation in PE Percentages at the Program Level

When one does not consider annual variation but rather only the mean PE percentage by district for the period 2004-2012 inclusive (i.e., the nine-case data set), only 2 of the 29 independent variables showed a bivariate correlation above 0.50 with the average PE percentage: percent of expenditures spent on minimum-plan or no-plan projects (Variable 2a) and percent of expenditures on enhancement projects (Variable 3). It is possible, however, to create a model that explains 89.3% of the variation in these average values based on three variables: Variable 2a; the percentage spent each year on large projects (Variable 1c); and the average percent of projects in the development phase (Variable 12c). In this model the signs are logical: an increase in either the percent of expenditures spent on minimum-plan or no-plan projects (Variable 2a) or the percent of expenditures spent on large projects (Variable 1c) will reduce the PE percentage, whereas an increase in the percent of projects in the development phase (Variable 12c) will increase the PE percentage. A practical implication of these findings is that, according to Model 4 developed in this report, a district could reduce the amount it spends on PE by about 8.5% if the district were, hypothetically, to reduce the percent of projects in the development phase by about 17%.

Appendix B examines models developed in this study (Models B1-B6) based on annual variation in PE percentages (i.e., the percentage by district and by year such that there are 81 possible cases based on 9 districts and 9 years of data from 2004-2012 inclusive). There was substantial random variation such that the best model could explain only about 70.5% of this variation. About one-fourth of the variation (25.3%) was explained by the district and the year. Another five independent variables could explain an additional 45% of the variation when used with the district and year. These variables were percent spent each year on large projects (Variable 1c), average cost of UPCs (Variable 1a), percent of expenditures for study-only projects (Variable 5), percent of expenditures for ARRA projects (Variable 6), and percent of expenditures on excluded projects (Variable 7b; note that UPCs excluded by Variable 7b will also be excluded by Variable 2a). Two findings from Appendix B are noteworthy:

1. *The percent of projects in the development phase (Variable 12c) is not significant unless the district variable is excluded.* In this instance, the value was similar to that given in Model 3 when annual variation was excluded, with the understanding that this variable is correlated with the individual districts.

2. *The percent of expenditures for study-only projects (Variable 5) varies by district and year.* In 1 of 81 district-year combinations, a model in Appendix B (Model B5) showed that this variable could cause a large (as much as 40.6%) swing in PE expenditures. However, for 90% of the district-year combinations, the swing would have been 3% or less.

Changes in PE Percentage After Excluding Non-Typical Projects

Given the interviewees' identification of non-typical construction projects, it was also of interest to ask how the program-level PE percentage would have changed had non-typical projects been excluded from the analysis. There was also special interest in one type of non-typical project: those administered by a local entity or some entity other than VDOT.

Accordingly, PE expenditures were analyzed for three successively smaller data sets.

- *Data Set 1:* the entire data set with all projects for which expenditure data are available (n = 4,345)

- *Data Set 2:* the entire data set minus projects meeting any of six criteria: enhancement, district-wide UPC, study-only, ARRA, minimum-plan / no-plan, or recommended for exclusion by district staff (n = 1,338)

- *Data Set 3:* the entire data set minus projects meeting any of the six criteria or not being administered by VDOT (n = 881).

The advantage of Data Set 1 was consistency with the original intent of the work plan, i.e., to examine PE expenditures at the program level as a total of all spending. The advantage of Data Set 2 was a recognition of interviewees' suggestion that certain types of projects were substantially different from a typical construction project. The advantage of Data Set 3 was exclusion of a category of projects some interviewees noted were fundamentally different, i.e., those administered by an entity other than VDOT, such as the Department of Rail and Public Transportation (DRPT), or a locality. Three key findings were noted with respect to the size of the data set, the change in the PE percentage, and the differences among the districts.

Change in the Size of the Data Set

In addition to being administered by a non-VDOT entity, the interviews had shown six characteristics that would identify a project as being a non-typical construction project: (1) the project is an enhancement project; (2) the project is a district-wide project; (3) the project is a study-only project; (4) the project is an ARRA project; (5) the project is a "no plan" or "minimum plan" project; or (6) the project is recommended for exclusion by district staff knowledgeable about the program. For example, two districts recommended excluding any rail safety projects (Interview HR7) or railroad crossing projects (Interview ST8); another district (Interview CU3) recommended excluding UPCs that reflected a maintenance/operations project that was nonetheless funded with construction allocations.

The application of these six criteria substantially shrank the size of the data set. For 2004-2012, there had been a total of 4,345 UPCs where monies were expended; with these six criteria, the number of UPCs that remained in the data set was 1,338—less than one third. Depending on the year, these remaining UPCs represented between 36% and 49%—less than one half—of expenditures that had been noted in the original data set.

Of the 4,345 UPCs identified in the SYIPs and for which expenditures were available, approximately 30% (1,283) were locally administered. Interviewees had raised the possibility that such locally administered projects might have different PE rates; for example, under one scenario, local governments might be able to use staff time for PE work that did not have to be charged to the project. While most other projects (63%) were administered by VDOT, the remaining 7% of projects were not listed as administered by VDOT nor locally administered; rather, they were listed as being administered by DRPT (or "rail") or the administration status indicated "other" or was blank or contained a zero. Thus, projects that were not administered by VDOT (most of which were locally administered) were excluded from the data set along with those identified by the six criteria noted. The resulting data set represented between 29% and 42% of the expenditures depending on the year and included 881 UPCs—about one-fifth of the

4,345 UPCs available in the first data set (see Figure 6). In sum, the majority of projects in the SYIP are not typical construction projects.

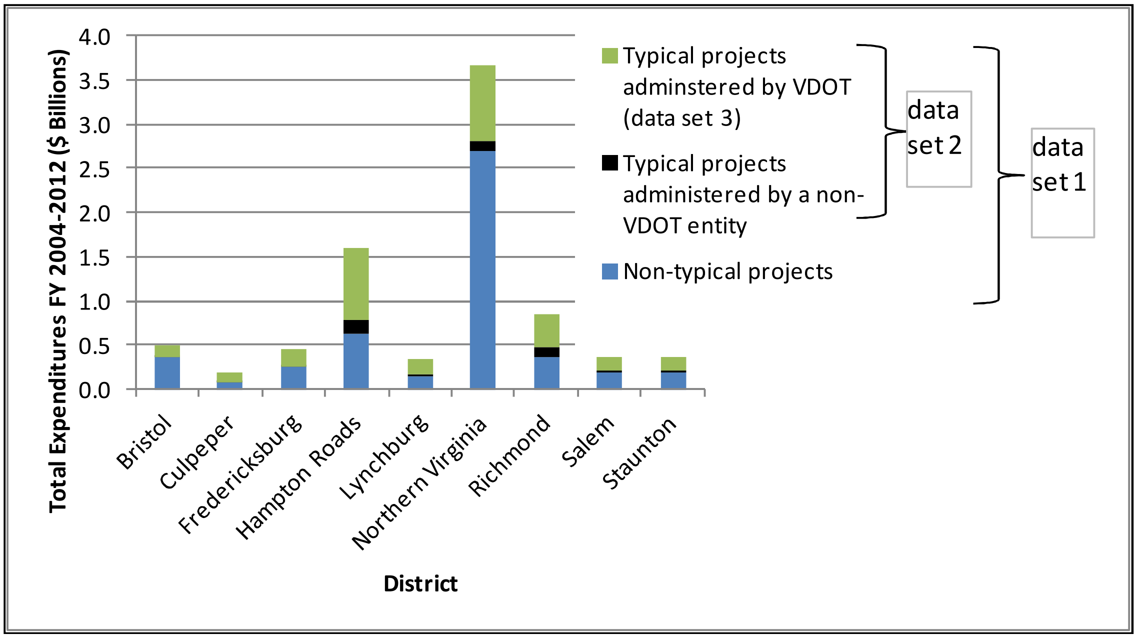


Figure 6. Three Successively Smaller Data Sets. Example: For Northern Virginia, total expenditures were $3.7B for all projects. Projects with any of six non-typical characteristics represented $2.7B of these expenditures. Of the $1B typical projects that remained, $0.1B expenditures represented projects administered by a non-VDOT entity such as a locality or Department of Rail and Public Transportation (DRPT) and $0.9B represented projects administered by VDOT.

Change in the PE Percentage

Table 6 showed that the average of the annual pooled percentages spent on PE by fiscal year at the statewide level was 14.7% (if all UPCs are considered). This average drops to 12.4% if UPCs for non-typical projects are removed and to 11.4% if non-typical projects and locally administered projects as well as projects not administered by VDOT are removed. To be clear, the exclusion of locally administered projects and projects not administered by VDOT lowered, rather than raised, the percentage spent on PE. There is a relatively strong degree of correlation at the statewide level among the three data sets. Figure 7 shows that the annual pooled PE percentage for the three data sets follows a similar trend over time. Over time, the correlation between Data Set 1 (all projects) and Data Set 2 (non-typical projects) is 0.79, and a stronger correlation of 0.86 exists between Data Set 1 (all projects) and Data Set 3 (non-typical projects and non–VDOT administered projects removed).

Removal of non-typical projects, including those not administered by VDOT, tended to reduce differences among districts and reduce the percentage spent on PE. With 9 construction districts, there are a total of 36 possible pairwise comparisons between districts. For 2004-2012 inclusive, when all projects were considered, there were 11 statistically significant differences among the districts in terms of this PE percentage (see Table 9). Removal of projects based on the six criteria yielded just 5 differences, and removal of such projects and those administered by entities other than VDOT yielded just 3 significant differences.

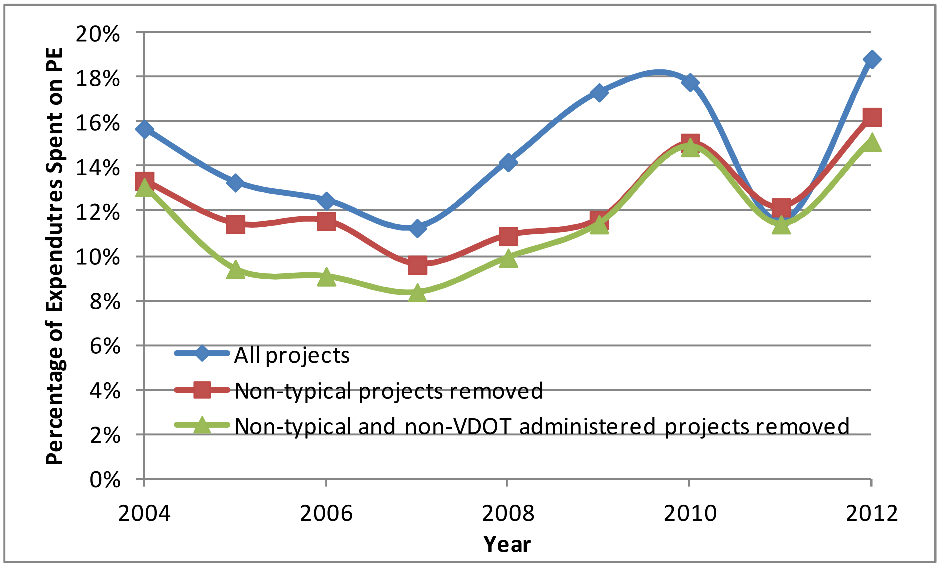


Figure 7. Trends in Preliminary Engineering (PE) Annual Pooled PE Percentage at the Statewide Level

In short, differences among districts tended to drop as the data set was restricted to more homogeneous projects.

Objective 5. Develop a Model to Forecast VDOT'S PE Expenditures at the Project Level

Question 5 in the "Purpose and Scope" asked: At the project level, which project characteristics have a statistically significant impact on PE costs? A project-level model would use project-specific characteristics available at the beginning of the scoping phase to predict the PE cost of a full construction project. The approach to develop candidate project-level models consisted of five steps:

1. Review the literature to identify methods for forecasting PE costs at the project level.
2. Identify candidate project characteristics.
3. Establish training and testing data sets.
4. Investigate models based on construction cost alone.
5. Develop models based on multiple variables.

Literature Review of Methods for Forecasting PE Costs at the Project Level

Four methods for forecasting PE costs at the project level were found in the literature: Virginia's PCES, a workbook for forecasting transit PE costs (FTA, 2011a, b), a sketch method for forecasting transit PE costs (AECOM et al., 2010), and approaches for forecasting bridge PE costs and roadway construction PE costs (Hollar et al., 2010; Liu et al., 2011).

Virginia's Project Cost Estimating System

The PCES provides an order of magnitude estimate of PE costs for a specific project. The PCES is a series of worksheets that subdivide a project into characteristics that affect its cost such as construction, traffic, bridge, RW, and utilities. Although the PCES uses a variety of factors to determine the total construction and RW costs of a project, the approach for

Table 9. *p*-values for Differences Between Districts Based on Preliminary Engineering Percentages (All Projects Included)[a]

District	Staunton (11.3%)	Lynchburg (11.6%)	Richmond (11.9%)	Hampton Roads (13.0%)	NOVA (16.8%)	Salem (17.3%)	Fredericksburg (17.4%)	Bristol (18.3%)	Culpeper (21.3%)
Staunton	--	0.90	0.73	0.15	0.00	0.01	0.20	0.02	0.00
Lynchburg	0.90	--	0.91	0.63	0.11	0.09	0.15	0.06	0.02
Richmond	0.73	0.91	--	0.51	0.04	0.06	0.28	0.01	0.01
Hampton Roads	0.15	0.63	0.51	--	0.02	0.07	0.40	0.06	0.00
NOVA	0.00	0.11	0.04	0.02	--	0.84	0.90	0.53	0.02
Salem	0.01	0.09	0.06	0.07	0.84	--	1.00	0.80	0.29
Fredericksburg	0.20	0.15	0.28	0.40	0.90	1.00	--	0.85	0.38
Bristol	0.02	0.06	0.01	0.06	0.53	0.80	0.85	--	0.35
Culpeper	0.00	0.02	0.01	0.00	0.02	0.29	0.38	0.35	--

NOVA = Northern Virginia District.

[a] *p*-values equal to or below 0.05 are considered significantly different.

determining the amount of funds that should be expended on PE is relatively straightforward. Information from Bourne (2012a-c) showed that PE cost estimates are initially determined by multiplying a specified percentage by the construction cost estimates. This specified percentage decreases as the construction cost increases, as was shown in Figure 4, where the PCES uses one of three equations depending on the construction cost estimate. For Regime 1, the PE percentage is calculated as 0.203 – (Construction cost estimate * 0.000000014). For Regime 2, the PE percentage is calculated as (0.06 * Construction cost estimate + 365,000) / (Construction cost estimate). For Regime 3, the PE percentage is 8% of construction costs.

A project with a $3M construction cost estimate may be used an example. Because this estimate is less than $5M, the percentage assigned to PE is calculated as 0.203 – $3M * 0.000000014 = 0.161, or 16.1%. Thus PE costs would be forecast to be 16.1% ($3M) = $0.483M. The PCES increases the PE estimate by 50% if the work is performed by consultants. Thus, if consultants were performing one-fourth of the PE work in this example, the PE cost estimate would increase from $0.483 to $0.483(1 + 0.5[25%]) = $0.543M. A project manager may then adjust this basic estimate with unusual or additional PE costs, based on the manager's experience and knowledge of the project.

The PCES performs PE estimates for roadway projects separately from bridge projects. Bourne (2012a) explained that there are no PE charges for RW and that the percentage of PE for bridges is computed as 3.145 + (12,119,300/bridge construction cost estimate).

Workbook for Forecasting Transit PE Costs

FTA created the Standard Cost Categories (SCC), a new capital estimation format to "establish a consistent format for the reporting, estimating, and managing of capital costs for New Starts projects" (FTA, 2011b). Transit project cost information was gathered from the FTA's Capital Cost Database. The sources of project costs are divided into 10 categories as shown in Table 10, with each category's contribution to the total construction cost and total project cost. (The percentages shown are from a sample project in the "Build Main" component of the worksheet [FTA, 2011a]).

Table 10. Federal Transit Administration Standard Cost Categories for Capital Projects

Row No.	Funding Source Category	% of CN Cost	% of Total Cost
1	Guideway & Track Elements	45	25
2	Stations, Stops, Terminals, Intermodal	13	8
3	Support Facilities	4	3
4	Sitework & Special Conditions	24	14
5	Systems	13	8
	CN Subtotal [a]	100%	57%
6	RW, Land, Existing Improvements		9
7	Vehicles		8
8	Professional Services	35	20
9	Unallocated contingency		5
10	Finance Charges		2
	Total		100%

The source of the data in this table is Federal Transit Administration (2011a).
CN = construction; RW = right of way.
[a] Rows 1-5 show 100% of the construction costs such that construction costs are 57% of total project costs; decimal percentages add to 57% but appear to add to 58% because of rounding.

The PE phase falls within the "Professional Services" category (Table 10, Row 8) and is standard cost category 80 and that PE is category 80.01. Another source (AECOM et al., 2010) further explained that standard cost category 80.01, includes costs associated with "early design, negotiations for operations and/or maintenance, developing financial plans, and ridership studies." Other tasks listed in this professional services category include, but are not limited to, final design, project management for design and construction, construction administration and management, legal, and surveys and start up (FTA, 2011a).

Sketch Method for Forecasting Transit PE Costs

AECOM et al. (2010) created a four-step process to estimate the "soft costs" for heavy and light rail transit projects, where such soft costs include what VDOT would characterize as PE but that may include non-PE activities, such as management of the construction project. Table 11 outlines the four steps of this process.

Table 11. Four-Step Process for Estimating Soft Costs for Transit Projects

Step	Process Name	Description
1	Begin with default averages.	Begin with the average actual historical soft costs for each component.
2	Adjust based on mathematical relationships.	Increase or decrease the soft cost percentages based on certain conditions, such as alignment length, interface with another guideway, or delivery method.
3	Adjust based on categorical relationships.	Adjust the soft cost estimate following the numerical relationship between the project's characteristics and historical soft costs.
4	Apply judgment.	Apply some degree of discretion based on knowledge about the unique and intangible qualities of the project and its sponsor.

Source: The data in this table came from AECOM et al. (2010).

These steps are summarized as follows (AECOM et al, 2010):

1. *Begin with default averages.* The default averages are "consistent with average midpoint estimates currently used in the industry, and so provide a safe and well-established starting point for estimation purposes." Table 12 shows that the starting point is to assume that soft costs can be estimated as 29.5% of the construction cost estimate.

2. *Adjust based on mathematical relationships*. The characteristics that should be evaluated when adjusting the default values are transit alignment length, construction costs, mode, installation conditions, delivery method, and economic conditions. Each of these attributes can increase or decrease the soft costs by implementing a specific formula reported therein.

3. *Adjust based on categorical relationships*. The categorical features are whether the project has an unusually long project development phase, unusual political influence, or agency tendency to minimize capital charges. These features are more difficult to assess because they cannot always be determined by a simple yes or no answer.

Table 12. Default Averages of Components of Soft Costs

Cost Type (Abbreviation)	% of CN Cost
Preliminary Engineering (PE)	2
Final Design (FD)	12
PM/CA (Project Management / Construction Administration)	12.5
Insurance	2
Legal permits, surveys, and start up (Other)	1
Total	29.5

Source: The source of the data in this table is AECOM et al. (2010).

4. *Apply judgment*. In this phase, the project managers must use experience and "knowledge about the unique and intangible qualities of the project" as well as the sponsor of the project, where the "sponsor" might be a local transit agency, an airports authority, a planning board, or some other entity receiving grant funds and building the transit project.

Because the sketch method is intended to help agencies better understand the factors that influence costs, the method may help identify possible obstacles early in the project development process.

Approaches for Forecasting Bridge and Roadway PE Costs

Liu et al. (2011) reported that FHWA indicated that state DOTs use three general approaches to estimate overall project costs (not just PE costs): (1) "parametric estimating using historical cost figures"; (2) "detailed estimating using quantity takeoff techniques and pricing of labor, equipment, and materials"; and (3) a combination of the two, but that states "typically estimate PE costs as a fixed percentage of estimated construction costs disregarding other project-specific parameters." For NCDOT, Liu et al. (2011) calculated the ratio of PE costs to construction costs for bridge projects separately from roadway projects; the ratio for the former was considerably higher (27.8%) than that for the latter (11.7%). The authors noted, however, that despite the practice of assuming PE costs are 10% of total project cost, many factors can affect the percentage (Liu et al., 2011).

Accordingly, Liu et al. (2011) developed a model to forecast this ratio better for both bridge projects and roadway projects. The general approach was to acquire project data; select predictive variables, applying regression techniques; and test the model on data not used to calibrate the model (Hollar et al., 2010). For example, for the bridge PE costs, a sample of 505 projects for the period 1999-2008 was chosen. Twenty-eight possible variables were examined and categorized into seven groups: class, cost, date, design, dimension, environmental, and geographic location. Models for forecasting the ratio of bridge PE costs to construction costs, using 8 to 14 variables, were developed and yielded R^2 values of 0.65 and 0.72, respectively.

Liu et al. (2011) noted that for the roadway projects, one particular linear regression model used six statistically significant independent variables with no interactions: (1) whether the project contained an interchange; (2) whether the project was a retrofit (as opposed to a new location); (3) the ratio of the RW cost estimate to the CN cost estimate; (4) the "roadway percentage of construction cost"; (5) the number of lanes; and (6) whether the project was located in one particular NCDOT division (such divisions are analogous to VDOT districts).

This model, calibrated from 150 roadway projects, yielded an adjusted R^2 of 0.52; the dependent variable was transformed to be the cubed root of the ratio of PE costs to construction costs.

In terms of assessing performance, Liu et al. (2011) selected an additional 38 roadway projects that were not used to build the models and compared the predicted ratio to the observed ratio. Considering the aforementioned linear regression model, the mean absolute average error for the model was 0.1159 in terms of the dependent variable (e.g., the cubed root of the ratio). Accordingly, the mean absolute error of ratio without the transformation would have been somewhat different. For instance, if for a given project the actual ratio of PE/CN = 11.7% and the predicted ratio = 22.14%, this will correspond to an average error of 0.1159 in the dependent variable (since $0.117^{1/3} - 0.2214^{1/3} = 0.1159$) but an error of only 0.1044 for the actual ratio (since 0.2214 – 0.117 = 0.1044). Although these represent a substantial improvement over NCDOT's previous practice of assuming a constant percentage for the ratio of PE to CN costs, Liu et al. (2011) cautioned that their models could not capture the "risk factors" that cause PE costs to rise dramatically for a given project, such as public opposition and environmental impacts, which were noted in the interviews with Fredericksburg (Interview FR1) and Bristol (Interview BR2) district staff.

Summary of the Literature Review

At the project level, a best practice reported in the literature review (AECOM et al., 2010) is to develop formal analytical procedures to estimate the funding required for PE rather than assuming that PE will be a fixed percentage of CN costs (Liu et al., 2011). Such procedures may also be supported by the availability of planning-level traffic impacts data (Dowling and Elias, 2012) and are necessitated by observations that forecast PE costs lower than actual costs (Liu et al., 2011). The analytical methods reviewed (e.g., AECOM et al. [2010]) require an element of judgment as is the case with Virginia's PCES.

Identification of Candidate Project Characteristics

Interview Question 9 asked for project characteristics that should be considered in the development of the model. Suggested characteristics fell into five categories: magnitude, infrastructure, funding, location, and external factors.

Magnitude

1. *Construction estimate.* Defining the scale of a project such as distinguishing whether the project is Tier 1 (under $5M) or Tier 2 (above $5M, design-build, or located on the interstate system) can impact the PE estimate (Interview ST8).

2. *Types of stakeholders.* Many projects have diverse types of stakeholders with varying motives affecting the PE estimate. Atypical stakeholders that can play a role in the PE phase are the National Park Service, the county board of supervisors, and the military (Interview HR7).

3. *Management.* Projects can be managed by one VDOT district, more than one VDOT district, VDOT's central office, private consultants, or the locality. Defining these categories is difficult as many projects have multiple management systems. Some projects use on-call consultants, which gives the consultant an incentive to do the project well in order to be retained for future projects (Interview RI10).

Infrastructure

1. *Type of intersection control.* A traffic signal would raise the CN cost of a project by $300,000 or more (Interviews BR2 and SA4).

2. *Type of materials and earthwork.* Various materials and earthwork such as laid back slopes, stabilization, and excavation may be required for a project. Additional changes may not be evident at the scoping stage (such as rock and or hazardous materials). The possibility of such unexpected findings will influence how much of a contingency should be established (Interviews BR2 and LY6).

3. *Type of survey.* Aerial surveys are more expensive than topographical surveys (Interview BR2). The interviewees also referred to the revised PM-100, which is a form for generating a scoping report which lists functional areas that project development might require, one of which is a survey supporting location and design work (VDOT, 2012c).

4. *Drainage.* Revised federal drainage regulations may require more RW because the method for calculating the amount of land required is now based on total RW rather than additional RW acquired for the project (Interview BR2).

5. *Inclusion of noise abatement.* An increase in project costs is attributed to the decision to include noise walls (Interview CU3).

6. *Construction vehicle access.* This may require separate contracts for easements (Interview LY6).

7. *Availability and number of culverts* (Interview ST8).

Funding

1. *Extent of funding in the SYIP. Fully funded* might be defined as estimated PE, estimated RW, and a significant portion of the estimated CN being in the SYIP (Interview SA4).

2. *State-funded or federally funded* (Interview SA4).

3. *Amount of funding per year* (Interview CO5).

Location

1. *Urban versus rural* (Interviews SA4 and, HR7).

2. *Environmentally sensitive area.* Areas in Virginia such as the tidal region can require additional environmental review and affects the Hampton Roads District (Interview HR7).

3. *Military presence.* In areas with a large military presence, e.g., the Hampton Roads District, many decisions are not made locally but rather are made at the "Pentagon" level. This adds stakeholders, lengthens decision-making time, and affects costs (Interview HR7).

External Factors

The external factors referenced in the district interviews such as political environment, PE duration, public involvement, and number of designs required, are largely dependent on one another.

1. *Political environment.* Interviewees used the phrase "political environment" to denote a fundamental shift in project expectations that increases the likelihood of a redesign and hence the percentage of funds spent on PE. These expectations could have reflected those of the designer; for example, the designer might need to perform PE multiple times in order to yield a design that meets the CN budget (Interview FR1). These expectations could also have reflected those of elected officials or others involved with public approval (Interviews SA4 and LY6).

2. *PE duration.* The PE duration can be measured as up to three variables: length of time in years, changes in internal stakeholders, and changes in external stakeholders (e.g., number of election cycles). Even projects with short PE durations can reflect a change in will, opinions, and desires. Although a bridge life cycle may be 75 years, an election life cycle can be 2 to 4 years, showing that technical work is evaluated in a political environment (Interview RI10). Projects with longer PE phases may require additional public involvement or duplication of key design tasks, both of which increase the PE cost (Interviews CU3, SA4, and HR7). Northern Virginia District interviewees pointed out that a better representation of duration is from PE Start to CN Advertisement (Interview NV9). The PE duration on the "Schedule and Estimates" section of the Project Pool has PE, RW, and CN in a start-to-finish relationship. Using the PE duration from PE Start to CN Advertisement includes PE tasks that occur during the PE and RW phases simultaneously.

3. *Public involvement.* This characteristic was suggested by several of the interviewees but can be difficult to quantify (Interview NV9). Metrics suggested to estimate the extent of the public involvement can measured by the length of the PE duration, number of design iterations, and use of the "design approval letter" (Interviews SA4, LY6, and NV9). The duration can increase as public involvement becomes more

complex. If designs are not approved, the need for multiple alternative designs lengthens the project duration. However, the VDOT design approval letter indicates the response to public input and can sometimes be found on the iPM.

4. *Number of designs.* The number of times a project was designed can double or triple the PE cost. However, it is difficult to ascertain the number of designs required other than by looking at PE cost and talking to the project manager (Interview HR7).

Establishment of Training and Testing Data Sets

The data collection process included preliminary screening by the researchers and district personnel, a further screening based on expenditures, a further exclusion of minimum-plan and no-plan projects, and an addition of projects without RW expenditures. This process was applied to a large list of VDOT projects to gather a sample of representative construction projects.

Preliminary Screening

The preliminary screening process removed projects that were an enhancement, district-wide, a study only, or part of ARRA. As part of this process, the researchers requested that district interviewees examine specific projects and identify any other projects that such staff considered to be anomalies in their district; for example, one interviewee identified a maintenance and operations project that nonetheless was funded with a construction allocation (Interview CU3).

Screening Based on Expenditures

After the projects passed the preliminary screening, they were selected for inclusion in the database if expenditures were reported for all three phases (PE, RW and CN) and a scoping construction estimate was uploaded to the Project Pool from the PCES. This criterion increased the likelihood that PE expenditures were complete (as most interviewees indicated that once CN began, PE was largely finalized) and a CN estimate was available. It was not feasible to rely exclusively on projects that had a workflow status of "archive" because, although projects with such a status were desirable, those projects were relatively few. This screening produced 157 projects, as shown in the second column of Table 13.

During the first interview conducted, district staff suggested that the data set be composed of archived projects (Interview FR1)—an indication that the project expenditures would not change. Although one interview indicated that if the CN phase had begun the PE phase was complete, making the use of only archived projects unnecessary (Interview CO5), one interview showed that the PE phase can remain open to charges after CN begins (Interview NV9). Therefore, in most cases the PE does not change after CN has begun, but there are instances where PE can change after CN has begun. Ultimately, after the preliminary screening, there were only 23 archived projects, and thus to enlarge the data set the criterion of using a project with CN expenditures was adopted.

Table 13. Candidate Construction Projects by VDOT District for Potential Inclusion in a Project-Specific PE Cost Estimation Model [a]

District	No. of Projects With PE/RW/CN	No. of Projects With PE/CN and NO RW	Total
Bristol	9	37	46
Culpeper	4	3	7
Fredericksburg	7	2	9
Hampton	7	18	25
Lynchburg	17	1	18
Northern Virginia	36	7	43
Richmond	39	93	132
Salem	11	14	25
Staunton	27	35	62
Total	157[a]	210[a]	367[a]

VDOT = Virginia Department of Transportation; PE = preliminary engineering; RW = right of way; CN = Construction

[a] Includes minimum-plan and no-plan projects. Removal of such projects means that there are 87 (rather than 157) projects with PE/RW/CN expenditures and 69 with PE/CN and NO RW expenditures, for a total of 156 projects.

Exclusion of Minimum-Plan and No-Plan Projects

Recognizing that district interviews had suggested excluding minimum-plan and no-plan projects from the data set (Interview SA4) or at least identifying them as a critical characteristic (Interview LY6), all such projects were removed from the data set as anomalies, which yielded 87 projects with PE, RW, and CN expenditures. Initially the researchers sought to develop a model that included minimum-plan and no-plan projects as an independent variable; however, the error rates with such models were quite large, confirming that minimum-plan and no-plan projects are fundamentally different from full construction projects.

Inclusion of Projects Without RW

One interview (Interview NV9) noted that there is a significant number of projects that do not have a RW phase but are still typical construction projects. The third column of Table 13 shows the additional projects for each district that have PE and CN but no dollars spent on RW.

A resultant concern was that the projects without RW are fundamentally different from those with RW. One way to verify this is to determine if the construction estimates and the PE expenditures between the projects with PE/RW/CN and projects with PE/CN and no RW were significantly different. The *t*-test, where unequal variances are assumed, showed that both the CN estimate and the PE expenditures are significantly different ($p < 0.01$) between these two groups (whether or not minimum-plan and no-plan projects are included). Since the two data sets were significantly different, subsequent model development considered inclusion of RW as an independent variable.

Resultant Data Set

The revised data set had 156 projects, 69 of which had PE and CN expenditures but no RW and 87 of which had PE, RW, and CN expenditures. These projects again were split into

80% training and 20% testing data sets. The training data had 124 projects, and the testing had 32 (see Table 14). The projects were then divided into projects that had a scoping construction estimate under $5M, from $5M to $18M, and over $18 M. Since most of the construction estimates were under $5M, Models 5 though11 are entirely based on those projects with an estimated CN cost under $5M.

Table 14. Revised Data Set for Project-Level Analysis

Data Type	Under $5M	$5M-$18M	Over $18M	Total
Training	97[a]	19	8	124
Testing	27[b]	4	1	32
Total	124	23	9	156

[a] Models 5-11 were calibrated from the 97 training projects under $5M.
[b] The ability of Models 5-11 to replicate actual preliminary engineering expenditures was evaluated with these 27 testing projects under $5M.

As discussed in the sections that follow, all models except Model 5 (Virginia's PCES) were calibrated with the training data set; the PCES had already been calibrated. Although most assumptions were verified in developing project-level models from the training data sets, one assumption was not—the normality of the errors—as reported in Appendix B, which means that to evaluate model performance better, one must examine how the model performs with a testing set of data—data that were not used to develop the initial models.

All models were evaluated with the testing data set of 27 projects, where the error was defined as the difference between the modeled PE expenditure and the actual PE expenditure for each project. The error associated with each model is presented in three different ways:

1. The *average absolute error* is the average error for all 27 projects, irrespective of whether the error is positive or negative.

2. The *average absolute percent error* is the average of the following quantity for all 27 projects: the magnitude of the error divided by the actual PE expenditure.

3. *The average percent error* is the average of the following quantity for all 27 projects: the error divided by the actual PE expenditure.

For example, if the testing data set contained just two projects where Project 1 had actual expenditures of $100,000 but the model forecast $140,000 for an error of +$40,000, which is +40%, and Project 2 had actual expenditures of $2 million that the model forecast as $1.8 million for an error of -$200,000, which is -10%:

- The *average absolute error* would be $120,000 based on ($40,000 + $200,000)/2.

- The *average absolute percent error* would be 25%, based on (40% + 10%)/2.

- The *average percent error*, where absolute values are not used, would be only 15% because the underprediction for Project 2 partially cancels the overprediction for Project 1 such that (40% – 10%)/2 = 15%.

Investigation of Models Based on Construction Cost Alone

Two single-variable project-level models were considered: Model 5 (PCES) and Model 6 (PCES With New Parameters).

Model 5. PCES

The PCES is what VDOT currently uses to predict the PE estimate. This model was applied to the testing data and compared to the actual PE expenditures as a base case against which to judge the accuracy of any future models.

Equation 2 is used to determine the PE estimate from the PCES for projects under $5M:

$$PE = (CN)*[0.203-(CN)*0.000000014] \quad \text{[Eq. 2]}$$

where

PE = forecast preliminary engineering cost in dollars
CN = forecast construction cost in dollars

Based on the 27 projects in the testing data set that are under $5M, the PCES model has an average absolute percentage error of 135% and an average absolute error of about $200,000.

Model 6. PCES With New Parameters

Model 6 used the training data to calibrate new coefficients for Equation 2. Although Equation 2 may be calibrated in a linear fashion as $a*CN + b*CN^2$, it is written as shown in Equations 3 and 4 to be directly comparable with the PCES approach (i.e., Model 5).

$$PE = CN*[a+b*CN] \quad \text{[Eq. 3]}$$

where

PE = forecast preliminary engineering cost in dollars
CN = forecast construction cost in dollars

$$PE = CN*[0.3197-0.0000000294*CN] \quad \text{[Eq. 4]}$$

where

PE = forecast preliminary engineering cost in dollars
CN = forecast construction cost in dollars

Based on the testing data, Table 15 shows the average percent error and average absolute error for PCES (Model 5) and PCES With New Parameters (Model 6). Model 5 had a lower average absolute percent error, and Model 6 had a lower average absolute error. However, the paired *t*-test showed there is not a significant difference between the two models for the average absolute percent error ($p = 0.09$) and average absolute error ($p = 0.07$).

Table 15. Average Error for PCES and PCES With New Parameters[a]

Model No.	Model Name	Average Absolute Percent Error	Average Percent Error (Absolute Values Not Used)	Average Absolute Error
5	PCES	133.6	77.1	$194,648.89
6	PCES With New Parameters	202.1 (p = 0.09)	172.1 (p = 0.01)	$153,972.08 (p = 0.07)

[a] Based on n = 27 testing samples.

Figure 8 shows the actual PE expenditures, Model 5 (PCES) estimates and Model 6 (PCES With New Parameters) estimates. Model 6 predicted a slightly higher estimate than Model 5 and showed substantial variation in the PE expenditures. The projects are listed in order of increasing CN cost from left to right, and the oscillation of the PE expenditures line suggests that factors other than CN cost likely contribute to this oscillation. The desire to use characteristics other than the CN estimate to reduce this variation was the motivation for developing models based on multiple parameters (Models 7-11).

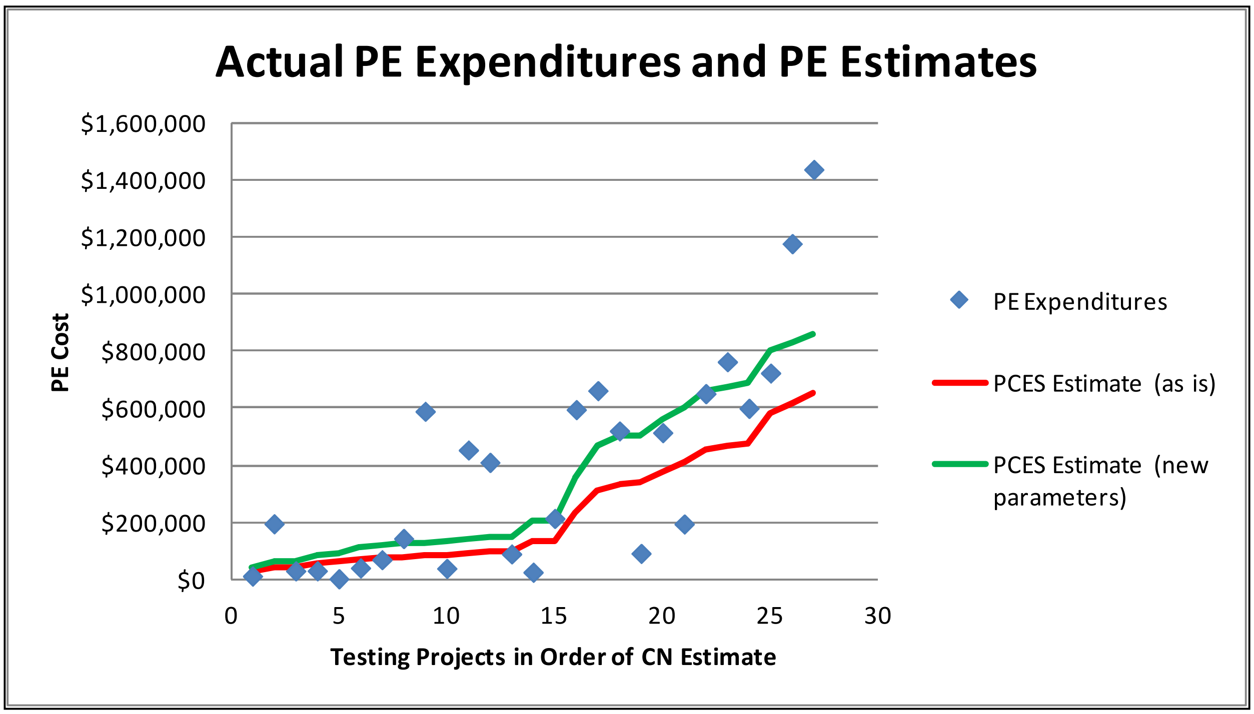


Figure 8. Actual Preliminary Engineering (PE) Expenditures and PE Estimates. PCES = Project Cost Estimating System; CN = Construction Estimate

Development of Models with Multiple Variables

Characteristic Selection

Project characteristics, such as environmental factors (e.g., were wetlands required); order of magnitude factors (e.g., how many homes will be taken or how long is the project); and the delivery method (e.g., design-build project), were collected to understand factors for forecasting the cost of PE, as shown in Table 16. Table 16 was generated from comments made during the first district interview (Interview FR1), responses to Interview Question 9 for the remaining district interviews, and examination of the Project Pool.

Table 16. Project-Level Model Characteristics

All Characteristics	Characteristics Tested in At Least 1 Model	Characteristics Used in At Least 1 Model
Environmental		
Environmental Work	X	X
Wetlands Mitigation		
Bio Retention (Water Quality) Basins Considered?		
Cost		
PE Pre-Scoping Estimate		
PE Expenditure	X	X
Magnitude of Total Cost		
Pre-scoping RW Estimate		
Ratio of RW to CN		
CN Estimate	X	X
RW Required	X	X
Order of Magnitude		
Functional Classification	X	
Facility Type	X	
Design Services Provider		
Transportation Management Plan Class		
No. of Bridges		
PE Phase Duration	X	X
Businesses to Be Taken		
Homes to Be Taken		
Railroad Involvement		
Bike Ped Accommodations		
District	X	
VDOT or LAP	X	X
Length	X	X
C, M, or N Plan	X	
Agreements		
Required National Historic Preservation Act		
HazMat Evaluation		
Utility Relocation		
IJR or IMR		
Memorandum of Agreement, Between Public Agencies		
Recoverable Slope Study		
Value Engineering Study		
Delivery Method		
Alternate Delivery Method?		
Alternate Designs Considered (When in Process)		

PE = preliminary engineering; RW = right of way; CN = construction; Bike Ped = Bicycle or Pedestrian; VDOT = Virginia Department of Transportation; LAP = locally administered project; C, M, or N = construction plan, minimum plan, or no-plan; HazMat = hazardous materials; IJR = interchange justification request; IMR = interchange modification request

The use of these characteristics led to the development of Models 7 though 11:

- Model 7. Non-Linear With a Single Environmental Variable
- Model 8. Non-Linear With Multiple Environmental Variables
- Model 9. Exponential With a Single Environmental Variable
- Model 10. Exponential With Multiple Environmental Variables
- Model 11. Non-Linear With RW and No Environmental Variables.

Rationale for Developing Models 7 Through 11

Generally, linear regression models are attractive because of their simplicity. Provided they accurately describe the dependent variable (PE cost), linearity can make the terms in such models more easily understood because of their additive nature. However, non-linear models and exponential models were considered because of the belief that the relationship between PE cost and the CN estimate is not constant. Rather, as CN increases, PE will also increase but at a slower rate, such that the ratio of PE to CN decreases as CN increases. This belief is also shown in the three regimes used by the PCES to forecast PE costs (see Figure 4). In short, whereas larger projects require more PE than smaller projects, the ratio of PE to CN is smaller for larger projects. Accordingly, models that could incorporate this trend were explored. The researchers focused on two model types that in this report are categorized as non-linear (Models 7, 8, and 11) and exponential (Models 9 and 10). An early approach to predict PE did use linear regression without transformations; however, the model did not fit the data as well as the non-linear and exponential transformations, and this linear approach was not pursued further. Models 7 through 11 used descriptive project characteristics to predict the PE cost.

Model 7. Non-Linear With a Single Environmental Variable

Model 7 used the construction estimate at the scoping phase, project duration, whether or not the project was administered by VDOT, project length, and whether or not the project required a CE environmental document. All parameters except the intercept (that is the constant which does not a coefficient for any of the independent variables) were statistically significant. The VDOT and CE are binary independent variables; thus their coefficient requires a transformation. Similarly, although the project length independent variable is not binary, there are projects that do require 0 mile of length; thus the coefficient requires a transformation as well.

Because Model 7 is non-linear, a logarithmic transformation was performed to develop a linear expression, shown as Equation 5.

$$\ln(PE) = [\ln(a)] + [b]^{*} \ln(CN) + [c]^{*} \ln(Duration) + VDOT^{*}[\ln(d)] + Length^{*}[\ln(f)] + CE^{*}[\ln(g)] \qquad \text{[Eq. 5]}$$

where

PE = forecast preliminary engineering cost in dollars

CN = forecast construction cost in dollars

Duration = expected duration of the project in years

VDOT = 1 if project is administered by VDOT, 0 otherwise

Length = project length in miles

CE = categorical exclusion under the National Environmental Policy Act of 1969 [NEPA]) = 1 if categorical exclusion, 0 otherwise.

Linear regression gave the coefficients, designated by brackets in Equation 5; the values of these coefficients are shown in the third column of Table 17. In order to apply the model in practice, it is convenient to reverse the logarithmic transformation, i.e., to apply the exponentiation operator to both sides of Equation 5. Equations 6 and 7 show the intermediate steps in this process. The reader will note that the exponentiation transforms the values of four of the parameters in the model: the coefficients ln(a), ln(d), ln(f), and ln(g) in the regression equation are (reverse-) transformed to the parameters a, d, f, and g in the model. Equation 8 shows the resulting version of Model 7. The values of the coefficients used in Model 7 are also shown in the fourth column of Table 17. The use of linear regression requires assumptions about the model, and the investigation of these assumptions is reported in Appendix B.

$$e^{\{\ln(PE)\}}=e^{\{[\ln(a)]+[b]*\ln(\text{CN Estimate})+[c]*\ln(\text{Duration})+[\ln(d)]*\text{VDOT}+[\ln(f)]*\text{Length}+[\ln(g)]\}} \quad \text{[Eq. 6]}$$

where

PE = forecast preliminary engineering cost in dollars
CN = forecast construction cost in dollars
Duration = expected duration of the project in years
VDOT = 1 if project is administered by VDOT, 0 otherwise
Length = project length in miles
CE = 1 if categorical exclusion, 0 otherwise.

$$PE=[a]*\text{CN Estimate}^{[b]}*\text{Duration}^{[c]}*[d]^{\text{VDOT}}*[f]^{\text{Length}}*[g]^{\text{CE}} \quad \text{[Eq. 7]}$$

where

PE = forecast preliminary engineering cost in dollars
CN = forecast construction cost in dollars
Duration = expected duration of the project in years
VDOT = 1 if project is administered by VDOT, 0 otherwise
Length = project length in miles
CE = 1 if categorical exclusion, 0 otherwise.

$$PE=2.22859*\text{CN Estimate}^{0.73010}*\text{Duration}^{0.32275}*2.8634^{\text{VDOT}}*0.64695^{\text{Length}}*1.70796^{\text{CE}} \quad \text{[Eq. 8]}$$

where

PE = forecast preliminary engineering cost in dollars
CN = forecast construction cost in dollars
Duration = expected duration of the project in years
VDOT = 1 if project is administered by VDOT, 0 otherwise
Length = project length in miles
CE = 1 if categorical exclusion, 0 otherwise.

Table 17. Model 7 Coefficients and *p*-values

Variable	*p*-value	Regression Coefficient (Eq. 5)[a]	Model 7 Coefficient (Eq. 8)
Intercept	0.65	0.80137	2.22859
CN Estimate	<0.01	0.73010	0.73010
Duration	0.00	0.32275	0.32275
VDOT	<0.01	1.05201	2.8634
Length	0.00	-0.43548	0.64695
CE	0.05	0.53530	1.70796

[a] Values in brackets in Eq. 5 are the coefficient estimated from linear regression in Eq. 5. For example, linear regression gave the intercept, which is [ln(a)] in Eq. 5, as 0.80137. The corresponding coefficient in Model 7, which is simply a, is $e^{0.80137}$ = 2.2285, as shown in Eq. 8.

Equation 8 is the median expectation of PE expenditures. Gillespie (2013a, b) noted that application of Equation 8 is the "median expectation" in the sense that forecast PE expenditures will be above actual PE expenditures half of the time and below actual PE expenditures half of the time. By contrast, to obtain the "mean expectation" in the sense that the forecast will tend to be correct on average, one should multiply Equation 8 by the quantity exp [0.5 * SSE / (n – k)], where SSE is the error sum of squares, n is the number of samples in the training set (thus n = 97 based on Table 14) and k is the number of independent variables including the intercept (thus k = 6). Because the use of the mean expectation with the testing data set for Model 7 increased the absolute error from approximately $109,040 to $264,005, this study used the median expectation as shown in Equation 8.

Model 8. Non-Linear With Multiple Environmental Variables

Model 8 (Table 18, Eq. 9) is comparable to Model 7, but it separated the environmental variable into more specific categories by adding in whether the project required a CE, programmatic CE (PCE), environmental assessment (EA), or no environmental work. Although this added more variables into the model, it clarified the specific type of environmental document needed for the project. The PCE and EA variables were not significant ($p > 0.05$) and thus may be removed. Model 8 is in the same equation format as Equation 8 for Model 7.

$$PE=1.139911*CN^{0.75025}*Duration^{0.30267}*2.844621^{VDOT}*0.657099^{Length}$$
$$*2.525477^{CE}*1.641204^{PCE}*0.889683^{EA}$$

[Eq. 9]

where

PE = forecast preliminary engineering cost in dollars

CN = forecast construction cost in dollars
Duration = expected duration of the project in years
VDOT = 1 if project is administered by VDOT, 0 otherwise
Length = project length in miles
CE = 1 if categorical exclusion, 0 otherwise.
PCE = 1 if programmatic categorical exclusion, 0 otherwise.
EA = 1 if environmental assessment, 0 otherwise.

Table 18. Model 8 Coefficients and *p*-values

Variable	*p*-value	Transformed Coefficient (Eq. 9)
Intercept	0.94	1.139911
CN Estimate	<.01	0.75025
Duration	0.00	0.30267
VDOT	<.01	2.844621
Length	0.00	0.657099
Categorical Exclusion	0.02	2.525477
Programmatic Categorical Exclusion	0.16	1.641204
Environmental Assessment	0.92	0.889683

Model 9. Exponential With a Single Environmental Variable

The exponential format used the same characteristics: duration, whether or not the project was administered by VDOT, project length, and whether or not the project required a CE environmental document (see Table 19, Eq. 10).

$$PE=1.29812*CN^{0.77742}*e^{(0.05091*Duration+1.00212*VDOT-0.45843*Length+0.65853*CE)}$$ [Eq. 10]

where

PE = forecast preliminary engineering cost in dollars
CN = forecast construction cost in dollars
Duration = expected duration of the project in years
VDOT = 1 if project is administered by VDOT, 0 otherwise
Length = project length in miles
CE = 1 if categorical exclusion, 0 otherwise.

Table 19. Model 9 Coefficients and *p*-values

Variable	*p*-value	Transformed Coefficient (Eq. 10)
Intercept	0.89	1.29812
CN Estimate	<0.01	0.77742
Duration	0.06	0.05091
VDOT	0.00	1.00212
Length	0.00	-0.45843
Categorical Exclusion	0.02	0.65853

Model 10. Exponential With Multiple Environmental Variables

Similar to the non-linear function, when the specific types of environmental documents were added to the model, the PCE and EA variables were insignificant as shown in Table 20 and Equation 11.

$$PE=0.50881*CN\ Estimate^{0.80475} *e^{(0.04692*Duration+0.98595*VDOT-0.43504*Length+1.20153*CE+0.69339*PCE+0.21509*EA)}$$

[Eq. 11]

where

PE = forecast preliminary engineering cost in dollars
CN = forecast construction cost in dollars
Duration = expected duration of the project in years
VDOT = 1 if project is administered by VDOT, 0 otherwise
Length = project length in miles
CE = 1 if categorical exclusion, 0 otherwise
PCE = 1 if programmatic categorical exclusion, 0 otherwise
EA = 1 if environmental assessment, 0 otherwise.

Table 20. Model 10 Coefficients and *p*-values

Variable	*p*-value	Transformed Coefficient (Eq. 11)
Intercept	0.73	0.50881
CN Estimate	<0.01	0.80475
Duration	0.09	0.04692
VDOT	0.00	0.98595
Length	0.00	-0.43504
Categorical Exclusion	0.00	1.20153
Programmatic Categorical Exclusion	0.06	0.69339
Environmental Assessment	0.86	0.21509

Model 11. Non-Linear With Duration, VDOT, Length, RW

Similar to Models 7 and 8, Model 11 (Table 21, Eq.12) uses a non-linear format but does not include the environmental independent variable of CE. Instead, the model includes whether or not the project required RW.

$$PE=2.02041*CN^{0.73033}*Duration^{0.31147}*2.2897^{VDOT}*0.68547^{Length}*2.06998^{RW}$$

[Eq. 12]

where

PE = forecast preliminary engineering cost in dollars
CN = forecast construction cost in dollars
Duration = expected duration of the project in years
VDOT = 1 if project is administered by VDOT, 0 otherwise
Length = project length in miles
RW = 1 if right of way required, 0 otherwise.

Table 21. Model 11 Coefficients and *p*-values

Variable	*p*-value	Transformed Coefficient (Eq. 12)
Intercept	0.68	2.02041
CN Estimate	<0.01	0.73033
Duration	0.00	0.31147
VDOT	0.00	2.2897
Length	0.01	0.68547
RW	0.00	2.06998

Summary of Performance of Project-Level Models (Models 7 Through 11)

In terms of performance with the *training* data set, Table 22 shows the adjusted R^2 values for Models 7 through 11; basically the five models explain slightly more than one-half of the variation in PE expenditures in the training data set.

Table 22. Project-Level Model Characteristics With the Training Data Set (Models 7-11)

Model No.	Model	Characteristic[a]	*p*-value	Coefficient	Adjusted R^2
7	Non-Linear With Duration, Length, VDOT, CE	Intercept	0.65	2.22859	0.58
		CN Estimate	<0.01	0.73010	
		Duration	0.00	0.32275	
		VDOT	<0.01	2.8634	
		Length	0.00	0.64695	
		CE	0.05	1.70796	
8	Non-Linear With Duration, VDOT, Length, CE, PCE, EA	Intercept	0.94	1.139911	0.58
		CN Estimate	<0.01	0.75025	
		Duration	0.00	0.30267	
		VDOT	<0.01	2.844621	
		Length	0.00	0.657099	
		CE	0.02	2.525477	
		PCE	0.16	1.641204	
		EA	0.92	0.889683	
9	Exponential With Duration, Length, VDOT, CE	Intercept	0.89	1.29812	0.52
		CN Estimate	<0.01	0.77742	
		Duration	0.06	0.05091	
		VDOT	0.00	1.00212	
		Length	0.00	-0.45843	
		CE	0.02	0.65853	
10	Exponential With Duration, Length, VDOT, CE, PCE, EA	Intercept	0.73	0.508810	0.53
		CN Estimate	<0.01	0.80475	
		Duration	0.09	0.04692	
		VDOT	0.00	0.98595	
		Length	0.00	-0.43504	
		CE	0.00	1.20153	
		PCE	0.06	0.69339	
		EA	0.86	0.21509	
11	Non-Linear With Duration, VDOT, Length, RW	Intercept	0.68	2.02041	0.60
		CN Estimate	<0.01	0.73033	
		Duration	0.00	0.31147	
		VDOT	0.00	2.2897	
		Length	0.01	0.68547	
		RW	0.00	2.06998	

[a]Possible characteristics are CN = forecast construction cost in dollars; Duration = expected duration of the project in years; VDOT = 1 if project is administered by VDOT, 0 otherwise; Length = project length in miles; CE = 1 if categorical exclusion, 0 otherwise; PCE = = 1 if programmatic categorical exclusion, 0 otherwise; EA = 1 if environmental assessment, 0 otherwise; RW = 1 if right of way required, 0 otherwise. Intercept is a constant in the equation that is not associated with any independent variable.

Table 23 shows the average percent error (with and without absolute value) and the average absolute error of each of the models based on the *testing* data set. The error in the PCES model (Model 5) is the base for comparison. These columns have a slightly different nuance: average absolute percent error weights each project equally, regardless of size, whereas average absolute error weights percentage errors associated with larger projects more heavily. Model 6 has a much higher average percent error than Model 5 but a lower absolute error. All five models using project characteristics (Models 7-11) have a lower average absolute error than Model 5 in a nominal sense. The values in parentheses indicate whether there is a significant difference between the error rates, for the 27 testing data set projects, for each of Models 6-11 and Model 5 based on the paired *t*-test. (For example, there is not a significant difference between the average absolute percent error for Model 6 and that of Model 5 since the *p*-value of 0.09 exceeds the significance threshold of 0.05.)

Table 23 offers two perspectives on PE costs. The first is that the actual average absolute errors, which range from approximately $103,000 (Model 10) to almost $195,000 (Model 5), are not that large given that the cost of construction projects in this regime could be up to $5 million. The second is that the high absolute percent errors (the smallest being roughly 44%) indicate substantial variability in the PE expenditures; i.e., even after accounting for variables such as construction cost, length of the project, duration, and level of environmental review required, the large average absolute percent errors indicate substantial variability in project-level PE costs.

Table 23. Average Percent Error and Absolute Error for All Project-Level Models (Models 5-11)

Model No.	Model Name	Average Absolute Percent Error	Average Percent Error (Absolute Values Not Used)	Average Absolute Error
5	PCES	133.6 (N/A)	77.1 (N/A)	$194,648.89 (N/A)
6	PCES With New Parameters	202.1 ($p = 0.09$)	172.1 ($p = 0.01$)	$153,972.08 ($p = 0.07$)
7	Non-Linear With Duration, Length, VDOT, CE	43.9 ($p = 0.08$)	-4.1 ($p = 0.013$)	$109,040.12 ($p = 0.02$)
8	Non-Linear With Duration, VDOT, Length, CE, PCE, EA	45.8 ($p = 0.08$)	-1.63 ($p = 0.12$)	$105,598.54 ($p = 0.02$)
9	Exponential With Duration, Length, VDOT, CE	54.9 ($p = 0.06$)	2.78 ($p = 0.09$)	$108,951.09 ($p = 0.02$)
10	Exponential With Duration, Length, VDOT, CE, PCE, EA	56.5 ($p = 0.06$)	7.34 ($p = 0.09$)	$103,316.41 ($p = 0.02$)
11	Non-Linear With Duration, VDOT, Length, RW	45.2 ($p = 0.09$)	-5.0 ($p = 0.09$)	$129,232.19 ($p = 0.005$)

PCES = Project Cost Estimating System; N/A = not applicable; VDOT = Virginia Department of Transportation; CE = categorical exclusion; PCE = programmatic categorical exclusion; EA = environmental assessment; RW = right of way.

SUMMARY OF FINDINGS

1. The district interviews and the literature indicate that VDOT's definition of *preliminary engineering* is a recursive process that prepares projects for construction, spanning activities that occur from the time a project charge number is made available until the date the project is awarded for construction. Such PE activities are diverse and, especially for smaller projects, may include developing a fundamental engineering definition of the project (e.g., raising the entire road bed versus designing a new drainage system).

2. The financial data are available to determine the percentage of funds spent on PE by VDOT district, fiscal year, and project, subject to several limitations, and although these data are reviewed at the project level, they are not reviewed at the program level.

3. Although it is not possible to strictly compare Virginia's PE percentages to those of other states, it is possible to compare Virginia's PCE percentages to those of other states, noting that Virginia's PCE percentages are comparable to those of other states that, like Virginia, manage, build, and maintain the equivalent of a secondary (or county) system.

4. At the program level, factors that affect the variability of PE expenditures within VDOT districts include expenditures spent on minimum-plan or no-plan projects, percent of expenditures spent each year on large projects, and percent of projects in the development phase.

5. At the project level, factors that influence the variability of PE expenditures for specific projects include construction cost (as was known prior to this study); project duration; project length; whether the project is administered by VDOT; and the level of environmental work required.

CONCLUSIONS

1. *PE expenditure data are available, but their interpretation is subject to caveats noted by interviewees.* These caveats include the facts that a district-wide pre-scoping is available such that some PE costs are not attributed to a specific project, a single project may use multiple UPCs; and multiple projects may share a single UPC. To be clear, such caveats do not inhibit the calculation of PE expenditures at the district-wide program level, but they may have an impact at the project level. Other caveats that complicate any project-level or program-level PE analysis are the facts that there are other sources for accomplishing PE work (e.g., maintenance projects); some activities may be placed in different phases (e.g., wetland banking in PE and wetland replacement in CN); and, as noted in Conclusion 3, there are non-typical projects in the SYIP.

2. *Virginia has a significantly higher PCE percentage (16.5%) than the national average (14.4%), but there is not a significant difference in the PCE percentages of Virginia and four other states that maintain the equivalent of a secondary system* (i.e., Alaska, Delaware, North Carolina, and West Virginia, which have a mean annual PCE percentage of 17.6%). The

addition of Texas to this group still showed no difference ($p = 0.88$) between the values for Virginia and those for the other five states (Alaska, Delaware, North Carolina, West Virginia, and Texas). This conclusion refers to national data for the period 1990-2010.

3. *Typical construction projects account for a minority of projects in the SYIP.* For the period FY 2004-2012, a majority of the projects in the SYIP were non-typical projects because they had at least one of the seven characteristics that district staff recommended for exclusion: enhancement, district-wide, study-only, ARRA, minimum-plan or no-plan, locally administered or administered by some entity other than VDOT, or recommended for exclusion by district staff for other reasons such as a maintenance project funded with construction allocations. Such projects accounted for four-fifths of the UPCs in the original data set, or, depending on the year, between 58% and 71% of all expenditures.

4. *Restricting the data set to typical projects as per Conclusion 3 reduces the program-level PE percentages*. Elimination of the non-typical projects reduced the average annual statewide pooled PE percentage from 14.7% to 11.4% and reduced the number of significantly different district pairwise comparisons from 11 to 3.

5. *There is substantial variation in the PE percentage by year, by district, and by district-year combination.* For the period 2004-2012, the statewide PE pooled percentage ranged from 11.2% in 2007 to 18.8% in 2012. (The mean of these PE percentages was 14.7%.) By district, the mean PE percentage ranged from 11.3% (Staunton) to 21.3% (Culpeper). By individual district and year, variation was greater, with the lowest value being 2.7% (Lynchburg in 2005) and the highest value being 45.5% (Fredericksburg in 2009). As interviewees suggested, there is substantial variation on an annual basis.

6. *Simple linear models suggest that without accounting for annual variation, three independent variables appear to explain 89% of the variation in the PE percentage:* (1) percent of expenditures spent on minimum-plan or no-plan projects; (2) percent of expenditures spent each year on large projects; and (3) percent of projects in the development phase. The first two variables have a negative impact on the PE percentage, and the third variable has a positive impact on the PE percentage.

7. *Less variation is explained when annual PE percentages are included.* A simple linear model based on five independent variables (average project cost, percent of expenditures spent each year on large projects, percent of expenditures for ARRA projects, percent of expenditures for study-only projects, and percent of expenditures for non-typical projects) explained about 52% of the variation in the data set; inclusion of a district and year variable meant that 70% of the variation could be explained. The model coefficients were consistent with theory: higher values for the first three variables have a negative effect on the PE percentage, and higher values for the last two variables increase the PE percentage.

8. *For smaller construction projects (those under $5M), a recently calibrated model based on additional significant variables to forecast PE costs at the project level improved forecast accuracy in the testing data set relative to the current approach in the PCES.* At the scoping stage, VDOT's current approach as reflected in the PCES is to forecast PE costs based solely

on the construction estimate, where the percentage of total project costs devoted to PE is inversely proportional to this construction estimate. Based on a training data set of 97 projects where the construction cost was under $5M, a new model (Model 7) for forecasting PE costs as a function of additional characteristics typically known at the project's inception, length, duration, level of required environmental review, and whether administered by VDOT was developed. Based on an additional 27 projects used to test the model that were not included in the training data set, Model 7 reduced the mean absolute error from about $200,000 to $110,000, and this reduction was statically significant (p = 0.02). Further, the new approach nominally reduced the mean percentage error from 135% to 47%.

RECOMMENDATIONS

1. *Staff of VDOT's Fredericksburg District should consider applying project-level Model 7 on a pilot basis in the Fredericksburg District.* For projects with a CN estimate under $5M, both Model 7 and the PCES should be applied and the accuracy of the results compared over time. The 27 projects in this testing data set suggested that Model 7 may be able to improve project accuracy. If Model 7 continues to offer improvements in accuracy, it may be incorporated into the PE estimation portion of the PCES.

2. *VDOT district staff should consider providing stakeholders with the historical annual percentage spent on PE at the program level, similar to what was reported in Table 6, during the planning or programming process.* Virginia's transportation planning and programming process includes both formal and informal communications with a variety of stakeholders such as localities, MPOs, and the public. This recommendation is that one additional piece of information—the percentage spent on PE at the program level—be provided to stakeholders. As Lynchburg District staff report they have already implemented this recommendation, as discussed in the next section, this study suggests that other districts consider doing so.

BENEFITS AND IMPLEMENTATION PROSPECTS

Benefits

There are five chief potential benefits of implementing the two study recommendations:

Recommendation 1offers three potential benefits:

1. If Model 7 is shown to be more accurate than existing approaches with additional data sets, forecasts of PE costs could be more accurate.

2. Regardless of whether Model 7 is more accurate, an understanding of the empirical confidence interval for the forecast is potentially beneficial (i.e., when a PE forecast

for a project-level cost is generated, one can say that the true expenditure will probably within $x of the forecast).

3. An improved cost estimation process may assist stakeholders in understanding the factors that influence project cost (e.g., if steps can be taken to shorten project duration, characteristics that increase project cost—staff turnover, changes in design standards, and changes in public opinion—may be less likely to occur. The project-level models quantify the benefit of such a reduction in duration.

Recommendation 2 offers two potential benefits.

1. Recommendation 2 would be used in the planning or programming process to help address the two goals noted at the outset of this study: prepare enough projects for CN for future years yet ensure sufficient funds are spent on CN in the present year to advance the transportation program.

2. Recommendation 2 would allow VDOT staff to show decision makers how certain factors, such as the number of projects in the development phase, increase the portion of the program that is focused on PE. If it were the case that stakeholders were concerned that PE costs were increasing at the program level, a comparison of such costs with the data provided in this study would help explain trends in PE costs.

To be clear, these two recommendations address a concern that could arise in the future. There was no evidence in this study that the topics of Recommendation 1 (PE model accuracy) or Recommendation 2 (PE expenditures at the program level) were generating widespread concern. Rather, Recommendations 1 and 2 address a topic that could be of interest in the future.

Implementation Prospects

Short-Term Pilots to Support Implementation

One way to proceed with Recommendation 1 is to implement it on a pilot basis in the Fredericksburg District, which is the district that initially suggested the idea of developing a project-level model to forecast PE expenditures based on various project characteristics. In that pilot, the PE expenditures forecast by Model 7 could be compared to actual values. If the results showed promise, this approach could be adopted by other districts. A spreadsheet that helps apply Model 7 has been developed and provided to the district.

One way to proceed with Recommendation 2 is to present the results of the experience in the Lynchburg District at a joint planning managers' meeting. Lynchburg District staff reported that they have already piloted Recommendation 2 in their district (R. Youngblood and J. Kessler, personal communication, 2014). The presentation, and ensuing discussion, could identify ways in which the additional information assists the planning and programming process. For example, in that district, staff noted that they shared historical PE cost estimates for corridor studies with MPO and planning district commission staff (Kessler, 2014).

As another example (not specific to the Lynchburg District), viewing the 2004-2012 data as a historical baseline, one would expect most (e.g., 95%) annual statewide pooled PE percentages to be within 1.96 standard deviations of the mean pooled percentage, or between 14.7% ± 1.96(2.8%) = 9.2% to 20.2%. The corresponding limits for a district PE percentage would be between 0.8% and 30.0%. If an annual PE percentage exceeded the upper limit, it would suggest that more is being spent on PE than had historically been the case. Similarly, if an annual PE percentage was below the lower limit, it would suggest that less was being spent on PE than had historically been the case. If the upper limit was exceeded in a given year, decision makers could follow one of two courses of action:

1. To the extent possible, encourage selection of projects that would reduce the amount that is expected to be allocated for PE, viewing an increase in the historical PE percentage as undesirable.

2. Decide that the increase in the PE percentage is justified in this situation, recognizing that other factors, such as the types of projects pursued, the timing of the construction program, VDOT's yearly federal obligation strategy, and random annual variation, will influence the PE percentage.

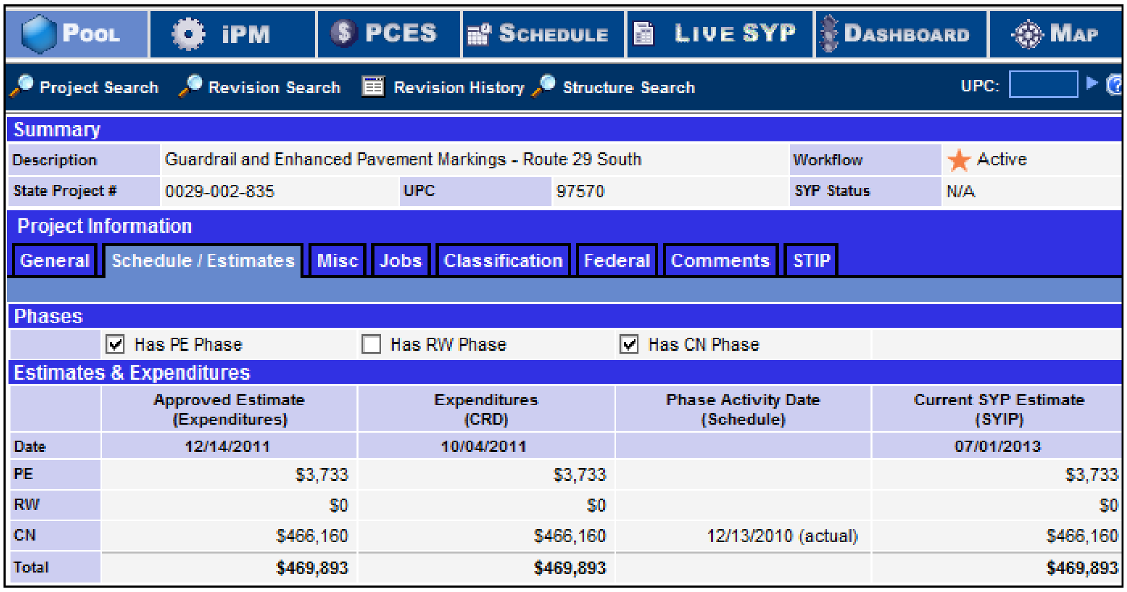
Longer Term Further Research to Support Implementation

There are two directions for further research that can help with Recommendation 1.

1. *Develop additional models to revise the PE estimate once PE is underway.* With the models developed in this study, the researchers sought, where possible, to use data available early in the project development process. An example of such a data element is the CN Estimate available at the scoping phase. However, some interviewees (Interview CU3) noted that models could be developed that would revise the PE estimate as new information was acquired later in the project development process. For example, new models could be developed that forecast the remaining PE expenditures based on the CN Estimate available at the Preliminary Field Inspection (PFI).

2. *Clarify the estimate and expenditure data in the Project Pool.* For example, the leftmost column of Figure 9, with the heading "Approved Estimate (Expenditures)" in the Project Pool shows the phase whose estimate is currently approved.

However, previous estimates can be found in the "PCES" section, as shown in Figure 10. For example, on 9/22/2010, when the pre-scoping estimate was created, Figure 9 would have shown $47,000 (for PE) and $868,240 (for CN) in the column labeled "Approved Estimate" in order to be consistent with the row indicating "Pre-Scoping" (Figure 10). Then, on January 21, 2011, when the Final Submission estimate was created (Figure 10), Figure 9 would have shown $47,000 (for PE) and $871,272 (for CN) in that same column ("Approved Estimate.") Presently, the "Expenditures" row in Figure 10, with the checkmark next to the type of estimate, indicates that it is "Approved" and is what is shown in the "Schedule / Estimates" section of the Project Pool under the column "Approved Estimate" (Figure 9).



Summary

Description	Guardrail and Enhanced Pavement Markings - Route 29 South			Workflow	Active
State Project #	0029-002-835	UPC	97570	SYP Status	N/A

Project Information

General | Schedule / Estimates | Misc | Jobs | Classification | Federal | Comments | STIP

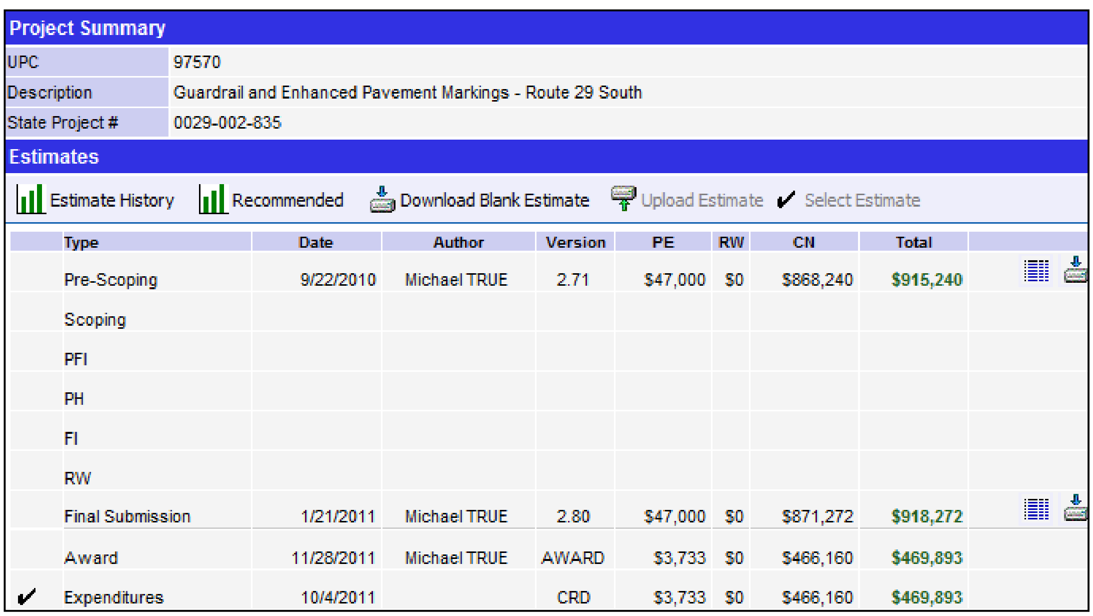
Phases

☑ Has PE Phase ☐ Has RW Phase ☑ Has CN Phase

Estimates & Expenditures

	Approved Estimate (Expenditures)	Expenditures (CRD)	Phase Activity Date (Schedule)	Current SYP Estimate (SYIP)
Date	12/14/2011	10/04/2011		07/01/2013
PE	$3,733	$3,733		$3,733
RW	$0	$0		$0
CN	$466,160	$466,160	12/13/2010 (actual)	$466,160
Total	$469,893	$469,893		$469,893

Figure 9. Schedule and Estimates for Universal Project Code (UPC) 97570



Project Summary

UPC	97570
Description	Guardrail and Enhanced Pavement Markings - Route 29 South
State Project #	0029-002-835

Estimates

	Type	Date	Author	Version	PE	RW	CN	Total
	Pre-Scoping	9/22/2010	Michael TRUE	2.71	$47,000	$0	$868,240	$915,240
	Scoping							
	PFI							
	PH							
	FI							
	RW							
	Final Submission	1/21/2011	Michael TRUE	2.80	$47,000	$0	$871,272	$918,272
	Award	11/28/2011	Michael TRUE	AWARD	$3,733	$0	$466,160	$469,893
✔	Expenditures	10/4/2011		CRD	$3,733	$0	$466,160	$469,893

Figure 10. "Project Cost Estimating (PCES)" Section Showing Past Estimates for Universal Project Code (UPC) 97570

ACKNOWLEDGMENTS

This work could not have been performed without the help of four groups of staff. The project was guided by a TRP composed of Jeff Kessler (chair, and Lynchburg District), Rob Case (Hampton Roads Transportation Planning Organization), Tommy DiGiulian (Salem District), and Abdul Hammadi (Fredericksburg District). Financial data were provided by Rob Carver; assistance with various aspects of data interpretation was provided by Corey Borne, Amy

Frye, Gene Holley, and Alan Saunders; key statistical interpretations were provided by Jim Gillespie. Insights from the interviews were a fundamental piece of this work, and interviewees included, in addition to the panel members, Jay Brown, Dic Burke, Chase Buchanan, Brian Casto, Rob Crandol, Matt Dana, Bruce Duvall, Mike Fulcher, Randy Hamilton, Sam Hayes, Jane-Ellen Hess, John Giometti, Claudia Llana, Kevin Northridge, Alex Price, Margit Ray, Mark Riblett, Steve Rowan, Terry Short, Bud Siegel, Brent Sprinkel, Kanti Srikanth, Wendy Thomas, Rob Walters, Zack Weddle, Jason Williams, and Jim Zeller. This project also benefited from review comments provided by the TRP along with Mary Bennett, Jose Gomez, and Amy O'Leary, and essential editing was provided by Linda Evans. However, the authors are responsible for any errors in this report.

REFERENCES

AECOM, Schneck, D., Touran, A., Raul V. Bravo + Associates, Inc., and Sharp & Company. *Estimating Soft Costs for Major Public Transportation Fixed Guideway Projects.* TCRP Report 138. Transportation Research Board of the National Academies, Washington, DC, 2010. http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_138.pdf. Accessed March 26, 2014.

Bourne, C. Email to J.S. Miller, November 30, 2012a.

Bourne, C. Email to J.S. Miller, December 3, 2012b.

Bourne, C. Email to B. Turner, December 6, 2012c.

Carver, R. Email to J.S. Miller, October 17, 2012a.

Carver, R. Emails to J.S. Miller, October 23, 24, and 25, 2012b.

Carver, R. Emails to J.S. Miller, February 6, 20, 21, 27, and May 8, 2013.

Cherry, Bekaert & Holland, L.L.P. Performance Audit of Significant Operations of the Virginia Department of Transportation. Richmond, VA, 2010. http://vtcaonline.com/images/uploads/CBH_Performance_Audit_Report_for_VDOT.pdf. Accessed March 26, 2014.

Cobb, K.L. Introduction to Sample Size and Power Calculation. Power Point Presentation. Stanford University, Stanford, CA, 2011. http://www.stanford.edu/~kcobb/hrp259/lecture11.ppt. Accessed October 17, 2013.

Dowling, R., and Elias, A. *Extent of Highway Capacity Manual Use in Planning.* NCHRP Synthesis 427. Transportation Research Board of the National Academies, Washington, DC, 2012. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_427.pdf. Accessed October 10, 2012.

Federal Highway Administration, Office of Highway Policy Information. *Highway Statistics.* 1990-2010. http://www.fhwa.dot.gov/policyinformation/statistics.cfm. Accessed March 15, 2013.

Federal Highway Administration, Office of Highway Policy Information. *A Guide to Reporting Highway Statistics.* 2000. http://www.fhwa.dot.gov/policyinformation/hss/guide/guide.pdf. Accessed March 15, 2013.

Federal Highway Administration. Value Engineering. 2012. http://www.fhwa.dot.gov/ve/vepolicy.cfm. Accessed June 10, 2013.

Federal Transit Administration. New Starts Fact Sheet. n.d. http://www.fta.dot.gov/12304_2607.html. Accessed December 7, 2012.

Federal Transit Administration. *FTA Major Capital Transit Investment Fact Sheet.* Washington, DC, 2007. http://www.fta.dot.gov/documents/PE_Fact_Sheet_9-18-07_.doc. Accessed September 12, 2012.

Federal Transit Administration. SCC Workbook. 2011a. http://www.fta.dot.gov/13070_2580.html. Accessed November 30, 2012.

Federal Transit Administration. Standard Cost Categories (SCC) for Capital Projects. 2011b. http://www.fta.dot.gov/13070_2580.html. Accessed November 30, 2012.

Gillespie, J.S. Email to J.S. Miller, B.A. Turner, and A.A. O'Leary, December 3, 2013a.

Gillespie, J.S. Email to J.S. Miller, B.A. Turner, and A.A. O'Leary, December 4, 2013b.

Hammadi, A. Email to John Miller, June 7, 2012.

Hollar, D., Arocho, I., Hummer, J., Liu, M., and Rasdorf, W. Development of a Regression Model to Predict Preliminary Engineering Costs. In *ITE 2010 Technical Conference and Exhibit: Meeting Transportation's 21st Century Challenges: Compendium of Technical Papers.* Institute of Transportation Engineers, Washington, DC, 2010. Accessed March 26, 2014.

Johnson, R.A., and Wichern, D.W. *Applied Multivariate Statistical Analysis.* Fifth Edition. Prentice Hall, Upper Saddle River, NJ, 2002.

Kerley, M.T. Preliminary Engineering Project Development Process. Instructional and Informational Memorandum IIM-LD-226.5. Virginia Department of Transportation, Richmond, 2011a. http://www.virginiadot.org/projects/concureng-default.asp. Accessed March 26, 2014.

Kerley, M.T. Project Management Policy. PMO-Policy-2011-1. Virginia Department of Transportation, Richmond, 2011b. http://www.virginiadot.org/business/resources/VDOT_PM_Policy.pdf. Accessed June 13, 2014.

Kessler, J.B. Email to J.S. Miller, March 6, 2014.

Liu, M., Hummer, J.E., Rasdorf, W.J., Hollar, D.A., Parikh, S.C., Lee, J., and Gopinath, S. *Preliminary Engineering Cost Trends for Highway Projects*. FHWA/NC/2010-10. North Carolina State University, Raleigh, 2011. http://www.ncdot.gov/doh/preconstruct/tpb/research/download/2010-10finalreport.pdf. Accessed December 5, 2012.

Newbold, P. *Statistics for Business and Economics,* 2nd Ed. Prentice Hall, Englewood Cliffs, NJ, 1988.

O'Leary, A.A. *Beyond the Byrd Road Act: VDOT's Relationship With Virginia's Urban Counties.* VTRC 98-R29. Virginia Transportation Research Council, Charlottesville, 1998. http://vtrc.virginiadot.org/PubDetails.aspx?id=297019. Accessed March 26, 2014.

O'Leary, A.A. Email to J.S. Miller. December 16, 2013.

Oman, A.E. Funding and Responsibilities for Virginia's Local Roadways. Richmond, 2006. http://hac.state.va.us/aarchives/2006/committee/files/09-18-06/Transportation--09-18-06.pdf. Accessed April 19, 2013.

Saunders, A. Email to John Miller, June 14, 2012.

Savin, N.E., and White, K.J. The Durbin-Watson Test for Serial Correlation With Extreme Sample Sizes or Many Regressors. *Econometrica,* Vol. 45, No. 8, 1977, pp. 1989-1996.

Smith, S.A. *Guidebook for Transportation Corridor Studies: A Process for Effective Decision-Making.* NCHRP Report 435. Transportation Research Board of the National Academies, Washington, DC, 1999.

Sprinkel, B. Email to J.S. Miller, January 10, 2013a.

Sprinkel, B. Email to J.S. Miller, March 18, 2013b.

Transportation Planning Research Advisory Committee. Draft Minutes, November 3, 2010. Virginia Center for Transportation Innovation and Research, Charlottesville, 2010. http://www.vtrc.net/tprac/pdf/MinutesFall2010.pdf . Accessed May 15, 2014.

Transportation Planning Research Advisory Committee. TPRAC Voting Results: Fall 2012. Virginia Center for Transportation Innovation and Research, Charlottesville, 2012. http://www.vtrc.net/tprac/pdf/ResearchNeedsResults.pdf. Accessed June 13, 2014.

Virginia Department of Transportation. *Road Design Manual, Volume 1.* Richmond, 2005. http://www.extranet.vdot.state.va.us/locdes/Electronic_Pubs/2005%20RDM/RoadDesignCoverVol.1.pdf. Accessed May 7, 2014.

Virginia Department of Transportation, Information Technology Division. *Project Pool Users Guide, Version 2.1.* Richmond, 2007. http://coapp57/pool/help/Project_Pool_User%20Guide.pdf. Accessed April 3, 2012.

Virginia Department of Transportation. Six-Year Improvement Program: Six-Year Improvement Program Database. 2008. http://www.virginiadot.org/projects/syp-default.asp. Accessed May 21, 2014.

Virginia Department of Transportation. Business Plan for FY13 – FY14. Richmond, 2011a.

Virginia Department of Transportation. Field Inspection Process and Team Meeting. Project Management Procedure PMO-7.2. Richmond, 2011b. http://www.virginiadot.org/business/resources/Field_Inspection_Team_Meeting.pdf. Accessed January 27, 2014.

Virginia Department of Transportation, Location and Design Division. Transportation Management Plan Requirements. Instructional and Informational Memorandum IIM-LD-241.5, TED-351.3. Richmond, 2011c. http://www.extranet.vdot.state.va.us/locdes/electronic_pubs/iim/IIM241.pdf. Accessed June 10, 2013.

Virginia Department of Transportation. Enhancement Program Procedure Manual, Richmond, 2011d. http://www.virginiadot.org/business/resources/local_assistance/2011_Enhancement_Manual_10-6-Clean_version_.pdf. Accessed June 13, 2014.

Virginia Department of Transportation. Project Development Process Flow Chart. 2012a. http://www.virginiadot.org/projects/concureng-default.asp. Accessed September 12, 2012.

Virginia Department of Transportation. How a Road Gets Built. 2012b. http://www.virginiadot.org/projects/pr-howroadblt.asp. Accessed January 27, 2014.

Virginia Department of Transportation. Scoping Report (Form PM-100), Richmond, 2012c. http://vdotforms.vdot.virginia.gov/SearchResults.aspx?filename=PM_100.doc. Accessed June 16, 2014.

Virginia Department of Transportation. Business Plan for FY14 – FY15. Richmond, 2013a. http://www.virginiadot.org/about/resources/2013_VDOT_Business_Plan.pdf. Accessed November 6, 2013.

Virginia Department of Transportation. VDOT's Budget [for Fiscal Year 2014]. Richmond, 2013b. http://www.virginiadot.org/about/vdot_budget.asp. Accessed November 6, 2013.

APPENDIX A

INTERVIEW QUESTIONS AND RESPONSES

For the nine interviews with VDOT districts, the interview questions and responses from each district are provided in this appendix. The researchers sought to ask the same questions of each district with two exceptions:

1. The first interview, which was conducted with Fredericksburg District, also served as a pilot to determine which interview questions were the most useful and whether additional questions were missing. Thus there were some differences in the questions asked of the Fredericksburg District and the questions asked of the other districts.

2. For the second and third interviews, the researchers initially posed Question 6 as follows:

   Are the data available to determine what percentage of funds are spent on PE?

   a. Are VDOT staff reviewing percentages, and if so, for what purpose?
   b. What is a range of appropriate percentages to be spent on PE relative to other project phases?

After those two interviews, the researchers believed that Question 6 would be clearer if the phrase "at the district level, for a given fiscal year" were added to the question in addition to a clarification that the percentage of funds spent on PE referred to PE "(versus RW or CN)." Thus Question 6 was modified as follows:

6. At the district level, for a given fiscal year,

a. Are the data available to determine what percentage of funds are spent on PE (versus RW or CN)?
b. Are VDOT staff reviewing percentages, and if so, for what purpose?
c. What is a range of appropriate percentages to be spent on PE relative to other project phases?

A separate set of questions was posed to staff representing VDOT's Programming Division and Fiscal Division.

Four minor changes were made to these interview notes since they were reviewed by interviewees. First, to accommodate report layout requirements, any references to specific page numbers were removed or modified. (For example, whereas one interview question referred to a taxonomy by indicating "see next page," the question now refers to this taxonomy by indicating "shown next.") Second, yellow formatting that was used to highlight items discussed in the interview was removed. Third, the font was changed to comply with VCTIR report formatting guidelines. Fourth, the interview questions are not repeated with each interview; only the responses are shown.

District Interview Questions

At this meeting we hope to identify closed-out UPCs and to better understand Preliminary Engineering within the VDOT Project Development Process. Potential questions are:

Questions about the VDOT Project Development Process

1) Do all 5 phases of the VDOT Project Development Process fall within the Preliminary Engineering phase in terms of SYIP allocations? Our understanding of this alignment is shown below.

<table>
<tr><th>VDOT Project Development Process Tasks</th><th>SYIP Phases</th></tr>
<tr><td>Scoping Phase</td><td rowspan="5">Preliminary Engineering</td></tr>
<tr><td>Preliminary Design Phase</td></tr>
<tr><td>Detailed Design Phase</td></tr>
<tr><td>Final Design & ROW Acquisition Phase</td></tr>
<tr><td>Advertise Plans</td></tr>
<tr><td></td><td>ROW</td></tr>
<tr><td>[Not shown, Occurs after advertisement]</td><td>Construction</td></tr>
</table>

2) FTA defines PE as "the engineering necessary to complete NEPA…or 30% of final design"
    a. Are we correct that VDOT's PE definition differs (e.g., PE includes all of final design)?
    b. Is there consistency between PE in the Project Development Process and PE in the SYIP?

3) To what extent do the end products of the Preliminary Design Phase, the Detailed Design Phase and the Final Design & ROW Phase typically change in terms of *money spent* and the *design product*?

4) Can you recommend a sample of (preferably closed-out) UPCs that help us better understand both
    a. the role of PE and
    b. how PE tasks are funded?

5) Where can we find details for specific projects besides the project Pool (http://isyp)?
    a. How often is information uploaded to the iPM and how is it determined what is uploaded? (Some projects have a scoping document 57044 , 78621, while others do not)

Questions About How Project Expenditures are Tracked

6) At the district level, for a given fiscal year,
    a. Are the data available to determine what percentage of funds are spent on PE (versus RW or CN)?
    b. Are VDOT staff reviewing percentages, and if so, for what purpose?
    c. What is a range of appropriate percentages to be spent on PE relative to other project phases?

7) Will tracking expenditures by phase (e.g., PE vs. RW) and by activity (e.g., 616 for road plans or 613 for location surveys) yield the entire amount VDOT spends on preliminary engineering activities?

8) Is there a credible way to identify a list of projects (including dead projects)-in each district-that will enable us to determine the portion of total project cost spend on PE?

9) Are there any characteristics you would add or remove from the taxonomy list? (The list follows.) Note: Variations in these questions were asked in the pilot interview in the Fredericksburg District).

Characteristics that May (Or May Not) Influence the Ratio of PE to Total Project Costs (Draft Taxonomy, May be Revised)

Characteristic	UPC 57044	UPC 75915	UPC 78621	UPC 13558
Environmental				
Environmental Work	EA	CE	CE	EA
Wetlands Mitigation	Yes	Yes	Yes	Yes
Bio Retention (water quality) basins considered?	Yes		Yes	Yes
Cost				
PE Pre-Scoping Estimate	$2,417,729	$506,512	$454,142	$11,474,054
PE Expenditure	$1,534,898	$224,141	$409.042	$4,210,417
Magnitude of Total Cost	$24,528,934	$5,168, 340	$3,528,048	$168,205,449
Pre-Scoping RW Estimate	$12,797,756	$559,015	$840,906	$29,200,000
Ratio of RW to CN	1.37	0.136	0.377	0.229
Order of Magnitude				
Functional Classification	Urban Minor Arterial	Rural Major Collector	Rural Major Collector	Rural Interstate
Facility type	Intersection	Secondary	Roadway	Interchange
Design Services Provider	District	District	District	Consultant
Transportation Management Plan Class	C (3)	A (1)	B (2)	B (2)
# of Bridges	0	0	0	3
PE Phase Duration	Start- 12/1/2000 End- 9/9/2011 10.9 years	Start- 7/6/2007 End-10/21/2013 6.3 years	Start- 5/8/2010 End- 2/27/2010 2.9 years	Start- 5/9/1994 End- 11/13/2013 19.5 years
Businesses to be taken	8		0	
Homes to be taken	8		0	
Railroad involvement	No	No	No	No
Bike Ped Accommodations	Widening sidewalk by 1 in, Paved shoulder, Pedestrian signals and Curb Ramps	Yes, proposed pavement wider to accommodate bicycles	Yes, Sidewalk and 4' bike lane	
Agreements				
Required National Historic Preservation Act	Yes	No		
HazMat Evaluation	Yes			
Utility Relocation	Yes	No	No	
IJR or IMR	IJR			IMR
Memorandum of Agreement, between public agencies	Yes, due to historic district		No	No
Recoverable Slope Study	No	No	No	
Value Engineering Study	Yes	No	No	Yes
Delivery Method				
Alternate Delivery Method?	No, DBB	No, DBB	No, DBB	
Alternate Designs Considered (when in process)	Project budget more than doubled with the bypass/ single point urban interchange options considered.			Yes

Fredericksburg District Meeting on September 25, 2012 (Interview FR1)

Meeting with Abdul Hammadi, Kevin Northridge, and Jason Williams (Fredericksburg)
and John Miller, Peter Ohlms, and Beth Turner (VCTIR)

Verified Notes (October 1-2, 2013)

Summary

The meeting provided several insights that relate Preliminary Engineering (PE) to the VDOT Project Development Process. In the short term, the next steps are twofold: (1) to review a sample of projects that have been suggested as illustrative of the role of PE and (2) to design a survey instrument that would be appropriate to apply in other VDOT districts. In the medium term, a next step is to quantify the portion of funds spent on PE relative to total construction given the items noted below. In the longer term, one product that was suggested toward the end of the interview is the development of a matrix showing the influence of various factors on the ratio of PE to total costs. As we move forward with other interviews, we would like to further explore this product.

Overview comments are given next, and answers to the various questions follow that summary.

Overview Comments

- In the project development process, each of the various disciplines (e.g., hydrology, structures, environmental) has a tendency to make their component of the project the best that it can be. A role of the project manager is to balance the competing goals of best design with lowest cost. The project manager also addresses the tension between finalizing the design quickly and continuously refining it to include newer, better options.

- The context of the project changes over time. Such changes may reflect external influences (such as political considerations), staff turnover, changes in budgets, and changes in "atmosphere" regarding local priorities.

- The uncertainty associated with PE is fundamentally different percentage-wise for "big" and "small" projects.

- Recent trends have not made the project design process more efficient. Examples are increased regulations (e.g., additional storm water management practices and the proposed constitutional amendment pertaining to RW acquisition that will likely lead to greater efforts to avoid settlement and damage costs (related to RW) and consequently greater project costs.

Questions about the VDOT Project Development Process

1) **Do all 5 phases of the <u>VDOT Project Development Process</u> fall within the <u>Preliminary Engineering</u> phase in terms of SYIP allocations? Our understanding of this alignment is shown below.**

VDOT Project Development Process Tasks	SYIP Phases
Scoping Phase	
Preliminary Design Phase	
Detailed Design Phase	Preliminary Engineering
Final Design & ROW Acquisition Phase	
Advertise Plans	
	ROW
[Not shown, Occurs after advertisement]	Construction

The short answer is yes for inside VDOT but no for outside VDOT.

A longer answer for VDOT is that a project "comes in the door" [e.g., from the SYIP] with typically limited information—a name, a UPC, a budget for PE, RW, and CN, and a basic problem description, such as a flooded road or a problem with the intersection. At that point PE authorization means that PE can begin for the project.

In the past, projects were "engineered"—that is, pre-scoped—at the residency level, where more details regarding the project's purpose and need were available. [While programming decisions were still implemented through the SYIP, the residency level involvement nonetheless provided some critical information.] Recently the "local perspective" of the residency has been lost due VDOT reorganization; this makes pre-scoping more difficult.) In short, detailed information on such projects are limited at the present time.

Presently, after the project enters the door, prescoping is done to better define the purpose and need. While these funds are charged to PE, these activities are fundamentally different than typical PE tasks, and a better approach would be to have a preliminary planning (PP) charge number. Such PP funds could be used as a bridge between the time when a project is conceptualized (based on the simple purpose and need) to the time when the preliminary field inspection (PFI) is completed. For instance, for the I-95 Exit 140 interchange project (UPC 13558), while PE was authorized in 1994, the activities until eight months ago [July 2012] represented prescoping. (If VDOT were to remove pre-scoping such that PE began with scoping day or PFI, then VDOT PE costs would align more with industry norms.)

2) FTA defines PE as "the engineering necessary to complete NEPA…or 30% of final design"
   a. Are we correct that VDOT's PE definition differs (e.g., PE includes all of final design)?
   b. Is there consistency between PE in the Project Development Process and PE in the SYIP?

The short answer is yes for both questions. Longer details are:

The VDOT project development process flowchart does not show some tasks that could be charged to PE. For instance, note the Stafford interchange at Exit 140 of I-95: a considerable amount of planning work has been performed such as the development of an Interchange

Justification Report (IJR). (Note also that this project demonstrates the potential length of the PE phase: PE was authorized in 1994 and in 2012 the project reached the 30% design phase.) Similarly location studies that are part of the EIS are also included in the PE phase.

There can be a series of changes to the PE budget. The scoping phase is not tracked to the same degree that RW and CN are tracked (e.g., where the Dashboard is used.) However, it is not necessarily the case that the Dashboard would be advantageous to tracking scoping.

3) To what extent do the end products of the Preliminary Design Phase, the Detailed Design Phase and the Final Design & ROW Phase typically change in terms of *money spent* and the *design product*?

- *For larger projects*, such as a $100 million interchange, there is some stability in the sense that the basic deliverable—an interchange—will not shift, partly because such large-scale projects gather sufficient momentum that as the PE process unfolds, there will be less desire to discard the large investment that is made in earlier design steps. Thus the benchmark of PFI reflecting 30% of the PE phase is fairly reliable, and there is confidence that at the prescoping stage the project can be defined.

- *For smaller projects*, the basic purpose and need may change based on the solution designed to solve the stated problem. For instance, the problem might be that a road is flooding. The cost of the potential solutions—build a bypass drainage system or elevate the roadway—vary considerably (in this case from around $600,000 to $800,000 for the former to about $5 million for the latter). Recently designs have been changing to meet fiscal requirements. (For instance, an initial estimate of the cost the Burley Road project was $2.8 M. Subsequent designs—which take time to generate—iteratively reduced costs to $1.8 M which was an improvement, but another series of designs was needed to reduce costs further to $0.9 M).

  Generally, the tools for estimating costs are imprecise: the tolerance for the project cost estimating system (PCES) is ± 25%, for TRNS*PORT (pronounced "Transport") it is +/-5%.

4) Has the portion of PE that is performed by consultants changed substantially since 2000?

The short answer is that to know for certain one would need to talk with Jim Lassiter [the Location and Design Program Manager in Central Office.]

That said, two key details about working with consultants are:

- One has better ability to control costs with consultant labor than with in-house labor: with the former, a contract can be executed that specifies limits on time for certain deliverables, whereas with the latter one has less ability to prevent an employee from charging additional time to a project. (However, it was noted that work with the Central Office design shop proceeds somewhat similar to a contract, where specific deliverables and budgets are established and adhered to.)

- The comparison of costs between consultants and in-house staff is not straightforward.

  - A comparison of hourly salaries alone shows VDOT staff as being cheaper (a VDOT loaded rate is about $60 compared to a consultant's loaded rate of $120).

- The overhead costs are recouped differently, however. For example, the electricity and office space for the consultant's office is included in the overhead rate (about 3 times the base salary) but not in the VDOT overhead rate (about 1.7 times the base salary).

That said, VDOT treats work done by consultants vs. in-house the same in Business Objects (BOXI) and other databases.

5) Can you recommend a sample of UPCs that help us better understand both
   a. the role of PE and
   b. how PE tasks are funded?

The following UPCs are recommended:

- UPC 50744 (Falmouth project that illustrates how the initial PE design was adopted) Project was done in-house and required change of scope
- UPC 13558 (an interchange project that illustrates the need to subtract the IJR report which has been included as a PE cost)
- UPC 75915 (a small project with poorly defined scope that has undergone iterative pre-scoping efforts to define a relatively small construction project)
- UPC 78621 (Ladysmith where PE ($0.45 M) was relative to a total cost of $2.2M and everyone bought into the scope; possibly a best-case scenario)
- UPC 4632 (a large project with better defined scope and minimal options)

Questions About How Project Expenditures are Tracked

6) Will tracking expenditures by <u>phase</u> (e.g., PE vs. RW) and by <u>activity</u> (e.g., 616 for road plans or 613 for location surveys) yield the entire amount VDOT spends on preliminary engineering activities?

The short answer is yes.

The longer answer is that the inability to track the PE budget at a level of detail that is useable to managers is a concern. While total costs can be obtained, it is not easy to extract details such as:

- *The amount individual disciplines (e.g., environmental versus hydraulics) are charging.*

- *The details regarding activities*. For example, the activity 616 on a given project may represent a substantive portion of a project's costs, but information about the specific components of activity 616 is not available.

- *Details that confound a separation of the PE, RW, and CN phases*. For instance, suppose a project will take existing wetlands. If the mitigation is to purchase wetland credits then that cost is charged to PE, but if the mitigation is to construct a new wetland then that cost is charged to CN.

- *Details that would facilitate a comparison of Virginia with other states*. Most other states leave local road design to localities, in which case more information about the project's need will be available to the local designer than is the case in Virginia.

- *Some districts create their own databases to track PE*, but it requires a lot of management and there isn't much incentive. For example, Central Office maintains an Access database only for its Design Services unit.

  This information is not easy to obtain, and there is not an incentive to obtain it (e.g., even if one had this level of detail it is not immediately clear how it could be used).

7) Is there a credible way to identify a list of projects (including dead projects)-in each district-that will enable us to determine the portion of total project cost spent on PE?

To tell for certain, someone with historical knowledge of the district would need to provide assistance. It may be possible to run a report in the integrated project manager (iPM, accessible through http://isyp/) to determine which projects are dead by identifying the status, where status has one of four classifications: active, candidate, archive, and inactive. This would be necessary because projects are rarely formally halted; rather, their status is changed to inactive.

8) When examining SYIP allocations or BOXI expenditures (or other financial systems), will the funds be reported differently if the work is done by consultant vs. in-house?

No.

9) Are SYIP phases solely consecutive or are portions concurrent?

PE and CN should be consecutive. However, RW may overlap with both PE and CN.

Note that the RW phase only includes the purchase of the land and labor related to negotiating such land purchases, such as appraisals and utility relocations. Comparable to the Project Development Process Flow Chart accessible at http://www.virginiadot.org/projects/concureng-default.asp, there exists a detailed RW flowchart.

Additional Notes

Currently there is more of a push to have projects in SYIP in development phase because the ARRA constructed a large portion projects that were shovel ready.

Additional Comment: A Matrix of Factors Influencing PE Costs

If one were to obtain a complete understanding of what amount is spent on PE, one could then explain why the amount spent on PE is relatively low or relatively high. While this might satisfy the initial goal of the research project, interviewees suggested a product that might be useful to the PE community. A cost information sheet provided by VDOT's TMPD suggests that PE might be typically assumed to be 25% of a project's cost. However, it is well known that a variety of factors influence this percentage. Qualitatively, these factors include the following:

- *Size of the project*. If the project is relatively small, then the percentage of total costs to be spent on PE is likely to be large as smaller projects tend not to be as well defined at the prescoping stage as larger projects.

- *Manner in which wetlands are mitigated*. If the project entails creation of wetlands, the percentage of total funds spent on PE will be smaller than if the project entails purchase of wetland credits, since purchase of credits is charged to PE but construction of replacement wetlands is charged to CN.

- *Changing political environment*. If there is a fundamental shift in project expectations during the PE phase, then the likelihood of a redesign increases, which would increase the percentage of funds spent on PE. Examples in the interview that describe such shifts are (1) increased emphasis on designing a project within certain funding constraints even if that means certain design practices cannot be followed; (2) a need to revisit PE multiple times in order to yield a design that meets the CN budget; (3) the proposed amendment affecting how RW costs are treated. [An inference is that as the time required for PE grows, the likelihood of a change in the political environment will also grow.]

- *Other factors not noted here but which could be learned by both (1) reviewing details of certain projects (see question 5) and (2) interviewing PE experts as was done in this meeting.*

Once these factors were identified, data from individual projects could be used to develop a model that predicts how the 25% figure suggested by VDOT's TMPD would be affected by a given factor. For instance, based solely on the bullets noted above, the model would predict how the proportion of total costs spent on PE should change if a given project was known to be relatively small and require the purchase of wetland credits.

Bristol District Meeting on November 2, 2011 (Interview BR2)

Meeting with Chase Buchanan, John Miller, and Beth Turner
Verified Notes on November 2 and 7 by Phone and Email

1. The SYIP phases (PE, ROW, CN) and the VDOT Project Development Process are not explicitly in alignment. Of the tasks stated on the Project Development Flow Chart the ROW Acquisition Phase of the VDOT Project Development Process should not be included in the PE phase, however any preliminary design of ROW may be charged to PE. Note that:

    - Tasks such as utility relocation, ROW appraisals, and ROW purchasing (performed by ROW agents) are charged to the ROW phase.
    - Some projects don't have ROW, but have utilities. In that case, design that is related utilities work are charged to PE. The actual movement of the utilities is charged to Construction.

2. VDOT's definition of Preliminary Engineering is different than FTA's. FTA defines PE as 30% of final design or the engineering necessary to complete NEPA. VDOT's definition includes scoping, preliminary design, detailed design, final design and Advertisement.
    - Generally PE should be closed out at award of the project.
    - Example: A contractor could be reviewing a plan and have a question about a traffic control pattern or street closure. (The question may result because there are restrictions concerning when the lane can be closed). The VDOT District would use PE funds to answer the question for the contractor and revise the plan accordingly.

3. The following is the breakdown of funding spent on Preliminary Design, Detailed Design and Final Design at the Bristol District. Preliminary Design is about 30% of funding depending on the survey type. ROW and Detailed Design, which usually occur about a month apart, are about 65%. Final Design is about 98-100%
    - Typically at Preliminary Design an alternative with horizontal, vertical alignment and typical sections is already chosen.
    - Some projects require multiple alternatives to be designed to determine how much it will cost, especially when there is substantial excavation or environmental mitigation required.
    - There generally is a six-month gap between the scoping day of decision and the Preliminary Field Inspection (PFI) if the survey has been completed prior to scoping. If survey is required there is generally a one year gap between scoping and PFI.

4. A total of five UPCs are given which may be examined to better understand the role of PE and how PE tasks are funded:
    - UPC 16383. Currently this project is not closed out but will be advertised in Dec 2012. This project will add two additional lanes to a 2.5 mile, two lane existing section of Route 58 between Abingdon and Damascus. The estimated constructions cost is $21 M, a consultant performed the design. And PE is estimated to be about 9% of the total project. (This is classified as "Tier 2" since it exceeds a cost of $ 5 M.)
    - UPC 76507. This project is on a rural primary road. Wetland mitigation costs (e.g., movement of a stream) drove up the project costs. Construction was estimated at $13 M, RW

at $2.2 M, and PE at $1 M for a total of about $16 M. Overall the district performed the design, but a consultant did the utilities and drainage work.

- UPC 76791 or 60791. This is a $4.4 M project on a rural secondary road to improve the horizontal and vertical alignment. Construction was estimated at $3 M, ROW at $650,000 and PE at $760,000. Because it is a Tier 1 (under $ 5M total cost) it is designed at the district level, and the district professional engineer can give approval for a ROW purchase.
- UPC 77323. Two or three different alternatives were evaluated at the PFI stage. This project required 2 bridges, one large and one small. It was a tier one project done in-house.
- UPC 17639 and UPC 82755. This is an urban bridge project at a signalized intersection. (The first UPC is for PE; the second is for actual construction). This project is currently under construction.

5. The iPM is very useful resource for information about specific projects; however RUMS may be a good alternative for ROW information.
    - All documents are uploaded into the iPM—generally the estimate is updated every 3 months or more frequently if milestones are closer than three months. Expenditures are updated twice a month.
    - FMS could be beneficial but is older. For current projects, we may use Cardinal to track who is charging time.
    - Project Manager Dennis Harris has a project day once a month in L&D. They use a project tracker to review the percentages of money spent on PE, ROW and CN at an individual project level.
    - A rule of thumb is that the project managers like to have $20,000 left in PE when going into Advertisement for scheduling, contract review and printing plans.
    - If PE is not funded, Districts will NOT work on it, but if it is and ROW and CN is not funded, they will to get it shelf ready.
    - Some districts in VA have distinctive funding sources such as the Coal Severance funds available to four counties in the Bristol District.

6. The data are available for PE expenditures. At the programmatic level, PIMs are generally the ones who may be looking at the overall percentages of PE. Bristol District staff noted that the highest and lowest PE percentages are around 35% and 8%, respectively.
    - There are some cases where the three year window to begin the ROW phase after public meeting runs out and plans may change due to new design standards and PE required for the initial plan is still accounted for in total cost.
    - Once a design public hearing is held, RW must begin within 3 years or else a new public hearing must be held. If the public hearing has not been held but changes are made to standards, then the new standards must be adhered to. If the public hearing has been held, then the old standards may be followed provided RW begins within 3 years of the design public hearing.
    - There are some projects that have two UPC numbers, one for PE and ROW and one for Construction, as was the case with UPC 17639 and UPC 82755. This can occur where funds are available for some, but not all, ROW.

- There have been some cases where PE is authorized, PE work is done, but the project is not built because the sponsor changed their mind and did not want it done. It is hard to pin down how often this occurs, but in the interviewee's experience this happened three times out of 20 recent projects. (In one case $0.5 M was charged to PE, the project was initially not constructed, and now it is desired with a new total PE estimate of $1.2 M.)

7. Tracking projects by phase and activity will yield the entire amount VDOT spends on PE activities with the exception of the pre-scoping charge.
    - Location and Design employees may have 4-5 projects so 40 hours is spread out over multiple projects
    - Bridge employees may work on 1-3 bridges at a time and charge all their time to one or two projects.
    - In terms of timing, Bridge designers may charge to design-related tasks to PE after ROW is completed.

8. There is a credible way to identify a list of projects that will enable us to determine the portion of the total project costs spent on PE. The iPM has a function where you can export a spreadsheet of all the projects and their defining characteristics, by district or for the entire state.

9. Here are a few characteristics to add to the Taxonomy Classifications:
    - Add whether the design was done *in house or by consultant* and note the specific design task (e.g., roadway, utilities)
    - Add whether a *traffic signal* was warranted
    - *Excavation*- How much excavation was required because it increases construction costs. (A rural roadway will require more excavation)
    - *Survey Information*: aerial surveys are more expensive than topographical surveys. (See the revised PM-100 for this.)
    - *Drainage*: Revised federal drainage regulations may require more ROW because the method for calculating the amount of land required is now based on total ROW rather than additional ROW acquired for the project.

Additional Notes From the Meeting (Relating to Question 6)

The information provided in this interview is useful for learning about PE from a project perspective. However, to learn about PE for the program as a whole, one should consult with the district Planning and Investment Manager (PIM). In Bristol, it is recommended that one talk with Matthew Cox (the PIM) or his assistant Amy Frye about the programmatic question (Question 6).

Culpeper District Meeting on January 4, 2013 (Interview CU3)

Meeting with John Giometti, Brent Sprinkel, Wendy Thomas, and John Miller
Verified Notes on January 9-10

1. Generally, the answer to question 1 is yes: the 5 phases of the VDOT Project Development Process (e.g., scoping, preliminary design, detailed design, final design & ROW acquisition, and advertisement) fall within the Preliminary Engineering phase in terms of SYIP allocation. [However, see question 2].

2. The answer to question 2a is yes: VDOT's definition of Preliminary Engineering is different than FTA's. For part b, the answer is yes from a funding standpoint but no from a scheduling standpoint.
   - There is consistency between PE in the Project Development Process and PE in the SYIP in terms of funding. That is, in the SYIP, PE ends when RW begins and then CN begins when RW ends. This serves an explicit purpose: the SYIP is a capital outlay plan that conforms to project schedules in the sense that the SYIP ensures each phase is adequately funded—e.g., the funds are available for the period where work will be performed.
   - There is not consistency in terms of scheduling. That is, in practice the RW phase may have some degree of overlap with both the PE and the CN phases. (To be clear, the SYIP does not drive the schedule for the project except to ensure that funds are available to complete a given phase.)

3. There is not a set rule indicating the extent to which the three phases of preliminary design, detailed design, and final design & ROW typically change in terms of money spent and the design product.
   - When you examine other states, you will find that they have some breakpoints (e.g., FTA defines PE design as 30% and detailed design as 60% to 80%). However, VDOT does not have any definitive breakdowns.
   - There are two contributing factors that should be kept in mind. First, there is a more definitive breakdown in terms of progression [from initial scoping] to final design for bridge related work. For example, a preliminary plan and front sheet must be completed prior to moving toward more specific sub-activities. Second, the PE process [e.g., the five phases] are iterative—it may be necessary to revisit earlier work as one progresses through project development. Note that the PE for an overall project generally has more external factors which will influence the process than the bridge component.

4. It is difficult to recommend a sample of closed-out UPCs that would help better understand both the role of PE and how PE tasks are funded, simply because it is very hard to think of any substantial project that has been through the process as intended. There are four critical points to consider.
   - *Limited resources are spread over many projects.* There are situations where the District is in the PE or RW phase for a large number of projects, yet, for many of these projects, the District does not know if money will be received for CN. In practice, the very limited financial resources have been spread very thin—like "peanut butter"—over a large number of projects, resulting in the occurrence of PE or RW for a particular project being initiated. This situation results from trying to satisfy many diverse constituents who each want their project(s) placed in the SYIP, and it is complicated by the fact that [when a new project is

programmed] one must do enough work [in the PE phase] to better understand the alternatives available and the cost of each.

- *This spreading of resources in the SYIP mimics what has happened in the past with the county-driven secondary system allocations*. In the past, when the county received an allocation for their secondary system, the county might program every project a citizen requested—even if the funds for such a project were not realistically available. Rather than make some difficult choices, a county might program, as an illustration, ten projects—such that a minimal amount of work on each could be undertaken—rather than, say, one large project which would be fully funded.
- *Defining the size of the program is not as straightforward as it appears.* The size of a construction program may be determined by (1) the amount of constrained funding available or (2) the number of projects—but these definitions are not necessarily the same. [For illustration, suppose that one realistically expects $200 M to be available over the next five years, and that constituents have requested 30 projects—each of which costs $25 M. One could define the size of the program as a "$200 million program" (where only 8 projects will be selected but all 8 will be fully constructed.) Alternatively, one could define the size of the program as a "$750 million program" where all 30 projects will have PE undertaken—even though not all projects will be built.]
- *Defining the size of the program drives interpretation of the PE percentage*. The above disparity in how the size of the program is defined influences how one interprets the percentage of funds devoted to PE. In the first definition—where a program is defined by the amount of available funds—one would expect a PE percentage to be around 10% (assuming relatively large ($25 M) projects which tend to minimize PE expenditures). In the second definition—where a program is defined by the projects desired by constituents—one might spend a much larger percentage of funds on PE due to some projects being engineered but not built.

In sum, a key question to consider is "what do we achieve" as a result of the PE process?

5. As noted in the December 14 conversation with John Giometti (see the material at the end of the group interview) the iPM has some information about specific projects; however, iPM may not be complete due to (1) not everything being uploaded into iPM and (2) some projects having relatively long PE phases [where over time some information or key personnel with experience with the project may no longer be available.]

6. Imperfect data are available to determine the percentage of funds spent on PE—and three caveats are critical for understanding the role of such a percentage.

   - *The data suffer from four limitations*. First, overhead cost centers [e.g., district wide charge numbers used for initial scoping work] may account for some of the PE expenditures, and such charges will not be recorded as part of the PE phase. Second, there can be times when it is difficult to obtain authorization to perform PE work on a project, and if a UPC is not available, then some other means may be used to get the PE work accomplished. Third, maintenance-related projects do not have an explicit PE phase but may have some PE-related tasks. Fourth, as noted in the response to question 5, the long duration of the PE phase yields complications; for instance, in the past (prior to 2001 or 2002, when FMS 2 had been implemented for only about a year or so), at least some secondary system projects did not have a PE phase but rather had all PE work charged to CN. For those four reasons, it is possible that not all PE tasks will show expenditures within the PE phase.

- *At this point, VDOT staff are not reviewing PE percentages at the program level*, partly because of the data limitations noted above and partly because it is not clear how such an analysis would be used. It was noted that if one did want to review such percentages, a credible approach would be to obtain projects listed in the SYIP but ensure that maintenance projects were excluded from such a list. Such a data set would not be perfect (due to the aforementioned limitations) but would avoid the problem of mixing construction and maintenance projects. [An example of such a list for the Culpeper District based on the final FY 2011 SYIP was provided and subsequent communications clarified how this list should be screened.]
- *The percentage of funds spent on PE* will differ based on at least two critical factors: (1) the extent to which a district pursues large versus small projects and (2) the costs of RW in that district. For instance, one would suspect that [even if all projects were constructed], Northern Virginia would spend a lower percentage on PE than Culpeper because (1) Northern Virginia tends to pursue a greater proportion of large scale projects than Culpeper (and larger scale projects entail a smaller percentage of PE) and (2) RW costs in Northern Virginia are higher than in Culpeper. Finally, a rough rule of thumb is that for a specific project would might assume PE is 15% to 20%--with the percentage dropping to 10% as the cost exceeds $20 M or with the percentage being as high as 50%, in some cases, for a $1 M project.

Another way to consider question 6 is to ask the following question: *what is the capacity of our program to add another project*? That is, are we adding a project because there is a bona-fide benefit or are we adding it as a political decision? One way to help decisions makers would be to have a quantifiable process which shows the impact of adding a project to the program. [While projects identified in the MPO TIP are required by federal law to be financially constrained, there is no such requirement for the development of projects in the SYIP.]

7. Tracking expenditures by phase (e.g., PE vs. RW) and by activity (e.g., 616 for road plans or 613 for location surveys) will not yield the entire amount VDOT spends on PE due to the limitations noted in question 6, however, if maintenance projects are excluded, the limitations may not be significant. A sensitivity analysis could be conducted to determine the importance of such limitations.

8. A credible way to identify a list of projects is, as noted in question 6, to identify projects in the SYIP and to exclude maintenance projects. There are three other considerations:
   - You will need to check with Dane Lewis in programming regarding whether a project has been closed out.
   - Regarding design-build projects, note that the PE activities are charged to construction (under the CN phase they will be activity 9104.
   - The decision to rely on federal funds to complete projects will affect the percentages. For example, as noted in response to question 6, when state funds were used for secondary projects there was no need to track PE separately from CN. It was only around 2001-2002

that the decision was made to have a separate PE and CN phase for secondary projects, owing to the increased federal role.

9. Generally the most important characteristic is (1) size of the project followed by (2) the length of time associated with the PE process (e.g., projects with longer PE phases may require either additional public involvement or duplication of key design tasks, both of which will increase the PE cost). That said, the taxonomy may benefit from two additional considerations:
   - Inclusion of noise abatement. In one recent project [believed to be UPC 85708], about $2 M of a $3.5 M increase in project costs are attributed to the decision to include noise walls. [See information also at http://www.virginiadot.org/projects/culpeper/rt._29-rt._250_interchange.asp]
   - Inclusion of such factors makes sense only for similarly sized projects, [so as one adds to the taxonomy items besides project size one must consider ways to either stratify the data set or ensure that size is controlled for independently.]

Culpeper District Telephone Comments from John Giometti, December 14, 2012

(Verified that same day)

- *At the program level, the dominant characteristic [affecting the extent to which funds should be given to PE/RW/CN] is the ability to get a given project ready for construction.* For at least the past six to seven years, VDOT's ability to program projects has been severely constrained by a lack of funds in the program such that one tends to seek, at present, projects that are "shovel ready" such that they can be implemented. To truly understand VDOT's programming policies, one would need to look at the program at a time when the Department enjoyed some latitude with respect to where investments should be made—e.g., at least 6-7 years ago and probably back in the 1990s.

- *At the project level, an unmet challenge is how to calculate the final PE estimate once PE is underway.* Although PCES provides an initial estimate of total PE spending when PE begins, the project manager needs to update this estimate as progress is made throughout the PE phase. However, PCES is not set up in such a way to provide update this estimate given the record of previous PE expenditures to date. [For example, suppose a given project has a PE estimate of $1 million, generated at the time PE was authorized. Conceptually, when one has moved part way through the PE phase and completed certain design tasks, one should be able to use these actual expenditures to either increase or decrease this $1 million estimate.]

- *As the PE phase length increases or when the members of the design team change, there is a tendency for certain PE-related tasks to be repeated, and this repetition increases costs.* Key tasks to watch are: (1) a shift in use from in-house work to consultants (or vice-versa) late in the PE phase, (2) a shift from the traditional procurement process (of having contractors bid on constructing a VDOT design) to the use of a design-build process late in the PE phase, (3) additional surveys (which may occur if an earlier survey is out of date), (4) additional location hearings, (5) additional design hearings, (6) regulatory changes (notably pertaining to stormwater management and drainage), and (7) a change in funding source (e.g., from state to federal). (This last factor may occur less frequently at present as most projects have already been shifted to federal funds).

- *An example of the impacts of a lengthening PE phase is a five-mile project on Route 3.* (This appears to be UPC 14657). This project has been underway for 17 years and entails 3 location hearings, between 2 and 3 survey updates, a shift from in-house design to on-call consultants (with the Department now using its third consultant), a shift from state to federal funding in 2007 (which necessitated additional historical work), and a change in the engineer of record. The P.E. costs have approached $4 million.

- *Besides PE phase duration, there is no easy way to obtain these historical changes (e.g., number of hearings, number of surveys) without interviewing a person familiar with the project.* [For instance, consider the Route 3 project (assuming it is UPC 14657). Figure 1 shown the schedule extracted from the project pool. While one can click on each row therein for additional information, doing so does not appear to indicate the repeated hearings and survey designs noted by an individual familiar with this project. Possibly of use is the duration for these items, however; for example, the location/design hearing shows a duration of almost 11 years, from December 8, 1998 (actual start) to August 10, 2011 (actual finish).

Summary

Description	RTE 3 - PARALLEL LANE (EAST OF STEVENSBURG TO LIGNUM)			**Download Project File** (req's Microsoft Project)
State Project #	0003-023-107	UPC	14657	

Task List

Task	Planned Start	Actual Start	Planned Finish	Actual Finish
DRAFT ENV. DOCUMENT OR CATEGORICAL EXCLUSION (CE)	05/01/2009	05/11/2009	11/15/2010	03/07/2011
PREP/HOLD INFO/LOC HRG	12/12/1995	12/12/1995	05/23/1996	05/23/1996
ADOPT CORR/CTB STUDY ACTION	05/24/1996	05/24/1996	07/18/1996	07/18/1996
CONDUCT LOCATION SURVEY	07/05/1995	07/21/1995	06/28/1996	08/13/1996
VALUE ENGINEERING	08/13/1996	08/13/1996	10/18/1999	10/18/1999
FINAL ENVIRONMENTAL DOCUMENT	03/08/2011	03/08/2011	12/29/2011	05/08/2012
FINAL SOILS SURVEY	11/14/2001	11/14/2001	10/15/2012	10/31/2012
PLAN DESIGN/FIELD INSPECTION	08/14/1996	08/14/1996	09/30/2003	11/05/2003
HYDRAUL PLAN DESIGN/P.H.	08/14/1996	08/14/1996	08/29/2011	03/23/2011
UTILITY F.I. PLANS	02/03/2012	02/03/2012	02/16/2012	02/16/2012
UTILITY FI DATE	02/16/2012	02/16/2012		
LOCATION/DESIGN HEARING	09/01/1998	12/08/1998	04/30/1999	08/10/2011
ADOPT LOCATION/DESIGN	07/01/2001	08/10/2011	02/28/2002	02/03/2012
FURNISH R/W&UT PLANS	01/18/2012	01/18/2012	07/09/2012	09/12/2012
R/W&UT PLAN DATE	07/09/2012	07/11/2012		
AUTHORIZE R/W&UT FUNDS	09/01/2011	08/06/2012	07/09/2012	09/12/2012
NOTICE TO PROCEED/RW ACQUIS	06/26/2012	09/12/2012	07/09/2012	09/13/2012
NOTICE TO PROCEED/TOTAL ACQUIS	06/26/2012	09/12/2012	07/09/2012	
PLAN DESIGN/FIELD INSPECTION	10/25/2011	10/25/2011	01/18/2012	01/18/2012
FI/CONSTRCTBILTY TEAM MTG DATE	01/18/2012	01/18/2012		
UTILITY RELOCATION BY UTILITY	01/07/2014		07/14/2014	
ACQUIRE RIGHT OF WAY	07/09/2012	09/13/2012	01/07/2014	
PREPARE FOR ADV	08/01/2013		10/30/2013	
CN AUTH OR ADV FUNDING REVIEW	03/17/2015		09/13/2015	
ADVERTISE PROJECT/BEGIN CN	11/30/2012		11/29/2013	
ADMINISTER CONTRACT	02/27/2014		02/27/2015	
CONTRACTOR FINAL VOUCHER DATE	05/28/2015			
CLAIMS PERIOD ENDS	07/27/2015			
DISTRICT CLOSEOUT COMPLETE	07/28/2015			

Figure 1. Schedule for UPC 14657. Source: VDOT Project Schedule, http://isyp/schedule/mpp_display.asp?project_id=14657, Accessed December 14, 2012.

Salem District Meeting on January 28, 2013 (Interview SA4)

Meeting with Tommy DiGiulian, Jane-Ellen Hess, Alex Price, John Miller, and Beth Turner
Verified Notes by Phone on April 15-16, 2013

1. Generally, the answer to question 1 is yes: the 5 phases of the VDOT Project Development Process (e.g., scoping, preliminary design, detailed design, final design & ROW acquisition, and advertisement) fall within the Preliminary Engineering phase in terms of *expenditures*, but do note that *allocations* in the SYIP are formally designated to a specific UPC but not necessarily a specific phase (although one can infer which phases are funded in the SYIP by comparing the estimated costs in the SYIP for each phase with the total amount that has been formally programmed.)

2. Yes, VDOT's definition of PE differs from that of FTA, and yes, generally, there is agreement between the SYIP and the project development process in terms of how PE is defined. (However, recognize that the SYIP contains allocations, not expenditures, and as noted in question 1 funds are programmed to specific UPCs but not specific phases.)

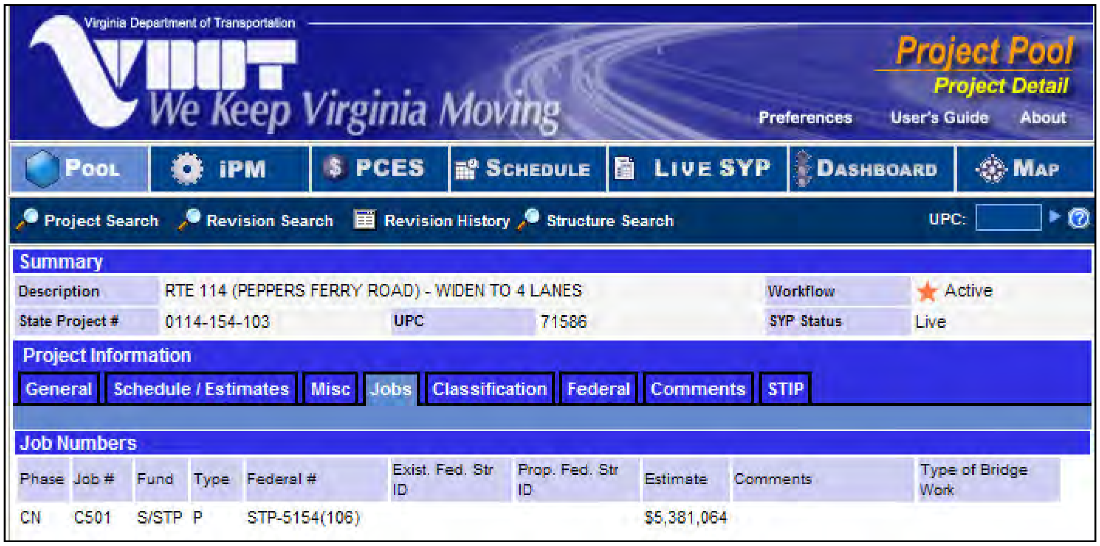
3. The end products of the Preliminary Design Phase, the Detailed Design Phase and the Final Design & ROW Phase may change very little, substantially, or somewhere in between. For instance, paving an unpaved road in Craig County may have a very short scoping phase with a signed waiver indicating no public involvement process is needed and a relatively quick final design. By contrast, projects such as the Charlottesville Bypass or the Springfield Interchange may have had 3, 4, or a dozen public meetings with detailed design changes throughout the process. That said, as noted in question 6c, factors that influence the extent to which these product change also include responsiveness to public opinion and the role of delegates [or other elected officials].

   (This question also prompted discussion of whether the percentage of cost each of the different sub-phases of the PE phase would vary by project; the consensus was that while the ratio of PE/CN will decrease for larger projects, one would expect the ratios of scoping/PE, preliminary design/PE, detailed design/PE, final design/PE, and advertise plans/PE to remain consistent across different types of projects.)

4. A sample of UPCs for the Salem District based on the FY2004-FY2012 SYIPs is shown on an attached excel spreadsheet. Salem District staff review of these projects would be especially helpful to account for the following anomalies:

   - There may be "co-mingled" UPCs where the PE phase and the CN phase are given two separate UPCs yet reflect the same project.
   - There may be projects where the PE reflects a given section [e.g., MP 0 to MP 4]), but the CN reflects only a portion of the project [e.g., construction from MP 2 to MP 4].
   - The "design-build" category adds a layer of complexity in that in theory one is providing a project that is already at 30% of design but in practice one is not necessarily at that point [when the project passes from VDOT to the firm doing the design-build work].
   - Ideally one would want only the "C" (meaning "Complete Plan" projects and one would want to exclude the "no plan" projects (which have minimal design) and the maintenance projects. These projects can be identified in the "jobs" section of the project pool, where for

PE/RW/CN, a code will show ("N501" for no plan, "M501" for minimum plan, "P501" for paving, or "C501" for construct. The projects with "N" or "M" should be excluded.) For example, for UPC 71586 as shown below, this project would included because the job# indicates "C501."



- There are several projects that might merit special attention because they convey some historical lesson:
    i. Route 687 in Pulaski County (PE reflected a 1.5 mile section but CN reflects just two spot improvements.)
    ii. Route 668 (illustrates the role of elected officials who can write letters of support.)
    iii. Route 460 near the police headquarters
    iv. Route 220 in Northern Botetourt (illustrates a project that was the victim of changes in funding and scope creep.)
    v. Route 8746 which was built under UPC 71586 (illustrates a project that was prepared when the funding outlook was considerably better than at present)
    vi. Route 58 project (illustrates a case where homes were condemned yet the project remained unbuilt for a substantial amount of time; at the same time there were homeless persons in the area who needed housing.)

While closed-out projects may be complete, recognize that district staff likely have stronger familiarity with more recent or ongoing projects.

5. Details for specific projects can be found in the Project Pool or, for earlier projects, possibly in a file folder for the specific UPC at the district office. The details that are available on iPM depend on the following:
    - The habits of the project manager: some managers place everything on iPM and some do not.
    - When the project was started: for projects initiated prior to the existence of iPM (which was roughly 2007 or 2008), some managers may have retroactively updated details to iPM and others may not have.

6. As noted in the free response section, keep in mind that when looking at expenditures it may make more sense to examine the ratio of PE to total costs or CN costs over a long period of time that encompasses multiple projects being completed rather than only on an annual basis.
    a. At the district level, for a given fiscal year, the data are available to determine the percentage of expenditures spent on PE/RW/CN. However, this is not a simple task as three different information systems are needed: Cardinal [for expenditures after 2012]), FMS2 [for expenditures for roughly the period 2003-2012]), and FMS 1 (for projects prior to FMS2).
    b. VDOT district staff are generally not reviewing overall percentages of funds spent on PE/RW/CN for the entire program, which is more of a Central Office Programming function. However, District staff do track expenditures for individual projects across all three phases (PE, RW, and CN) to keep the project on budget.
    c. When considering an entire program—not just an individual project—an appropriate percentage to be spent on PE relative to other project phases might be 15%, however, such a percentage is driven by at least four other factors:
        i. *The "non-predictability of funding"* where the amount of funds available for investments changes over time, and in fact changes more quickly in some cases than the project development process (e.g., a funding outlook can radically shift during a four year period, VDOT has only a six year SYIP, and for some projects the PE phase alone may take 8 years.) A key example is the City of Roanoke's urban program, where one particular project has had 16 managers and was designed many years ago when funding was more plentiful.
        ii. *The role of politics*: some projects involve state or local elected officials [which influences the time, and hence cost, for the PE phase of specific projects and hence the PE program as a whole]
        iii. *The age of projects* that are included in such a program's analysis (e.g., it would make sense to exclude projects with three and four digit UPCs as those were started some time ago.)
        iv. Characteristics of individual projects such as the use of "no plan" projects (where 10% might be a good PE estimate), the use of consultants (where hourly costs are higher for consultants based on the manner in which hourly costs are tracked in VDOT systems), and the cost of individual projects. (Some general rules of thumb for individual projects are that PE/CN is typically in the range of 15% to 20% for projects between $5M and $10 M, with a 10% figure for larger projects and concerns being raised if the PE/CN ratio exceeds 20%.)

7. Tracking expenditures by phase (e.g., PE vs. RW) and by activity (e.g., 616 for road plans or 613 for location surveys) will yield the entire amount VDOT spends on preliminary engineering activities except for the three following exceptions:
    - In the past, PE work for some projects was done by residencies, and this work may not be captured as PE expenditures but rather would be charged to some other cost center.
    - Each district has prescoping funds that may be used prior to PE being authorized. The amount of funding by district for prescoping was $750,000 (year 1) and $1 M (year 2 at present).

- For maintenance projects, all PE may be charged to a single UPC: e.g., there are 28 paving projects in Salem whose PE is handled by a single UPC.

8. Regarding a credible way to identify a list of projects (including dead projects)-in each district-that enable us to determine the portion of total project cost spend on PE, see question 5 where district staff need to help review the list of UPCs to ensure that anomalies for individual projects have been addressed. In addition, consider the following which would guide the interpretation of such a list:
   - Many projects have long time frames such that one must account for the projects that have not been built (see comments following question 9).
   - The funding outlook changes over time such that large-scale construction projects previously thought to be realistic may no longer be feasible (see question 6c).

9. There are several characteristics that may be added to the taxonomy list.
   - *Whether the project was fully funded in the SYIP*. (Fully-funded might be defined as estimated PE, estimated RW, and a significant portion of the estimated CN being in the SYIP). For instance the Orange Avenue project is now that the PFI [Preliminary Field Inspection] stage but it will not progress to the public hearing stage unless it becomes clear that funding will be available—otherwise it could be 15 years—or never—when the project is built.
   - *The project duration*. A project that sits for 5 years may need to have portions, or all of, PE redone. Salem District still has projects in the PE phase that have 3 digit UPCs.
   - *Clarity of project purpose*.
   - *Clear public support and/or changes resulting from public input*.
      i. One way to capture this might be to review the formal "design approval letter" indicating VDOT's response to public input. To be clear, it is the response to input that influences costs (e.g., if the Department made no changes in design, that would presumably lower PE costs.) This letter, if not available in the Project Pool (iPM), might be available in the project file at the district office (see question 5).
      ii. A different way to capture this information might be to examine the length of time between the public hearing and the design approval steps, which is the difference between steps 49 and 52 as reflected in the scheduler section of iPM. (These steps are not immediately evident in the project scheduler unless one hits "print" in which case a screen shot such as that shown in the figure that is shown next appears.)

Schedule Report

UPC	71586	**Project #**	0114-154-103		
Description	RTE 114 (PEPPERS FERRY ROAD) - WIDEN TO 4 LANES				

PPMS Code	Task	Planned Start	Actual Start	Planned Finish	Actual Finish
18	SERP-NOTICE TO STATE AGENCIES	9/1/2004	8/31/2004	12/31/2004	11/10/2004
22	SCOPE PROJECT	10/1/2004	9/1/1989	3/31/2005	10/13/1995
24	ENVIRONMENTAL PERMITS	1/3/2005	9/13/2004	1/31/2005	9/14/2004
34F	FINAL SOILS SURVEY	4/1/2005	4/1/2005	7/29/2005	6/21/2005
35C	TRAFFIC CONTROL DEVICE PLANS CO	10/29/2004	10/21/2004	10/3/2005	9/30/2005
40	MINOR STRUCTURES DATA	3/22/2005	3/22/2005	3/31/2005	3/31/2005
43H	HYDRAULIC PLAN DESIGN/F.I.	2/1/2005	8/2/2004	5/31/2005	3/23/2005
45	MINOR STRUCTURE REPORT	4/1/2005	4/1/2005	7/29/2005	6/21/2005
51H	HYDRAULIC REVIEW FOR PAC	9/1/2005	7/11/2005	4/18/2008	6/24/2008
53F	FINAL LANDSCAPING PLANS	10/3/2005	10/3/2005	3/23/2006	3/23/2006

iii. Be aware that elected officials' involvement with public approval can complicate matters.

iv. *Scope creep*. Some projects start with a clear purpose and others do not. [There is no easy way to identify this but it may be possible to review changes in the project scope as reported in iPM, with the caveat that, as noted in question 5, some project managers place all details in iPM and others do not.]

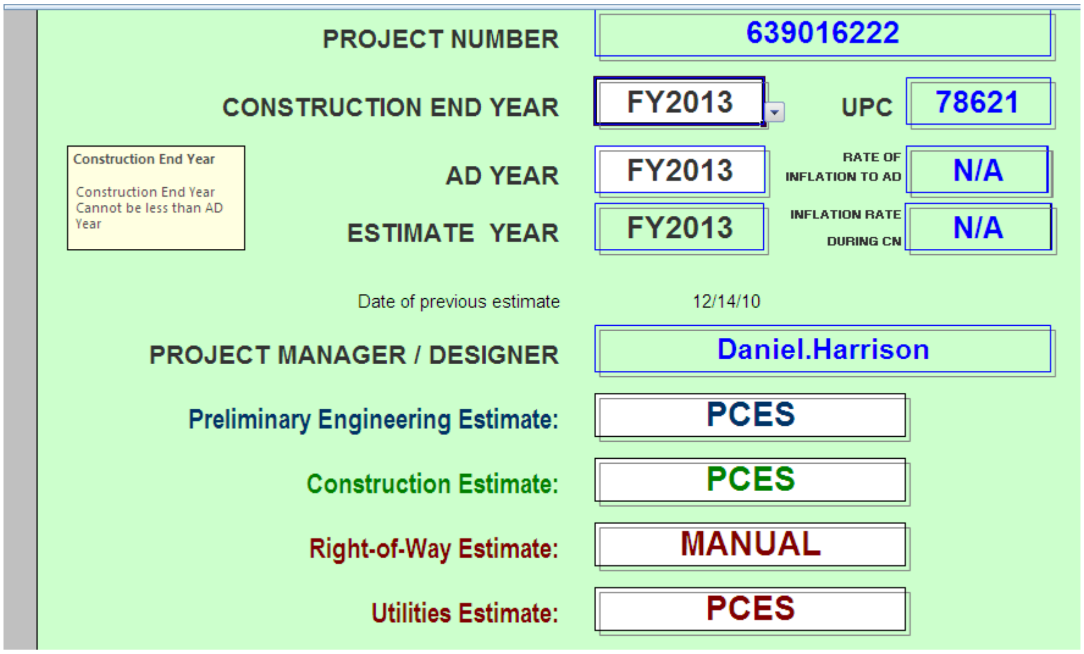
- *State-funded versus federal funded.*
- *Inclusion of a traffic signal* (as this would raise the CN cost of a project by $250,000 in the past and $300,000 or more at present).
- *Urban versus rural.*
- Support was expressed for developing a model that predicted the ratio of actual PE expenditures to forecasted construction costs, as was performed with a study done in North Carolina. (It was suggested that it may be preferable to use the TRNS*PORT forecasts rather than the PCES forecasts, and the TRNS*PORT forecasts may be available either in the Project Pool or on the PCES page as shown in the screen shot on later in the interview).

Other Comments

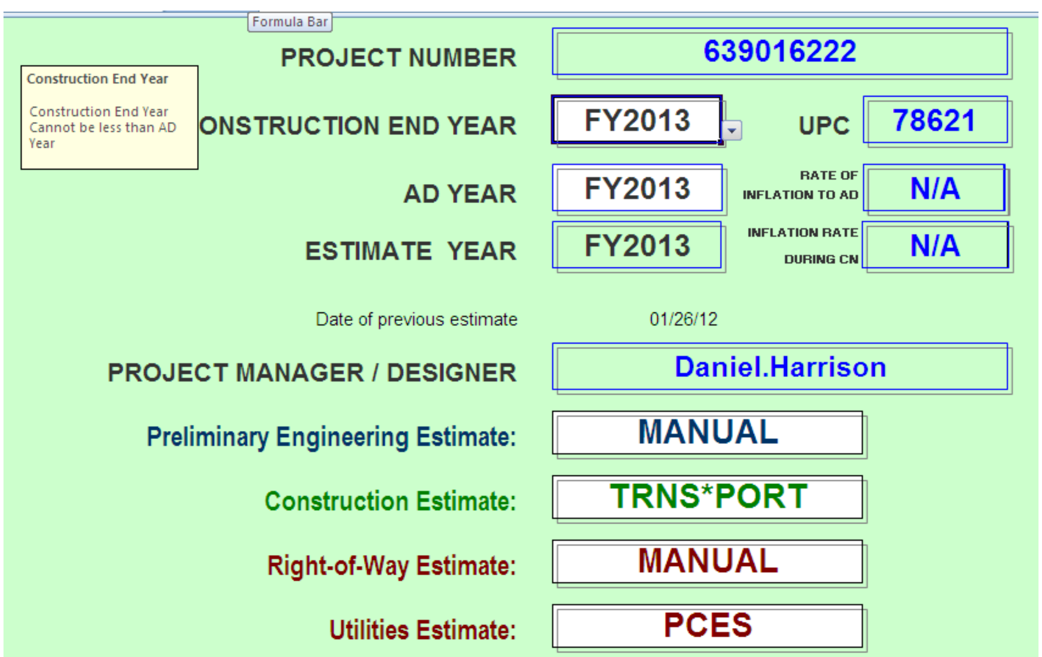
- While many people have asked "are we programming too much on PE" another question needs to be "are we programming enough for PE?" The reason is that lately the Federal stimulus projects and the state's Governor's package have emphasized having shovel-ready projects that can use these funds—but now VDOT does not have those types of projects in the pipeline.
- A fundamental challenge is that VDOT now has large-scale projects designed when the funding outlook was better. How does VDOT mover forward given this large backlog of projects where, for the foreseeable future, funds are not available?
- Note some districts have separate Assistant Division Administrator (ADA) functions which split the programming-related tasks and the project-management (e.g., Location and Design) tasks. In the Salem District, however, both programming and project management are included within the PIM [Planning and Investment Manager] function.

- As was noted in the project kickoff meeting, there is a difference in the interpretation of the ratio of annual PE/CN and PE/CN over multiple years. The reason is that projects have relatively long lifetimes spanning multiple years.
- There is a difference between what is *programmed (e.g. allocated)* and what is spent (e.g., *expenditures*). Expenditures are of course reported by phase. By contrast, while the SYIP shows estimated amounts by phase, the SYIP formally programs amounts only to a specific UPC—e.g., when an SYIP shows a given amount for a particular project, that amount could, in theory, be intended for any of the three phases. That said, one can draw some inferences by comparing the estimated and programmed amounts. [For instance, a project with an estimated PE cost of $1 M, an estimated RW cost of $2 M, and an estimated CN cost of $3 M that shows an SYIP allocation of $6 M would be inferred to be fully funded.]
- It would be interesting to compare the results of PCES to the results of TRNS*PORT after a project had been constructed, to evaluate the tradeoffs in accuracy (favoring the latter) and time required (favoring the former).
- Funding is unpredictable, it takes an average project 8 years to complete the Project Development Process, which is 2 beyond longer the SYIP and there can be a lot of fluctuation between the beginning and end.
- VDOT's outlook on projects is very different than it used to be. There are fewer large projects because maintenance of existing infrastructure is taking priority.

UPC 78621 Prescoping PCES Spreadsheet.
Preliminary Engineering and Construction estimates used PCES while ROW was entered manually



UPC 79621 Field Inspection PCES Spreadsheet
Construction estimates was entered using TRNS*PORT, while PE and RW were entered manually.



Meeting with Staff of VDOT's Programming Division and Fiscal Division on January 30, 2013 (Interview CO5)

Bob Carver (Fiscal), Margit Ray (Programming), Rob Walters (Programming), and John Miller, Amy O'Leary, and Beth Turner (VCTIR)

Verified April 18, 2013

The initial interview questions are shown on at the end of the interview, however, the comments are organized across two areas: data acquisition (how the researchers might obtain expenditure and project information) and analysis suggestions (how the data should be interpreted, including other factors that are not evident from the database alone.)

Data Acquisition

- The best way to obtain expenditure data is to obtain FMS 2 data from Bob Carver for financial information prior to 2012. For expenditures after that period, one may either use business objects (which will give information by phase) or Cardinal (to also obtain activity and account; Bob may be able to assist with this option). While FMS 2 only goes back to about 1998, note that expenditure data which has been ported into FMS 2 from earlier periods is believed to be accurate. (Further, if a UPC appears in FMS 2, the data therein should be complete, although it is acknowledged that some information may be lost generally as financial systems change.)

- The best way to determine which UPCs reflect financial information that is unlikely to change is to request, from Rob Walters, a list of UPCs that have been "archived." Prior to the interview, John had used the term "closed-out," however, because we wish to know which UPCs are unlikely to change, the category "archived" better reflects what we seek. (While archival status is available in the Project Pool, the database that Rob can provide will make this process faster.) A database for project closeout is maintained by VDOT.

- There exists a "large-record PCES database that reflects data entered by project managers when using PCES. It is recommended that the PCES "owner" be contacted regarding access to information. This database offers a way to glean characteristics of individual projects and may be a substitute for using the Project Pool.

Analysis Suggestions (listed in order of importance)

1. In response to the question "Is there a target for total money allocated to PE," it may not be appropriate to establish a single percentage. The reason is that such a target would logically depend on the agency's priorities, and such priorities may change over time. For example, in the past VDOT almost "ran out of work" because *too little* money was spent on PE, owing to the large portion of funds dedicated to construction and debt service; further, the portion of funds recently focused on PE has been relatively low because of the emphasis on ARRA projects. Generally, for a project to appear in the SYIP, the PE phase (not necessarily the entire project) must be fully funded. At present, VDOT's Business Plan has an established target of 10-15%.

2. With respect to programming practices, be careful that any lessons learned must be tempered by the fact that project-specific cost estimates appear in the SYIP are generated by sources other than the VDOT Programming Division. These other sources may include, but are not limited to, a project manager with an approved UPC who is updating PE, RW, or CN costs, an MPO that is estimating such costs for a project in the TIP, or other VDOT staff. Thus, subsequent changes to these project-

specific cost estimates, whether they result from a change in design or better information, typically result from the project manager. Estimates are not given to VDOT Programming. Rather, a project manager updates estimates in PCES or Transport and a revision request is generated. The estimate is approved at the district level and the revision request processed by programming staff. The SYIP is developed based on schedules and estimates in the system.

3. The <u>period of analysis should not necessarily be a single year</u> for at least two reasons. First, the project development cycle may take longer depending on the complexity of the project and many other factors (e.g., for some projects the PE phase alone may be six years) such that it may be more appropriate to examine PE percentage over a long period of time for some basket of projects). Second, funding changes may affect delivery of a project: priorities change, funding changes, scopes change – there are many reasons that a project could be cancelled or redesigned. Revenue projections are not based on available projects. A six year financial plan is prepared each year and a budget developed for maintenance and construction projects. The budgeted funds (state and federal) are programmed to projects based on schedules and estimates.

4. Two factors which will influence the overall PE percentage for an entire program are the <u>level of funding available</u> (see comment 1) and the fact that <u>new prescoping funds by district</u> have become available, and these will affect the PE costs (since some PE will be charged to these funds). This is the second year of this two-year effort. That said, the primary factor is related to priorities. VDOT has been in a phase of limited growth and addition of new projects due to reduced funding over recent years. New revenue projections provide opportunity to identify new projects and new PE phase starts. Pre-scoping funds are to assist in identifying and conducting early activities on new projects.

5. The <u>analysis could be skewed by certain types of projects</u> if no thought was given to the following categories: large-scale projects (e.g., PPTAs or mega-projects); long-duration projects (especially ones that might span two of the three financial systems [FMS 1, FMS 2, Cardinal]), design-build projects (although this risk is mitigated by the fact that such projects are relatively few, 5-10 per year), and rural-rustic or safety-only projects (which tend to be smaller scale.) One technique that could be considered is in the PCES to examine the "complexity" scale which indicates simple, medium, or complex (see Figure 1). Another technique is to classify projects (e.g., enhancement versus safety versus interstate.)

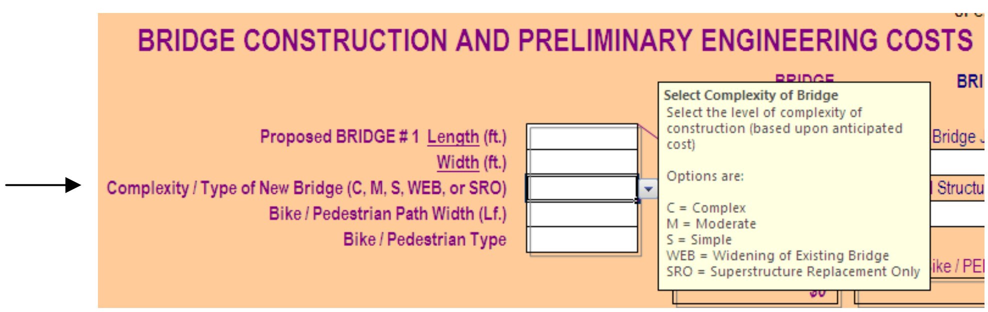


Figure 1. PCES Complexity Scale UPC 57044 (Complex, Medium, Simple, Widening of Existing Bridge, Superstructure Replacement Only)

6. In thinking about the goal of developing a way to forecast PE costs for specific projects—what was described as the fourth goal of the study—<u>consider the following possibilities</u>:

    a. As was mentioned with the North Carolina study, it may make sense to forecast the ratio of the *actual* PE expenditures/*initial* CN cost estimate. (The rationale for such a calculation is that at the time a PE estimate is needed, the project manager only has an estimated CN cost and will not know CN expenditures until after the project is completed.) However, as the Project Pool shows multiple estimates made over time for both PE and CN, there is some question as to whether *the very first CN estimate should be used or a later estimate should be used*. It is our process during project closeout that the final estimate is selected as expenditures as there is value in understanding how estimates compare with actual costs. (Also consider the fact that estimates later in the project development process come from TRNS*PORT rather than PCES.)

   b. With respect to the "large record PCES database" consider characteristics such as duration (start and end date), terrain, and so forth. [Rather than only doing a linear regression analysis, it may be productive to look at *correlations among certain types of factors* as a prescreening exercise and then use the results of this exercise to determine which variables should be considered for inclusion in the model. It may also be appropriate to ask others in Virginia, including other VDOT/VCTIR staff, about physiographic regions in Virginia that affect characteristics such as soil hardness and, by extension, construction cost.]

   c. [This was not explicitly stated but follows from the discussion: perhaps we should document, for the projects studied, the variability in the PE estimates and the variability in the CN estimates. For example, knowing that for all small-scale projects (under $5 M), that median change from initial PE estimate to the final PE estimate was 50% of final cost might be of interest.]

   d. It may be interesting to detect how often the *override feature in PCES is used*, where the analyst can replace the PCES estimate with their own estimate.

   e. If one carefully examined the activities and accounts, one could examine certain *CN activities that actually reflect preliminary engineering work*.

7. In an ideal world, you could find projects whose cycle began in 2004 or later (meaning their characteristics would be in the Project Pool and the various related databases.)

8. In the past Rob noted that VDOT had done some spot checks of total expenditures in the Project Pool and those in the financial databases, and in those spot checks the results were consistent by phase [which is good news].

9. A possible characteristic for the model could be the amount of funding per year.

Initial Interview Questions

1. What is the best way to obtain a database that shows expenditures (ideal) or allocations (acceptable) by phase (PE/RW/CN), year, and district?

2. The VDOT FY13-14 Business Plan states that a goal is to "Program 10 percent to 15 percent of the annual construction program for new preliminary engineering." Related questions are:

   a. Is there a target for total money allocated to PE (as opposed to "new PE")

   b. Can the database for item (1) indicate how much has been allocated to PE, RW, and CN by fiscal year, and if so, for how many fiscal years can we do this analysis?

   c. If the database for item (1) is allocations, is there a comparable database for expenditures?

3. To do our homework, we have begun exploring some other approaches but perhaps there are caveats you would recommend. These other approaches are:

    a. Business objects (“Boxi”) [we have received help from Jill Kocolis and Alan Saunders].

    b. FMS 2 queries [we have received help from Jennifer Ward and Bob Carver]

    c. I know that a key issue is looking at projects that have already been closed out but there are probably other items you recommend.

I would also be glad to come to Richmond and explain what we are doing as an introduction to the questions. (The full “research need” is spelled out in the pages that follow and a summary is given first. A big component of this involves talking with VDOT districts, but I would like to speak with you or someone you recommend from Programming regarding the various databases.)

Lynchburg District Meeting on March 5, 2013 (Interview LY6)

Jay Brown, Brian Casto, Randy Hamilton, Jeff Kessler, Zack Weddle, and John Miller

Verified Notes April 8, 2013

1) Do all 5 phases of the VDOT Project Development Process fall within the Preliminary Engineering phase in terms of SYIP allocations? Our understanding of this alignment is shown below.

VDOT Project Development Process Tasks	**SYIP Phases**
Scoping Phase	Preliminary Engineering
Preliminary Design Phase	
Detailed Design Phase	
Final Design & ROW Acquisition Phase	
Advertise Plans	
	ROW
[Not shown, Occurs after advertisement]	Construction

Yes, except note that actual right of way acquisition is not part of preliminary engineering.

2) FTA defines PE as "the engineering necessary to complete NEPA…or 30% of final design"
   a. Are we correct that VDOT's PE definition differs (e.g., PE includes all of final design)?
   b. Is there consistency between PE in the Project Development Process and PE in the SYIP?

Yes for both questions.

3) To what extent do the end products of the Preliminary Design Phase, the Detailed Design Phase and the Final Design & ROW Phase typically change in terms of *money spent* and the *design product*?

Since the reductions in staff that resulted from the VDOT Blueprint, projects have been designed at the district level rather than the residency level, and thus the district is able to get a better handle on forecasting project costs. For example, the cost estimate is no longer based on mileage but rather is based on specific construction elements as noted in PCES. Generally, when the District initiates projects, staff know how the scope will be defined and can follow the philosophy of "budget, then design." Projects may change because of the availability of funds but they do not typically "grow" in terms of size. That said, some types of changes in project scope that have resulted in the past have been noted:

- The longer a project stays active, the higher the PE costs will be. This can result from staff still charging to the project, changes in the scope, or changes in design standards [if there is a long gap between PE and advertisement.] An example of such a project was noted in South Boston.

- Changes in subsequent funding may render some PE irrelevant, which will increase the ratio of PE/CN. For example, prior to the Blueprint staff reductions, a series of widening (to four lanes) and intersection improvements were planned for Route 15; however, with insufficient funds the project was scaled back to more modest improvements (e.g., instead of adding a turn lane at one intersection as desired by the residency, flashing lights were installed.)

- Generally the projects where the scope had to be cut substantially to meet available funding levels were those that started at the residency level prior to the Blueprint staffing reductions. For example, a town project—the Hamilton Boulevard widening to four lanes—had to be scaled back due to reduction in forecasted future allocations.

4) Can you recommend a sample of (preferably closed-out) UPCs that help us better understand both
   a. the role of PE and
   b. how PE tasks are funded?

- A good project for understanding *how PE has traditionally fit into the project development process* is UPC 5543, which reflects a project performed for Route 626 in Campbell County. A good project for understanding the concept of "*budget first then design*" is the passing zone project on Route 501, which sought to improve the sight distance for the passing zone (UPC 87994). (The budget constrained the type of work that was done, where work was performed between two discrete points in the corridor.)

- To be clear, the VDOT accounting systems record very specific tasks within the CN phase, however, this is not the case within the PE phase. In reference to construction projects, there are three ways to fund PE activities: through the PE phase for a UPC that contains and CN, through prescoping funds that have been allocated to the districts for the past two years, and through a UPC that is dedicated to PE only. An example of this third approach is a Robertson Bridge Project in Danville, which had a separate UPC for PE/RW, was driven by ARRA funds, and which required that a [utilities] mitigation be performed within two to three years. (It is believed that there are three UPCs for this project: UPC 17740 contains the PE/RW phases, UPC 93335 contains the construction phase, and UPC 95453 contains the utilities mitigation.)

5) Where can we find details for specific projects besides the project Pool (http://isyp)?
   a. How often is information uploaded to the iPM and how is it determined what is uploaded? (Some projects have a scoping document 57044 , 78621, while others do not)

   A good project to examine is UPC 87994 –the route 501 improvement to sight distance for a passing zone; especially see the schedule in PCES.

6) At the district level, for a given fiscal year,
   a. Are the data available to determine what percentage of funds are spent on PE (versus RW or CN)?

b. Are VDOT staff reviewing percentages, and if so, for what purpose?
c. What is a range of appropriate percentages to be spent on PE relative to other project phases?

The short answer is that percentages are tracked at the project level but not at the program level. Further, when considering the percentages at the project level, the following caveats are noted:

- The percentage of funds spent on PE is meaningless if one has not budgeted for the project phases (PE, RW, and CN) correctly. For example, if one spent 50% of total project costs on PE then probably a mistake was made in doing a complete preliminary engineering process on a very small construction project.

- Not all projects will fit into the "mold"—for instance, a recent review of select projects showed that the percentage of funds spent on PE ranged from 13% to 58%. (In concert with the comment above, the meaning of the "13%" depends on the ability to manage a project within a [correctly specified] budget, as is done with the construction portion of the budget.)

- The PE phase is susceptible to some types of influences which can increase PE costs. One influence is the public involvement process: for instance, on a recent Horsley Creek project, the Garden Club halted the project until certain design and environmental changes were made. A second influence is the role of consultants: for some small projects, it may be the case that it would be more cost effective to do the work in-house (with some modest increase in the budget) than to write a contract for the work to be done by outside forces (where a 50% increase in the cost might result from having to write the contract plus an additional 25% increase in the cost might result from having to manage the contract.)

- At the project level, the percentages might be useful for the five types of construction projects specified by the Project Management Office. For example, for category 1, one might not want to exceed 50% for the PE portion of the project. [These five categories reflect, respectively, no-plan projects, minimum plan projects, construction projects (also known as "C-Plan" projects of medium complexity, larger-scale C-plan projects typically exceeding $100 M, and major multi-contractor construction projects.]

7) Will tracking expenditures by <u>phase</u> (e.g., PE vs. RW) and by <u>activity</u> (e.g., 616 for road plans or 613 for location surveys) yield the entire amount VDOT spends on preliminary engineering activities?

There are two known exceptions:

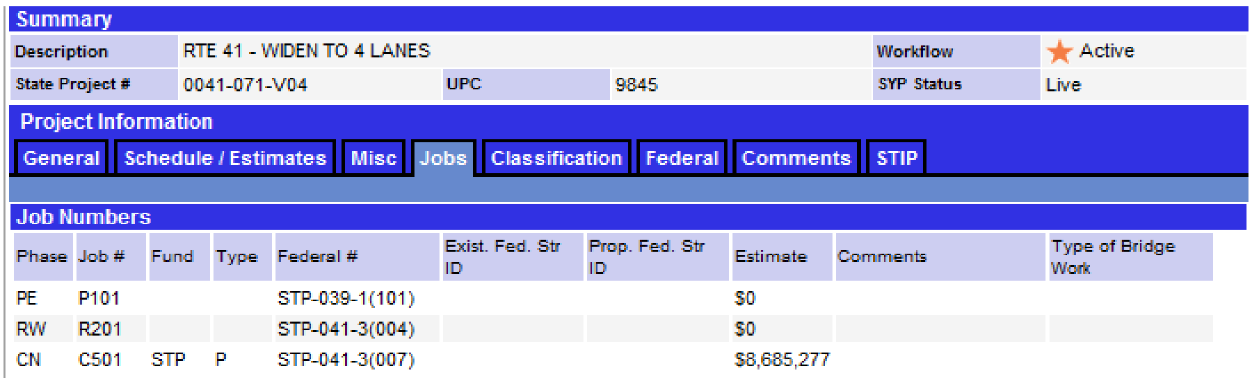
- Some RW costs (not acquisition of RW but related costs) may be charged to PE if RW tasks are needed but the RW phase is not yet open to charges.

- Some PE-related charges may be captured under planning costs, administrative costs, or the prescoping funds made available to each district.

That said, such exceptions are believed to be minor if one is concerned about the percentage of PE to CN costs, since these items (e.g., administration) would affect RW and CN phases as well as PE.

8) Is there a credible way to identify a list of projects (including dead projects)-in each district that will enable us to determine the portion of total project cost spend on PE?

It was clarified that these are "C" jobs as opposed to "M" jobs [as shown in the jobs section of the project pool.] For example, UPC 9845 is a "C" job as shown in the figure below.



Summary

Description	RTE 41 - WIDEN TO 4 LANES			Workflow	Active
State Project #	0041-071-V04	UPC	9845	SYP Status	Live

Project Information

General | Schedule / Estimates | Misc | Jobs | Classification | Federal | Comments | STIP

Job Numbers

Phase	Job #	Fund	Type	Federal #	Exist. Fed. Str ID	Prop. Fed. Str ID	Estimate	Comments	Type of Bridge Work
PE	P101			STP-039-1(101)			$0		
RW	R201			STP-041-3(004)			$0		
CN	C501	STP	P	STP-041-3(007)			$8,685,277		

Note that maintenance projects (e.g., slurry seal) are performed with no PE phase per se. A sample of UPCs for the Lynchburg District based on the FY2004-FY2012 SYIPs is shown on an attached excel spreadsheet, and we would welcome Lynchburg District staff review of these projects to account for anomalies such as projects with a separate UPC for PE from the CN phase or, if they exist, maintenance/operations projects which are nonetheless funded with construction (603) allocations. The spreadsheet also identifies these other anomalies: projects that are enhancement, district-wide, study-only, or ARRA.) These projects are shown in a separate spreadsheet.

Note also that to identify dead projects one can pull up inactive or archived projects in the project pool.

9) Are there any characteristics you would add or remove from the taxonomy list that has been provided?

Consider the impacts of the following characteristics:

- Role of politics. As noted in the earlier example with the Garden Club, such involvement can change the project scope. This can also happen with access management or crossover-related projects. A good example of a UPC where the scope changed was the Midtown Connector (believed to be UPC 8759) which was initially a four lane project but which became a series of intersection improvements and a flush median, with concerns about accommodation of emergency vehicles playing a role. Such influences are not always desired at the inception of the project but do influence the scope.

- Materials and earthwork, such as laid back slopes, stabilization, and changes that may not be evident at the scoping stage (such as rock and or hazardous materials). The possibility of such unexpected findings will influence how much of a contingency should be established.

- Physical access for construction vehicles, which was a factor for projects such as the John Randolph Bridge (required a separate contract for easements [possibly this is UPC 18878 for the bridge and UPC 85212 for the detour) and Route 29 in Pittsylvania [possibly this is UPC 8757].

- It is possible that the PE percentages are increasing over time. In the mid 1990s, a rule of thumb was that about 15% of a project's costs were PE, but in practice very few projects have such a low percentage. Today a typical range for a Lynchburg project might be 20% to 25%. This results in part because such projects are smaller (e.g., smaller projects tend to have a bigger PE percentage than larger projects) but it may also result because PE costs have been rising due to more stringent environmental regulations and changes in available funds [which necessitate changes in project design to meet lower budgets, thus invalidating earlier PE work.] For example, there was a Farmville project where 58% of the project cost was in PE; the high percentage resulted because a 2.5 mile section of a four lane divided roadway was designed, but only 0.75 miles of that roadway was constructed. A more extreme example was a Route 6 project where half a million dollars were spent on design but ultimately was not built except for installation of signing. Additional factors influencing PE are increased administration and process cost.

  Generally, anything that has been designed but not built by 2019 will likely require new PE as the new regulations for storm water and drainage will thus be in effect.

Other Comments

Better cash flow is possible. A solution may be to start the project development process without fully funding the PE phase. Years ago, a practice was to put a small amount of funds, on the order of $5,000 to $10,000, into the SYIP for a project and then begin work. [When this practice was followed for many projects] a benefit was that more funds become available for other projects—including construction. When one considers that a typical project development process is 4½ years, this kind of approach enables one to "start spacing out the money." As an illustration, suppose a project PE phase requires an estimated $100,000 and that only $10,000 is available. At present, VDOT requires that the $10,000 be banked until the remaining $90,000 is available, and then PE can begin in the year that $100,000 is allocated to the UPC; this approach is viewed by some as beneficial because it demonstrates a commitment to delivering that specific project. An alternative, however, would be to relax the requirement to fully fund each phase, do a small amount of PE work with the $10,000 that is available, and then put the remaining $90,000 when it becomes available on [more pressing] CN needs.

This full-funding requirement also affects other phases; for instance, suppose a 27-month RW phase: one cannot begin until funds for all 27 months are available, even though in practice one might not need all RW fund in the first fiscal year. [In short, fully funding each phase may eliminate some needed flexibility given the length of the project development process.]

Consider a resource titled Addressing Uncertainty in Cost Estimating (NHI Course 134068). [A review of this material shows an interesting observation: at the point where scoping is initiated, which corresponds to what the course titles "Budget Authorization") the expected accuracy for forecasting total costs—not PE only—is given as between -20% and +40%. Presumably any forecasts of PE project costs as a percentage of construction costs would be affected by this uncertainty.

Hampton Roads District Meeting on March 29, 2013 (Interview HR7)

Bruce Duvall, Stephen Rowan, John Miller, and Beth Turner

Verified on April 16, 2013

1) Do all 5 phases of the VDOT Project Development Process fall within the Preliminary Engineering phase in terms of SYIP allocations? Our understanding of this alignment is shown below.

VDOT Project Development Process Tasks	SYIP Phases
Scoping Phase	Preliminary Engineering
Preliminary Design Phase	
Detailed Design Phase	
Final Design & ROW Acquisition Phase	
Advertise Plans	
	ROW
[Not shown, Occurs after advertisement]	Construction

Yes, it generally seems accurate, but note three caveats:

- To be clear, the costs of ROW acquisition are with the ROW phase.
- As a practical matter, once VDOT receives from FHWA the "notice to proceed with the ROW phase," all costs associated with ROW such as ROW acquisition, court costs, appraisals, and attorney's fees are charged to ROW.
- Whether utilities are included in ROW or CN depends on the project. Private utilities (e.g., cable and electric) are performed in the ROW phase, but municipal utilities (water and sewer) are performed in the CN phase.

  (A separate issue that does not affect the phase but which does affect the use of federal funds is whether the utilities are merely moved or are improved: if the latter, it is classified as a "betterment" and the incremental cost of such an improvement (relative to simply moving the utility) may not receive federal funds.)

2) FTA defines PE as "the engineering necessary to complete NEPA…or 30% of final design"
   a. Are we correct that VDOT's PE definition differs (e.g., PE includes all of final design)?
   b. Is there consistency between PE in the Project Development Process and PE in the SYIP?

Yes for question a: developing and satisfying NEPA, conducting public involvement, and achieving both 30% and 100% of final design are all included in VDOT's definition of PE.

For question b, yes except there is overlap for the PE, RW, and CN phases. The SYIP shows PE, RW, and CN as a start to finish relationship, but the most critical date is the start date, as that date indicates when funds are available. PE in the SYIP shows that PE ends right before ROW begins but in reality it ends when CN begins. Table 1 illustrates how the actual schedule and SYIP might align for a hypothetical project: notice that in practice, PE may continue beyond ROW. (For example, while property is being acquired, one might have only 60 to 65% of the design complete.)

Phase	Actual Schedule		SYIP Schedule	
	Start	Finish	Start	Finish
PE	**Jan. 2013**	Dec. 2015	**Jan. 2013**	Dec. 2013
ROW	Jan. 2014	July 2014	Jan. 2014	Dec. 2014
CN	Jan. 2016	Dec. 2016	Jan. 2015	Dec. 2016

One clarification regarding the schedules for PE, RW, and CN – PE and RW typically overlap, as do RW and CN phases. The RW overlap of the CN phase is primarily due to property acquired under eminent domain that are settled at a later date in court, which can occur during and even after construction is completed. The only hard fast rule is that PE ends when the CN phase begins.

3) To what extent do the end products of the Preliminary Design Phase, the Detailed Design Phase and the Final Design & ROW Phase typically change in terms of *money spent* and the *design product*?

Overall, each project brings its own complexities making this a difficult question to answer. Some general characteristics that influence the extent to which a project design will change include the following

- High profile projects that have extensive involvement from the community and multiple stakeholders may require additional or new design treatments that were not previously anticipated.

- In an urban area the risk of geotechnical challenges (whether due to buried utilities, rock, results of structural integrity tests based on the CBR [California Bearing Ratio] or other design variables) increases.

- When land development occurs during the PE process, it can be the case that new property owners are not satisfied with conditions agreed to by previous property owners. For example: a vacant lot that is developed may require new noise barriers (if residential property) and/or new median treatments, entrance designs, or signals (if commercial property).

In sum, one might accomplish 30-40% of design before one of the above bullets necessitates a change in the product.

4) Can you recommend a sample of (preferably closed-out) UPCs that help us better understand both
    a. the role of PE and
    b. how PE tasks are funded?

- The Dominion Boulevard project may be of interest.

- To be clear, one should not assume that PE will be a given percentage of project costs. For example, HSIP [Highway Safety Improvement Projects] are generally smaller in total dollar cost but nonetheless require PE work, such that their percentage of PE is generally higher than larger scale projects.

- Notice that <u>locally administered projects</u> may show a lower PE percentage because not all localities represent their PE staff time in the PE phase. This applies to counties (e.g., James City County has some locally administered projects) but is especially acute for Hampton Roads given the large number of incorporated cities within the District. About 50% of projects are locally administered projects.

- A list of UPCs is attached as a separate Excel file. (We have marked any projects that are enhancement, district-wide, study-only, or ARRA. If there are any additional UPCs that should be excluded (e.g., because they are maintenance/operations projects funded with construction (603) allocations), please add a "1" to column H or just let us know. One example from the Culpeper District was UPC 84707, which was a bridge maintenance repairs that used SYIP construction funds).

  I recommend removing all of the rail safety projects (Example: UPC 18705). The Rail Safety Projects typically do not have a PE phase.

5) Where can we find details for specific projects besides the project Pool (http://isyp)?
    a. How often is information uploaded to the iPM and how is it determined what is uploaded? (Some projects have a scoping document 57044 , 78621, while others do not)

  Besides iPM, the only other location where information is available is the hardcopy project files available at the district office.

  Note that iPM is not designed to contain every record for a project but rather is expected to have the critical documents and decisions for a given project and provide information for people that are higher up to have access to project documents to make decisions. iPM relies heavily on the project manager—and in this District such managers are strongly encouraged to ensure that the critical files are uploaded.

6) At the district level, for a given fiscal year,
    a. Are the data available to determine what percentage of funds are spent on PE (versus RW or CN)?
    b. Are VDOT staff reviewing percentages, and if so, for what purpose?
    c. What is a range of appropriate percentages to be spent on PE relative to other project phases?

The short answer is that percentages are tracked at the project level but not at the program level. At the program level, note that the "appropriate percentage" will depend on the portfolio of projects. For example, in the Hampton Roads District, a significant number of smaller projects now make up the program—especially HSIP investments as noted in question 4—and these have relatively high ratio of PE to CN. (These are typically in the $500,000 to $750,000 range).

To be clear, when expenditures are tracked at the project level, the following are considered:

- Managers do of course monitor project expenditures to stay on budget, to ensure projects are receiving accurate charges, and to ensure that FHWA is receiving allowable project charges.

- Note that the estimate one receives from PCES when forecasting PE costs is made when about 98% of the information for a project is unknown. That said, it may be appropriate to provide a range of estimates rather than just a single point estimate.

- Although we don't have line items in PCES for estimating PE costs for a particular project, perhaps that is a possibility, which leads to discussion of the information shown in response to question 9.

7) Will tracking expenditures by <u>phase</u> (e.g., PE vs. RW) and by <u>activity</u> (e.g., 616 for road plans or 613 for location surveys) yield the entire amount VDOT spends on preliminary engineering activities?

   Yes with two exceptions: prescoping funds made available to each district are one source of funds for PE work, and locally administered projects may not have all PE staff time recorded therein.

8) Is there a credible way to identify a list of projects (including dead projects)-in each district-that will enable us to determine the portion of total project cost spend on PE?

   Some projects are initiated and designed but are cancelled. Such projects will skew the analysis. Determining whether a project is cancelled by using the iPM is difficult. Some projects will have a letter uploaded to notify that the project is dead but some cases a letter won't be available. Note also that some UPCs are PE only [with CN as a separate UPC.]

9) Are there any characteristics you would add or remove from the taxonomy list that has been provided?

   Consider adding following characteristics:

   - <u>Urban versus rural</u>, based on the discussion shown in response to question 3 (see the second bullet).

   - Location in an <u>environmentally sensitive area</u>, such as the tidal area, which affects the Hampton Roads District.

- Types of stakeholders. For example, Route 17 was a normal project in the sense that it was a widening, but three diverse types of stakeholders affect PE costs: Newport News Waterworks, National Park Service, and the York County Board of Supervisors. As another example, Hampton Roads works with military bases—and for some projects, the decision is made not locally but at the Pentagon level. This means that some decisions will take longer—and hence costs will be affected.

- Short time requirements. Suppose that it is relatively efficient for a given project to be designed by four people over a 24 month time frame—but that for political reasons it becomes critical to design the project within 10 months. This is possible with more people, [but it is likely that the staff costs will be higher as some efficiency is lost].

- Long span of time. In one instance, a project was designed four times: the first design was rejected after public objection, the second design entailed a 20% grade that was rejected by the business community, and the third design was adequate but with no funding for ten years conditions changed such that a fourth design was required.

- Applicable rules. A VDOT project that receives federal funds must follow the appropriate statues in the CFR [Code of Federal Regulations.] For a locally funded project that does not receive Federal funds, some of the CFR provisions will not be applicable.

- Military Presence-Specifically in Hampton Roads, there is a large military presence which adds additional stakeholders. Many decisions are not made at the local level and can add additional time to PE phase.

- Number of Designs-The number of times a project was designed can double or triple the PE cost. However it is hard to tell the number of designs required other than by looking at PE cost and talking to Project Manager.

A completely different way to get at this question would be to still compute PE as a percentage of CN but to do a better job of forecasting CN costs, using tools such as "RS Means" (a construction industry publication that has a method for developing CN forecasts from line items such as types of soils, fuel, and so forth.)

Other Comments

- There are both good and bad uses of the information shown in question 9. A good use might be a tool that enables one to better forecast PE as a percentage of construction costs based on readily available factors. A bad use would be to develop some type of rule that requires PE costs to be below some threshold amount.

  Thus, it is critical that a limitation of any analysis is that it is impossible to capture all sources of variability: there will be some projects that do not fall within expected norms. As an illustration, the following scenario is possible: a project is submitted for advertisement and at that point a key stakeholder desires a change. The simple fact is that there are times when key stakeholders cause PE costs to escalate, [and these cannot be prevented unless one chooses to ignore key stakeholders.]

- There is a potentially bad use of the information in response to question 6c. There is at least one situation where it may be advantageous to have a relatively high PE/CN ratio. This situation is where a set of smaller spot improvements (e.g., HSIP investments) are programmed along a corridor. Such improvements may address safety but not capacity. Accordingly, one might then choose to perform further PE work such that the entire corridor is analyzed from both a safety and an operations perspective. The additional analysis may increase PE costs but enables one to complete the construction at one point in time rather than first constructing safety improvements and second constructing capacity improvements.

Staunton District Meeting on May 9, 2013 (Interview ST8)

Meeting with Michael Fulcher, Mathew Dana and Terry Short
Verified June 18 and July 5

1. Generally, the answer to question 1 is yes: the 5 phases of the VDOT Project Development Process (e.g., scoping, preliminary design, detailed design, final design & ROW acquisition, and advertisement) fall within the Preliminary Engineering phase in terms of SYIP allocations. Figure 1 below shows the relationship between the three phases; notice PE and ROW may overlap but that both should stop once CN begins.

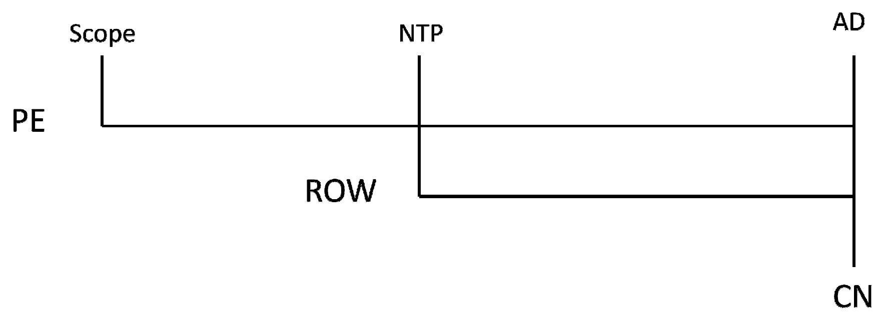


Figure 1 Scoping to Advertisement Relationship between PE, RW, CN.

(NTP = Notice to Proceed, AD = Advertise for Construction)

Note that certain ROW costs—basically the cost of acquiring ROW and staff costs for negotiations and appraisals—fall under ROW.

2a. Yes the two definitions are different. In VDOT, PE includes everything from Pre-Scoping to Advertisement.

2b. Yes the definition of PE in Project Development Process and the SYIP are consistent. Two related points were discussed in the context of this question:

- Given the FTA's definition of PE, what occurs after 30% of design? The initial source we reviewed suggests that PE may be followed by the NEPA process, final design, and then the full funding agreement, which is FTA's decision to provide federal funds for a transit related project. A slight variation is given in FTA's New Starts Fact Sheet, which has the PE process include NEPA with the phase that follows being final design. These sources are: www.fta.dot.gov/documents/PE_Fact_Sheet_9-18-07(1).doc and http://www.fta.dot.gov/12304_2607.html.

- In some cases, intensive design tasks such as environmental work occurs before specific details of the project are determined, because such environmental work takes the longest and the Project Development Process is focused on delivery. Thus there can be instances where, for example, traffic volumes are still being forecasted while environmental mitigation is being designed. (This can happen on interchange projects where the environmental component will be time consuming.)

3. Rather than relying on specific benchmarks (e.g., “this is 30% of final design”), there are four principles that illustrate how the end products change in terms of money spent and design product. First, as time and money are spent, the uncertainty associated with a the project decreases; this uncertainty reflects both the existence of multiple design options and details for those options that might not be resolved. Second, as shown in Figure 2 (hand drawn by the interviewees), there is one benchmark that is meaningful: the point at which a public hearing is held, which is generally when the right of way impacts are fully understood. Third, the uncertainty decreases exponentially at the beginning of the project [due to multiple design options being considered] but linearly after the public hearing (when details such as culvert placement are being established; these details require a substantial amount of effort to resolve). Fourth, aside from a modest startup cost, the spending of PE funds is generally linear—e.g., at 10% of design one would expect about 10% of PE funds to be spent.

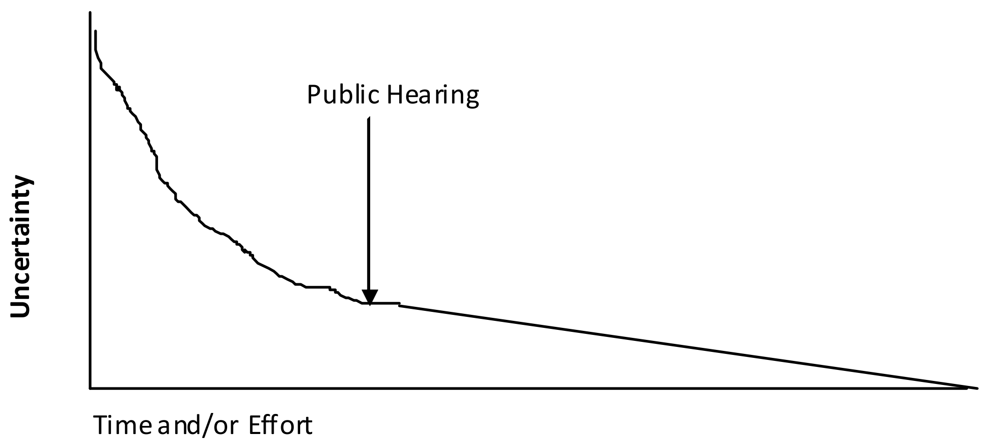


Figure 2. Relationship Between Project Uncertainty and Project Time

4. The Staunton District initially suggested the Exit 91 project but then noted that this project used the Design-Build delivery method, which has a complicated PE process. However, other projects are shown in the attached Excel sheet and these may be possibilities. Projects where construction has not yet begun may be of use if the project is within 6 months of advertisement, because they can give you a good idea of PE costs based on the expenditures to date. In fact, many of these projects may be better examples than other projects in the list because they are more current and will have more information available in IPM and will better reflect current PE costs.

5. The Business Objects Database can capture any information from the Project Pool.

5a. Most information should be uploaded to the Project Pool. When supporting documents are not uploaded to the iPM, the project is most likely an anomaly. Locally Administered Projects are also anomalies and should not be included. Some projects may not have information in the Project Pool because they are maintenance or paving projects.

Generally it is up to the project manager what is uploaded to the iPM. Older projects may not have as much information uploaded. However, in Staunton making sure documents are uploaded is a priority, especially recent projects. UPC 11090 is a good example of a project where extensive project documents are uploaded to the iPM.

6. The expenditure data could be available from both Business objects or PCES. However, when looking at such data, consider the following:

    - *Some projects are anomalies*, such as maintenance projects and paving jobs which are not typical construction projects. [A list of UPCs is attached as a separate Excel file. We have marked any projects that are enhancement, district-wide, study-only, railroad crossing improvements, projects for which there were no construction expenditures (as a surrogate for projects that were not advertised), or ARRA. If there are any additional UPCs that should be excluded (e.g., because they are maintenance/operations projects funded with construction (603) allocations), please add a "1" to column H or just let us know. An example of this latter is UPC 84707, which was a bridge maintenance repairs that used SYIP construction funds

    - *When looking at just one year of data, there may be too many outliers.* Thus consider looking at the most recent three years to get a better picture of what VDOT spends on PE. (One does not want to look too far back because there have been changes over time: for example, in the 2000s substantial money was spent on PE for projects that were never built; this can be contrasted with the 1960s era interstate system.)

    - *While PE expenditures are of course reviewed for individual projects, the district does not review PE expenditures for the program as a whole.*

    - *There is no such thing as a "shovel-ready" project.* The project development process is not nimble: it can take five years to deliver a large project. Keep in mind that each phase must be fully funded before proceeding, that the available funding may change between PE initiation and the date of advertisement, and that costs (e.g., for asphalt which is governed by the price of oil) may vary. Additionally, there are requirements regarding how fast funds must be spent: for instance, if one sought to develop a smaller number of projects in order to accelerate their PE time, one risks there being a period where not enough projects are ready for construction such that the state cannot expend all available monies during a given fiscal year. Thus, it may make sense to develop projects on a priority basis.

7. This approach should generally work. One complication is the availability of prescoping funds for each district; these funds allow the acceleration of PE on projects for which the notice to proceed has not yet been given. (For example, suppose a project's PE is in the SYIP beginning July 1, 2014: with the prescoping funds, one can begin work on the project immediately.) Second, some projects are interdependent (e.g., the termini intersect) such that the environmental portion of one must be done prior to PE on the other being completed. In that case, some of the PE for one project may be linked to the other project.

8. Note that it is possible to obtain project characteristic data from Business Objects, which may be considered in addition to using the Project Pool.

9. There are two items that may be considered: (1) whether the project is tier 1 (under $5 M) or tier 2 (above $5 M, design-build, or located on the interstate system); and (2) the availability of culverts. Unfortunately, there is not a field that signifies the extent to which public involvement is necessary, although there are certainly projects where this involvement influences the amount of PE effort required). Note also that when you see the PE start and end date being the same, this may mean you

have a “child” UPC [where presumably the PE for the project is shown in a different UPC.] While the template mentions the possibility of using the pre-scoping estimate [as an independent variable to forecast PE cost], keep in mind that this estimate is very rough: sometimes little is known about the project when the estimate is generated, and sometimes the actual project is rescoped to a smaller level of effort.

Northern Virginia District Meeting on June 17, 2013 (Interview NV9)

Dic Burke, Claudia Llana, Bud Siegel, Kanti Srikanth, Jim Zeller, John Miller, and Beth Turner
Verified July 5, 11, and 15

The meeting began by discussing the three research questions outlined in the July 2012 proposal:

1. As a best practice, <u>are the data available</u> at the district level to answer the following question: what percentage of funds (whether at a project level or a program level) are spent on PE?

    - Yes the data are available. There are a number of databases with different focus areas that are available to locate project expenditures. However, the Project Pool was described as most likely to have the current project expenditures.

    - Additionally, looking at the list of projects programmatically there are several types of projects that are unusual. For example, some projects are PE-only and others have funding for PE, RW and CN. Similar to the Hampton Roads District, Locally Administered Projects (LAPs) are account for over half of the projects in Northern Virginia.

    - At the program level it is important to note that <u>not all projects follow the same PE "model</u>." The method in which a project is initiated influences the level of detail included in the project when the PE phase begins. For example if a project starts in the pre-scoping phase, many details are established very early in the process. By contrast, other projects may undergo a significant number of iterations involving public hearings and design revisions to find appropriate alternatives. Besides the availability of prescoping funds, PPTA projects, LAP projects, and Base Realignment and Closure (BRAC) projects may all have differences in the amount of information available when PE begins.

    - A number of diverse activities may be included in PE. Examples are environmental studies (e.g., EA, EIS, PE), TDM/rideshare programs, and, some components of park and ride programs.

2. If the answer to question 1 is yes, then <u>are VDOT Central Office or district staff reviewing these percentages</u>, and if so, for what purpose?

    VDOT Northern Virginia staff do not review these percentages at the program level, although expenditures for individual projects are tracked.

3. Given variations in PE definition and project type, <u>what is a range of appropriate percentages</u> to be spent on PE relative to the other project phases?

    For individual projects, about 15% is spent on PE relative to other project phases in Northern Virginia. This may be higher than other districts because, contrary to those other districts, NOVA has no staff designers. (Also, the answer may have changed since the passage of HB 2313 and ARRA: about 8 years ago VDOT had a "'don't say no" attitude towards new projects. Many projects began with only enough money for PE and none for RW or CN. After ARRA every project needed to be "shovel ready" within two years. As a result, only projects that had reliable funding through

Construction were started. Now, there is a focus back on starting newer projects, and because of ARRA, fewer projects are currently shovel ready.) Three other suggestions related to this question are:

- Examine how much money is allocated to PE from the SYIP for comparison.

- Refine the overarching question: specify the type of money to which we refer (i.e., federal, state or local) when determining how much money is spent on PE.

- When you select projects in response to question 9—developing a model—rather than only selecting projects that have expenditures in all three phases (PE, RW, CN), consider projects that may not have a RW phase. The reason is there are potentially a lot of projects that have no RW phase but which are nonetheless construction projects (e.g., they have a PE and CN phase.)

Interview Answers

1. All five phases of the VDOT Project Development Process fall within the PE phase of the SYIP as shown in the table for question 1. However, the table should include the various tasks associated with those phases, such as NEPA, survey, public involvement, and additional planning, conceptual, or environmental studies. Conceptually, one could add a fourth "phase" that precedes PE, RW, and CN; this new phase could be called "planning" and includes activities such as developing a cost estimate that will be placed in the program; some of these activities may be funded with the prescoping funds for the district.

   - The alignment of PE, RW and CN differs for Northern Virginia. Unlike other districts, the PE phase does not end when construction begins. This is done to allow for contingencies. Some districts charge additional PE activities to the CN phase once CN has begun, however Northern Virginia keeps the PE phase open until the end of the project.

   - Most projects don't have the finances "closed out" for all three phases. In the past, it was noted that there were 90,000 phases that were still open, and a recent effort to close out the associated projects resulted in about 45,000 phases being closed out.

   - As new transportation funds become available, the District is being asked to deliver the program on very compressed schedules.

2. Yes, the VDOT definition differs from the FTA definition. In Northern VA, PE includes all of final design and lasts until the end of CN. Yes, there is consistency between PE in the Project Development Process and PE in the SYIP in terms of tasks, although there is some overlap in terms of the schedule. For example, whereas the SYIP presents the three phases as sequential with no overlap, in reality there may some engineering during the CN phase which is funded by PE.

3. It is very difficult to state the extent to which the end products of preliminary, detailed, and final design typically change because the answer varies enormously by project.

In general, about 2/3 of the design is completed between preliminary design and detailed design, while the final 1/3 of design is completed between detailed design and final design. Also, at detailed design, about 70% of the PE money is expended between preliminary and detailed design.

- An example where a project can accrue abnormally high PE costs is when a project gets stuck in the public involvement phase. The project can iterate between preliminary and detailed design until a suitable design is agreed upon. In some cases, this can cause PE to be more than CN depending on the number of iterations, especially if it is discovered at the public involvement stage that the wrong [design] path was chosen. The only way to tell if a project underwent multiple iterations is by examining the PE duration, which this district recommends defining as from when PE is started until CN advertisement. (If the PE lasts longer than 3-4 years, then there may have been multiple iterations.)

- To be clear, except for measuring duration, it is impossible to get a qualitative answer regarding the number of iterations required. That said, getting both the project team and the public on board with a design is the most important event in the project development cycle.

4. NOVA has projects that may be examined: examples are a project on West OX Road as well as UPC 57416. However, instead of recommending a sample set of UPCs, a list of projects to review has been provided and NOVA will flag projects that are considered anomalies. NOVA also suggested that projects of the following types be removed when estimating PE costs at the project level: LAP, Mega Projects, Design Build, Operational Programs, and projects that that have co-mingled UPCs.

   - *Locally Administered Projects*: LAP projects can charge time to overhead while in VDOT there is a large focus to have time charged to a specific project. When looking at LAP projects expenditures in the VDOT databases, it may not represent all the money spent on PE. Sometimes LAP projects will bill VDOT but it is largely based on the funding source.

   - *Mega Projects*: Base Realignment and Closure (BRAC)

   - *Design Build*: It is hard to delineate between the PE and CN expenditures due to the compressed schedule and the inconsistent reporting of activities.

   - *Operational Programs*: Programs such as Travel Demand Management are funded under PE. Northern VA has a large TDM operating expense of about $3 M per year. Other operational programs include park and ride and commuter connection.

   - *Co-Mingled Projects*- Some projects have a different UPC for PE and CN. For larger projects the construction phase may even have two UPCs, for phase 1 and 2. Linking the co-mingled projects to get an accurate representation of how much money was spend on PE in terms of total project costs will be difficult. In the notes section of the Project Pool, it <u>should</u> show if there is another UPC for the same project.

     When selecting projects, please consider the following:

     - PE percentages can vary considerably (the 15% mentioned in the notes may be typical; percentages are likely higher for smaller projects than for larger ones).

- Project phase closings. Lately I have noticed our Central Office Programming staff close phases for charges based on the schedules in Project Pool.

- For project Spreadsheet:
  - Titles frequently identify when a project may be not a traditional PE, RW, CN project. For example, among Prince William Projects:

    - UPC 16623: Roadway Lighting
    - UPC 54632: Relocation
    - UPC 65072: Close crossover
    - UPC 77580: Pre-NEPA Study….
    - UPC 84570: NOVA PAVING OVERLAY OF ….
    - UPC 84686: Demolition contract

- Some UPCs contain one or two phases, with remaining phases in other UPC(s). For example, there are notes regarding linked UPCs in Live SYP (3 UPCs for Route 1/123: UPC 14693 for PE & RW, UPC 94102 for CN Phase 1, UPC 10098 for CN Phase 2). POOL project description notes sometimes denote such linked or child UPCs.

- I would not use Woodrow Wilson Bridge, 95 HOT Lanes, or Springfield Interchange as they have financial plans and the expenditures are different.

- I would also not use Rte 28 PPTA as that too has a financial plan.

5. The Project Pool is the best location to find specific details for projects. There will be some projects that do not have documents uploaded to the iPM because some project managers can have up to 130 projects at once. Uploading documents and maintaining estimates for each stage of the process is impossible. Also, LAP projects do not require scoping documents and many of their estimates do not come from PCES so they are likely to have very little uploaded to the Project Pool. Projects that are older may not have information uploaded as well. However, all Tier 1 projects (under $5 M) have an estimate, even if it is not found in the above database.

6. As noted on previously, data are available but are not tracked at the program level by district staff. However, individual project expenditures are tracked.

7. Tracking expenditures by phase and activity will not yield the entire amount that VDOT spends on PE because of the new Pre-Scoping phase. Pre-Scoping is a statewide UPC designed to answer questions early on in project development to determine is a project is viable. Pre-Scoping funds are also helpful because a project can begin while waiting for federal funding or getting into the SYIP. High profile projects that begin in the Pre-Scoping phase may have a lower PE because pre-scoping can take care of some of the early tasks. (Note that the prescoping phase has a separate UPC for each District. However, there are identifiers for specific tasks (projects) under this UPC.)

8. [Initially, we thought to strike all ARRA projects as well as projects that did not have expenditure data in all three phases.] However, some ARRA projects have normal project development processes. Further, given that Northern Virginia is an urban district there are a significant number of projects that do not have a RW phase but are not anomalies.

9. Public involvement an important characteristic that should be added to the list. However without proper documentation in the iPM or contact with the Project Manager it is hard to quantify.

Note also that the real drivers of project costs are the iterations (see question 3) and compliance with VDOT policies—and it may be the case that these cannot be correlated to the project characteristics are described in the table.

Finally, although duration was already one of the main characteristics, Northern Virginia pointed out that a better representation of duration is from PE Start to CN Advertisement. (Please confirm that we should use CN Advertisement Date as opposed to CN Award.)
For example, consider UPC 57416 shown in Figure 1. The Programming Tab indicates that PE began 7/3/2003 and CN began 2/14/2012, and that CN award was 5/3/2012. Figure 2 shows that 2/14/2012 was indeed the date of advertisement.

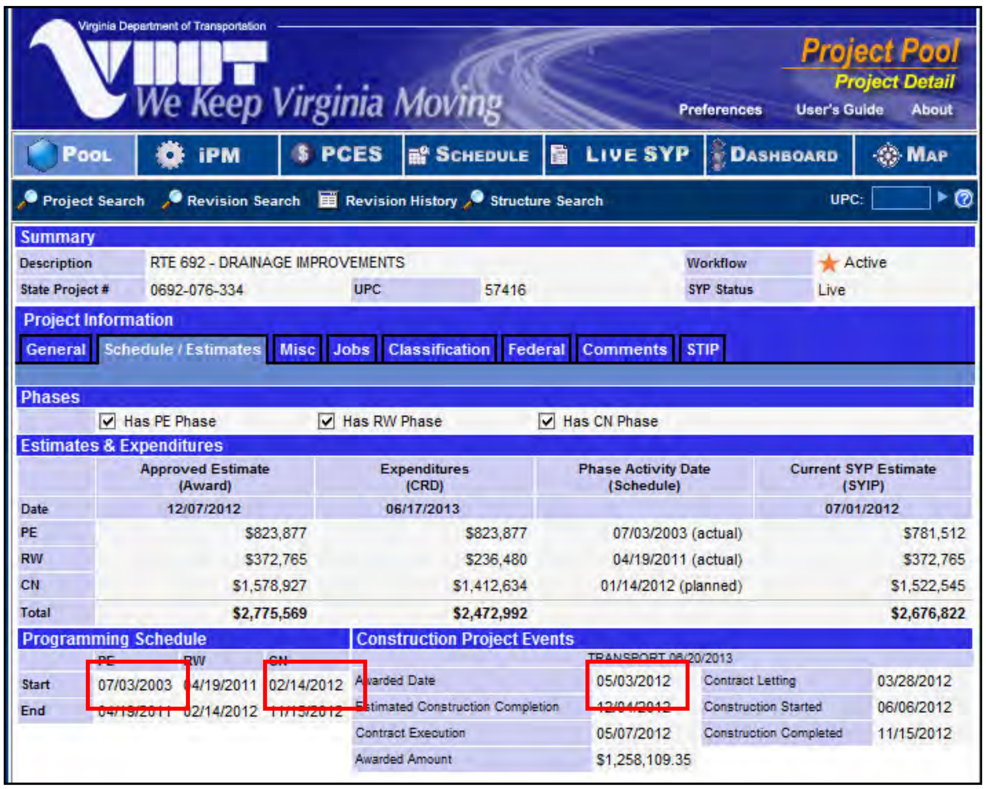
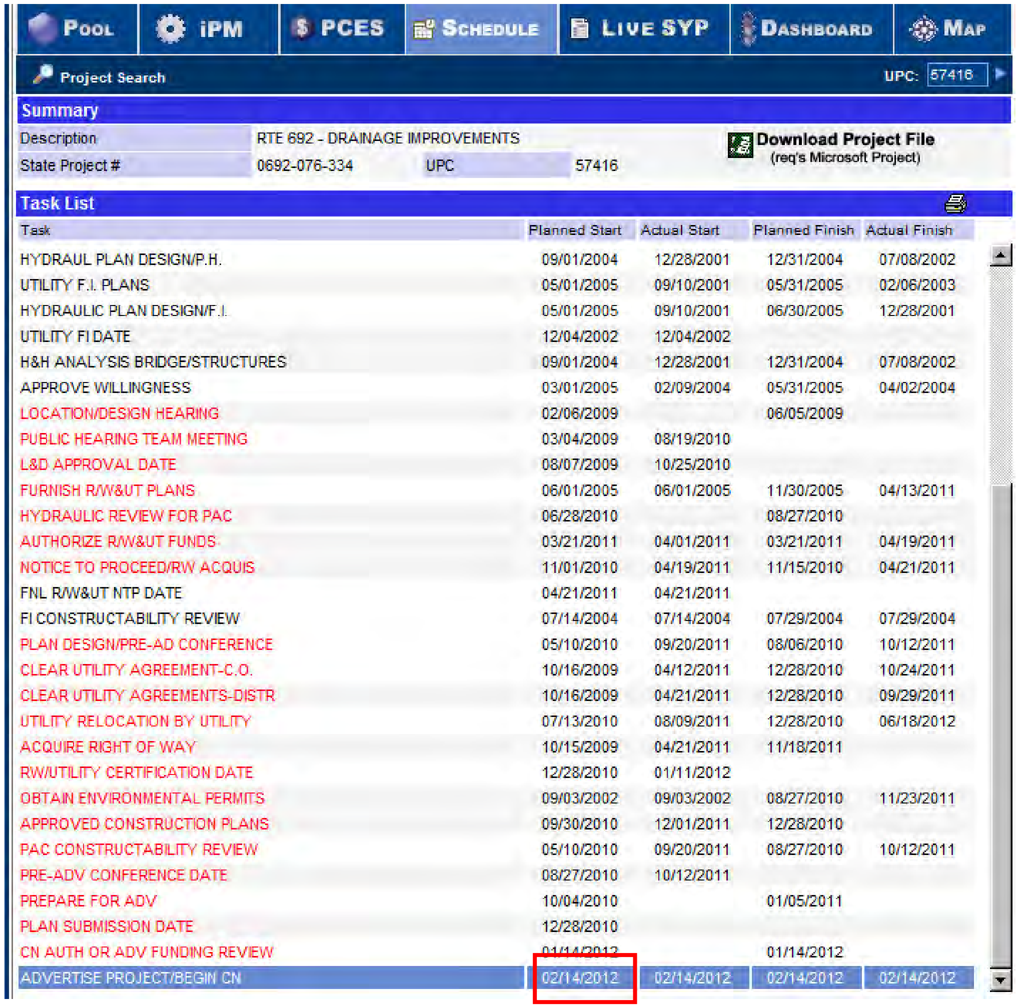


Figure 1. Programming Schedule and Award Date for UPC 57416



Summary

Description	RTE 692 - DRAINAGE IMPROVEMENTS		
State Project #	0692-076-334	UPC	57416

Task List

Task	Planned Start	Actual Start	Planned Finish	Actual Finish
HYDRAUL PLAN DESIGN/P.H.	09/01/2004	12/28/2001	12/31/2004	07/08/2002
UTILITY F.I. PLANS	05/01/2005	09/10/2001	05/31/2005	02/06/2003
HYDRAULIC PLAN DESIGN/F.I.	05/01/2005	09/10/2001	06/30/2005	12/28/2001
UTILITY FI DATE	12/04/2002	12/04/2002		
H&H ANALYSIS BRIDGE/STRUCTURES	09/01/2004	12/28/2001	12/31/2004	07/08/2002
APPROVE WILLINGNESS	03/01/2005	02/09/2004	05/31/2005	04/02/2004
LOCATION/DESIGN HEARING	02/06/2009		06/05/2009	
PUBLIC HEARING TEAM MEETING	03/04/2009	08/19/2010		
L&D APPROVAL DATE	08/07/2009	10/25/2010		
FURNISH R/W&UT PLANS	06/01/2005	06/01/2005	11/30/2005	04/13/2011
HYDRAULIC REVIEW FOR PAC	06/28/2010		08/27/2010	
AUTHORIZE R/W&UT FUNDS	03/21/2011	04/01/2011	03/21/2011	04/19/2011
NOTICE TO PROCEED/RW ACQUIS	11/01/2010	04/19/2011	11/15/2010	04/21/2011
FNL R/W&UT NTP DATE	04/21/2011	04/21/2011		
FI CONSTRUCTABILITY REVIEW	07/14/2004	07/14/2004	07/29/2004	07/29/2004
PLAN DESIGN/PRE-AD CONFERENCE	05/10/2010	09/20/2011	08/06/2010	10/12/2011
CLEAR UTILITY AGREEMENT-C.O.	10/16/2009	04/12/2011	12/28/2010	10/24/2011
CLEAR UTILITY AGREEMENTS-DISTR	10/16/2009	04/21/2011	12/28/2010	09/29/2011
UTILITY RELOCATION BY UTILITY	07/13/2010	08/09/2011	12/28/2010	06/18/2012
ACQUIRE RIGHT OF WAY	10/15/2009	04/21/2011	11/18/2011	
RW/UTILITY CERTIFICATION DATE	12/28/2010	01/11/2012		
OBTAIN ENVIRONMENTAL PERMITS	09/03/2002	09/03/2002	08/27/2010	11/23/2011
APPROVED CONSTRUCTION PLANS	09/30/2010	12/01/2011	12/28/2010	
PAC CONSTRUCTABILITY REVIEW	05/10/2010	09/20/2011	08/27/2010	10/12/2011
PRE-ADV CONFERENCE DATE	08/27/2010	10/12/2011		
PREPARE FOR ADV	10/04/2010		01/05/2011	
PLAN SUBMISSION DATE	12/28/2010			
CN AUTH OR ADV FUNDING REVIEW	01/14/2012		01/14/2012	
ADVERTISE PROJECT/BEGIN CN	02/14/2012	02/14/2012	02/14/2012	02/14/2012

Figure 2. Schedule for UPC 57416

Richmond District Meeting on May 29, 2013 (Interview RI10)

Rob Crandoll, Sam Hayes, Mark Riblett, and John Miller
(Revised and redistributed June 13, 2013)

Overview Comments

- There are three high level characteristics that influence PE costs at the program level:

  - *Duration*: the longer that a project costs, the more expensive it becomes. This is partly due to fixed staffing costs but it is also due to changes in personnel—both for internal staff and for external stakeholders, such as the Board of Supervisors. One way to minimize PE costs is to have a "guerilla" approach where you quickly start and then finish the project. Otherwise, longer duration may be associated with *more turnover of external stakeholders*, which can lead to priorities changing over time—and hence higher PE costs.
  - *Project type*. Maintenance projects (e.g., an overlay) require considerably less PE than capacity expansion projects (e.g., an intersection improvement) because of the reduced complexity. To be clear, there are some projects that do not expand the infrastructure footprint—such as a full depth reclamation where the roadway is rebuilt—which nonetheless are full construction projects because of their complexity. (An MPO might view this latter case as a maintenance project but it really is closer to construction. Two decades ago one could determine easily from the SYIP which projects were construction versus maintenance; today that distinction is more difficult.)
  - *Project Specificity*. When a project does not have a well defined scope; PE costs will arise to address this uncertainty. (In some cases there may need to be an interim step between program and the formal initiation of PE: for example, $500,000 was set aside in the draft SYIP for a planning study of Route 288/360. That amount may or may not be enough for PE, because the study could recommend improvements costing anywhere between $45 M or $450 M—an order of magnitude difference. In short, that interim step advances the project to a "next level" of specificity but is appropriate in this case because there is an expectation that constructing the full project will eventually be funded.)

- Some unresolved questions have arisen over the years:

  - *Are we putting enough funds into PE to sustain a program*? The answer relates to the type of program we want to have-whether it is capacity-based or maintenance-based.
  - *Are the projects for which PE is done likely to be built*? It may be the case that we are spending too much on PE in the sense that we perform PE on projects that, realistically, may not be built because there is not enough CN available. This happened in the 1990s, where PE was performed and then later many projects were cut. This concern may return to the forefront given the forthcoming influx of transportation funds.
  - *How do we overcome constraints from funding types?* Not all monies are equally flexible. For example, a few years ago a three-lane bridge was rehabilitated; FHWA maintenance

money restrictions did not permit a capacity expansion; however, it has been observed that, had a fourth lane been added, the bridge would not be a congestion point.

- *Is it better to have expensive plans that eliminate all risk or cheap plans that have much risk?* There is a continuum—described as a "trumpet" (see Figure 1)—between plans that cost much to generate but which eliminate construction risk [e.g., presence of geotechnical difficulties] and plans which can be generated cheaply but which incur a risk of some alternative's cost being more than expected.

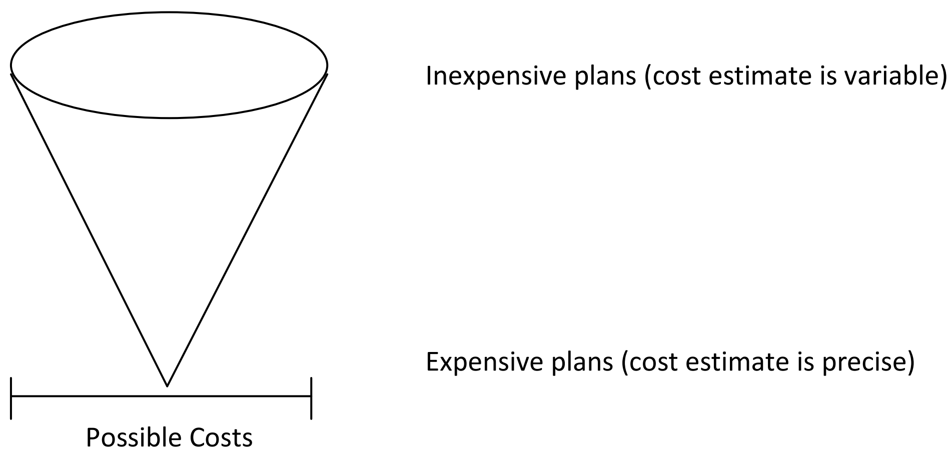


Figure 1. Trumpet Describing the Tradeoff Between Planning Costs and Risk. At the beginning of the project, the standard deviation of acceptable estimate variance should be wider than the bell of the trumpet. As a project develops over time, and more detail for design and requirements becomes available, that variance should becomes less and closer to the actual cost for the project, as represented by the mouthpiece of the trumpet).

- There are some conditions that influence how projects are managed:
  - Projects have multiple owners. For instance, localities are partial owners of revenue sharing projects, and the 50/50 match may encourage acceptance of projects that cannot necessarily be built for the funds available. This concern has arisen elsewhere: the City of Petersburg has asked VDOT to administered a NEPA study for a train station, where the funds available are $250,000 (one would expect the NEPA study to cost substantially more.)
  - Project managers have a lot of projects. It is not unusual for a project manager to have 20-25 projects at a given time, and as noted earlier there was at least one case where an individual had 80 projects ongoing.
  - There may be opportunities to learn lessons from either the private sector or localities in terms of how a project is specified. For example, suppose one has a "dangerous" at-grade intersection. A challenge is being able to quickly indicate the options available (e.g., add a stoplight, improve drainage, etc.) so that one can map the options to costs and determine which can fit within the project budget. By contrast, in the private sector—say an expansion of a grocery store chain—there is a well defined set of expectations for what will constitute the project. Some software tools (e.g., Primavera) may also be applicable. Localities' ability to execute contracts quickly (6 weeks vs. VDOT's 6 months) may also be worth studying.

Responses to Questions

1. Responses to question 1:

- PE does not end until the project is awarded; the figure would be correct if "advertisement" was changed to "award."
- A lot of ROW tasks that could legitimately be part of ROW are funded with PE because ROW tasks need to be open but charges cannot yet be placed in the ROW phase. Some functions can only be charged to ROW, such as negotiations, relocations, and condemnations. However, other ROW-related tasks (e.g., appraisals) may be funded under PE.
- Note that perhaps we should add a 4th phase called "Planning" which would precede these steps and would offer practical and paradigm benefits.

2. Yes to both questions. Note also that federal planning funds can be used to achieve 30% of final design.

3. The best answer is that uncertainty is reduced as one moves through the process as was shown with Figure 1.

4. For now, we have attached an Excel spreadsheet with Richmond district projects. We have marked any projects that are enhancement, district-wide, study-only, or ARRA. If there are any additional UPCs that should be excluded (e.g., because they are maintenance/operations projects funded with construction (603) allocations), please add a "1" to column G or just let us know. An example of this latter is UPC 84707, which was a bridge maintenance repairs that used SYIP construction funds)]. In response, the district did highlight a dozen or so lines that "appear" like projects but are actually cost-center type line entries (and not true projects).

(I've indicated the projects that I think you should STRIKE in the EXCEL file. I did not try to discern between different types of projects to determine which would be better than others………but I did highlight a dozen or so lines that "appear" like projects but are actually cost-center type line entries (and not true projects). I think you will want to strike those for sure.)

5. Keep in mind that each of these systems (e.g., the Project Pool, isyp, ipm, CEDAR, RUMS, and so forth) were designed to answer a specific question and they have since been melded together. Two obstacles to using this system of tools are that there is not a strict organizational convention and it is up to the individual district or project manager to decide which items to upload. For example, a scoping document is not required by VDOT for locally administered projects nor paving projects, but this district's practice is to complete such documents nonetheless. (It was also noted that years ago the district used project folders (e.g., right of way, environmental, and so on) with a consistent naming convention; such folders did help organize the material for each project.

6. For question **6a**, the short answer is that yes the data are available—but one must be aware of four limitations that influence how these data are interpreted:

   1. The PE costs for a project may be reflected in a different UPC for either of these reasons:
      - There is a child/parent UPC (e.g., UPC *x* for PE and UPC *y* for construction)

   - Sometimes a given UPC will have PE from more than one project (e.g., PE for projects *x* and *y* is charged to a single UPC)
2. The PE costs for projects where the work was done a while ago may not be completely valid—even if the close-out date is recent—because older projects can suffer from the following:
   - Before FMS 2, there was no PE for secondary projects, rather, all PE was charged to CN.
   - Proration, which ended in 2002, was used to varying degrees throughout VDOT, where some costs were charged to a statewide UPC and then those costs were charged to all UPCs that were open for charges. (Thus for projects from 1994 to 2002, the PE costs could be artificially low if a given project benefitted from this statewide UPC, or artificially high if the project tasks were never funded from the statewide UPC).
3. Related to item 2 but a distinct concern: when a project is open to charges but is delayed, there may still be a tendency to charge time to that project.
4. There may be some discrepancies that result from the use of non-archived projects or the use of special funding types.

Given these concerns, it would be better to analyze a large set of projects (e.g., all projects from the district) rather than a small set of projects (e.g., 5 or 50).

For question **6b**, in the past this district did look at PE costs programmatically, however, the Blueprint staffing reductions of 2009 eliminated many quality assurance and quality control staff who performed this function. (Twenty years ago VDOT had almost twice as many internal staff with a smaller program.) To be clear, the district does look at costs on a project basis—not to determine a percentage per se but rather to ensure that costs are within budget.

For question **6c**, the answer given by another district is also appropriate here: the question as asked is not meaningful, rather, the question should be "what type of program do you want?" One factor that would influence the use of such a percentage would be whether it would be used to form a hard, arbitrary rule (bad) versus whether it could offer a baseline that helps one spend less money to manage the program overall (good).

7. There are five possible exceptions.

- Prescoping funds allocated to each district.
- Staff who charge a significant amount of their time to administration may have charged some time to administration that could also have been instead charged to a given UPC.
- Some maintenance projects will have a separate UPC for PE.
- Some planning staff are 100% funded by TMPD but may put some time into PE.
- A best practice is to ensure PE costs are charged to the appropriate UPC. However, there can be cases where one UPC has PE for more than one project. For instance, suppose UPC *x* is between mileposts 1 and 4 below and has been authorized; suppose UPC *y* is between mileposts 4 and 10. It is possible that PE could be done for the entire section but all charged to UPC *x*.

8. In the future, the district expects to have a utility that will automatically produce a report that answers these types of questions based on the various financial systems (FMS 1, FMS 2, Cardinal) and for various project characteristics (including dead projects). That report is not yet ready for deployment;

it is being tested and may be completed in October of this year. Even when the utility is built, however, the more important aspect is not "what does the report contain" but better "what do we do with the information?" Thus the report will likely be used to help determine, for instance, which types of funds have not been spent (as different funding sources have different restrictions) and whether additional resources are needed to deliver the program. Two additional caveats to keep in mind while looking at projects are:

- There may be bundling of PE from multiple projects into a single UPC. For instance, in the City of Richmond, there is one UPC which contains all the PE for 10 separate CN-only UPCs.
- Better results may be obtained if one analyzes all of the projects in the district rather than selecting only a few projects for detailed study, because there may be some anomalies within the few projects that are selected.

9. Several characteristics should be <u>added</u>:

- *PE Duration* measured as up to three variables: length of time in years, changes in internal stakeholders, and changes in external stakeholders (e.g., number of election cycles). Even 2.9 years can reflect a change in will, opinions and desires, and keep in mind that while an engineer might think of a 75 year bridge life cycle, and election life cycle can be 2 to 4 years. This is a reminder that the technical work product is evaluated in a political environment.
- *Management of the project*—which could be defined as any of these alternatives: (1) managed by this VDOT district; (2) managed by another VDOT district; (3) managed by Central Office; (4) consultant hired by VDOT; (5) locally administered; (6) locally administered with a consultant. Some judgment is needed in defining these categories. For instance, consider category (4)—VDOT with a consultant. Richmond District has recently hired a district on-call consultant, which gives the consultant an incentive to do this project well in order to be retained for future projects. [This might differ from a case where a consultant was hired as a one-time project manager with no firm expectation of future projects.] The delineation of categories (1) and (2) results accounts for the possibility that one tends to manage projects better if one is physically closer to it.
- *Regional significance* (measured as yes/no) as a yes answer means conformity, TIP/STIP, and related requirements will increase costs.

Some characteristics should be <u>dropped</u> in the sense that their additional detail may not explain PE costs as much as the variables noted above. An example of such a characteristic is the bike/ped accommodations.

Finally, consider the following points when developing a model:

- o *A parametric cost estimate (e.g., PE should cost 12% based on a certain data set) may or may not be desirable*. It can be desirable if used properly. Unfortunately, too often we want to use parametric estimates to judge whether or not an estimate is acceptable—a situation which arises because most decision-makers don't have anything more, different, or better with which to judge the accuracy or quality of the estimates they are given.   An alternative is to build a "bottom-up" model where one estimates costs based on certain characteristics (e.g., include x costs for overhead, y costs for environmental, and so forth). Note also that perhaps a better measure of "quality" would be to compare initial estimates with final estimates over time.

- o *It may be possible to estimate costs from the budget constraints, in that in a given year one knows for cert*ain what payroll costs will be and one has some estimate of what will be spent on consultants. In a larger sense, the critical question may be not what are the financial costs but what are the opportunity costs that are missed?
- o *The data may be helpful or they may be harmful*. Data can be helpful if one can use them to develop probing questions that lead to a better estimate. (For example, a project manager who carries 80 projects has, in a given month with some uncompensated overtime has about 200 hours, about 2.5 hours per project per month. Thus if this manager forecasted her or his costs for a single project were 1200 hours over a six month period—rather than 15 hours—one would at least want to ask why. Data can also be helpful if they are based on historical patterns if those patterns can be expected to repeat in the future (e.g., revenue sharing projects have *x* impact on PE costs). Data can be harmful if one is not fully aware of the limitations noted in response to question 6. Key examples would be failure to recognize limitations of earlier projects (e.g., prior to 2002, proration would have influenced PE estimates), the use of a very small sample of projects, or using only a single UPC when in fact PE was spread across multiple UPCs.

APPENDIX B

VERIFICATION OF MODELS

Both the program-level models (Models 1 through 4) and the project-level models (Models 5 through 11) required assumptions that were in part based on regression and that were in part based on this particular data set. This appendix provides the results of verifying these assumptions. In addition, program-level Models B1-B6 are described.

Program-Level Models

Analysis of District PE Percentages Without Annual Variation (Models 1-4)

For Models 1 through 4, which had only nine values for the dependent variable, three assumptions were of interest: that the parameters identified in the model have a practical interpretation, that nonconstant variance is avoided, and that the residuals are normally distributed.

Examination of the parameters yielded a concern with Model 4: given that the average PE percentage runs from about 11% to 21%, the large intercept (10.1%, $p = 0.13$), despite there being three other independent variables, may indicate that much of the explanatory power remains in the intercept and not in the independent variables. Although not necessarily a fatal flaw, given the existence of other models with smaller intercepts makes Model 4 became less attractive than Models 1 through 3. Model 1 also has a large and statistically significant intercept; however, given just one independent variable that essentially serves as a linear reduction, Model 1 was retained as a candidate. For Models 1 through 3 and for all variables shown in all four models, it is encouraging that the signs of the independent variables did not change and are consistent with theory: the percentage of expenditures spent on large projects (Variable 1c) and the percent of expenditures spent on minimum-plan and no-plan projects (Variable 2a) should reduce the amount spent on PE (and thus be negative), and the percentage of projects in the development phase (Variable 12c) should increase the amount spent on PE and thus should be positive. The correlations of these independent variables are all below 0.50: they are 0.30 (Variables 2a and 12c), 0.39 (Variables 2a and 1c), and 0.44 (Variables 1c and 12c).

To check for nonconstant variance of the residuals (heteroscedasticity), a test suggested by Newbold (1988) was performed, where, using the square of the residual as the dependent variable and the predicted value as the independent variable, a new regression is performed and the quantity nR^2 is estimated, which for Model 3 was $(n = 9)(R^2 = 0.033) = 0.297$. The test is that if this value does not exceed the appropriate Chi-square variable (which is 2.71 given a 10% level test and 1 degree of freedom), the data are not heteroscedatic. According to this test, Models 1, 2, and 4 were also not heteroscedatic.

Another regression assumption is that the errors are normally distributed; e.g., a Q-Q plot would ideally show a straight line for the residuals plotted against their standard normal quantiles; such a plot for Model 2 is shown in Figure B1. A test suggested by Johnson and Wichern (2002) is to compute the correlation coefficient for the standard normal quantiles (e.g., where the residuals would lie if they were perfectly normally distributed) and the actual points where the residuals lie. For n = 9, interpolation shows that the correlation coefficient should be above 0.9116 for normality to be presumed at the 5% significance level; the actual correlation is 0.9839 (Model 2), 0.9703 (Model 3), 0.9498 (Model 1), and 0.9746 (Model 4). Thus the models meet this criterion, which is more evidence that they are robust from a statistical standpoint.

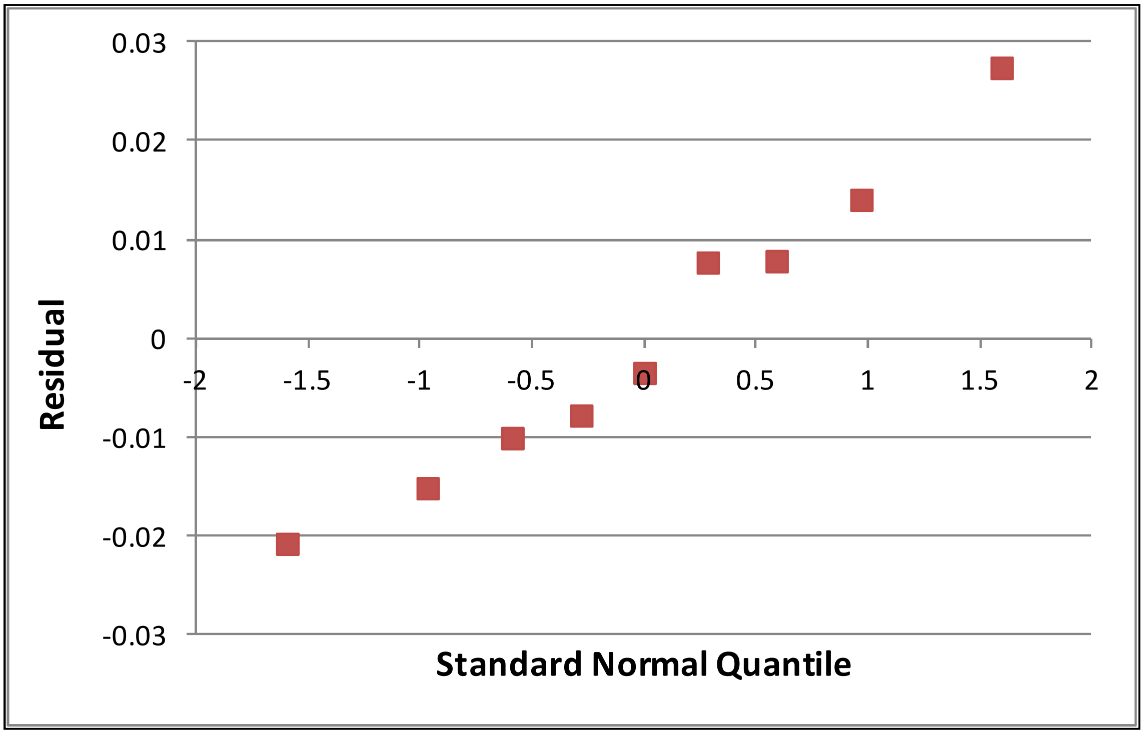


Figure B1. Plot of Residuals for Model 2 Against Their Standard Normal Quantiles

Analysis of District PE Percentages With Annual Variation (Additional Program-Level Models B1-B6)

Table 8 in the body of the report showed that three variables explain a large proportion of the variance in the PE percentage by district. However, it was not clear whether annual variation could also be explained by these or other variables. To address fully Question 4 in the "Purpose and Scope" section of the report—which characteristics explain the variation in PE by fiscal year—annual variation was considered.

With 9 years of data and 9 districts, there are 81 values of the dependent variable—the percentage of funds spent on PE in each district each year. A key question is whether any of the variables shown in Table 7, besides district and year, further explains the variation in these PE percentages. Although it is tempting to perform an ordinary least squares regression using 81 rows of data without inclusion of district and year, there are two weaknesses of such an approach—one practical and one statistical.

The practical concern is that one might simply overfit the model with too many independent variables. For example, for this particular data set, it was possible to develop a model that included Variables 10d and 10e as significant—which would appear undesirable, given that both of these variables measure the percentage increase in the SYIP, albeit in different ways; in fact, these variables are highly correlated (0.977). Thus both (1) correlations among the independent variables and (2) similarity in their meaning were considerations.

A subset of this concern is that some of the promising independent variables—those that initial experimentation showed might be associated with the PE percentages—might be correlated with the district. For example, Variable 1a—the average cost of each UPC—tends to be higher in some districts than in others (e.g., the expenditure per UPC was 3.7 times higher in the Northern Virginia District than in the Culpeper District). In fact, the district explains 63.5% of the variation in Variable 1a. This concern does not mean that the variable or the district is useless, but it does mean that one needs to determine whether the independent variables offer any explanatory power beyond what is provided by the district variable.

A statistical concern is that regression presumes there is no correlation among the error terms—and one cannot assume that there is no correlation from year to year. This concern was later addressed by modifying the model, as appropriate, based on detected autocorrelated errors.

Model development used the SPSS General Linear Modeling procedures and took place in three stages: development of a baseline model with district and year alone (Model B1), the addition of other explanatory variables (Models B2 and B3), and subsequent testing to determine whether these additional variables by themselves were appropriate (Models B4, B5, and B6).

Development of a Baseline Model: Models B1 and B3

Model B1, which uses only year and district as binary independent variables, was developed, and the district coefficients are shown in Table B1. For example, the binary district variable would have a value of 1 for the Bristol District and a value of 0 for the other eight districts. The Staunton District had the lowest average PE percentage; if this percentage is used as a baseline, district variables that were significantly different from that of the Staunton District were usually those districts with a substantially higher mean PE percentage, such as the Bristol (mean PE percentage of 18.3%), Culpeper (mean PE percentage of 21.3%), Fredericksburg (mean PE percentage of 17.4%), and Salem (mean PE percentage of 17.3%) districts. Model B1 explained 25.3% of the variation in the 81 PE percentages (Table B1).

Table B1. Program-Level Coefficients of VDOT District Parameters for Models B1, B2, and B3[a]

District	Model B1 Coefficient (p-value)	Model B2 Coefficient (p-value)	Model B3 Coefficient (p-value)
Bristol	0.070 ($p = 0.03$)	0.056 ($p = 0.02$)	0.054 ($p = 0.02$)
Culpeper	0.100 ($p < 0.01$)	0.078 ($p < 0.01$)	0.082 ($p < 0.01$)
Fredericksburg	0.061 ($p = 0.05$)	0.033 ($p = 0.19$)	0.032 ($p = 0.20$)
Hampton Roads	0.017 ($p = 0.57$)	0.061 ($p < 0.01$)	0.056 ($p < 0.01$)
Lynchburg	0.003 ($p = 0.92$)	0.036 ($p = 0.16$)	0.021 ($p = 0.34$)
Northern Virginia	0.055 ($p = 0.07$)	0.128 ($p < 0.01$)	0.127 ($p < 0.01$)
Richmond	0.006 ($p = 0.85$)	0.004 ($p = 0.83$)	0.010 ($p = 0.62$)
Salem	0.061 ($p = 0.05$)	0.045 ($p = 0.03$)	0.053 ($p < 0.01$)
Staunton	0 (baseline)	0 (baseline)	0 (baseline)

[a] Models B1, B2, and B3 give the PE percentage for a given district and year based on district parameters (shown), year parameters for 2004-2012 inclusive (not shown), and an intercept.

Addition of Other Explanatory Variables: Model B2

Model B2 was developed through a trial-and-error approach of examining which groups of variables were statistically significant in terms of predicting the PE percentage. Six promising independent variables that had no intercorrelations above 0.5 and that appeared to explain additional variation in the PE percentage were identified. Except for Variable 1a as noted previously, the amount of variation in each promising independent variable that is explained by the district was modest: district explained virtually none of the variation (27.2% or less) for Variables 1c, 5, and 6, and for Variables 12c and 7b, district explained 40.1% and 48.1% of the variation, respectively.

A general linear model (not to be confused with a generalized linear model) showed that five independent variables other than district and year were statistically significant and explained some of the variation in the annual district PE percentages: average project cost (Variable 1a), percent of expenditures for large projects (Variable 1c), percent of expenditures for study-only projects (Variable 5), percent of expenditures for ARRA projects (Variable 6), and percent of expenditures for projects that were non-typical (Variable 7b). These coefficients are reported as Model B3 in Table B2, and the district coefficients are reported as Model B3 in Table B1.

In four of the nine districts, inclusion of these five additional independent variables altered the significance of the district variables shown in Table B1. For example, for the Fredericksburg District, with an average PE percentage of 17.4%, the district variable changed from being significantly different from that of the Staunton District (in Model B1) to not being significantly different (in Model B3). A reason for this is found by examining the newly added independent variables to Model B3, such as the percent of funds for studies only (Variable 5). The Fredericksburg District had the highest average value for this variable, which according to the coefficient in Model B3, would explain the higher amount spent on PE for the Fredericksburg District, rather than the district itself. By contrast, for the Salem District, which had no funds expended for studies only, the PE percentage would tend to decrease according to this model. According to Model B3, the fact that the average project cost for the Fredericksburg District is 83% higher than that for the Salem District would suggest that the PE percentage for the Fredericksburg District would tend to decrease, as shown by the coefficient for Variable 1a.

As shown in Table B2, the addition of five independent variables meant that 70.5% of the variation was explained, compared to Model B1 that explained 25% of the variation in PE expenditures. Model B3 does not include Variable 12c (percent of projects in the development phase) because this variable was not significant ($p = 0.25$) in the model as constructed. However, if one were to exclude the district, Variable 12c does become significant ($p = 0.02$). Thus the percent of projects in the development phase is associated with the PE percentage but so is the district. All other variables are significant even when the district and the year are included in the model.

Subsequent Model Testing: Models B4-B6

Additional analysis, reflected in Models B4, B5, and B6, was performed to interpret the regression results in terms of influence of independent variables (Model B4), role of autocorrelation (Model B5), and importance of the constant (Model B6).

Model B4, an almost-final model, was generated without the district and the year as explanatory variables in order to detect the extent to which the other independent variables alone could explain variation. As noted previously, one variable—percent of projects in the development phase (Variable 12c)—is associated with individual districts. In addition, one variable—the percentage of expenditures spent on ARRA projects (Variable 6)—is associated with the individual years. The reason for this assertion is that although year explained virtually none (17.3% or less) of the variation in five of the promising variables (Variables 1a, 1c, 5, 7b, and 12c), year explained 70.8% of the variation in Variable 6. This relationship was expected because ARRA projects were not available until the last 3 years of the study period (2010-2012). However, given that Variable 6 has the expected sign and that *higher* PE percentages were generally observed in 2010 and 2012 when ARRA spending began, it appears that the ARRA variable, which correctly is associated with lower PE percentages, is offering explanatory power in the model, with its sign and magnitude comparable to that given in Model B3. To the extent that ARRA projects are "shovel ready" (Interview FR1), one would expect them to have lower PE costs than projects that were not shovel ready.

Model B5 was developed to address autocorrelation. For Model B4, the lag 1 autocorrelation (e.g., the correlation between residuals for a given year e_t and the preceding year e_{t-1}) appeared nominally low (0.25); however, the Durbin-Watson statistic, computed in Excel as shown in Equation B1, yielded a value of 1.20, suggesting autocorrelation when compared to the test statistic of 1.362 (for K = 6 independent variables at the $\alpha = 0.01$ confidence level and for n = 85 (Savin and White, 1977). Accordingly a procedure suggested by Newbold (1988) was followed to remove this autocorrelation. This procedure entails computing the sample autocorrelation r as 1 – d/2 (where d was defined in Eq. B1); computing new independent and dependent variables based on the relationship $x_t = x_t - rx_{t-1}$ (where x_t is the variable for a given year and x_{t-1} is the same variable for the prior year); performing a new regression with the new x_t values; and reporting the new results, except the intercept term is also adjusted by dividing the intercept from the new regression by the amount 1– r). All parameters were statistically significant except for Variable 12c ($p = 0.15$), which had a coefficient of 0.201—which was almost identical to the value in Model B4. Thus the model was re-estimated without Variable 12c, and the results are reported as Model B5 in Table B2. Because Model B5 addresses autocorrelation, it does not make full use of the first year (2004) data.

$$d = \frac{\sum_{t=2005}^{t=2012} (e_t - e_{t-1})^2}{\sum_{t=2004}^{t=2012} e_t^{\,2}} \qquad \text{[Eq. B1]}$$

where

d = Durbin-Watson statistic
e_t = residual for year t.

Model B6 was developed to determine the impact of the constant. Model B5 is the final model in the sense that it indicates the extent to which these parameters explain the variation without the district and the year: these other independent variables on their own would appear to explain about 52.0% of the variation. This is roughly consistent with the change from Model B1 to Model B3, where the addition of independent variables explained an additional 45% of the variation in PE percentages. However, a concern with Model B5 is the relatively large constant value. To confirm that the independent variables are meaningful without this constant, a model was estimated from the same data set as that used for Model B5 except the intercept was removed. The results showed that the independent variables are significant if Variable 12c is included; if it is excluded, Variable 6 is insignificant with a *p*-value of 0.22. The independent variables have the same sign as those shown for Model B5. The coefficients have similar signs and orders of magnitude for Models B3, B4, B5, and B6, suggesting that the various assumptions in each of these models do not materially alter the interpretation of the independent variables.

To determine the practical significance of these findings, one may first assume that the project size and amounts spent on large projects (e.g., Variables 1a and 1c), project type (e.g., ARRA projects as Variable 6), and excluded projects (Variable 7b) are beyond a district's control. The median value for a district's percent of expenditures for study-only projects (Variable 5) by year and district was 0.0011. According to Model B5, which has a coefficient of 1.377 for this variable, a district that had the median percentage of expenditures in study-only projects would have seen its PE percentage rise by approximately (1.377)(0.0011) = 0.15%. Because the highest value for Variable 5 was 0.295, according to Model B5 it is theoretically possible that study-only projects could have been responsible for as much as (1.377)(0.295) = a 40.6% swing in PE expenditures for a given year. However, the second and third highest values for Variable 5 were 0.180 and 0.109, respectively; in fact, of 81 possible values, the ninth highest value (0.022) would have corresponded to a (1.377)(0.022) = 3% swing in PE expenditures.

Table B2. Program-Level Models B1-B6 for Explaining Variation in District and Year Preliminary Engineering Percentages

Model	Adj. R^2	Constant	Average Project Cost (Variable 1a) ($x\ 10^{-8}$)	Percent of Expenditures Spent Each Year on Large Projects (Variable 1c)	Percent of Expenditures for Study-Only Projects (Variable 5)	Percent of Expenditures for ARRA Projects (Variable 6)	Percent of Expenditures for Excluded Projects (Variable 7b)	Percent of Projects in Development Phase (Variable 12c)
B1[a]	0.253	0.147 ($p < 0.01$)	--	--	--	--	--	--
B2[a]	0.707	0.193 ($p = 0.03$)	-13.31 ($p < 0.01$)	-0.177 ($p = 0.04$)	0.830 ($p <.01$)	-0.289 ($p = 0.01$)	0.102 ($p = 0.02$)	0.144 ($p = 0.25$)
B3[a]	0.705	0.277 ($p < 0.01$)	-13.43 ($p < 0.01$)	-0.154 ($p = 0.02$)	0.808 ($p <.01$)	-0.276 ($p < 0.01$)	0.094 ($p = 0.03$)	
B4	0.522	0.178 ($p < 0.01$)	-6.213 ($p < 0.01$)	-0.338 ($p < 0.01$)	0.825 ($p <.01$)	-0.211 ($p < 0.01$)	0.128 ($p <.01$)	0.203 ($p = 0.02$)
B5	0.520	0.383 ($p < 0.01$)	-11.63 ($p < 0.01$)	-0.429 ($p < 0.01$)	1.377 ($p <.01$)	-0.404 ($p < 0.01$)	0.168 ($p = 0.01$)	
B6	*b*	--	-10.07 ($p < 0.01$)	-0.376 ($p < 0.01$)	1.407 ($p <.01$)	-0.372 ($p < 0.01$)	0.204 ($p < 0.01$)	0.479 ($p < 0.01$)
Minimum and maximum values for each independent variable[c]			221,552 1,959,132	0.263 0.838	-0.012[d] 0.295	0.000 0.351	0.148 0.983	0.508 0.841

[a] Models B1, B2, and B3 also included terms for each district and each year, and these terms were statistically significant ($p < 0.02$). The terms for the district are shown in Table B1.

[b] For Model B6, the adjusted R^2 of 0.819 is not shown because it is not appropriate to compare models with and without an intercept term. For example, had Model B1 been executed without an intercept, its adjusted R^2 would have been 0.858.

[c] The district where and the year when the minimum and maximum values for each variable were observed are as follows: Variable 1a (Salem 2007, Northern Virginia 2009); Variable 1c (Fredericksburg 2011, Fredericksburg 2006); Variable 5 (Fredericksburg 2011, Fredericksburg 2009); Variable 6 (all districts prior to 2010, Lynchburg 2011); Variable 7b (Culpeper 2005, Northern Virginia 2004); Variable 12c (Lynchburg 2004, Culpeper 2007).

[d] The negative value appears to result from Project 77616 where a negative expenditure was reported; all other values were zero or positive.

Impact of Other Definitions on the Program-Level Models

Two other modifications to the variables did not appear to affect the results materially. One modification was to define the dependent variable as PE divided by PE, RW, CN, and funds in the "Other" or "Incidental" category in case inclusion of such funds, although seemingly small, could affect the results. Examination of a few UPCs suggested that such funds could refer to a variety of services; for example, for UPC 72066, funds placed in the Incidental category referred to activity codes 536 and 563 (plant mix treatments and pipe entrances across culverts, respectively). For UPC 74042, activity code 63103 was used (protective measures for temporary facilities). For UPC 77136, activity code 930 was used (default activity to be used for administration projects).

When Models 3 and B2 were run with this new dependent variable, however, the results did not change substantially in that all significant variables remained significant and the magnitudes and signs of the coefficients were similar. For example, re-execution of Model 3 with this new dependent variable changed the coefficient for Variable 1c from -0.278 to -0.276 and changed its significance level from $p = 0.030$ to $p = 0.032$. When the same variable was included in Model B2 (which initially included Variable 12c, later dropped from the model to yield Model B3), the coefficient changed from -0.177 to -0.176 and its *p*-value changed from 0.020 to 0.021.

A second modification was to alter Variables 9a, 9b, and 9c (total balance, 5-year balance, and out-year balance) such that they were divided by the current SYIP expenditures. For example, whereas previously Variable 9a was defined as the total balance in the SYIP (e.g., the funds needed to complete the program in future years), Variable 9a was modified to be this total balance divided by the SYIP allocation for the current year. The reason for this modification was to detect if normalizing these variables would influence their explanatory power. However, these modified Variables 9a, 9b, and 9c were insignificant when compared to the terms used in Models 3 and B2. In Model B2, modified Variable 9a had a *p*-value that was not significant but very close the conventional significance threshold: $p = 0.054$ with the modified dependent variable or $p = 0.052$ with the original dependent variable. Modified Variable 9a had a modest impact on the amount of variation explained (72.1% when the variable was included compared to 70.7% when the variable was not included). Although modified Variable 9a was significant in Model B3 ($p = 0.04$), it was not significant ($p = 0.89$) when the district and year terms were removed, as shown in Model B4.

A third modification, relative to Models 1 through 4, was to compute the independent variables as ratios such that they reflected a pooled percentage, rather than an average of annual values. For example, rather than computing Variable 2a as the average of the annual percent of expenditures on minimum-plan or no-plan projects, it was computed as the ratio of the sum of all expenditures on such projects divided by the sum of all expenditures. When the modified Variables 1c, 2a, and 12c were directly entered into a regression model used to predict the (ratio-based) district PE percentage, the results were similar to those for Model 4 in that Variable 1c was not significant ($p = 0.25$) and Variables 2a and 12 were significant ($p < 0.01$) and had the same sign as they did in Model 4. When a new regression model based only on modified Variables 2a and 12 was developed, the model explained less of the variation (76.5%) compared to 89.9% which had been explained by Model 4. Further, in this new regression model, the coefficient for Variable 2a (-0.828) had a similar magnitude to that of Model 4 (-0.869), and the coefficient for Variable 12 (0.612) had a similar magnitude to that of Model 4 (0.497). Both variables were significant ($p < 0.01$).

In this third modification (where independent variables were computed as ratios such that they reflected a pooled percentage), forward regression rather than stepwise regression was used—that is, the researcher directly placed three variables into the model and then determined which ones were significant. However, had a stepwise regression model been executed—one where all variables shown in Table 7 in the report were considered candidate independent variables—three different independent variables would have been selected for the model: Variable 3 (with a positive coefficient, meaning that as the number of enhancement projects increases so does PE); Variable 7a (with a positive coefficient, meaning that as the number of projects identified by district staff as non-typical but otherwise considered to be typical based on Variables 2 through 6 increases so does PE); and Variable 2b (with a negative coefficient, which, consistent with Variable 2a, would mean that expenditures for projects without a construction job would be associated with lower PE). It is not clear why these variables were significant when computed as a ratio except to say that there was variation by year (for example, the amount spent on enhancement projects in 2011 was 2.4 times that spent in 2010).

Verification of Project-Level Models 7, 9, and 11

Although a variety of assumptions is inherent in any model, seven principal assumptions affected the models used to predict project-level costs as discussed in this report: (1) linearity of the relationship between dependent and independent variables; (2) independence of the errors; (3) homoscedasticity (constant variance); (4) normality of the error distribution; (5) verification that coefficients are reasonable; (6) impact of forecasting independent variables; and (7) interpretation of the Type 2 error. The first four assumptions relate directly to the use of linear regression, where their violation could render forecasts, confidence intervals, and insights less useful. If the fifth and sixth assumptions are violated, the model may not be applied in practice. The seventh assumption governs how non-significant differences between models are interpreted.

The first five assumptions were tested for all models but are highlighted for Models 7, 9, and 11 because these three models appeared promising based on the results shown in Table 23 in the report. The last two assumptions are highlighted for Model 7.

Assumption 1. Linearity

To understand the relationship between dependent and independent variables, it is important to look at the plot of the observed versus predicted values and the plot of regression residuals versus predicted values. For the former, the data should be should be symmetrically distributed around a diagonal line; for the latter, the data should be symmetrically distributed around a horizontal line.

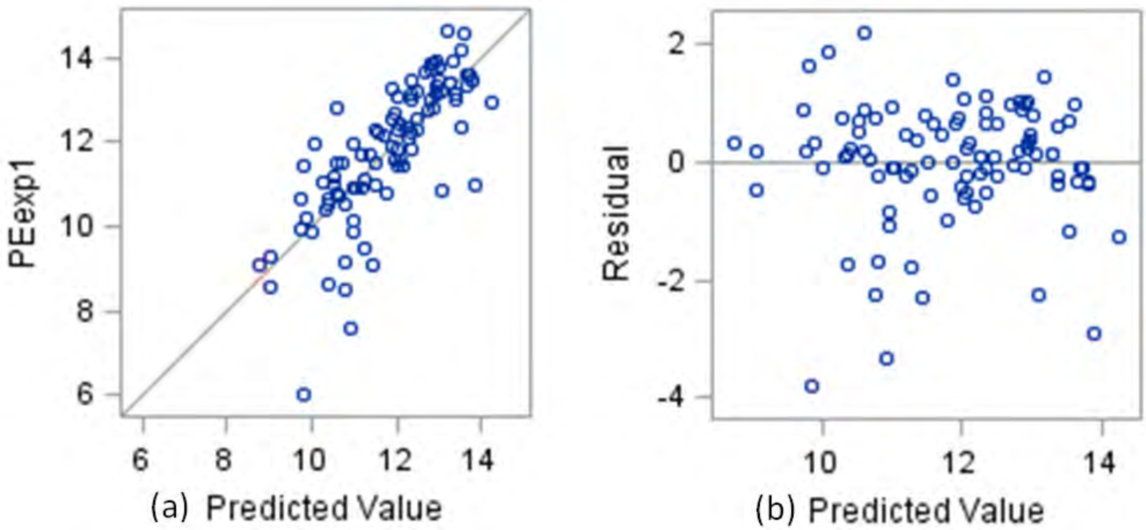


Figure B2. (a) Observed vs. Predicted Values, (b) Residuals vs. Predicted Values

For Model 7, Figure B2(a) shows the observed vs. predicted values. The data are generally balanced around the regression line. Figure B2(b) shows the residuals vs. predicted values. In this plot, the data are symmetrically distributed around the horizontal line, proving that there is a linear relationship between dependent and independent variables. The results for Models 9 and 11 are similar, suggesting a linear relationship between dependent and independent variables.

Assumption 2. Independence of the Errors

The correlation coefficient quantifies the degree of linear association between two variables. Table B3 shows that the highest correlation is between the dependent variable of PE expenditures and an independent variable: the construction estimate (0.61). Such a correlation is not problematic and is in fact expected given the use of the construction estimate to forecast PE expenditures. The correlations of interest are those between the pairs of independent variables; the highest such correlation was between RW and VDOT (0.50). The correlations between the binary variables CE, PCE, and EA are not a concern because these jointly define the environmental factor.

Table B3. Correlation Between Variables in the Project-Level Models

Variable	PE	CN	Duration	VDOT	Length	ROW	CE	PCE	EA
PE	1.00	0.61	0.46	0.50	0.08	0.53	0.45	-0.26	-0.05
CN	0.61	1.00	0.31	0.35	0.39	0.33	0.39	-0.35	-0.08
Duration	0.46	0.31	1.00	0.13	0.14	0.19	0.19	-0.05	-0.01
VDOT	0.50	0.35	0.13	1.00	0.22	0.50	0.34	-0.26	0.08
Length	0.08	0.39	0.14	0.22	1.00	0.02	0.12	-0.15	-0.02
RW	0.53	0.33	0.19	0.50	0.02	1.00	0.33	-0.34	0.10
CE	0.45	0.39	0.19	0.34	0.12	0.33	1.00	-0.74	-0.06
PCE	-0.26	-0.35	-0.05	-0.26	-0.15	-0.34	-0.74	1.00	-0.13
EA	-0.05	-0.08	-0.01	0.08	-0.02	0.10	-0.06	-0.13	1.00

PE = preliminary engineering; CN = construction; Duration = duration (years); VDOT = administered by the Virginia Department of Transportation; Length = length in miles; RW = right of way; CE = categorical exclusion; PCE = programmatic categorical exclusion; EA = environmental assessment.

A second method to show independence of the errors begins with a model that has only one independent variable, where one tracks how the *p*-values and adjusted R^2 values change as additional variables are included. Table B4 shows how the adjusted R^2 value changes as additional variables are added to Models 7 and 9. The *p*-values did not increase; therefore, there is not a high correlation between the variables. The adjusted R^2 did increase with the smallest increment of about 2% between iteration 2 and 3. For Model 9, the *p*-value for duration decreased between the second and third iteration but increased slightly between the third and fourth iteration. In the fifth and final iteration, the *p*-value for duration was 0.0646. The adjusted R^2 increased the most between the third and fourth iteration when a variable indicating whether or not the project was administered by VDOT was added to the model.

Table B4. Models 7 and 9: Progression Based on Addition of Independent Variables

	Model 7			**Model 9**		
Iteration	**(Non-Linear)**	**p-value**	**Adjusted R^2**	**(Non-Linear)**	***p*-value**	**Adjusted R^2**
1	CN Estimated	<0.0001	0.36	CN Estimated	<0.0001	0.36
2	CN Estimated Duration	<0.0001 0.0004	0.44	CN Estimated Duration	<0.0001 0.1366	0.37
3	CN Estimated Duration Length	<0.0001 0.0002 0.0156	0.46	CN Estimated Duration Length	<0.0001 0.0140 0.0606	0.40
4	CN Estimated Duration Length VDOT	<0.0001 <0.0001 0.0019 <0.0001	0.57	CN Estimated Duration Length VDOT	<0.0001 0.1012 0.0026 <0.0001	0.50
5	CN Estimated Duration Length VDOT CE	<0.0001 0.0001 0.0025 <0.0001 0.0499	0.58	CN Estimated Duration Length VDOT CE	<0.0001 0.0646 0.0031 0.0003 0.0243	0.52

CN = construction; Duration = duration in years; Length = length in miles; VDOT = administered by the Virginia Department of Transportation, CE = categorical exclusion

Assumption 3. Homoscedasticity

Common graphical methods for detecting heteroscedasticity are the plots of the residuals versus independent variables. Heteroscedatic plots will have the magnitude of the errors increase, showing that the errors are not constant. Homoscedatic plots will have no systematic relationship between the residuals and independent (or dependent) variables.

The residuals should cluster near the horizontal line with some above and some below in a random pattern. The construction estimate residual plot (CN1) is the most random and shows a heteroscedatic relationship. The other independent variable plots are not as random and may suggest that there is some heteroscedasticity, where the error terms do not all have the same variance.

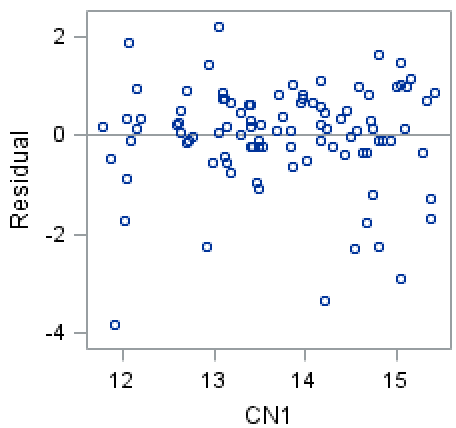


Figure B3. Residual vs. Construction (CN) Estimate

To check for nonconstant variance of the residuals (heteroscedasticity), aside from the graphs, a test suggested by Newbold (1988) was performed where using the square of the residual as the dependent variable and the predicted value as the independent variable, a new regression is performed and the quantity nR^2 is estimated, which for Model 7 was (n = 97)(R^2 = 0.02) = 1.95. The test is that if this value does not exceed the appropriate Chi-square variable (which is 2.71 given a 10% level test and 1 degree of freedom), the data are not heteroscedatic with respect to the dependent variable. Models 9 and 11 were similarly not heteroscedatic with nR^2 quantities of 0.75 and 0.48, respectively.

Assumption 4. Normality of the Error Distribution

Another regression assumption is that the errors are normally distributed; e.g., a Q-Q plot would ideally show a straight line for the residuals plotted against their standard normal quantiles; such a plot for Model 7 is shown in Figure B4. Different patterns suggest residuals have excessive skew or kurtosis. A test suggested by Johnson and Wichern (2002) is to compute the correlation coefficient for the standard normal quantiles (e.g., where the residuals would lie if they were perfectly normally distributed) and the actual points where the residuals lie. The correlation coefficient for both Model 7 and Model 9 is 0.95 and for Model 11 is 0.96. The critical value point for the Q-Q plot correlation coefficient test for normality (for n = 97 and a = 0.05) is 0.9873. This test suggests that the residuals for all three models are not normal. This places greater importance on using the results of the models' performance with the *testing* data set to determine the model's performance.

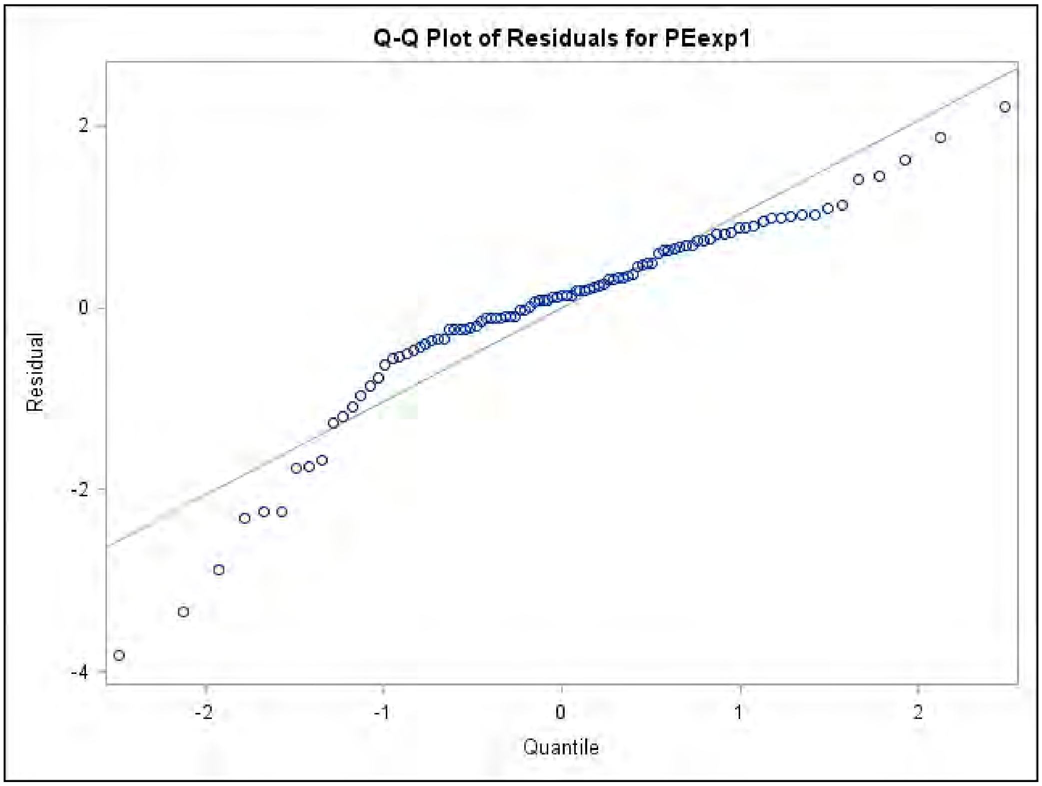


Figure B4. Q-Q Plot of Residuals for Model 7

Assumption 5. Reasonableness of the Coefficients

Model 7 was used to examine the reasonableness of the coefficients, meaning whether the coefficient signs were in the direction one would expect and of a reasonable magnitude. As discussed here, the environmental coefficient is surprising, the VDOT coefficient is plausible, and the duration coefficient is logical.

The project with the median CN estimate ($691,240) was used to examine the environmental coefficient. Model 7 predicted the PE estimate to be $296,475 for a project that was 4.6411 years long, was 0.233 miles long, required a CE environmental document, and was administered by VDOT. By changing the environmental work from being eligible for CE to not being eligible for CE, the PE estimate decreased by 40% to $173,584. This is surprising because the CE is generally not considered as expensive as other environmental requirements such as an environmental impact statement (EIS), EA, or PCE.

For the same project and also for Model 7, changing the VDOT variable to indicate the project was not administered by VDOT decreased the PE estimate by 65% from $296,475 to $103,539. The fact that non–VDOT administered projects would have lower PE costs was consistent with the interviews (Interviews HR7 and NV9), although as shown in Figure 7, projects not administered by VDOT had higher PE costs as a basket. These results are not necessarily inconsistent, as the interview comments referred to specific projects and Figure 7 refers to them collectively.

Because the duration variable can take a range of values (rather than being limited to values of 0 or 1 that are associated with binary variables such as VDOT), one approach to assess its impact is to examine how changing duration from its maximum to minimum observed value influences the PE estimate. For example, for projects under $5M, the project with the longest duration is 11.25 years. The actual PE Expenditure and CN Estimate were $454,229.46 and $1,245,000, respectively for this particular project; also, it was 0.386 miles in length, administered by VDOT, and required a CE environmental review. Thus its PE cost was forecast to be approximately $567,223. When the duration was changed to the lowest duration in the *testing* data set, i.e., 0.3068 years, the PE estimate was reduced by 69% to approximately $177,368. For Model 9, when the duration for the project was similarly changed from the longest to the shortest duration, the PE estimate decreased by 43%. For Model 11, a change from the longest to the shortest duration decreased the PE estimate by 67%. Table B5 shows the influence of duration on the PE estimates for Models 7, 9, and 11.

Another sensitivity test for the duration coefficient is to examine how the PE estimate changes if duration is increased by 10%. For Model 7, for the same project described previously, if the duration is changed to the mean duration of 3.75 years, the PE estimate will be $397,866. A 10% increase in duration to 4.125 years increases the PE estimate by 3%. For Model 9, a 10% increase in duration increases the PE estimate by 2%. For Model 11, a 10% increase in duration increases the PE estimate by 3%.

Table B5. Influence of Duration on Project-Level Models 7, 9, and 11

Duration	Model 7 PE Estimate	% Difference	Model 9 PE Estimate	% Difference	Model 11 PE Estimate	% Difference
High (11.25 yr)	$567,223	-69	$555,859	-43	$497,494	-67
Low (0.3068 yr)	$177,368		$318,395		$162,014	
Average (3.75 yr)	$397,866	3	$379,397	2	$353,308	3
10% increase (4.12 yr)	$410,295		$386,710		$363,954	

PE = preliminary engineering.

Assumption 6. Ability to Forecast Independent Variables

There is one independent variable that must be forecast when using Model 7: the project duration. Additional tests to account for the impact of not knowing this duration at the time of project scoping were conducted. The accuracy was computed for Model 7 using four scenarios: (1) the actual post-project duration (as if the user could forecast this duration perfectly); (2) the average duration; (3) a correct estimate of whether the duration would be long or short; and (4) an incorrect estimate of whether the duration would be long or short.

Table B6 shows the accuracy of the model using the four scenarios. Surprisingly, when the user uses the average duration (scenario 2) or the correct high or low estimate (scenario 3), the average absolute error is nominally lower than when the exact duration is used (scenario 1). That is, in the testing data set, the extra information was not nominally helpful. However, as expected, forecasting a high duration for a project that really had a low duration or vice-versa (scenario 4) yielded a nominally higher error than scenarios 1, 2, and 3.

Table B6. Impact of Accuracy of Duration on Accuracy of PE Estimate

Scenario	Accuracy of Duration	Average Absolute Error
1	Actual Post-Project Duration	\$109,040.12 ($p = 0.02$)
2	Average Duration (3.75 yr)	\$104,035.03 ($p = 0.01$)
3	Correct High and Low Duration	\$107,728.17 ($p = 0.01$)
4	Incorrect High and Low Duration	\$137,099.44 ($p = 0.04$)

Assumption 7. Interpretation of the Type 2 Error

Table 23 in the report showed that that there is not a significant difference, based on the paired *t*-test, for the average absolute percent error. The reason for this may be the relatively high probability of a Type 2 error—the probability of failing to detect a significant difference even though such a difference exists—for this particular data set. An operating characteristic curve for the paired *t*-test based on the sample size n = 27 and the sample standard deviation of σ = 259% suggests that if the difference in the average absolute paired error is 60%, there is only a 23% probability of detecting that error.

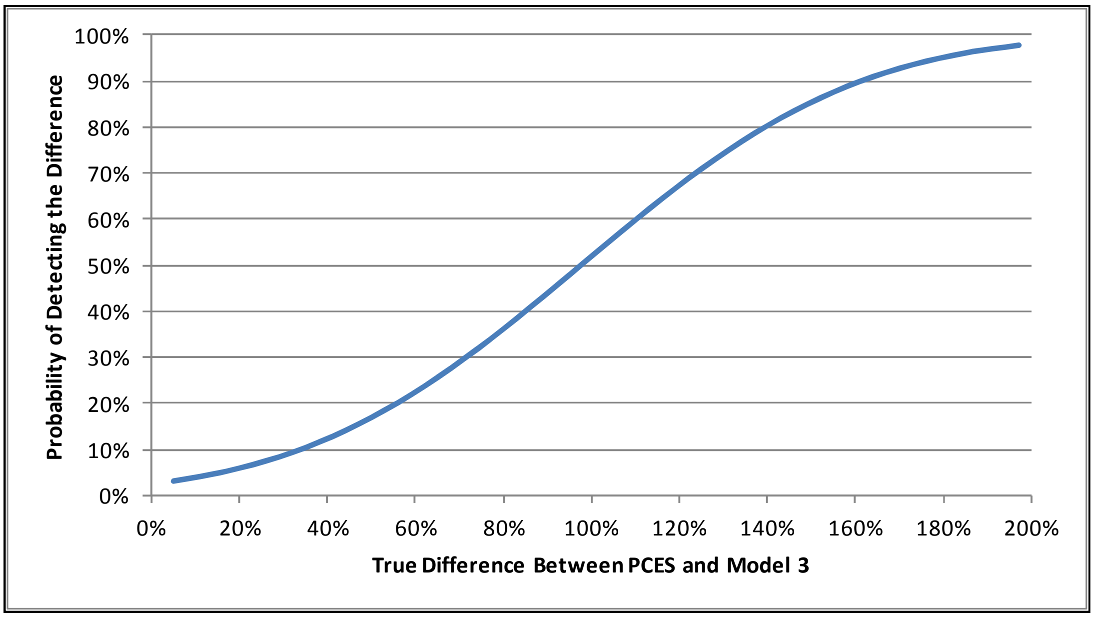


Figure B5. Power Curve for Paired *t*-Test Results in Table 23 (Model 7). The values on the vertical axis are plotted based on the relationship shown in Eq. B2, where Φ is the standard normal cumulative distribution. Values for n, true difference, and σ are specific to this study, and the equation is rearranged based on the "sample size for paired data" reported by Cobb (2011). PCES = Project Cost Estimating System.

$$\Phi\left[\sqrt{\frac{(n=27)(\text{true difference})^2}{(\sigma=258\%)^2}}-(Z_\alpha=1.96)\right] \quad \text{[Eq. B2]}$$

where

Φ = the standard normal cumulative distribution

n = the sample size of the testing data set

true difference = the true difference between PCES and Model 3 shown on the horizontal axis

σ = sample standard deviation

For this particular data set, Figure B5 is instructive because the probability of detecting a true difference between model performance is relatively low (below 40%) if the true difference between the models is below \$60,000. Two factors explain why it is difficult to detect such differences. One is the relatively small n, with just 27 testing samples. The other factor is a large σ owing to scatter in the data set: when one compares how close PCES came to the true PE cost and how close Model 7 came to the true PE cost, the difference between these two quantities ranged from \$1,129 (the models were very close) to \$748,098 (one model performed much better than the other). Thus, it is probable that although the researchers minimized the likelihood of Type 1 error with a value of 0.05, the fact that some models show nominal average differences of under \$100,000 leads one to suspect that the probability of Type 2 error is larger. In short, the researchers are more confident that the models that are cited as being different in terms of performance truly are different, but they are less confident that they have detected all of the significant differences between the models.

APPENDIX C

DETAILED METHODOLOGY FOR DATA COLLECTION

This appendix describes how the three main sets of project-level data were obtained:

1. financial data
2. engineering data
3. frequency of projects.

Financial data refers to expenditures for PE, RW, and CN. *Engineering data* refers to the characteristics that describe each project, such as environmental work and design complexity. *Frequency of projects data* includes the types of projects found statewide and by VDOT district.

How Financial Data Were Obtained

Financial data were obtained by VDOT staff from the FMSII database used by VDOT from approximately 1990 through part of 2011 and the Cardinal database (via a Business Objects user interface) used by VDOT since 2011. During 2011, VDOT transitioned from FMSII to Cardinal such that FMSII was active in the earlier part of the year and Cardinal in the latter part of the year.

Six steps were performed to collect financial data for each of VDOT's nine construction districts.

1. Identify universal project codes (UPCs).
2. Remove anomalies from the data set.
3. Obtain expert screening from each district.
4. Compile UPCs that passed the initial and expert screenings.
5. Obtain expenditures for each UPC.
6. Identify Candidate UPCs for the Preliminary Engineering Estimation Model.

Steps 1 through 5 yielded the raw data that were used to determine the percentage of funds VDOT spent on PE at the program level. Step 6 yielded the data used to develop a model to forecast VDOT's PE expenditures at the project level.

Step 1. Identify UPCs.

All UPCs for one district were obtained from VDOT's SYIP database (VDOT, 2008) for FY04 through FY13 inclusive. As may be seen in the SYIP database, for FY09 and FY10, there were two "final" SYIPs (i.e., the first "final" and later "revised final"), and for those 2 years the data for both SYIPs were examined. For example, to obtain projects for the Culpeper District, the first step was to select "FY04 FINAL" in the drop-down menu and then select "Culpeper" in the "District" drop-down menu as the one to be analyzed. The next step was to export the project list for that fiscal year (2004), which yielded an Excel document with all the UPCs for that fiscal year and for that district (i.e., the Culpeper District). This process was repeated for the remaining fiscal years, and the data were compiled into one master list with UPC data for FY05, FY06, FY07, FY08, FY09, FY09 Revised, FY10, FY10 Revised, FY11, FY12, and FY13. The next step removed the duplicate UPCs for projects that spanned more than one fiscal year such that the UPC descriptive information appeared only once. At the conclusion of Step 1, this Excel document contained for each UPC the project description, route, district, road system, jurisdiction, and planned allocations over the next 6 years. Then, UPCs that began with a "T" were excluded from the list, as these designated projects for which no data were available within VDOT's system (Carver, 2012a).

Step 2. Remove Anomalies From Data Set.

Sprinkel (2013a) suggested that certain "special funded" projects, even though they are in the SYIP, should be excluded from the data set. Examples of such projects are enhancement projects; district-wide projects; studies; and ARRA projects. The reason for the exclusion of these projects is that each represented an anomaly that could adversely affect the ratio of PE to construction costs. For example, ARRA projects were included in the SYIP because they were shovel-ready and would presumably have lower-than-expected PE costs compared to an average construction project. Accordingly, any projects that fulfilled any of these four criteria (i.e., enhancement, district-wide, study-only, and ARRA projects) were excluded.

Step 3. Obtain Expert Screening From Each District.

The four categories of anomalies were identified by the researchers using the UPC description. A fifth category of projects that Sprinkel (2013a) suggested be excluded was maintenance/operations projects, which are nonetheless funded with construction allocations. An example of such a project was UPC 84707, which was a bridge maintenance repairs project that used SYIP construction funds (Sprinkel, 2013b). Such anomalies, however, can be identified only with the help of an expert. Thus, for each district, an expert was asked to identify from the UPCs any maintenance/operations projects that remained after the four criteria were applied. For example, for the Culpeper District, of a total of 103 projects, application of the four criteria correctly classified 90 projects. A manual review was required because 1 of the 90 projects had initially been excluded incorrectly since the street name "Barracks" contained the acronym "ARRA." The remaining 13 projects were noted by the expert as meriting exclusion but were not captured by these criteria. These results varied by district; for example, in the Salem District, the four criteria identified 74 projects but the expert identified an additional 149 projects that should be excluded. (Experts had the opportunity to identify any anomalous projects.) The results of applying the criteria were compiled into an Excel spreadsheet.

Step 4. Compile UPCs That Passed the Initial and Expert Screenings.

In a separate Excel spreadsheet, the UPCs that passed the initial (Step 2) and expert (Step 3) screenings were compiled.

Step 5. Obtain Expenditures for Each UPC.

Expenditures were obtained from VDOT (e.g., R. Carver, 2012b, 2013) for the UPCs given in Step 4. As discussed preciously, these expenditures reflected two sources: FMSII and Cardinal. The expenditures showed the total amount spent by phase (PE, RW, or CN) for each UPC for each fiscal year. The financial data were also stratified by activity. These expenditures served two purposes: to determine the percentage of funds spent on PE at the program level and to develop a model to forecast PE expenditures at the project level.

Step 6. Identify Candidate UPCs for the Preliminary Engineering Estimation Model.

The financial data were compiled to show the total amount of money spent on a project by phase. Candidate UPCs were those that met three minimum criteria: (1) the project had a CN estimate at the scoping phase uploaded to the "PCES" database linked to the Project Pool; (2) the project job type was a construction plan; and (3) the PE phase was considered complete because the project had CN expenditures.

How Engineering Data Were Obtained

Overview

Each project has a unique set of project characteristics that influence how much money is spent on PE. As discussed previously, VDOT's Project Pool contains fundamental project characteristics. Some projects have more specific information uploaded into the "Project Documents" section of the Project Pool, such as data related to scoping, preliminary field inspections, public hearings, pre-advertising, and construction.

The difficulty of gathering the data for each project varied. For projects that were initiated relatively recently, the broad project characteristics that can be found in the Project Pool are consistently available for each project. Most projects that have an "active" status in the Project Pool have more documents uploaded and therefore more data available to determine project characteristics. Older projects generally do not have documents uploaded to the Project Pool; therefore, gathering specific data about the project is more difficult. Some of the older projects created prior to the creation of the Project Pool in 2003 have little data uploaded into the Project Pool. Unique project characteristics can be found in the scoping document, environmental records, and records of field inspections.

Before the determination of which project characteristics were most important and thus considered for the model, a literature review was conducted to ascertain how certain characteristics influenced project development. Characteristics such as geographic location (e.g., coast, mountainous, piedmont); environmental review (e.g., CE, EA, EIS); party responsible for the planning document (e.g., department of transportation, private engineering firm); and the scope of the project construction had a considerable impact in a study of cost estimation regarding PE in North Carolina (Liu et al., 2011).

The VDOT district interviews suggested related characteristics such as the role of environmental regulation, project duration, type of design services provider, type of wetlands mitigation, and project delivery method. The importance of environmental regulation may vary by location. For example, the interviewees in the Hampton Roads District noted that the amount of environmental work needed for projects in that district is substantial because of its proximity to the Chesapeake Bay watershed.

Additional characteristics were identified by using a sample set of projects provided in the Fredericksburg District interview. Interviewees explained that the sample set had projects that followed the VDOT Project Development Process (VDOT, 2012a) and projects that did not follow this process. Through analysis of both types of projects, various characteristics were found in the scoping document available in the Project Pool. Some characteristics, mostly originating from the standard projects, were expected by the researchers, such as the functional classification of the facility. However, the existence of certain characteristics for a subset of the projects, such as requiring a National Historic Preservation Study or requiring a HazMat (i.e., hazardous materials) Evaluation, showed the breadth of characteristics that were conceivable.

Types of Project Characteristics

Five types of project characteristics were identified: environmental, approved estimates, order of magnitude, agreements, and delivery method. An additional characteristic that would have been desirable to include was *public approval*. This term was mentioned during the Bristol District interview: if the public does not approve a design, the PE process can return to the beginning, repeating the cycle. If project managers are not available, reviewing documents uploaded to the Project Pool that show attendance forms at the public hearings might be one way to gather these data. Ultimately, however, the researchers did not find a cost-effective way to gather this characteristic.

Environmental Characteristics

Environmental Work. The various types of environmental work required for projects vary in magnitude. The National Environmental Policy Act of 1969 (42 U.S.C. §§ 4321-4347) states that agencies "are required to systematically assess the environmental impacts of their proposed actions and consider alternative ways of accomplishing their missions in ways which are less damaging to the environment." Projects are classified into three groups based on the amount of environmental work necessary: CE, EA, or EIS. Thus, the type of environmental work directly impacts the overall PE costs.

Wetlands Mitigation. After the Fredericksburg District interview, wetlands mitigation developed into an important topic because if the mitigation is to purchase wetland credits, the cost is charged to PE, but if the mitigation is to construct a new wetland, the cost is charged to CN. Thus, the manner in which wetlands are mitigated is key to the total percentage of funds spent on PE.

Bioretention Basin Consideration. A bioretention basin is a specific type of best management practice (BMP) used in stormwater management.

Approved Estimate Characteristics

The project estimates and expenditures for PE, RW, CN and their sum can define the magnitude of the overall project. This section of the Project Pool, although labeled "Approved Estimate," contains current project expenditures. More reliable estimates are found in the "PCES" section of the Project Pool.

Order of Magnitude Characteristics

Functional Classification. The functional class of a project helps define the type of area in which the project is located. Some of the possible functional classes examined were rural major collectors, rural principal arterials, urban collectors, and rural interstates.

Facility Type. Facility type defines the type of project.

Design Services Provider. In most of the district interviews, VDOT staff suggested that the design services provider played a large role in the overall PE costs. According to the Fredericksburg District interview, projects designed by VDOT staff were less expensive than those designed by consultants.

Transportation Management Class. This classification defines the complexity of the project based on how the transportation network will be affected.

- *Type A (Project Management Project Category I & II): No-Plan, Minimum-Plan, Single-Phase Construction, Maintenance Projects, Utility and Permitted Work:* Project types include simple projects such as widening pavement or adding turn lanes or entrances.

- *Type B (Project Management Project Categories III & IV): Typical Projects:* These projects have a moderate level of construction activity with the primary traffic impact limited to the roadway containing the work zone. Project types include moderately complex projects such as pavement or bridge widening for additional through lanes and pavement rehabilitation.

- *Type C (Significant Project—Project Management Category V):* These project types are anticipated to cause sustained and substantial work zone impacts greater than what is considered tolerable based on policy or engineering judgment. They should be identified early in the design process in cooperation FHWA. Typical projects are long-duration construction or maintenance projects on interstates and freeway projects that occupy a location for more than 3 days with intermittent or continuous lane closures (VDOT, 2011c).

Number of Bridges. The number of bridges on a project plays a large role in the overall scale of a project.

PE Phase Duration. The Bristol District interview made it clear that the overall PE phase duration has a large effect on PE cost. One of the factors that either accelerated or delayed the PE phase duration was the position of the public, whether in favor of the design or against the project. If the public hearings were unsuccessful in persuading citizens, the PE phase often took longer for alternate design consideration.

Interchange Justification Reports / Interchange Modification Reports. Often these reports suggest a large-scale project with multiple components.

Businesses/Homes to Be Taken. If a project needs to purchase RW that takes a number of business or homes, the PE estimate will likely be affected.

Length of Time. In general, the longer the project's duration, the higher the PE estimate.

Railroad Involvement. Projects located near a railroad require coordination with multiple agencies and often entail more complex design features to avoid distress on the existing railroad crossings or system.

Job #. The Salem District interview clarified that the "job #" should be included as a characteristic. Such projects can be identified in the "Jobs" section of the Project Pool (see Figure C1) and are designated by the letter associated with the CN phase. For example, for the UPC shown in Figure C1, the letter is C. The significance of this characteristic is that interviewees suggested only C projects (meaning "Complete Plan" according to the interview) would be wanted: "no plan" projects (designated with an N) and minimal design projects (designated with an M) would not be wanted.

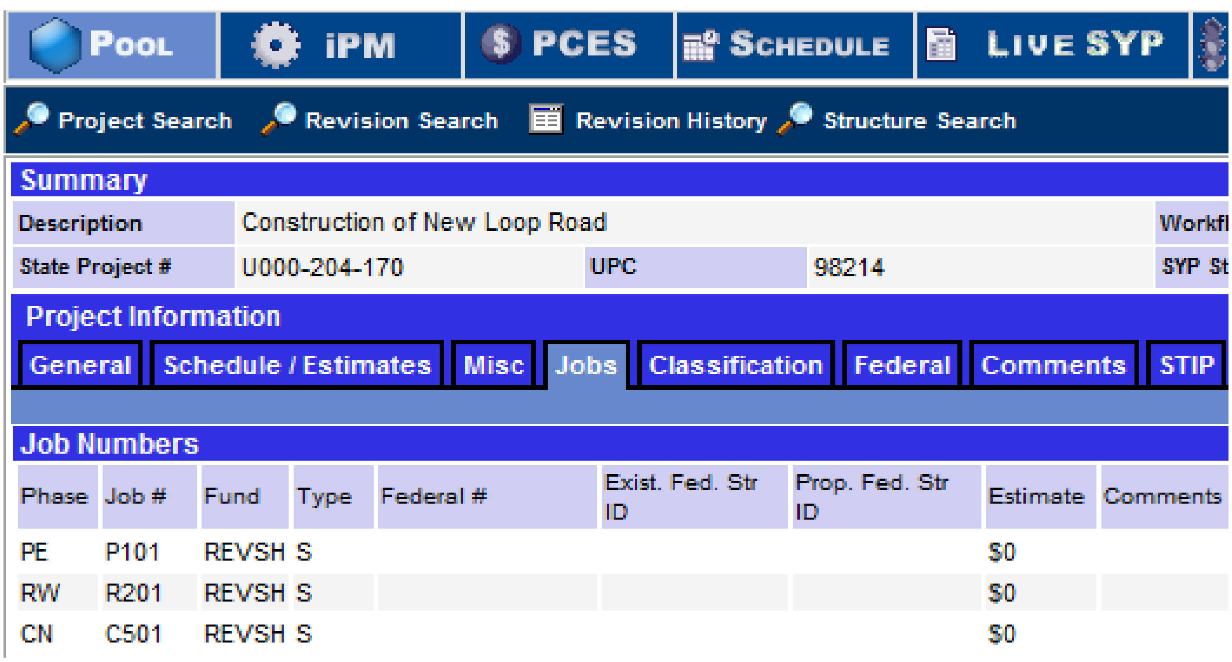


Figure C1. Example of Project With Job Type C, Meaning Either "Construction" or "Complete Plan." Screen shot of Jobs Section, UPC 98214, as it appears in the Project Pool.

VDOT (2007) clarified that there are many job types other than the C, N, and M types, and these job types did not arise in the interviews. The job types are B (Bridge), D (Drainage), G (Grading), P (Paving), FS (Flashing Signals), L (Landscaping), and SG (Signing). VDOT (2007) also refers to the C designation as Construction.

Agreements Characteristics

Required National Historic Preservation Study. Projects that are located in historic districts must undergo a National Historic Preservation Study. The National Historic Preservation Act of 1966 (16 U.S.C. 470 et seq.) states that "the historical and cultural foundations of the Nation should be preserved as a living part of our community life and development in order to give a sense of orientation to the American people."

Hazardous Materials Evaluation. Various projects located near a warehouse or manufacturing facility may require a hazardous materials evaluation to determine whether the area of the proposed project is not contaminated.

Utility Conflicts or Relocation. This is a broad characteristic that can vary extensively and also play a major role in how PE is estimated. Projects that span two municipalities can have major utility conflicts, whereas other projects may have a simple issue.

Bicycle and Pedestrian Accommodations. Projects that require additional design work for bicycle and pedestrian infrastructure can affect the PE estimate.

Memorandum of Agreement (MOA). The scoping document that VDOT uses for its projects asks whether the project involves any MOAs with any state, federal, or private agency regarding special treatment for consideration for aesthetics or scenic quality for a corridor, bridge structure, view shed, or historic property, thus requiring mitigation of aesthetic impacts.

Recoverable Slope Study. Recoverable slope studies are performed to evaluate whether the terrain adjacent to a roadway complies with VDOT's slope threshold.

Value Engineering (VE) Study. According to FHWA (2012), a VE study is defined as follows:

> A systematic process of review and analysis of a project, during the concept and design phases, by a multidiscipline team of persons not involved in the project that is conducted to provide recommendations for:
> - providing the needed functions safely, reliably and efficiently and at the lowest overall cost
> - improving the value and quality of the project; and
> - reducing the time to complete the project.

FHWA (2012) also stated that the following projects are required to conduct a VE Study (VE Policy):

> [those that] utilize Federal-aid highway funding with an estimated total cost of $25 million or more that are located on the National Highway System (NHS), and all bridge projects with an

estimated cost of $20 million or more that are located on or off of the NHS that utilize Federal-aid highway funding (as specified in 23 U.S.C. 106(e)).

Delivery Method Characteristics

Alternate Delivery Method. A majority of projects use the Design-Bid-Build Project Delivery Method. Other methods such as Design-Build are somewhat common and tend to have higher PE costs.

Alternate Designs Considered. In the scoping document that VDOT uses for its projects there is a section to describe whether alternate designs were considered. In the early stages of all projects, various designs are considered; however, when designs change late in the project development process (such as after a preliminary public hearing), it can influence the PE cost greatly.

Workflow Status. As a result of the meeting with staff of VDOT's Programming Division, the Workflow Status developed into an important characteristic in order to determine which projects were complete in that no more money would be spent on the project in any phase. Projects can be active, inactive, or archived. For projects that are active or inactive, expenditures are likely to change. For projects that are archived, all three phases have been completed and no more expenditures will be required. Projects that are inactive or archived tend to have less documentation, and active projects generally have up-to-date information. However, the interview with staff of VDOT's Programming Division and Fiscal Division (Interview CO5) indicated that only archived projects should be used, and these tend to have fewer characteristics available.

Availability of Project Characteristic Data

The Project Pool contains the characteristics for each UPC. The Project Pool has broad information located in the "General Information" and "Schedule and Estimates" sections. More specific information, in the form of project documents, is located in the integrated Project Manager (iPM), which is accessible from the Project Pool for a specific UPC.

- *The General Information section* of the Project Pool has characteristics such as the type of environmental work, functional class, facility type, project length, work flow status, and number of bridges required. This information is routinely available except for some cases where environmental work and functional classification are blank.

- *The Schedule / Estimates section* of the Project Pool provides characteristics such as estimates for PE, RW, and CN and the programming schedule (which gives the PE Phase Duration). This information is routinely available except in some cases where no information was recorded for the duration.

- *Other detailed information in the Project Pool.* If it is uploaded, a complete scoping document will contain characteristics such as (1) Bicycle/Pedestrian Accommodation, (2) Bio Retention (Water Quality) Basin, (3) Memorandum of Agreements, (4) Recoverable Slope Study, (5) Value Engineering Study, (6) Transportation

Management Plan Type, (7) Design Services Provider, (8) Businesses to Be Taken, (9) Homes to Be Taken, (10) Railroad Involvement, (11) Utility Relocation (also called Utility Conflicts in some cases), and (12) Alternate Delivery Method. If applicable, documents other than the scoping document may show characteristics such as (1) if wetlands are affected, (2) the need for a hazardous materials (HazMat) evaluation, and (3) National Historic Preservation Study Evaluations. Whether this information is available depends on the project manager. Salem District interviewees noted that when documents are not uploaded to the Project Pool, it is nearly impossible to get any detailed information about a project without contacting the project manager directly.

Table C1 summarizes the availability of these project characteristics by UPCs for six of VDOT's nine districts. The characteristics fall into three categories:

1. *Usually available.* The only reason a characteristic would be missing is a data entry error or some unexplained event. For example, in the Bristol District, 25 of the 29 projects had environmental characteristic data.

2. *Sometimes available*. These characteristics are often available when the scoping document is uploaded. For example, in the Bristol District, 6 of the 29 projects indicated the design services provider.

3. *Rarely available.* These characteristics were observed less frequently even when extensive documentation was uploaded to the Project Pool. For example, in the Bristol District, 3 of the 29 projects indicated wetlands mitigation data.

Judgment was required by the researchers to interpret the meaning of a blank data field. It is not always clear that a blank data field constitutes an error. For example, a project not on the interstate system would not have an Interchange Justification Report (IJR) —thus a blank IJR field would not be an error. Similarly, if the number of bridges is not recorded, it is likely that the project does not require a bridge. By contrast, a project without a functional classification would likely constitute an omission of a data element. It was also suggested by staff of VDOT's Programming Division that when PE duration has zero days, the data element is likely in error because all projects have a PE start and end date (J. Brown, personal communication, 2013). However, projects that are in sequential UPC order and have exactly the same duration are not uncommon and are likely accurate (J. Brown, personal communication, 2013).

Only six districts are reported in Table C1 because the data for the districts were obtained incrementally, and once findings from six districts were available, the researchers decided to collect only those elements in the remaining three districts that were usually available.

Table C1. Summary of Available Characteristics by Project

Availability	Characteristic	Bristol	Hampton Roads	Culpeper	Salem	Lynchburg	Fredericksburg
Usually	Environmental Work	25/29	52/63	20/24	21/28	40/43	11/12
	PE Cost	29/29	63/63	24/24	28/28	43/43	12/12
	Magnitude of Total Cost	29/29	63/63	24/24	28/28	43/43	12/12
	Amount of RW	29/29	63/63	24/24	28/28	43/43	12/12
	Ratio of RW to CN	29/29	63/63	24/24	28/28	43/43	12/12
	Duration	29/29	63/63	23/24	28/28	40/43	12/12
	Functional Class	29/29	63/63	24/24	28/28	42/43	12/12
	Length	29/29	63/63	24/24	28/28	42/43	12/12
	Workflow Status	29/29	63/63	24/24	28/28	43/43	12/12
	Facility Type	29/29	63/63	24/24	28/28	43/43	12/12
Sometimes[a]	Design Services Provider	6/29	7/63	2/24	7/28	9/43	1/12
	Transportation Management Class	4/29	2/63	3/24	6/28	8/43	0/12
	Business/Homes to Be Taken	10/29	11/63	4/24	11/28	11/43	7/12
	Railroad Involvement	8/29	11/63	6/24	11/28	12/43	7/12
	Number of Bridges	14/29	43/63	13/24	18/28	38/43	7/12
	Utility Conflicts or Relocations	9/29	11/63	6/24	11/28	12/43	5/12
	Bike and Ped Accommodations	5/29	10/63	4/24	7/28	14/43	4/12
	Recoverable Slope Study	9/29	10/63	5/24	11/28	13/43	4/12
	Value Engineering Study	9/29	10/63	5/24	10/28	14/43	4/12
	Alternate Delivery Method	5/29	3/63	3/24	3/28	7/43	1/12
Rarely[a]	Wetlands Mitigation	3/29	7/63	1/24	3/28	2/43	1/12
	Memorandum of Agreement	2/29	0/63	0/24	3/28	8/43	2/12
	Bio Retention (Water Quality Basin) Consideration	2/29	3/63	2/24	5/28	9/43	2/12
	National History Preservation Study	0/29	1/63	0/24	0/28	1/43	2/12
	HazMat Evaluation	0/29	3/63	0/24	3/28	1/43	2/12
	Alternate Designs Considered	0/29	1/63	1/24	1/28	1/43	0/12
	IJR and or IMR	0/29	0/63	0/24	1/28	0/43	1/12

PE = Preliminary Engineering; RW = right of way; CN = construction; Ped = pedestrian; IJR = interchange justification report; IMR = interchange modification report.

[a] The division between "sometimes available" and "rarely available" is arbitrary except that the characteristics in the former category could be obtained more often than characteristics in the latter category.

How Frequency of Projects Was Determined

Tables C2, C3, and C4 summarize the types of projects across three categories: environmental work, workflow status, and construction cost. Tables C5 through C10 provide district-by-district results for the six VDOT districts where the availability of data elements was studied.

Table C2. Projects With Environmental Characteristics by VDOT District

Characteristic	Bristol	Hampton Roads	Culpeper	Salem	Lynchburg	Fredericksburg
CE	11	29	18	9	7	8
EA	5	15	0	0	1	1
PCE	9	6	2	9	20	2
EIS	0	2	0	1	12	0
N/A	4	11	4	4	3	1
TBD	0	0	0	5	0	0
Total	29	63	24	28	43	12

CE = Categorical Exclusion; EA = Environmental Assessment; PCE = Programmatic Categorical Exclusion; EIS = Environmental Impact Statement; N/A = Not Applicable; TBD = To Be Determined.

Table C3. Workflow Status of Projects by VDOT District

Status	Bristol	Hampton Roads	Culpeper	Salem	Lynchburg	Fredericksburg
Active	16	43	17	15	35	8
Inactive	7	15	5	7	6	4
Archived	6	5	2	6	2	0
Total	29	63	24	28	43	12

Table C4. Magnitude of Construction Estimate by VDOT District

CN Estimate From PCES	Bristol	Hampton Roads	Culpeper	Salem	Lynchburg	Fredericksburg
CN under $5M	22	34	19	19	30	10
CN between $5M and $18M inclusive[a]	5	18	5	6	6	2
CN over $18M	2	11	0	3	7	0
Total	29	63	24	28	43	12

PCES = Project Cost Estimating System; CN = construction.
[a] This row includes projects with a cost of exactly $5M or exactly $18M.

Table C5. Summary of Available Characteristics by Project (Bristol District)

Availability	Characteristic
Usually Available	• Environmental Work (25/29)[a,b] • PE Cost (approved estimate) (29/29)[c] • Magnitude of Total Cost (approved estimate) (29/29) • Amount of RW (approved estimate) (29/29) • Ratio of RW to CN (approved estimate)(29/29) • Duration (29/29) • Functional Classification (29/29) • Length (29/29) • Workflow Status (29/29)[d] • Facility Type (29/29)
Sometimes Available	• Design Services Provider (District, Consultant, Other) (6/29) • Transportation Management Class (4/29) • Businesses/Homes to Be Taken (10/29) • Railroad Involvement (8/29) • Number of Bridges (14/29) • Utility Conflicts or Relocation (9/29) • Bike and Pedestrian Accommodations (5/29) • Recoverable Slope Study (9/29) • Value Engineering Study (9/29) • Alternate Delivery Method (5/29)
Rarely Available	• Wetlands Mitigation (3/29) • Memorandum of Agreement (2/29) • Bio Retention (water quality basins consideration) (2/29) • Required National History Preservation Study (0/29) • HazMat Evaluation (0/29) • Alternate Designs Considered (0/29) • IRJ and or IMR (0/29)

PE = preliminary engineering; RW = right of way; CN = construction; IJR = interchange justification report; IMR = interchange modification report.

[a] Numbers in parentheses indicate the number of projects with the characteristic and total number of projects, respectively; 25/29 projects had environmental work noted, 4 had N/A recorded.

[b] Of the 29 projects evaluated, 25 had a specific type of environmental work in the Project Pool. Five had an EA, 11 a CE, 9 a Programmatic CE, and 4 N/A.

[c] PE estimates were mostly below $1M; however, the PE estimates for three were more than $1M. PE phases were mostly around 4 years but for one case was 12 years.

[d] Of the selected projects, the Bristol District had 16 active, 7 inactive, and 6 archived. For 11 projects, nothing had been uploaded to the Project Pool; therefore, only the general information was recorded.

Table C6. Summary of Available Characteristics by Project (Hampton Roads District)

Availability	Characteristic
Always Available	• Environmental Work (52/63)[a,b] • PE Cost (approved estimate) (63/63)[c] • Magnitude of Total Cost (approved estimate) (63/63) • Amount of RW (approved estimate) (63/63) • Ratio of RW to CN (approved estimate) (63/63) • Duration (63/63) • Functional Classification (61/63) • Length (63/63) • Workflow Status (63/63)[d] • Facility Type (63/63)
Sometimes Available	• Design Services Provider (District, Consultant, Other) (7/63) • Transportation Management Class (2/63) • Businesses/Homes to Be Taken (11/63) • Railroad Involvement(11/63) • Number of Bridges (43/63) • Utility Conflicts or Relocation (11/63) • Bike and Pedestrian Accommodations (10/63) • Recoverable Slope Study (10/63) • Value Engineering Study (10/63) • Alternate Delivery Method (3/63)
Rarely Available	• Bio Retention (water quality basins consideration) (3/63) • Required National History Preservation Study (1/63) • HazMat Evaluation (3/63) • Alternate Designs Considered (1/63) • IRJ and or IMR (0/63) • Memorandum of Agreement (0/63) • Wetlands Mitigation (7/63)

PE = preliminary engineering; RW = right of way; CN = construction; IJR = interchange justification report; IMR = interchange modification report.

[a] Numbers in parentheses indicate the number of projects with the characteristic and total number of projects, respectively; 52/63 projects had environmental work noted, 11 had N/A recorded.

[b] Of the 62 projects evaluated, 52 had a specific type of environmental work in the Project Pool. Fifteen had an EA, 29 a CE, 6 a Programmatic CE, and 11 N/A.

[c] Half of the PE estimates were below $1M; however, the PE estimates for four were over $10M. PE phases were mostly around 5 years, but 12 were more than 10 years.

[d] Of the selected projects, the Hampton Roads District had 43 active; 15 inactive, and 5 archived. For 40 projects, nothing had been uploaded to the Project Pool; therefore, only the general information was recorded.

Table C7. Summary of Available Characteristics by Project (Culpeper District)

Accessibility Level	Characteristic
Always Available	• Environmental Work (20/24)[a,b] • PE Cost (approved estimate) (24/24)[c] • Magnitude of Total Cost (approved estimate) (24/24) • Amount of ROW (approved estimate) (24/24) • Ratio of RW to CN (approved estimate) (24/24) • PE Phase Duration (23/24) • Functional Classification (24/24) • Length (24/24) • Workflow Status (24/24)[d] • Facility Type (24/24)
Sometimes Available	• Design Services Provider (District, Consultant, Other) (2/24) • Transportation Management Class (3/24) • Businesses/Homes to Be Taken (4/24) • Railroad Involvement (6/24) • Number of Bridges (13/24) • Utility Conflicts or Relocation (6/24) • Bike and Pedestrian Accommodations (4/24) • Recoverable Slope Study (5/24) • Value Engineering Study (5/24) • Alternate Delivery Method (3/24)
Rarely Available	• Bio Retention (water quality basins consideration) (2/24) • Memorandum of Agreement (3/24) • Required National History Preservation Study (0/24) • HazMat Evaluation (0/24) • Alternate Designs Considered (1/24) • IRJ and or IMR (0/24) • Wetlands Mitigation (1/24)

PE = preliminary engineering; RW = right of way; CN = construction; IJR = interchange justification report; IMR = interchange modification report.

[a] Numbers in parentheses indicate the number of projects with the characteristic and total number of projects, respectively; 20/24 projects had environmental work noted, 4 had N/A recorded.

[b] Of the 24 projects evaluated, 20 had a specific type of environmental work in the Project Pool. Eighteen had a CE, 2 a Programmatic CE, and 4 N/A.

[c] Sixteen of the PE estimates were below $1M; however, the PE estimate for one was $3.5M. Fifteen projects had a PE phase duration under 5 years, and 1 had a PE phase duration of 37.5 years.

[d] Of the selected projects, the Culpeper District had 17 active; 5 inactive, and 2 archived. For 11 projects, nothing had been uploaded to the Project Pool; therefore, only the general information was recorded.

Table C8. Summary of Available Characteristics by Project (Salem District)

Accessibility Level	Characteristic
Always Available	• Environmental Work (21/28)[a,b] • PE Cost (approved estimate) (28/28)[c] • Magnitude of Total Cost (approved estimate) (28/28) • Amount of ROW (approved estimate) (28/28) • Ratio of RW to CN (approved estimate) (28/28) • PE Phase Duration (28/28) • Functional Classification (28/28) • Length (28/28) • Workflow Status (28/28)[d] • Facility Type (28/28)
Sometimes Available	• Design Services Provider (District, Consultant, Other) (7/28) • Transportation Management Class (6/28) • Businesses/Homes to Be Taken (11/28) • Railroad Involvement (11/28) • Number of Bridges (18/28) • Utility Conflicts or Relocation (11/28) • Bike and Pedestrian Accommodations (7/28) • Recoverable Slope Study (11/28) • Value Engineering Study (10/28) • Alternate Delivery Method (3/28)
Rarely Available	• Required National History Preservation Study (0/28) • Bio Retention (water quality basins consideration) (5/28) • HazMat Evaluation (3/28) • Alternate Designs Considered (1/28) • IRJ and or IMR (1/28) • Wetlands Mitigation (3/28) • Memorandum of Agreement (3/28)

PE = preliminary engineering; RW = right of way; CN = construction; IJR = interchange justification report; IMR = interchange modification report.

[a] Numbers in parentheses indicate the number of projects with the characteristic and total number of projects, respectively; 21/28 projects had environmental work noted, 4 had N/A recorded, and 5 had the TBD status of "BCE/PCE/CE."

[b] Of the 28 projects evaluated, 21 had a specific type of environmental work in the Project Pool. Nine had a CE, 9 a Programmatic CE, 1 an EIS, 4 N/A, and 5 TBD.

[c] Sixteen of the PE estimates were below $1M; however, the PE estimate for one was $5.5M. Fourteen projects had a PE phase duration under 5 years, and 1 had a PE phase duration of 15 years.

[d] Of the selected projects, the Salem District had 15 active, 7 inactive, and 6 archived. For 14 projects, nothing had been uploaded to the Project Pool; therefore, only the general information was recorded.

Table C9. Summary of Available Characteristics by Project (Lynchburg District)

Accessibility Level	Characteristic
Always Available	• Environmental Work (40/43)[a,b] • PE Cost (approved estimate) (43/43) • Magnitude of Total Cost (approved estimate) (43/43) • Amount of RW (approved estimate) (43/43) • Ratio of RW to CN (approved estimate) (43/43) • PE Phase Duration (38/43)[c] • Functional Classification (42/43) • Length (43/43) • Workflow Status (43/43)[d] • Facility Type (43/43)
Sometimes Available	• Design Services Provider (District, Consultant, Other) (9/43) • Transportation Management Class (8/43) • Businesses/Homes to Be Taken (11/43) • Railroad Involvement (12/43) • Number of Bridges (38/43)[d] • Utility Conflicts or Relocation (12/43) • Bike and Pedestrian Accommodations (14/43) • Recoverable Slope Study (13/43) • Value Engineering Study (14/43) • Alternate Delivery Method (7/43)
Rarely Available	• Required National History Preservation Study (1/43) • HazMat Evaluation (1/43) • Bio Retention (water quality basins consideration) (9/43) • Memorandum of Agreement (8/43) • IRJ and or IMR (0/43) • Wetlands Mitigation (2/43) • Alternate Designs Considered (1/43)

PE = preliminary engineering; RW = right of way; CN = construction; IJR = interchange justification report; IMR = interchange modification report.

[a] Numbers in parentheses indicate the number of projects with the characteristic and total number of projects, respectively; 40/43 projects had environmental work noted, and 3 had N/A recorded

[b] Of the 43 projects evaluated, 40 had a specific type of environmental work in the Project Pool. Seven had a CE, 20 a Programmatic CE, 12 an EIS, 1 an EA, and 3 N/A.

[c] Twenty-six projects had a PE phase duration under 5 years, and 4 had a PE phase duration over 10 years.

[d] Of the selected projects, the Lynchburg District had 35 active, 6 inactive, and 2 archived. For 20 projects, nothing had been uploaded to the Project Pool; therefore, only the general information was recorded.

C10. Summary of Available Characteristics by Project (Fredericksburg District)

Accessibility Level	Characteristic
Always Available	• Environmental Work (11/12) [a,b] • PE Cost (approved estimate) (12/12)[c] • Magnitude of Total Cost (approved estimate) (12/12) • Amount of RW (approved estimate) (12/12) • Ratio of RW to CN (approved estimate) (12/12) • PE Phase Duration (12/12) • Functional Classification (12/12) • Length (12/12) • Workflow Status (12/12)[d] • Facility Type (12/12)
Sometimes Available	• Design Services Provider (District, Consultant, Other) (1/28) • Transportation Management Class (0/12) • Businesses/Homes to Be Taken (7/12) • Railroad Involvement (7/12) • Number of Bridges (7/12) • Utility Conflicts or Relocation (5/12) • Bike and Pedestrian Accommodations (4/12) • Recoverable Slope Study (4/12) • Value Engineering Study (4/12) • Alternate Delivery Method (1/12)
Rarely Available	• Required National History Preservation Study (2/12) • HazMat Evaluation (2/12) • Alternate Designs Considered (0/12) • IRJ and or IMR (1/12) • Wetlands Mitigation (1/12) • Memorandum of Agreement (2/12) • Bio Retention (water quality basins consideration) (2/28)

PE = preliminary engineering; RW = right of way; CN = construction; IJR = interchange justification report; IMR = interchange modification report.

[a] Numbers in parentheses indicate the number of projects with the characteristic and total number of projects, respectively; 11/12 projects had environmental work noted, 1 had N/A recorded.

[b] Of the 12 projects evaluated, 11 had a specific type of environmental work in the Project Pool. Eight had a CE, 2 a Programmatic CE, 1 an EA, and 1 N/A.

[c] Ten of the PE estimates were below $1M; however, the PE estimate for one was $1.2M. Seven projects had a PE phase duration under 5 years, and one had a PE phase duration of 10 years.

[d] Of the selected projects, the Fredericksburg District had 8 active, 4 inactive, and 6 archived. For 5 projects, nothing had been uploaded to the Project Pool; therefore, only the general information was recorded.