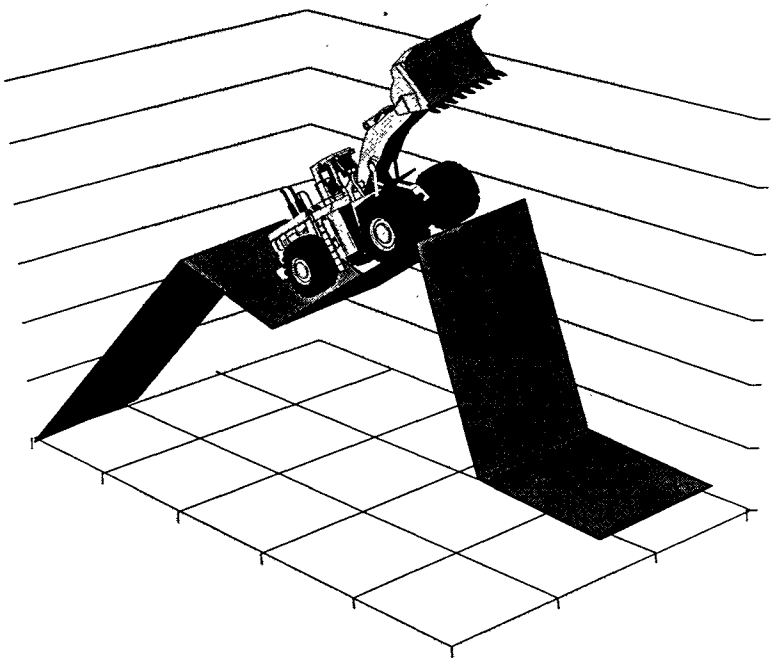
FINAL REPORT

A REVIEW OF THE VIRGINIA DEPARTMENT OF TRANSPORTATION'S MAINTENANCE COST INDEX



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Supplementary Notes

Abstract

This report details research done to review and update the Virginia Department of Transportation's Maintenance Cost Index (MCI), the first such review since its development in 1986. The study re-examined the composition of items within the MCI, provided an up-to-date mix of items upon which to base the index, and explored alternate formulae for the calculation of the MCI. The study recommended that the Törnqvist Index be adopted for this purpose.

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

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EXECUTIVE SUMMARY

The Virginia Department of Transportation relies on a Maintenance Cost Index (MCI) to calculate annual adjustments in lane mile allocations to localities for urban street payments. The MCI, consisting of a list of 29 items in three categories (materials, equipment, and labor), is calculated annually by the Maintenance Division. The formula brings the unit costs of these items together, weighted by their relative importance. The index measures the cost changes of the items from the base year (FY 1985) to the current year. These changes in the MCI are taken to be reflective of statewide maintenance cost changes. Urban street payments per lane mile for cities and towns equal the base payment per lane mile established by statute in 1986, multiplied by the value of the MCI for the previous fiscal year. The MCI has not been updated since 1986.

Changes in the way maintenance is performed, new equipment and materials, the growth of contracted work, and administrative changes like broadbanding have led to concerns among several VDOT divisions that the MCI has become out-of-date. This project reviewed and updated the MCI. The authors developed a new mix of items to reflect current maintenance conditions and practices, evaluated alternative index formulae and recommended a new way of calculating the MCI.

In order to ensure that the MCI is representative, the study recommended that the index use a new mix of maintenance items. The new list contains 62 items rather than the current 29, and accounts for a much larger percentage of total maintenance costs. The authors also recommended that the Maintenance Division adopt a new formula called the Törnqvist Index for the calculation of the MCI. This formula uses more realistic assumptions and allows changes in its base year and item make-up. The Törnqvist Index is easier to set up in a spreadsheet, is statistically superior to other alternatives, and accommodates the inclusion of maintenance contracts. It also has the advantage of resembling the current MCI formula. For FY 1998, the current MCI gives total statewide lane mile allocations of $172,146,473. Using the Törnqvist formula (current item mix) gives allocations of $168,169,221. The Törnqvist formula also grows at a slower rate than the current MCI formula.

Because it ignores contract work, the current index will be based on an ever-smaller fraction of total VDOT maintenance experience. To address this problem, the authors recommended that price and quantity variables for contract work be constructed using total expenditures on contract maintenance together with an appropriate national or state construction cost index, until such time as appropriate contract data become available. Contract work would then be added to the list of index items as a fourth category consisting of a single item. It is also recommended that VDOT require contractors who perform maintenance to provide a breakdown of their costs by units of work and quantity or by cost and quantity of equipment, labor, and materials.

The study further recommended that the most recent fiscal year be taken as the new base year for the MCI. In order to maintain consistency in lane mile allocations, the allocations per lane mile in the most recent fiscal year should be taken as the base values to which the

adjustment factor is applied in future years. In order to keep the MCI item mix reflective of actual maintenance costs, the report recommends that this list be reviewed and updated every five years.

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INTRODUCTION

Problem Statement

In the fall of 1996 the Virginia Department of Transportation (VDOT) received a number of inquiries from the officials of cities and incorporated towns in the state, expressing dismay at the disappointing size of the street maintenance payments that VDOT planned to make to their localities in FY 1997. Local governments had expected more because in April 1996, VDOT's Division of Financial Planning and Debt Management (FPDM) had predicted a considerably larger increase. Also street payments that year increased by only a small amount compared with previous years. Jesse A. Hall, Deputy Director of Finance for the City of Roanoke, summarized the problem in a letter to Commissioner Gehr, "Obviously this budgetary shortfall will have a significant impact on our maintenance program. I would appreciate any further explanation you could offer that may assist us in future budget periods to make more accurate revenue estimates for our highway maintenance payments" (Jesse A. Hall, October, 1996).

The amount of funding a Virginia municipality receives for urban street maintenance depends on the following: (1) its number of eligible lane miles of road (in two categories); (2) the base allocation rates in dollars per lane mile per year that were established by statute in 1985; and (3) the maintenance cost index (MCI) that VDOT's Maintenance Division (MD) calculates annually. Section 33.1-41.1 of the 1996 Code of Virginia states, "The Department of Transportation shall establish a statewide maintenance index of the unit costs for labor, equipment, and materials used on roads and bridges in the fiscal year 1986, and use changes in that index to calculate and put into effect annual changes in the base per-lane-mile rate payable under this section". The MCI has not undergone a systematic review or revision since its creation in 1986.

Concerns arose in the MD over whether the mix of items upon which the MCI is based represents current maintenance practices and provides an appropriate measure of changes in maintenance costs from year to year. With the introduction of new items into the field, such as B-VI tape, and increasing reliance on contract work, it was felt that the underlying item mix may have become out of date. An additional issue is the fact that broadbanding has changed the composition and influence of the labor categories on the MCI.

The above concerns regarding the appropriateness of the mix of items, taken together with the new expressions of concern from the municipal governments, led the Urban Division (URB), that administers payments to the cities and towns, and the MD to seek a review of the MCI in 1997. Such a review necessarily seeks to answer a number of questions: Does the index formula capture accurately the impact of the prices of all the items that VDOT purchases or hires? Does the index formula have the mathematical properties that are desirable for a price index? Does the formula produce an accurate and appropriate index of maintenance cost?

History and Background

Early Legislation

Legislation passed by the General Assembly in 1932 required the State Highway Commissioner to make road maintenance and construction payments to cities and towns with populations over 3,500. The payments were originally based on the number of center-line miles in each municipality. In 1972, legislation changed the basis for mileage calculations from center-line miles to lane miles; a one-time 65 percent jump in assistance payments from FY 1972 to FY 1973 followed the law's passage. Legislation in 1979 established base amounts per lane mile for each of two types of road, and required the Virginia Department of Highways and Transportation (VDHT) to adjust the payments to each city and town annually based on "maintenance experience" in the surrounding VDHT construction district. The rate of growth of maintenance assistance payments increased markedly following the passage of this act. As of 1984, 74 cities and incorporated towns were receiving quarterly payments, totaling $69.9 million, based on approved lane mileage in each municipality. Two types of road, "primary extensions" and "other streets", were distinguished (JLARC, 1984).

The 1984 JLARC Report and Resulting Legislation

In its 1982 Appropriations Act, the General Assembly directed the Joint Legislative Audit and Review Commission (JLARC) to conduct a study of the "reasonableness, appropriateness, and equity" of the current statutory provisions for allocating highway construction funds. Following JLARC's submission of an interim report in January 1983, dealing solely with highway construction, the General Assembly further directed that the study be expanded to include other major programs of the Highway Maintenance and Construction Fund. In June 1984 JLARC completed a report containing both empirical analysis and recommendations for improvement. Th report dealt with construction and maintenance allocations in the state systems, allocations to Arlington and Henrico Counties, assistance for public transportation, and urban street payments.

JLARC found that although VDHT was paying more assistance for each mile of primary extension than for each mile of other streets, the two classes as defined did not show distinguishable maintenance cost differences. By contrast, when urban streets were grouped into the functional classifications defined by the Federal Highway Administration (FHWA), the

average maintenance cost for principal and minor arterials differed significantly from the average cost for collector roads and local streets. JLARC therefore recommended that the General Assembly establish payment rates for urban streets on the basis of functional classifications defined by the FHWA.

JLARC found that although in 1983 the payments per lane mile had differed by up to 40 percent from one municipality to another, no significant difference in average maintenance cost per lane mile existed among functionally equivalent urban streets in different VDHT construction districts. The Commission therefore recommended that the General Assembly establish payment rates for urban streets on the basis of functional classifications that matched the FHWA functional classifications used to categorize VDOT-maintained county roads. JLARC also recommended that the General Assembly eliminate the use of different payment rates for maintenance in the eight (at that time) districts.

In addition to cross-sectional inequity, JLARC found other weaknesses in the method by which VDHT calculated the annual adjustment to each city's assistance payments. VDHT construed relevant "maintenance experience" to include most ordinary maintenance and maintenance replacement. This meant that the costs for a variety of activities that did not exist in cities and towns, such as weigh station operations and ferry boat service, were influencing the annual inflation adjustment to urban street payments. It also meant that the expenditures on large maintenance replacement projects, which frequently varied from the allocations for such projects within a given fiscal year, were causing the cost adjustment factor to fluctuate wildly. The report also concluded that using the current year's payment rate to each municipality as the base for calculating the payment rate for the following year would allow a single aberration in a district's maintenance costs to have a distorting effect on the payments to cities and towns for years to come. In fact, an extension of the logic would have shown that an aberration in one year would tend to cause an equal and opposite aberration in the following year, unless the cost of other maintenance activities were rising at a rate different from that of ordinary maintenance. JLARC therefore recommended that the General Assembly tie the definition of "maintenance experience," critical in calculating the annual inflation adjustment factor, "to the level of maintenance funding that VDHT provides, as well as the activities that occur in cities and towns." JLARC also recommended that the General Assembly establish a new unit cost index, with 1983 as the base year, as the basis for adjusting payments to cities and towns in all subsequent years (JLARC, 1984).

Guided by these JLARC recommendations, the General Assembly amended several sections of the state code that pertained to transportation financing. The Assembly repealed Section 33.1-41 of the Code of Virginia, and enacted Section 33.1-41.1 (see Appendix 1). The new law set the payment to each eligible city and town at $7,787 per lane mile for principal and minor arterials and $4,572 per lane mile for collector roads and local streets.

The 1986 Index Formula

The MD developed a maintenance cost index (MCI) in 1986. The FY 1986 index formula included 14 specific types of equipment, 13 specific types of materials, and four labor classifications (Table 1). The MCI's equation and other comments are contained in Appendix 2.

Table 1. MCI fixed basket items

Labor	Materials	Equipment
Equipment Operator A	Asphalt	Chipper 041
Equipment Operator B	No. 8 Stone	Motor Grader 286
Equipment Operator C	Yellow Paint	Tractor Loader 333
Transportation Crew Leader[1]	White Paint	Wheel Loader 336
	Salt	Wheel Loader 338
	Concrete Pipe[2]	Roller Tandem 540
	Metal Pipe[2]	Roller 573
	Abrasives (Sand)	Sweeper 693
	Crusher Run Stone	Mower Tractor 723
	Sign Sheeting[3]	Van Survey 820
	Sign Blank Aluminum[3]	Pickup 828
		Utility Truck 832
		Dump Truck 864
		Bucket Truck 949

Notes:

1) Foreman was changed to Transportation Crew Leader in the FY 91 MCI calculation.
2) Concrete pipe and metal pipe was divided into 18 and 30 inch categories in the early years of the MCI. Metal pipe was combined in FY 1996, concrete in FY 1994.
3) Sign sheeting and sign blank aluminum were dropped from the calculation in 1994.

The MCI is based on a fixed "basket" or mix of equipment, labor, and materials which remain the same each year. A change in the costs of these items is considered to be representative of changes in maintenance costs statewide (W.W. Woodward, internal memorandum, August 1986). Each category or class is composed of a number of items, each of which is weighted in the class index by its contribution to total cost for that class. For example, the equipment class has 14 types of equipment, one of which is a pickup truck. The pickup truck is weighted by its portion of the total cost for all 14 equipment items, as are the other 13 items. The change in the unit cost of the pickup from the base year and the given year is calculated by dividing the given year unit cost by the base year unit cost. The calculation for the pickup item index is done by multiplying the change in unit cost by the weight. All 14 item indices are summed to give the index for the equipment class. This same procedure is done for the labor and materials classes. For an illustration of these calculations, see Table 2. All three class indices are brought together into a composite MCI. Each class index is weighted by its contribution to overall cost and then all three are added together to form the MCI. The composite MCI may therefore be represented by the following formula:

$$MCI = (LaborIndex \times LaborWeight) + (EquipIndex \times EquipWeight) + (MatIndex \times MatWeight)$$

Table 2. Example of Equipment Class Index Calculation FY 1996

Column	1	2	3	4	5	6	7	8	9
Items	1996 Total Cost	1996 Total Hours	1996 Unit Cost	1985 Total Cost	1985 Total Hours	1985 Unit Cost	Unit Cost Change	Weight	Item Index
Chipper 041	172,193	10,770	15.99	127,500	21,248	6.00	2.6645	0.0055	0.0147
Motorgrader 286	3,283,195	183,209	17.92	3,905,518	344,716	11.33	1.5817	0.1051	0.1662
Loader 333	436,743	48,022	9.09	265,722	41,026	6.48	1.4042	0.0140	0.0196
Loader 336	699,287	56,287	12.42	546,651	67,018	8.16	1.5231	0.0224	0.0341
Loader 338	2,227,967	237,130	9.40	1,782,456	277,175	6.43	1.4610	0.0713	0.1042
Roller Tandem 540	654,832	67,370	9.72	301,918	59,771	5.05	1.9243	0.0210	0.0403
Roller 573	70,476	2,668	26.42	79,738	10,883	7.33	3.6053	0.0023	0.0081
Sweeper 693	485,280	11,736	41.35	197,358	6,852	28.80	1.4356	0.0155	0.0223
Tractor 723	2,765,088	250,370	11.04	2,276,661	362,505	6.28	1.7585	0.0885	0.1557
Vans Survey 820	822,017	294,186	2.79	646,450	309,369	2.09	1.3372	0.0263	0.0352
Pickup 828	3,347,456	1,423,083	2.35	4,255,232	2,700,388	1.58	1.4928	0.1072	0.1600
Trucks 832	756,285	285,989	2.64	709,241	375,577	1.89	1.4004	0.0242	0.0339
Dump Truck 864	14,790,138	2,066,527	7.16	13,932,439	2,852,734	4.88	1.4654	0.4735	0.6938
Bucket Truck 949	725,721	69,710	10.41	515,968	77,032	6.70	1.5543	0.0232	0.0361
TOTAL	**31,236,678**								**1.5243**

The unit cost for each item is obtained by dividing the entries in column 1 by column 2. The unit cost change is calculated by dividing column 3 by column 6. Next, the weight for each item is obtained by taking each entry in column 1 and dividing it by the total equipment cost. These results are in column 8. Each item index is determined by multiplying entries in column 7 by those in column 8. The results are in column 9. Column 9 entries are summed to give the class index.

In January of each year, VDOT's FPDM forecasts the MCI, and the increase in city/town street mileage. This forecast is used in developing the budget estimate for submittal to the Department of Planning and Budget (DPB) for inclusion in the Legislative Appropriation Act, which is subsequently approved by the General Assembly. The municipalities in the Commonwealth have FPDM's forecast at hand when they develop their budgets, well before the MCI is determined. The MD calculates the MCI each August, or as close to the end (30 June) of the preceding fiscal year as possible. The MCI is then sent to the URB for use in determining street payments to the cities and towns. In September, the Commonwealth Transportation Board approves the final eligible lane mileages for the localities and the amount of payments to be made quarterly during the fiscal year (Bruce Clarke, internal memorandum, March 26, 1997).

The Time Path of the MCI and the Applied Adjustment Factor

An index number is simply a statistical construct used to measure differences between groups of data. Economists and statisticians have come up with many different index formulations during the last century. The formula chosen will generally reflect the purpose of the index number itself. An index number measures the change in some broad average over time. The value of an index number calculated for one period (or point) in time is meant to be compared against values of the same index calculated for other periods. In fact, it has little meaning outside of that context. The point of reference, or benchmark, is called the base year. In the base year, the value of the index is generally given as 1.0 or equivalently, 100. By comparing prices in previous and ensuing years with prices in the base year, we can tell how much prices have increased or decreased relative to what they were in the base year. In the case of the MCI, the value of the index in the base year is 1.0. The MCI shows the average change in maintenance costs from the base year (currently FY 1985) to the given year, such as FY 1998. For example, if the index number in FY 1998 is 1.5, this means that the cost of the items in the index has increased by 50 percent since FY 1985. Since the index is taken to represent all maintenance costs, we can extrapolate that overall maintenance costs have increased by 50 percent. Since the basket contains items of unchanging or equivalent quantity or quality, the index reflects only pure movements in cost.

The MCI values calculated for FY 1985 through FY 1997 are shown in the second column of Table 3. The third column shows the annual change of the index, in percent, and the fourth column shows the cost adjustment factor that was actually applied to the maintenance assistance payments in each fiscal year.

Table 3. Maintenance Cost Index FY 1985- FY 1997

Fiscal Year	Calculated MCI	Percentage Change	Applied MCI
1985	1.0000		
1986	1.0790	7.90	1.0000
1987	1.1150	3.34	1.0790
1988	1.1680	4.75	1.1150
1989	1.2040	3.08	1.1680
1990	1.2670	5.23	1.2040
1991	1.3220	4.34	1.2040
1992	1.3150	-0.53	1.2040
1993	1.3290	1.06	1.2040
1994	1.3870	4.36	1.2670
1995	1.4160	2.09	1.3220
1996	1.4230	0.49	1.3150
1997	1.4500	1.90	1.4230

At the time the MD developed the MCI, it planned to use the cost index calculated for each year to determine the adjustment to maintenance assistance payments for the succeeding year. VDOT applied this rule from 1987 to 1990. In order to address revenue shortfalls that occurred from FY 1990 through FY 1992, the General Assembly froze the MCI at the FY 1990 applied rate. The freeze remained in place through FY 1993. The FY 1990 MCI was used to calculate payments for FY 94. The General Assembly then required VDOT to apply the FY 1991 MCI for FY 1995 payments and the FY 1992 MCI for FY 1996 payments (MD, internal memorandum, January 1995).

The Maintenance Division received authorization to revert to its original scheme in FY 1997. The FY 1997 applied rate equaled the MCI calculated for FY 1996. This practice is expected to continue.

PURPOSE AND SCOPE

The purpose of this study was to review and update the Virginia Department of Transportation's MCI. The study developed a representative mix of items for inclusion in the MCI and examined the MCI's formulation to determine if an alternative formula would lead to a more accurate reflection of changing maintenance costs and lane mile allocations to cities and towns.

METHODS

The authors first conducted a literature review to explore the subject of price and cost indices and their inherent limitations. The review involved searches of the TRANSPORT database, agency libraries including the Bureau of Labor Statistics and Statistics Canada library,

and economic journal collections. Second, background information on the development of the MCI was obtained through memoranda, the Code of Virginia, and interviews and meetings with VDOT personnel familiar with the MCI from the MD, URB, and FPDM. The information gathered permitted a comparison between the mathematical properties of the MCI and the formulae that receive the strongest endorsement from economic theory.

Next, the items contained in the MCI calculation were revisited to determine whether they were representative of current maintenance activities. This involved several steps. All VDOT District Maintenance Engineers were asked about new items in use in the field. Next, the availability and quality of data on cost and quantity of all of VDOT's equipment, materials, labor, and contracts pertaining to maintenance were assessed. Cost and quantity data for equipment, materials, and labor were obtained from several Central Office Divisions. Equipment data were obtained from the Information Technology Division (ITD), materials data from Administrative Services Division (ASD), and labor data from the Human Resources Division (HRD). The data encompassed FY 1994 through FY 1997.

As the information was gathered and analyzed, the researchers were able to determine which items should be in the index and which could be removed. Correlations between items and elasticities of substitution were calculated to determine if there was a statistical method to remove items from the index. Correlated items could be removed from the calculation without losing any information. Calculating the elasticities of pairs of items would enable the researchers to determine if items are substitutes for each other. Each item's share of total cost (cost being price/unit cost multiplied by quantity) for each subindex was calculated to determine the "high use" maintenance items. Out of 67 materials items, 42 labor classes, and 171 equipment items, those items with shares of total category cost greater than 0.5 percent were chosen for the new item mix. These items were then reviewed by a study committee which included representatives from MD, FPDM, and URB. These efforts resulted in the formation of a new, more representative mix of items upon which to base the MCI.

In order to make the MCI as representative of current maintenance conditions as possible, it was necessary to include contract maintenance data. At the time of the study, appropriate cost and quantity data for Virginia was not available. Total contract expenditures were available from FY 1991, but data on quantity was not. To account for this lack of data, several alternate construction indices were evaluated as possible proxies for contract maintenance.

A survey of other state highway agencies was conducted to learn whether any other state highway agency maintained a maintenance cost index or a similar statistic, for what purpose that agency used its index (if any), and how that agency determined maintenance allocations to the cities and incorporated towns. This allowed the researchers to compare VDOT's practices with those of other states. In addition, a variety of construction and highway statistics known or expected to be related to the cost of urban street maintenance in Virginia were collected. These statistics were compared to the MCI to assess how the MCI and the urban street payment allocation formula have performed over time.

Finally, alternate formulae recommended by the literature review were investigated for the calculation of a new MCI. This task involved testing two alternative index formulae, the Fisher Ideal Index and the Törnqvist index, for appropriateness, practicality, and ease of use. This final analytical approach combined the best mathematical formulae garnered from the literature, additional maintenance cost data available within VDOT, and additional statistics available elsewhere, to construct hypothetical alternative maintenance cost index formulae. The researchers compared the behavior of these alternatives with that of the current MCI and with actual trends in maintenance costs. The resulting index numbers were applied to all localities to compute possible lane mile allocations.

FINDINGS

This section details the results of the study to review VDOT's MCI. A literature review was conducted to explore the limitations with indices like the MCI and determine desirable index properties. This effort was followed by a search for representative maintenance items for inclusion in the index. The process for incorporating maintenance contracts is described. The results from the two alternative formulae recommended by the literature are compared to the current MCI.

Literature Review and Staff Input

Many price indices are based on price relatives, which are ratios between the price of each item in the current period and the price of the same item in a chosen base period. For such indices, one must choose a base period in order to define the index. The Bureau of Labor Statistics (BLS) uses a complex example of this type to calculate the Consumer Price Index (CPI). VDOT's current MCI is also based on price relatives (equation 2 in Appendix 2).

When an index is designed to summarize a very large number of data values, it often includes only a representative sample of all of the values. This choice reduces the costs both of data collection and of computation. While many of the early index numbers were composed of simple unweighted sums or averages of data values, most modern indices use weights that reflect the relative importance of index element. This choice permits the more important data values to exert more influence over the value of the index (Merrill and Fox, 1970).

For example, in calculating the CPI, the BLS collects price data on only a representative sample of goods and services. Rather than simply average the prices of all the goods and services in the sample, the BLS weights the prices in each category (foods and beverages, apparel, housing, etc.) with a weight equal to that category's share of a typical family's total expenditures in the base year (Advisory Commission to Study the Consumer Price Index, 1996). Likewise, the MD collects data on a relatively small number of maintenance-related items for the MCI and weights them by their contribution to total cost.

In 1987 a study of the FHWA Highway Maintenance and Operations Cost Index was conducted. This index was based on a fixed market basket of 34 items of labor, materials, and equipment. Unit prices or costs were applied to quantities of items annually. The resulting total cost was then compared to the base year total cost. The basket was formed in 1947 and had not been updated since that time. As in the case of the Virginia MCI, there were strong concerns that the index was no longer representative of maintenance conditions. The conclusions of the feasibility portion of the study (the only part to reach completion) led the authors to recommend revising the composition of the basket and the formula of the index (Markow, Seguin, Ireland, and Freund, 1990). The index itself has since been discontinued since the number of users was relatively small.

A "good" index is up-to-date and accurately reflects cost trends. Such an index should have its foundation in realistic assumptions about how VDOT operates and it should be easy to adjust. For example, a base year change should not disrupt the index formula. A desirable formula is accurate, flexible, and representative of maintenance conditions.

Limitations of a Fixed Basket Index

In 1996, a Senate Committee chaired by economist Michael J. Boskin reviewed the CPI and reported on several shortcomings and biases stemming from the index's formula and composition. Many of the committee's criticisms are applicable to the MCI, since both indices are based on fixed baskets. In addition to Boskin's review, a wealth of literature has emerged over the past several years delineating the problems inherent to fixed basket indices and possible solutions. The fixed basket formulation fails to reflect the fact that consumers, in the case of the CPI, tend to substitute relatively less expensive items when relative prices change (Advisory Commission to Study the Consumer Price Index, 1996). This limitation is referred to as "substitution bias" in the literature. In fact, the underlying assumption underlying a fixed basket index is that consumers keep the quantitative proportions among commodities unchanged (Statistics Canada, 1995). For example, if the price of beef rises relative to chicken, consumers will likely purchase chicken, or other beef substitutes. But the index will miss the substitution and will instead merely show an increase in prices when, in actuality, consumers are no worse off since they are paying roughly the same for a different set of groceries. The same phenomenon occurs within the MCI. For example, the index includes two types of wheel loaders: wheel loader 336 and 338. Assuming the two loaders can perform the same tasks and the cost of one of the loaders falls, an engineer would likely switch to the lower cost vehicle. The MCI does not capture this substitution and so overestimates the cost increase of the "true" basket employed.

Another limitation of the CPI originating from the fixed basket make-up is that the basket tends to become less and less representative of consumer's behavior and tastes over time. This limitation is known as "new product bias". Until the BLS's most recent update, the CPI's basket was only fully rotated every 5 years. This meant the introduction of new goods was delayed (Hulten, 1997). For example, until the January 1998 update of the basket, cellular phones had not been included despite the fact that 40 million Americans own them (Berry, February 24, 1998). Under the new procedures for the CPI, one fifth of the basket will be rotated or changed every year, thereby speeding up the introduction of new items. As with the CPI, the need for the

MCI basket to be fixed and relevant at the same time creates a conflict within the index. The quantitative proportions among the commodities purchased undergo shifts over time (Statistics Canada, 1995). These changes may come from the introduction of new equipment or materials, changes in available labor, changing maintenance practices, an aging road system, and a changing VDOT environment. Since a fixed basket like the MCI reflects quantitative proportions among commodities that were used in the basket reference period it *is* relevant to that period. However, it may not be relevant in the observed period. In other words, the MCI item mix from FY 1985 may not be relevant or at least not representative in FY 1998. For example, the FY 1985 basket does not include items such as thermoplastic, B-VI tape, or contract work, all of which have become significant components of maintenance costs. The reverse is also true; some items in the FY 1985 basket, such as brush chippers, account for a relatively small share of total cost from FY 1994 through FY 1997.

The substitution and new product biases can be alleviated by frequent updates of the basket. However, the biases cannot be eliminated completely due to the difficulty of continuously updating any index. A large bias is unlikely to build up, however, if a fixed basket is maintained for only a limited time (Statistics Canada, 1995).

Studies have also demonstrated examples of formula bias in the CPI that apply to the MCI as well. In the case of the MCI, weights reflect the share of total cost for each item used in the index in the given year. This assumes that these weights are the same for every given year and the base year, which is not a realistic assumption. For example, the share of total index item cost taken by materials, labor, and equipment in FY 1997 is 28, 51, and 21 percent, respectively. On the other hand, for FY 1985 the shares are 26, 53, and 22 percent. In FY 1996 shares for the same items are 26, 54, and 19 percent. Alternate formulae, referred to as "superlative indices", consider the weights in both periods by taking an average of them, i.e., a moving average. Since the weights reflect both years, this approach has the effect of creating a "new" basket each year. In this way, members of this class of indices are more realistic and also can reflect the effects of substitution among items (Shapiro and Wilcox, 1997).

Another problem with using indices to measure changes in cost is that they are not formulated to account for changes in quality and productivity to the items in the basket. Changes in quality and productivity have the same effect on an index: the index tends to miss their effect, but their sources are slightly different. Quality change occurs when improvements in product design cause consumers to shift their spending to superior varieties, or when the product mix changes in response to price or income changes (Hulten, 1997). In terms of the MCI, a tractor with added features may allow the maintenance work to be completed faster and for less cost. Although the literature has identified possible ways to capture the impact of quality gains, the methods require large amounts of data and are really still in their infancy. It is possible to handle some quality change by assuming that an improvement in quality in a good is equivalent to a price reduction in that good, but this assumption is not applicable to all quality change (Fisher and Shell, 1972). The BLS uses several methods to account for quality change. However, some of these methods may be biased as well (Hulten, 1997). Productivity gains, exemplified in the road maintenance industry by such innovative practices as mechanized pothole-filling and radio communication between snow plows and headquarters, may be defined as obtaining a greater

quality or quantity of work without spending additional money. Technical innovation, if not offset, would unambiguously decrease average annual maintenance costs in dollar terms. Technical innovations developed in Virginia or borrowed from other states have probably enabled VDOT to obtain more from a given mix of labor, materials, and equipment than it did twenty or thirty years ago. Such productivity gains, as they occur, cause a reduction in the cost of a unit of maintenance work, which the MCI misses. At the present time, however, no cost or price index formula is able to account for quality and productivity changes in a truly satisfactory and practical manner.

There is some reason to suspect that the average prices VDOT pays for certain items can be either higher or lower than the average prices that municipalities pay, or the average prices that private contractors pay. For instance, VDOT may be able to take advantage of volume discounts that are unavailable to smaller buyers. On the other hand, according to staff interviewed in the ASD of VDOT, urgent public needs or state procurement rules may occasionally force VDOT to settle for a higher price than that available to smaller buyers. The MCI takes account only of the cost of labor, equipment, and materials that VDOT itself procures for maintenance work with state funds, not of the prices paid by municipalities nor of the cost of contract maintenance. The possibility of differences between the labor, equipment, and materials prices that VDOT pays and the prices that the cities and independent towns pay means that the MCI may be a less accurate measure of the change in urban maintenance prices than is now assumed. The price index calculated from VDOT's costs might under- or overestimate the change in prices that the municipalities face in a given year. It is likely, however, that the average prices paid by VDOT (and measured by the MCI) would nevertheless rise about as fast as the average prices paid by the cities and towns over the longer run.

Alternative Indices

The literature recommended the use of "superlative indices" rather than fixed basket index formulae such as the MCI. Two of these superlative indices are the Fisher Ideal Index and the Törnqvist Index (equations 4 and 5 in Appendix 2.) Since the Törnqvist and Fisher Indices adhere to certain mathematical properties, they tend to be more reflective of reality. These properties translate into an index being easy to manipulate and change, as necessary, to mirror changing conditions. The Fisher and the Törnqvist indices take information from two time periods instead on just one by relying on a geometric mean. In the case of maintenance costs, these formulae would draw on prevailing maintenance conditions in the base year and the year in question to calculate the index number. The geometric mean embodied in the Törnqvist and Fisher indices represents realistic assumptions about VDOT's ability to shift expenditures from one year to the next, while the arithmetic mean embodied in the current index does not. The use of expenditure weights that are equal to the average of the expenditure shares in the base year and the current year, rather than simply equal to the expenditure shares in the current year, is also more realistic. The MCI is not a "superlative" index. This means that it may track the changes in cost per unit of work fairly closely in any given year, but that one cannot always rely on it to do so. For a more technical presentation, please see Appendix 2.

The Use of a Fixed Base Year

One of the hallmarks of a good index number is that it exhibits the same annual percentage changes regardless of what year is chosen as the base year. (See the section, *Alternative Index Formulae* in the Appendix 2.) Use of a moving base year or a fixed base year does not cause the miscalculation of one year's index to distort the payment rate in future years, as long as a superlative index formula is used. In the case of the Fisher and the Törnqvist indices, a base year in the traditional sense is not necessary, since a comparison can be made between any two years (Advisory Commission to Study the Consumer Price Index, 1996). For the sake of comparison, however, during the course of this project the researchers treated either FY 1985 or FY 1994 as points of reference.

Data Analysis

The data used in this project encompassed FY 1994 through FY 1997. The equipment data consisted of equipment rental revenue charged to maintenance budget activities and the rental hours charged by type of equipment. The rental rate is what MD pays the Equipment Division (ED) for the use of equipment. All of the materials data, with the exception of data on B-VI tape, came from the Purchasing and Inventory Management System (PIMS) database and consisted of fiscal year issues (quantity), and statewide average unit cost for each item. In the case of materials, data for FY 1994 was not available from PIMS so it was estimated using FY 1995 through FY 1997 growth trends. Since information on B-VI tape was not available from PIMS, cost and quantity data was obtained from seven of nine VDOT districts. This cost data includes the cost of the tape itself as well as its installation. Labor data consisted of salary and number of positions pertaining to maintenance activities, based on work group code, excluding tunnels and tolls. The labor data included the minimum and maximum salary for each position. The minimum and maximum salary were averaged to obtain the mean salary for each position. The salary data were adjusted to reflect total cost by an "additive" provided by the MD to account for vacation, sick leave, holiday, workers' compensation, social security, retirement, group life insurance, and health care. To obtain the total cost or total fully-loaded compensation for labor, the salary figures, adjusted by the additive, were multiplied by the total number of filled positions. VDOT's recent practice of "broadbanding," whereby some labor positions are combined, made data collection and calculation for the current labor class cumbersome, difficult and not reflective of maintenance positions. To account for the broadbanding of certain positions, Highway Equipment Operators A, B, C, and Bridge Construction Repair Worker were combined with Maintenance Crew Member in the analysis. Vacant positions were removed from the database.

Basket Formulation

The researchers formulated a broader basket of items in order to encompass a larger share of total maintenance costs, making the index more representative of maintenance trends than the current item mix. For the equipment, materials, and labor classes, each item's share of total cost for its particular class was calculated. This share of total cost was used to judge which items

were relatively "high use." Items with shares larger than 0.5 percent were chosen for the new basket. The list of new items was reviewed by personnel from the MD, URB, and FPDM. Table 4 lists the new items. Table 5 provides a comparison of the current and proposed baskets. This table also displays the portion of total maintenance each basket composes.

Correlations between items were calculated to determine if any statistical evidence existed to remove items whose costs move together over time. If this were the case, one of a pair of highly correlated items could be removed without any loss of information. However, four years of data were not sufficient for strong conclusions regarding correlations. The same held true for the calculation of elasticities. This calculation was performed to determine if items were substitutes or complements for each other. Complements are items which are demanded together, such as coffee and milk or rollers and asphalt. Complements could be removed from the calculation. Again, however, the data collection period did not encompass enough years to allow firm conclusions.

Table 4. Proposed Item Mix for MCI (Current MCI items in bold type)

EQUIPMENT	MATERIALS	LABOR
Trucks – Utility Body – 8500 GVW (Trucks 832: ¾ Ton Utility)	Post, Salt treated 4x4x12	Transportation maintenance worker
Wheel loaders - 140 hp - 3 cu. yd.	Stone, NO 57	Transportation resident maintenance operations manager
Tractor-loader-backhoes – 4WD	Stone, No 22	Fiscal assistant
Mowers – non-extension-side rotary or flail	Stone aggregate base (dry rip rap class I)	**Transportation crew leader**
Graders – 6WD	Stone , cbr No 30 (select material)	Transportation maintenance supervisor
Trucks – survey van – passenger – 7500 GVW	Thermoplastic (White, 6" and 12")	
Pavers – bituminous (lee-boy)	Stone, No 21 A	Transportation maintenance superintendant
Distributors – truck mounted - 1,000 gallon	**Paint, Water base, traffic, white**	**Transportation maintenance crew member** (Equipment operator A, B, C, and Bridge Construction Repair Worker and crew members Already broadbanded)
Trailers – variable message sign, engine driven	Calcium chloride in liquid, bag, and bulk form	
Tractor-loader-backhoes – 2WD (loader 333)	Stone, No 8	
Mowers-tractors-right & left cutter bar	**Paint, Water base, traffic, yellow**	
Sweepers – vacuum – 4 to 7 cu. yd. – truck mounted (Sweeper 693)	Sand (Grade A and B)	
Trucks-van-15 passenger-9000GVW (Vans Survey 820)	**Asphalt (Liquid)**	
Trucks-utility body-15000 GVW	**Abrasives (Chemically Treated and Untreated)**	
Trucks-bridge-crew cab w/lift - 30000 GVW	**Crusher Run Stone (CR Stone No 24, 25, 26)**	
Trucks –stake body-standard 14 ft. - 28000 GVW	**Sodium Chloride Bulk**	
Trucks-dump-4WD - 30000 GVW	B-VI tape	
Wheel loaders - 110 HP - 2 cu. yd. w/backhoe (Loader 336)		
Crash cushoins –truck -mounted		
Rollers - 4 to 6 ton - Tandem (Roller Tandem 540)		
Markers-paint-truck-mounted - 400 or 800 gal. capacity		
Trucks – stake or utility – 10000 GVW		
Loaders – belt type (athey)		
Trucks – aerial bucket – 300 lb - 24000 GVW (Bucket Truck 949)		
Excavators – truck-mounted		
Trucks –pickup-construction - 6100 GVW		
Trucks – replaced standard dump for crash cushion - 30000 GVW		
Mowers-extension-brush cutter-rotary or flail		
Trucks-pickup-4WD-maintenance - 6100 GVW		
Trucks-pickup-crew cab - 8500 GVW		
Trucks-dump-crew cab - 30000 GVW		
Wheel loaders - 110 HP - 2 cu. yd. (Loader 338)		
Graders - 150 hp - 30,000 lb.		
Trucks-pickup-maintenance - 6100 GVW (Pickup 828)		
Trucks-dump-tandem - 50000 GVW		
Graders - 125 hp - 27,000 lb. (Motorgrader 286)		
Mowers-tractor-right-hand cutter bar (Tractor 723)		
Trucks-dump-standard - 30000 GVW (Dump Truck 864)		

Table 5: Comparison of the Current and Proposed MCI Baskets

Current MCI FY	Equipment	Materials	Labor	Contracts	Total	Total as % Total Maintenance[3]
94	$32,988,268	$38,398,183	$101,145,751		$172,532,202	31.99%
95	$30,430,051	$41,319,373	$86,739,234		$158,488,658	25.99%
96	$31,236,678	$42,112,883	$87,351,141		$160,700,702	25.79%
97	$29,807,434	$40,769,621	$72,800,843		$143,377,898	22.50%
Number of Items[1]	14	9	4		29	
Proposed MCI FY	**Equipment**	**Materials**	**Labor**	**Contracts[2]**	**Total**	**Total as % Total Maintenance**
94	$50,447,924.13	$23,068,952.38	$112,807,889.46	$249,743,384	$436,068,149.97	80.86%
95	$43,054,429.48	$27,787,911.69	$110,094,397.52	$338,735,465	$519,672,203.69	85.21%
96	$49,567,159.57	$21,899,477.23	$100,626,945.46	$329,477,531	$501,571,113.26	80.48%
97	$43,222,580.66	$30,829,641.13	$107,148,473.93	$363,896,937	$545,097,632.72	85.53%
Number of Items	38	17	7		62	

Notes:
[1]As of FY 97.
[2]The contracts column includes total OM and MR contracts (OM and MR contracts, hired equipment, and project ledgers).
[3]The total maintenance figure includes the expenditure items state force labor, inmate labor, materials, state force equipment, hired equipment, contracts, and project ledgers. Figures were supplied by MD.

Inventory of Available Cost Data

In order to meet the basic data requirements for a price index, data on price and quantity must be available in some form. Knowledge of the quantity and average purchase price of each item is enough; total expenditures (equal to price times quantity) permit the indirect calculation of average price when only quantity is retrievable, and vice versa. The MD has access to the following data within VDOT:

- State Forces Work:
  - Equipment: The number of pieces of each type purchased each year; number of pieces of each type in use each year; the average unit price of each year's new purchases; total cost (including purchase cost, overhead, depreciation, fuel and repair cost, i.e., how much it costs the ED to operate the equipment), the rental revenue charged from and the hours charged to maintenance activities for each fiscal year by equipment class code

- Materials: The quantity of each item issued each fiscal year; the statewide average unit cost of each year's purchases; and the balance on hand

- Labor: The total number of employees in each class on the payroll at the end of the fiscal year; the total cost of compensation for employees in each class during each fiscal year (loaded and unloaded)

- Units of work performed: Available for some maintenance activities (i.e., asphalt spreading).

• Contract Work:

- Equipment, materials, and labor: VDOT has the right to ask contractors to supply this information but does not currently do so. VDOT currently maintains records only on the total expenditure for contract maintenance work.

- Units of work performed: These data is not available. The contract records do not permit ready tabulation of the number of units of work in each maintenance activity.

Inclusion of Contracts

To deal with the lack of sufficient contract data, the researchers tested several proxies intended to capture the influence of contracts. These proxies took the form of two state and two national construction contract indices. Used in conjunction with VDOT contract cost figures, these formed a fourth component of the MCI. The contract proxies were tested with the current, Törnqvist, and Fisher formulae and both item baskets. The Törnqvist Formula lends itself well to the inclusion of a contract proxy. It is somewhat more difficult to include a proxy in the Fisher Formula/

In an attempt to incorporate a state-specific construction index as a maintenance contract proxy, the researchers investigated VDOT's construction cost index. Based in 1973, this index was a composite of 18 cost items in five activity areas. Since the index had become out-of-date, it was phased out in the spring of 1998 and replaced with a method adapted to VDOT from an AASHTO shareware package. The new index was not yet available at the time of this project. The FHWA Bid Price Index, available since 1933, was also tested as an alternate proxy. As changes have occurred over time, the market basket and the item weights have been adjusted. The current FHWA index is based in 1987. The basic data are obtained from contract awards greater than $500,000 for Federal-aid highway projects. The data consist of quantities, contract unit prices, and costs for six indicator items. These items include common excavation, portland cement concrete surfaces, bituminous concrete surfaces, structural reinforcing steel, structural steel, and structural concrete (Mirack, 1991). The index shows what it would cost at any given time for the quantity of Federal-aid construction contracted for

during the base period (FHWA, 1981). The index is compiled from information on contracts reported by each state according to FHWA reporting guidelines. In the interest of examining another state-specific index, the index numbers for Virginia were obtained and tested. Since the individual state indices are based on data submitted for contracts greater than $500,000--a small sample in some cases--the indices may not be representative of long term price trends. Aberrations could arise due to unusual projects awarded during the period in question or low volumes of work (FHWA, 1996). The Engineering News Record (ENR) General Construction Index was also tested as a proxy. This national index is computed on the basis of a hypothetical unit of construction requiring specific amounts of portland cement, lumber, structural steel, and common labor (U.S. Department of Commerce, Economics and Statistics Administration, Bureau of the Census, 1995).

Survey of States

Following discussions with MD personnel, fifteen states were contacted regarding the use of a cost index to track maintenance costs. States surveyed were: Florida, Kansas, Pennsylvania, Delaware, North Dakota, Wisconsin, Ohio, Oregon, Texas, New Jersey, Maryland, California, Louisiana, Missouri, and Colorado. Of the nine states that responded, only Florida uses a similar unit cost-based calculation. It tracks maintenance costs as part of its annual zero-based budget process. Costs are reported and stored by a Maintenance Management System, which is used to plan, direct and control state highway system maintenance (Florida Department of Transportation, 1996). Maintenance work completed by both in-house and contract forces must be reported to the system. The information includes among other items, man hours worked, number of units completed, and vehicle usage. This information is reported for each type of maintenance activity or work type. Unit prices are calculated for each maintenance activity. The individual unit costs are combined based on what proportion of each maintenance activity is done in-house or by contract in order to develop an overall statewide unit price. This statewide unit price is applied to the statewide workload and this is used to support the budget request each year. Activities such as wetland mitigation and stormwater management are added to the calculation as needed. The list of activities is reviewed each year and augmented or consolidated according to prevailing conditions. State officials were asked whether they knew of other states that rely on index calculations. No others were found.

Comparison with Other Statistics

VDOT statistics indicate that financial assistance to localities for road maintenance rose sharply after the Special Legislative Session of 1986, and has fluctuated since then with no pronounced trend. Table 6 shows local maintenance assistance's share of the VDOT revenue by fiscal year. As a percentage of total VDOT revenue, local maintenance assistance rose from 6.81 percent in 1985 to 11.16 percent in 1986, and has since fluctuated in the range of 7.76 to 9.51 percent, with a median value of 8.58 percent. As a percentage of total VDOT disbursements for highway maintenance, local maintenance assistance rose from 19.28 percent in 1985 to 27.44 percent in 1986, and has since fluctuated in the range 20.46 to 26.29 percent, with a median value of 25.06 percent. In short, the new urban street categories and the new baseline assistance rates set by the General Assembly appear to have caused maintenance payments to cities and towns to increase. The MCI-based adjustment factor, however, has not caused the payments to rise or fall over time relative to the VDOT budget. This

observation holds true even if the annual urban street payments are modified to show what would have happened if the MCI adjustments had not been "frozen" from 1991 to 1993 (VDOT, 1984-86 and 1987-95).

Table 6. VDOT maintenance disbursements

FY	Financial Assistance to Localities	Assistance as % Total VDOT Revenue	As % VDOT Maintenance Disbursements
1996	$197,149,100	9.05	24.35
1995	$175,861,709	8.58	20.46
1994	$166,951,125	9.01	21.59
1993	$156,935,130	9.51	25.57
1992	$154,383,868	8.75	26.19
1991	$152,070,082	8.58	25.06
1990	$149,697,687	8.37	24.22
1989	$141,150,498	7.76	25.73
1988	$131,708,687	7.85	24.91
1987	$127,390,038	8.26	25.55
1986	$135,764,001	11.16	27.44
1985	$72,347,341	6.81	19.28

Table 7 shows that the city and town systems account for a steadily growing percentage of the total lane miles of all systems in the Commonwealth. The 1985 legislation that established the MCI redefined the categories of streets that are eligible for urban maintenance assistance, causing a large one-time jump in eligible urban lane mileage. Since then, the percentage has grown from 14.06 percent in 1986 to 15.38 percent in 1996 (Traffic Engineering Division, Virginia Department of Transportation, 1997).

Table 7. Lane miles over time

FY	City and Town Lane Miles (as of June 30)	VDOT Lane Miles (as of December 31)	City and Town As % of Total State Lane Miles
1997	21,919	120,558.90	15.38
1996	21,709	120,193.65	15.30
1995	21,500	119,766.04	15.22
1994	21,338	119,197.22	15.18
1993	21,130	118,766.62	15.10
1992	20,728	118,017.49	14.94
1991	20,520	117,574.84	14.86
1990	20,145	116,897.59	14.70
1989	19,857	116,250.38	14.59
1988	19,328	115,938.26	14.29
1987	19,121	115,407.34	14.21
1986	18,823	115,027.20	14.06
1985	14,864	114,617.02	11.48

Table 8 shows the BLS producer price indices (PPI) for sand, gravel, crushed stone, construction machinery and equipment, and the average annual compensation per full-time employee in the construction sector, from 1985 to 1995. Comparison between these and the MCI basket shows that materials prices have grown at a slower average annual rate than the index as a whole, and that the compensation of labor has grown at a faster average annual rate. The evidence on equipment prices is ambiguous. These statistics imply that if wages and prices continue to follow these trends, and if item weights continue to be calculated according to the current formula, deletion of an item from the materials class index or addition of an item to the labor class index will tend to make the MCI grow faster. Addition of an item to the materials class index or deletion of an item from the labor class index will tend to do the opposite.

Table 8. Producer Price Indices and Annual Earnings (1985=100)

Year*	PPI Sand, Gravel, and Crushed Stone	PPI Construction Machinery and Equipment	Total Compensation Construction	Materials Index	Equipment Index	Labor Index	Calculated MCI
1985	1.000	1.000	1.000	1.0000	1.0000	1.0000	1.000
1986	0.806	1.012	1.074	1.0497	0.9797	1.1290	1.079
1987	0.938	1.033	1.116	N/A	N/A	N/A	1.115
1988	0.911	1.061	1.175	1.0763	1.0864	1.2531	1.168
1989	1.016	1.112	1.178	1.0962	1.0879	1.2934	1.204
1990	1.138	1.154	1.261	1.1044	1.1788	1.3702	1.267
1991	1.034	1.188	1.276	1.0864	1.2938	1.4310	1.322
1992	0.999	1.221	1.307	1.0614	1.2606	1.4308	1.315
1993	0.998	1.252	1.360	1.0831	1.3191	1.4233	1.329
1994	1.028	1.268	1.374	1.0735	1.3222	1.5264	1.387
1995	N/A	1.297	N/A	1.1714	1.4389	1.5247	1.416
1996	N/A	N/A	N/A	1.1618	1.5244	1.5134	1.423
1997				1.2647	2.0805	1.2949	1.4500

*The first three indices are based in calendar year; MCI is a fiscal year index.

Table 9 tracks the values of the ENR General Construction Cost Index and the FHWA Composite Highway Construction Index, for the period 1985-1995. Comparison shows that the MCI has grown at a faster annual rate than either of these. While the MCI grew by 38.7 percent from 1985 to 1994, the ENR General Construction Index grew by 28.9 percent and the FHWA Highway Construction Index grew by 12.8 percent. The differences may be due in part to the fact that maintenance activities require a different mix of labor, materials, and equipment than construction activities do. The differences may also be due in part to the fact that the FHWA index is an index of finished cost per unit of work, while the MCI and the ENR index are indices of labor, materials, and equipment prices. (Department of Commerce, Economics & Statistics Administration, Bureau of the Census, U.S., 1995; FHWA and ENR staff, personal communication for the 1995 and 1996 values).

Table 9. Contract Proxies*

Year	ENR General Construction Index	FHWA Highway Construction Index	Calculated MCI
1985	1.000	1.000	1.0000
1986	1.024	0.997	1.0790
1987	1.050	0.990	1.1150
1988	1.078	1.045	1.1680
1989	1.100	1.056	1.2040
1990	1.128	1.064	1.2670
1991	1.152	1.054	1.3220
1992	1.188	1.030	1.3150
1993	1.242	1.062	1.3290
1994	1.289	1.128	1.3870
1995	1.304	1.200	1.4160
1996	1.339	1.238	1.4230
			1.4500

*The values for the FHWA and ENR indices were taken from the Statistical Abstract for the United States 1995. Additional values were obtained through personal communication with FHWA and ENR publication staff.

Comparison of the MCI with Alternative Indices

The literature review, the inventory of available data, and the comparison of the MCI with other cost statistics yielded several lessons which the researchers used to construct a set of alternative index formulae. Thirty options for the MCI were calculated and evaluated. Tables 10 and 11 display the alternatives by actual index number and show the changes from year to year. Table 10 displays options under the current basket, while Table 11 displays options under the proposed basket. Each of the alternatives differs from the current maintenance cost index in one or more of the following five ways:

1) A Törnqvist or a Fisher mathematical formula is substituted for the mathematical formula in the current index.

2) A revised list of equipment, materials, and labor items takes the place of the list that the current index employs.

3) Hourly rental rates are used as the price variables for the equipment items, in place of the cost of the operation figures that the current index uses.

4) Contract work, using a national or state construction cost index as the price variable and the ratio of total contract payments to the construction cost index value as the quantity variable, is added as a single item in a fourth category alongside equipment, materials, and labor.

5) The weights on the equipment, materials, and labor (and contract work, if applicable) class indices are set equal to each class's share of the total cost of the indexed items. An alternate

set of weights was calculated by taking the class portion's share of total maintenance expenditure (see Table 12).

The close correlation between the expenditure shares and the index weights suggest that the current formula tracks the year-to-year changes in expenditures on each cost category relatively well. The only exception is materials, which probably stems from the inventory nature of the data. As VDOT cost statistics revealed, any index that excludes contract work will become progressively less representative of what is actually going on in maintenance. For this reason, contract expenditures were added experimentally as an extra item to both the current and the alternative lists of items. Furthermore, each of these permutations was tested using each of four construction cost indices as the contract work price variable: the ENR national index, the FHWA national index, the FHWA Virginia state index, and the VDOT Construction Cost Index. Table 13 shows how maintenance contracts have grown since 1991.

Table 10. Options Based on Current Item Mix

	Current Formula		Fisher Formula		Törnqvist Formula	
	Index Value	% Annual Change	Index Value	% Annual Change	Index Value	% Annual Change
No Contract Proxy						
FY 94	1.0000	NA	1.0000	NA	1.0000	NA
FY 95	1.0210	2.10	1.0229	2.29	1.0211	2.11
FY 96	1.0263	0.52	1.0299	0.69	1.0278	0.66
FY 97	1.0451	1.83	1.0271	-0.28	1.0231	-0.46
ENR Proxy						
FY 94	1.0000	NA	1.0000	NA	1.0000	NA
FY 95	1.0362	3.62	1.0340	3.40	1.0340	3.40
FY 96	1.0476	1.11	1.0445	1.02	1.0444	1.01
FY 97	1.0825	3.33	1.0603	1.51	1.0573	1.23
FHWA Proxy						
FY 94	1.0000	NA	1.0000	NA	1.0000	NA
FY 95	1.0527	5.27	1.0494	4.94	1.0493	4.93
FY 96	1.1014	4.63	1.0942	4.27	1.0940	4.26
FY 97	1.1450	3.96	1.1154	1.94	1.1124	1.68
VDOT Construction Index						
FY 94	1.0000	NA	1.0000	NA	1.0000	NA
FY 95	1.0985	9.85	1.0913	9.13	1.0911	9.11
FY 96	1.1536	5.01	1.1411	4.56	1.1409	4.57
FY 97	1.1931	3.43	1.1569	1.38	1.1539	1.13
FHWA VA Proxy						
FY 94	1.0000	NA	1.0000	NA	1.0000	NA
FY 95	1.1592	15.92	1.1454	14.54	1.0911	9.11
FY 96	1.1446	-1.26	1.1331	-1.08	1.1329	3.83
FY 97	1.1363	-0.72	1.1078	-2.23	1.1048	-2.48

Table 11. Options Based on New Item Mix

	Current Formula		Fisher Formula		Törnqvist Formula	
	Index Value	% Annual Change	Index Value	% Annual Change	Index Value	% Annual Change
No Contract Proxy						
FY 94	1.0000	NA	1.0000	NA	1.0000	NA
FY 95	0.9929	-0.71	1.0125	1.25	1.0098	0.98
FY 96	1.0574	6.49	1.0716	5.84	1.0710	6.06
FY 97	1.0998	4.01	1.1076	3.36	1.1074	3.39
ENR Proxy						
FY 94	1.0000	NA	1.0000	NA	1.0000	NA
FY 95	1.0222	2.22	1.0280	2.80	1.0268	2.68
FY 96	1.0525	2.96	1.0583	2.95	1.0580	3.04
FY 97	1.0856	3.15	1.0898	2.97	1.0895	2.98
FHWA Proxy						
FY 94	1.0000	NA	1.0000	NA	1.0000	NA
FY 95	1.0380	3.80	1.0416	4.16	1.0415	4.15
FY 96	1.1051	6.46	1.1072	6.30	1.1068	6.27
FY 97	1.1438	3.50	1.1435	3.28	1.1433	3.29
VDOT Construction Index						
FY 94	1.0000	NA	1.0000	NA	1.0000	NA
FY 95	1.0819	8.19	1.0628	6.28	1.0814	8.14
FY 96	1.1561	6.86	1.0770	1.33	1.1530	6.62
FY 97	1.1885	2.81	1.1270	4.65	1.1836	2.66
FHWA VA Proxy						
FY 94	1.0000	NA	1.0000	NA	1.0000	NA
FY 95	1.1399	13.99	1.0387	3.87	1.1329	13.29
FY 96	1.1472	0.64	1.0804	4.02	1.1451	1.08
FY 97	1.1357	-1.01	1.1495	6.39	1.1359	-0.80

Table 12 shows that setting the class index weights equal to each category's share of total maintenance expenditures, rather than equal to each category's share of expenditures on indexed items only, would have made a small difference in the value of the maintenance cost index.

Table 12. Class index weights as percentage of total cost

FY	Current MCI[1]				Proposed MCI				Actual Expenditures			
	Equip-ment	Materials	Labor	Contracts	Equip-ment	Materials	Labor	Contracts	Equip-ment	Materials	Labor	Contracts
94	0.0909	0.0781	0.2395	0.5914	0.1157	0.0529	0.2587	0.5727	0.1085	0.1017	0.3267	0.4631
95	0.0612	0.0831	0.1744	0.6813	0.0828	0.0535	0.2119	0.6518	0.0776	0.0771	0.2900	0.5554
96	0.0637	0.0859	0.1782	0.6722	0.0988	0.0437	0.2006	0.6569	0.0909	0.1000	0.2804	0.5287
97	0.0588	0.0804	0.1435	0.7174	0.0793	0.0566	0.1966	0.6676	0.0816	0.0814	0.2660	0.5710

[1]Assumes the presence of a contract proxy.

The data for Table 12 represents total expenditures for all districts. Contracts includes total maintenance contracts, hired equipment, and project ledgers. Labor includes state forces labor and inmate labor. Equipment is defined as state force equipment.

Table 13. VDOT maintenance contracts

FY	Contracts as % of total ordinary maintenance	Contracts as % of maintenance replacement	Contracts as % of total maintenance
91	10.0	71.9	41.8
92	10.3	69.4	39.3
93	13.6	71.3	40.2
94	15.3	74.0	43.6
95	17.9	80.4	53.1
96	25.6	75.7	49.7
97	25.8	76.5	53.6

Allocations

In order to determine how the various options and baskets would have affected allocations to localities, sample lane mile allocations were calculated for all individual Virginia localities and statewide. The FY 1997 lane mile allocations from the URB were used as a baseline figure. FY 1998 allocations were calculated by applying the change in the MCI from FY 1996 to FY 1997 to the FY 1997 lane mile figures. The lane mile rates under each option for 15 sample localities are shown in Table 14 in Appendix 3. Allocations were calculated for each of the 30 options for all localities and sample ones are presented in Tables 15 through 20 in Appendix 3.

DISCUSSION

The VDOT maintenance cost index tracks the cost of inputs, i.e., equipment, materials, and labor, rather than the cost of outputs, i.e., units of work. As was noted above, the current calculation takes account only of state forces' use of equipment, materials, and labor. In the case of equipment, the number of rental hours charged to each type of equipment supplies the quantity, and the total cost divided by that quantity supplies the price or unit cost statistic. In the case of materials, the amount of each item issued by the end of the fiscal year supplies the quantity and the statewide average unit cost supplies the price. In the case of labor, the number of employees on payroll in each class represents the quantity, and the total fully-loaded compensation for each class, divided by the number of employees in the class, supplies the price.

Statewide average unit cost is a fairly good measure of materials prices. Data on issued items is not necessarily ideal for inclusion in a cost index because items issued may not be used. The measures of labor price and quantity appear well-chosen and are the same measures used in the update.

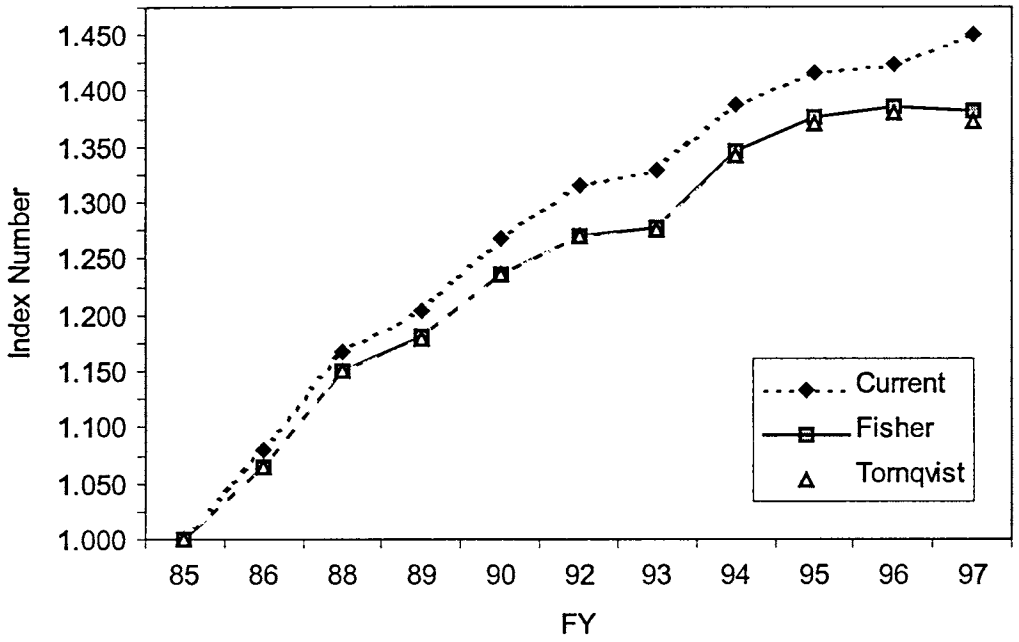
The omission of contract costs is a serious weakness. The share of VDOT-financed maintenance work that is contracted out has grown fairly steadily during the 1990s. A cost index that ignores contract work runs a considerable risk of under- or overstating trends in the average cost of all VDOT-financed maintenance. The MCI's role in determining street payments makes the inclusion of contract work even more desirable since some localities rely on contract work.

Employment of each maintenance cost item changes over time. The current formula, however, assumes purchase of fixed portions of equipment, materials, and labor from the base year to the current year. This is not a realistic model. By contrast any superlative index formula, such as the Törnqvist or Fisher formulae, allows for changes in the employment of each cost item. The consequences for the change in the value of the maintenance cost index over time have been twofold.

The current formula will systematically overstate price increases since the base year FY 1985. Comparison between the values of the MCI and the values of the FHWA index in Table 9 corroborates this theoretical expectation. Comparison of the values of the current index formula with the Törnqvist or Fisher formulae in Tables 10 and 11 show the difference that either of these alternative formulae would have made. When the year- to- year changes for each formula option are compared, it can be seen that these changes are smaller in magnitude than those under the current formula because the two alternative indices take item substitution into account. Although past performance is not a guarantee of future performance, a Törnqvist or Fisher index will grow more slowly (or shrink faster) than the current index. This gap between formulae grows larger over time.

It appears that either of the alternative formulae would have generated a slightly less volatile series of index values than the current formula did. Figure 1 displays the year-to-year changes in the current MCI, Fisher, and Törnqvist indices. Each alternative uses a FY 1985 base year and the current MCI basket. FY 1987 and FY 1991 are not included in the graph because data on the basket items was missing for those years.

Figure 1. Comparison of Alternative Indices, FY 1985 Base Year, Current Basket



Indexing Urban Street Maintenance's Fair Share of the VDOT Budget

The MCI and the use to which it is put, namely calculation of the annual amount of assistance for maintenance to each city and incorporated town, ignore a number of factors that one might take into consideration in determining urban street maintenance's equitable share of transportation funds. It might be appropriate to consider a broader array of variables than just the number of lane miles and the price of maintenance inputs.

Appraisal of the Goals of the 1985 Legislation

As noted above, the General Assembly's 1982 Appropriations Act directed JLARC to conduct a study of the "reasonableness, appropriateness, and equity" of the statutory provisions for allocating highway construction funds. Following JLARC's submission of an interim report in January 1983, dealing solely with highway construction, the General Assembly further directed that the study be expanded to include other major programs of the Highway Maintenance and Construction Fund. The subsequent JLARC report addressed most of the programs that were supported by the Highway Maintenance and Construction Fund. The legislative changes that the General Assembly passed in 1985 were likewise comprehensive.

The Assembly created six different funds to support the various programs that had been supported by the Highway Maintenance and Construction Fund, including three funds that are not VDOT's responsibility.

Senate Joint Resolution 7

The General Assembly convened in a special session in the fall of 1986 to deal with a perceived critical shortage of funds for transportation. The legislature's primary response to the problem was a host of tax and fee increases, commonly known today as the "Special Session Revenues". One of the General Assembly's secondary responses was Senate Joint Resolution No. 7 (SJR 7). It stated that "the Governor's Commission on Transportation in the Twenty-First Century... has predicted that, unless taxes are raised, no funds for highway construction in Virginia will be available beyond 1991; and... if the state highway program's administrative and maintenance costs were contained or reduced, more money would be available to fund highway construction projects." SJR 7 concluded with a request that VDHT (which was shortly thereafter renamed VDOT) compare its administrative and maintenance costs with those in neighboring states, and that VDHT produce a plan to reduce administrative and maintenance expenditures in FY 1989 by at least five percent from their levels in FY 1988.

Both the causes and the consequences of the "Special Session" illustrate the fact that maintenance needs compete with construction needs for available transportation revenue. Transportation revenue available to the Commonwealth as a whole depends on the amount collected from certain taxes and fees. This yearly amount may rise or fall in response to a variety of causes.

Although the 1986 statutes assigned shares of each revenue source to the Transportation Trust Fund (TTF) and the Highway Maintenance and Operations Fund (HMOF), the General Assembly has seen fit to transfer money from one of these funds to another on a few occasions.

In 1987 VDOT issued a report to comply with SJR 7. It pointed out numerous administrative areas where VDOT might find opportunities to save money. The report found that Virginia's administrative costs, as a percentage of total costs, compared favorably with those of North Carolina, Maryland, and Pennsylvania. The report also found that Virginia's ordinary maintenance costs per lane-mile of road compared favorably with those of North Carolina and Maryland (Pennsylvania data were lacking). The report noted, in a section on "Maintenance Payments to Municipalities", that "The other state's formulas [sic] for distribution are based upon amount of revenues, population percentages, vehicles registered in the jurisdictions, and system mileage. Virginia, however, is the only state that distributes funds to municipalities and to counties on the basis of a rate per lane mile" (VDOT, 1987).

The Broken Link Between Construction and Maintenance

The historical documents and the researchers' discussions with VDOT management both indicated that the General Assembly's goal in mandating the creation and application of the MCI was to ensure a "fair" or "equitable" share of highway maintenance funds for Virginia's cities and towns. It is also clear that the concept of equity behind the creation of the MCI and the use to which it is put embraced both the maintenance and construction of highways, in both the state

system and in cities and incorporated towns. Arguably, the concept included the maintenance and construction of other transportation facilities as well.

The allocation of funding for construction and maintenance might reasonably be expected to confront local governments with the statewide reality that maintenance competes with construction for revenue. For the Commonwealth as a whole, a dollar spent on construction is a dollar that will never be transferred to the HMOF to meet maintenance needs, and vice versa. A single municipal allocation, to be divided between construction and maintenance, would subject the city's use of state funds to the same joint limit.

The current funding, however, breaks at the local level the real link that exists at the state level. For instance, the revenue growth that attended an economic expansion would make more money available for construction and maintenance in the state, yet under the current rules, the urban maintenance program would not automatically share in the growth. On the other hand, the revenue to the HMOF may or may not increase as more lane miles of highway are built, yet the current urban maintenance assistance formula automatically sets aside more urban maintenance assistance for each municipality in which new lane miles are added.

Factors in Determining Urban Maintenance's Fair Share

The MCI and its application ignore a number of factors that could be taken into consideration in determining urban street maintenance's equitable share of transportation funds. For example, it might be appropriate to consider a broader array of variables than just the number of lane miles and the cost of maintenance inputs. Further research is needed to address this issue, however.

Although the share of state highway funds available for urban street maintenance increased markedly from FY 1985 to FY 1986, the share has remained roughly constant since FY 1987. A rough calculation in Appendix 2 (in "Factors in Determining Urban Maintenance's Fair Share") suggests that this stability may be due less to the quality of the current allocation rule than to the lucky fact that the equity factors the rule ignores have tended to offset one another.

RECOMMENDATIONS

1. *It is recommended that MD adopt the Törnqvist formula to calculate the MCI.* Any of the superlative price indices would be superior in many technical respects to the current index, and all would perform about equally well. The Fisher and the Törnqvist indices yielded very similar results in the options calculated in this study. Both indices also possess mathematical properties that allow them to be changed or updated easily. However, the Törnqvist formula accommodates a contract proxy well, while the Fisher requires more manipulation to do so. The Törnqvist formula also has the advantage of bearing a strong resemblance to the current formula with which Maintenance staff are already familiar. It is relatively simple to create in a spreadsheet software program like Excel and easy to calculate.

2. *It is recommended that the list of items currently included in the maintenance cost index, shown in Table 1, be replaced by the alternative list shown in Table 4.* While most items in the original index continue to account for a large part of maintenance costs, some items have dropped in importance and some new ones are not represented. The new list will make the MCI more representative of current maintenance practices.

3. *In order to maintain consistency in lane mile allocations, it is recommended that VDOT use the most recent fiscal year as the new base year for the MCI.* The allocations per lane mile in the most recent fiscal year should be taken as the base values to which the adjustment factor is applied in future years.

4. *It is recommended that the MD and Administrative Services collect and store purchase data on materials in the form of amounts **used** by VDOT, rather than those **issued**.* Currently, materials data are in the form of amounts issued, which is not ideal for index purposes.

5. *It is recommended that VDOT add contract work to the list of index items as a fourth category consisting of a single item.* Contract payments account for a rising share of the maintenance budget. The current index, as it ignores contract work, will be based on an ever-smaller fraction of total VDOT maintenance experience. Price and quantity variables for contract work should be constructed using total expenditures on contract maintenance together with an appropriate national or state construction cost index, until such time as appropriate contract data become available. The FHWA Bid Price Index, since it is an index of finished cost per unit of work, may be the best choice among those tested. A future state-specific index may be the VDOT Construction Contract Index, currently under development.

6. *It is recommended that VDOT require contractors who perform maintenance to provide a breakdown of their costs by units of work and quantity, or by cost and quantity of equipment, labor, and materials.* Currently, the requisite data to include the cost of contract maintenance in the index are not collected, making it necessary to construct price and quantity variables by indirect means.

7. *It is recommended that VDOT discourage municipal budget planners from using 100 percent of the best MCI forecast to plan their budgets.* Because localities tend to use the forecast MCI to plan their budgets, there is little room for adjustment if that forecast is changed. FPDM should consider providing an intentionally conservative forecast of the next year's MCI, for instance, by emphasizing the lower end of the 50 percent confidence interval rather than emphasizing the best point estimate.

8. *It is recommended that the MCI basket be reviewed and, if necessary, updated, every five years.* Updating is necessary in order to keep the index reflective of prevailing maintenance practices and costs.

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APPENDIX 1

Section 33.1-41.1 of the Code of Virginia (original and updated)

Editor's note. — Section 33.1-41, referred to in the last sentence of the second paragraph, was repealed by Acts 1985, c. 42.

§ 33.1-40: Repealed by Acts 1977, c. 578.

Cross references. — For present provisions as to allocation of funds for urban highways, see §§ 33.1-23.1 and 33.1-23.3.

§ 33.1-41: Repealed by Acts 1985, c. 42.

§ 33.1-41.1. Payments to cities and certain towns for maintenance of certain highways. — The Commonwealth Transportation Commissioner, subject to the approval of the Commonwealth Transportation Board, shall make payments for maintenance, construction or reconstruction of highways, as hereinafter provided, to: (i) all incorporated towns having more than 3,500 inhabitants according to the last preceding United States census; (ii) all incorporated towns which, according to evidence satisfactory to the Commonwealth Transportation Board, have attained a population of more than 3,500 since the last preceding United States census; (iii) all incorporated towns which, on June 30, 1985, maintained certain streets under § 33.1-80 as then in effect; (iv) all cities operating under charters designating them as cities, regardless of their populations; and (v) the Town of Wise, the Town of Lebanon, and the Town of Blackstone. Such payments, however, shall only be made if those highways functionally classified as principal and minor arterial roads are maintained to a standard satisfactory to the Department of Transportation.

No payments shall be made by the Commissioner to any such city or town unless the portion of the highway for which such payment is made either (a) has (i) an unrestricted right-of-way at least fifty feet wide and (ii) a hard-surface width of at least thirty feet; or (b) has (i) an unrestricted right-of-way at least eighty feet wide, (ii) a hard-surface width of at least twenty-four feet, and (iii) approved engineering plans for the ultimate construction of an additional hard-surface width of at least twenty-four feet within the same right-of-way; or (c) (i) is a cul-de-sac, (ii) has an unrestricted right-of-way at least forty feet wide, and (iii) has a turnaround that meets applicable standards set by the Department of Transportation; or (d) either (i) has been paved and has constituted part of the primary or secondary system of state highways prior to annexation or incorporation or (ii) has constituted part of the secondary system of state highways prior to annexation or incorporation and is paved to a minimum width of sixteen feet subsequent to such annexation or incorporation and with the further exception of streets or portions thereof which have previously been maintained under the provisions of § 33.1-79 or § 33.1-82; or (e) was eligible for and receiving such payments under the laws of the Commonwealth in effect on June 30, 1985; or (f) is a street established prior to July 1, 1950, which has an unrestricted right-of-way width of not less than thirty feet and a hard-surface width of not less than sixteen feet.

However, the Commissioner may waive the requirements as to hard-surface pavement or right-of-way width for highways where the width modification is at the request of the local governing body and is to protect the quality of the affected local government's drinking water supply or, for highways constructed on or after July 1, 1994, to accommodate some other special circumstance where such action would not compromise the health, safety, or welfare of the public. The modification is subject to such conditions as the Commissioner may prescribe.

For the purpose of calculating allocations and making payments under this section, the Department shall divide affected highways into two categories, which shall be distinct from but based on functional classifications established by the Federal Highway Administration: (i) principal and minor arterial roads and (ii) collector roads and local streets. Payments to affected localities shall be based on the number of moving-lane-miles of highways or portions thereof available to peak-hour traffic in each category of highways in that locality. For the fiscal year 1986, payment to each city and town shall be an amount equal to $7,787 per moving-lane-mile for principal and minor arterials and $4,572 per moving-lane-mile for collector roads and local streets.

The Department of Transportation shall establish a statewide maintenance index of the unit costs for labor, equipment, and materials used on roads and bridges in the fiscal year 1986, and use changes in that index to calculate and put into effect annual changes in the base per-lane-mile rate payable under this section.

The fund allocated by the Board shall be paid in equal sums in each quarter of the fiscal year, and no payment shall be made without the approval of the Board.

The city or town receiving this fund shall make annual reports, in such form as the Board may prescribe, accounting for all expenditures and certifying that none of the money received has been expended for other than maintenance, construction or reconstruction of the streets. Such reports shall be included in the scope of the annual audit of each municipality conducted by independent certified public accountants. (1985, c. 42; 1991, c. 353; 1992, c. 267; 1994, c. 459; 1996, cc. 149, 821.)

Editor's note. — Acts 1992, c. 893, item 569, as amended by Acts 1993, c. 994, item 569, and Acts 1994, c. 966, item 609, as amended by Acts 1995, c. 853, provides: "Notwithstanding the provisions of §§ 33-1-41.1 and 33.1-23.5:1 of the Code of Virginia, the payment rates per lane mile for maintenance to cities and certain towns and counties not in the State secondary system for the first year shall be adjusted to reflect the 1991 maintenance cost index. For the second year the payment rates shall be adjusted to the 1995 maintenance cost index, as provided in the provisions of §§ 33.1-41.1 and 33.1-23.5:1, Code of Virginia."

The 1996 amendments. — The 1996 amendment by c. 149, effective March 8, 1996, in the first paragraph, inserted "construction or reconstruction" following "maintenance" in the first sentence and rewrote the second sentence which formerly read: "Such payments, however, shall only be made if, in the opinion of the Commonwealth Transportation Board, such highways are maintained in accordance with the applicable standards of the Commonwealth Transportation Board"; in the second paragraph, deleted "and" following "eighty feet wide" in clause (b)(i), deleted "has" preceding "a hard-surface" in clause (b)(ii), deleted "there are" preceding "approved" in clause (b)(iii); deleted "and" following "cul-de-sac" in clause (c)(i), in clause (c)(iii), inserted "has" preceding "a turnaround" and substituted "set by the Department of Transportation" for "of the Commonwealth Transportation Board"; and rewrote the seventh paragraph which formerly read: "The city or town receiving this fund will be required to make quarterly reports, audited annually, in such form as the Board may prescribe, accounting for all expenditures and certifying that none of the money received has been expended for other than maintenance of the streets."

The 1996 amendment by c. 821, effective April 8, 1996, in the first paragraph, inserted "construction or reconstruction" following "for maintenance" in the first sentence, in the second sentence, substituted "shall only be made if those" for "shall only be made if, in the opinion of the Commonwealth Transportation Board, such," inserted "functionally classified as principal and minor arterial roads" following "highways," and substituted "to a standard satisfactory to the Department of Transportation" for "in accordance with the applicable standards of the Commonwealth Transportation Board"; in the second paragraph, deleted "and" at the end of clause (a)(i), deleted "has" preceding "a hard-surface" in clause (a)(ii), deleted "there are" preceding "approved engineering plans" in clause (a)(iii), in clause (c)(i), substituted "(i) is a" for "is (i) a" and deleted "and" following "cul-de-sac," in clause (c)(iii), inserted "has" preceding "a turnaround" and substituted "set by the Department of Transportation" for "of the Commonwealth Transportation Board," and in the final paragraph, in the first sentence, substituted "shall make annual reports in such form" for "will be required to make quarterly

Improvement Program of the Commonwealth Transportation Board and the city's or town's capital improvement program.

A portion of allocations made to any city or town under this section may be used on streets functionally classified as arterial for (i) the purchase of residue parcels of land resulting from highway system construction or reconstruction projects where the purchase will result in necessary access control or land use control directly related to the purpose and need for the project, (ii) improvements to traffic safety, (iii) improvements to traffic flow and transportation system utilization, or a combination of (i), (ii), and (iii).

When the city or town presents a resolution requesting that a portion of its annual urban system apportionment be set aside for reimbursement under this section for a specific eligible project, the Commonwealth Transportation Board shall, subject to appropriation and allocation, set aside no more than one-third of the anticipated annual apportionment of urban system funding to the city or town for such purpose, provided such funds have not been previously committed by the Board for projects contained in the Six Year Improvement Program.

Reimbursement to localities under this section shall be subject to such terms and conditions as may be prescribed by the Commonwealth Transportation Commissioner.

The provisions of this section shall not constitute a debt or obligation of the Commonwealth Transportation Board or the Commonwealth of Virginia. (1977, c. 578; 1985, c. 42; 1987, cc. 523, 536, 545; 1989, c. 303; 1997, c. 494.)

The 1997 amendment substituted "means either the population" for "shall mean either population" in the last sentence of subsection A and added the third paragraph following subsection B.

ARTICLE 2.

The State Highway System.

§ 33.1-41.1. Payments to cities and certain towns for maintenance of certain highways. — The Commonwealth Transportation Commissioner, subject to the approval of the Commonwealth Transportation Board, shall make payments for maintenance, construction or reconstruction of highways, as hereinafter provided, to: (i) all incorporated towns having more than 3,500 inhabitants according to the last preceding United States census; (ii) all incorporated towns which, according to evidence satisfactory to the Commonwealth Transportation Board, have attained a population of more than 3,500 since the last preceding United States census; (iii) all incorporated towns which, on June 30, 1985, maintained certain streets under § 33.1-80 as then in effect; (iv) all cities operating under charters designating them as cities, regardless of their populations; and (v) the Town of Wise, the Town of Lebanon, and the Town of Blackstone. Such payments, however, shall only be made if those highways functionally classified as principal and minor arterial roads are maintained to a standard satisfactory to the Department of Transportation.

No payments shall be made by the Commissioner to any such city or town unless the portion of the highway for which such payment is made either (a) has (i) an unrestricted right-of-way at least fifty feet wide and (ii) a hard-surface width of at least thirty feet; or (b) has (i) an unrestricted right-of-way at least eighty feet wide, (ii) a hard-surface width of at least twenty-four feet, and (iii) approved engineering plans for the ultimate construction of an additional hard-surface width of at least twenty-four feet within the same right-of-way; or (c) (i) is a cul-de-sac, (ii) has an unrestricted right-of-way at least forty feet wide, and (iii) has a turnaround that meets applicable

standards set by the Department of Transportation; or (d) either (i) has been paved and has constituted part of the primary or secondary system of state highways prior to annexation or incorporation or (ii) has constituted part of the secondary system of state highways prior to annexation or incorporation and is paved to a minimum width of sixteen feet subsequent to such annexation or incorporation and with the further exception of streets or portions thereof which have previously been maintained under the provisions of § 33.1-79 or § 33.1-82; or (e) was eligible for and receiving such payments under the laws of the Commonwealth in effect on June 30, 1985; or (f) is a street established prior to July 1, 1950, which has an unrestricted right-of-way width of not less than thirty feet and a hard-surface width of not less than sixteen feet; or (g) is a street functionally classified as a local street and constructed on or after January 1, 1996, which at the time of approval by the city or town met the criteria for pavement width and right-of-way of the then-current edition of the subdivision street requirements manual for secondary roads of the Department of Transportation (24 VAC 30-90-10 et seq.).

However, the Commissioner may waive the requirements as to hard-surface pavement or right-of-way width for highways where the width modification is at the request of the local governing body and is to protect the quality of the affected local government's drinking water supply or, for highways constructed on or after July 1, 1994, to accommodate some other special circumstance where such action would not compromise the health, safety, or welfare of the public. The modification is subject to such conditions as the Commissioner may prescribe.

For the purpose of calculating allocations and making payments under this section, the Department shall divide affected highways into two categories, which shall be distinct from but based on functional classifications established by the Federal Highway Administration: (i) principal and minor arterial roads and (ii) collector roads and local streets. Payments to affected localities shall be based on the number of moving-lane-miles of highways or portions thereof available to peak-hour traffic in each category of highways in that locality. For the fiscal year 1986, payment to each city and town shall be an amount equal to $7,787 per moving-lane-mile for principal and minor arterials and $4,572 per moving-lane-mile for collector roads and local streets.

The Department of Transportation shall establish a statewide maintenance index of the unit costs for labor, equipment, and materials used on roads and bridges in the fiscal year 1986, and use changes in that index to calculate and put into effect annual changes in the base per-lane-mile rate payable under this section.

The fund allocated by the Board shall be paid in equal sums in each quarter of the fiscal year, and no payment shall be made without the approval of the Board.

The city or town receiving this fund shall make annual reports, in such form as the Board may prescribe, accounting for all expenditures and certifying that none of the money received has been expended for other than maintenance, construction or reconstruction of the streets. Such reports shall be included in the scope of the annual audit of each municipality conducted by independent certified public accountants. (1985, c. 42; 1991, c. 353; 1992, c. 267; 1994, c. 459; 1996, cc. 149, 821; 1997, c. 49.)

The 1997 amendment, in the second paragraph, inserted "or" at the end of clause (f) and added clause (g).

§ 33.1-46.2. Designation of high-occupancy vehicle lanes; use of such lanes; penalties. — A. In order to facilitate the rapid and orderly

APPENDIX 2

The 1986 Index Formula

Alternative Index Formulae

Desirable Properties for Indices

APPENDIX 2

The 1986 Index Formula

The MCI's indexing method, unchanged since its creation, can be expressed by the formula:

$$(1.) \qquad MCI_{t,o} = \frac{\sum TE_t^{\,i}\left(p_t^{\,i} / p_o^{\,i}\right)}{TE_{to}}$$

where TE_t^i is the total expenditure on item i in the given year or year under consideration, p_0^i is the price of item i in the base year, and i indexes all of the included items irrespective of class.

The index may also be represented by the equation:

$$(2.) \qquad MCI = \frac{\sum\left(p_t^{\,i} / p_o^{\,i}\right) p_t^{\,i} q_t^{\,i}}{\sum\left(p_t^{\,i} q_t^{\,i}\right)}$$

where p is price and q is quantity and where the numerator is a simple aggregate index of prices in the given and base year periods multiplied by the total cost for each class. The denominator is the total cost for all items in the index. The index is similar in form to the Paasche Index, which is given by the following:

$$(3.) \qquad I_P = \frac{\sum p_t q_t}{\sum p_o q_t}$$

where p_0 is the base year price, p_t is the given year price, and q_t is the given year quantity (Merrill and Fox, 1970). The MCI may be seen as a modified Paasche index since the weights (shares of total index costs) come from the given year and are multiplied by a simple aggregate index.

Alternative Index Formulae

The superlative indices have several desirable mathematical properties. Both of these indices require the same information as the Paasche index but involve gathering information between the two time periods rather than treating one of them as a base period. The Fisher and the Tornqvist Indices tend to approximate each other very closely in empirical tests (Diewert, 1997).

The Fisher Ideal Index is represented by the following equation:

$$(4.) \quad I_{id} = \left[\frac{\sum p_t q_0}{\sum p_0 q_0} \bullet \frac{\sum p_t q_t}{\sum p_0 q_t} \right]^{1/2}$$

where p_0 and q_0 are price and quantity in the base year and p_t and q_t are price and quantity in the given year.

The Tornqvist Index can be expressed by the following:

$$(5.) \quad I_T = \prod \left[\frac{p_t}{p_0} \right]^{1/2(s_t + s_0)} \quad \text{and } s_t = \left[\frac{p_t q_t}{\sum p_t q_t} \right]$$

Fixed basket indices like the Paasche and the Laspeyres Index rely on an arithmetic mean. The Fisher formula is a geometric mean (the square root of the product) of two fixed basket indices, the Laspeyres and the Paasche (Fisher, 1927). The Tornqvist Index is a weighted geometric average of the growth rates in prices with relative weights equal to the average of the weights in the two periods (Advisory Commission to Study the Consumer Price Index, 1996).

Desirable Properties for Indices

Ease of Manipulation: The Fisher Tests for Index Numbers

Over time a series of index values is likely to undergo manipulation in order to maintain and enhance its usefulness. The base year may be changed, and items may be added to the index or deleted from it. The series may be spliced together with a series of values from another earlier index to construct a single, longer series.

The economist Irving Fisher, in an often-cited 1922 article, and a subsequent book, *The Making of Index Numbers: A Study of Their Varieties, Tests, and Reliability*, identified eight desirable qualities for index numbers (Fisher, 1927). Fisher demonstrated that all the forms of index numbers that satisfy his few simple tests will be relatively easy to manipulate. Fisher investigated many index formulae during the course of his work, among them being the formula named after him. The following criteria for a "good" index number proposed by Fisher are as follows:

1) Commodity reversal – Reordering of the items included in the index does not affect its numerical value. Simply put, any rule for averaging commodities must be so general as to apply interchangeably to all of the items averaged. The MCI passes this test.

2) Identity – If there is no change in either price or quantity, the numerical value of the index is 1. The MCI passes this test.

3) Commensurability – A change in units of measurement, leaving real prices and quantities unchanged, does not affect the index's numerical value. The MCI passes this test.

4) Determinateness – The index's numerical value does not approach zero or infinity when the price or quantity of a single item included in the index approaches zero. The MCI passes this test.

5) Proportionality – An equiproportional change in all prices causes an equiproportional change in the value of the price index. The same holds true for the quantity index. This is true for the MCI.

6) Time/Point Reversal – The index should remain the same even if underlying prices undergo a reversal. In other words, the formula for calculating an index number should give the same ratio between one point of comparison and the other point, no matter which of the two years, in our case, is taken as the base (Note: Given identity and circularity, time/point reversal is redundant.). The relative changes from year to year in a series of index numbers should be the same regardless of the base year selected (Diewert, 1976). Such reversibility does apply to any individual commodity - if sugar, to use Fisher's example, cost twice as much in 1995 as it did in 1990 then it cost half as much in 1990 as it does in 1995. Fixed basket indices like Paasche and Laspeyres fail this test. Recall that the MCI is a modified Paasche Index.

7) Circularity – A change in the base year has an equiproportional effect on the index's numerical value in all years. The choice of base year, while affecting the index's numerical value in every year, does not alter the year-to-year percent changes in the index's numerical value.

8) Factor reversal – The price index multiplied by the quantity index equals current year expenditures divided by base year expenditures. A price index multiplied by its corresponding quantity index must be equal to the value index, which is, by definition,

(6.) $$V = \frac{\sum p_t q_t}{\sum p_o q_o}$$

Of all the tests, Fisher viewed the Time Reversal Test, #6 and the Factor Reversal Test, #8 as the most relevant. VDOT's maintenance cost index possesses only the first five of the eight desirable qualities Fisher described and therefore not the most important ones. This means that if the MD were to calculate the change in maintenance costs between 1992 and 1996 directly, using 1992 as the base year, it would obtain a different answer than it obtains when it calculates the change indirectly, using 1985 as the base year against which both 1992 and 1996 are compared. The eighth quality, "factor reversal", is not applicable as VDOT does not at this time have a quantity index with which to complete the comparison. In contrast, the Fisher and the Tornqvist Indices both possess all of the above qualities.

Realism: Exactness and Superlativeness.

It is desirable that the index formula imitate reality fairly closely. The index is then likely to reflect the quantity changes and other adjustments that are made in response to a price change, and in the case of the MCI, measure the impact that a price change has on the cost of doing maintenance work. Both "exactness" and "superlativeness" are considered desirable characteristics for an index. An index is said to be "exact" for a certain unit cost function if it represents exactly the ration between the unit costs for any two sets of individual input prices (Diewert, 1976). A price index is said to be "superlative" if it happens to be exact for a cost function that can provide a good approximation to any well-behaved cost relationship. (That is, in the jargon of mathematicians, if the function form can provide a local second-order approximation to *any* linearly homogeneous, twice-continuously-differentiable unit cost function.) One can count on a superlative index to track the changes in cost per unit of work fairly closely regardless of what the true cost relationship happens to be, provided that the prices of individual items do not change drastically from year to year. Note: For a complete and in-depth presentation of these mathematical properties, please see Diewert (1976).

Factors in Determining Urban Maintenance's Fair Share

One might posit that urban street maintenance's fair share of the VDOT budget equals VDOT revenue (in dollars), times urban maintenance needs (in dollars), divided by the sum of all state transportation needs funded out of VDOT revenue (in dollars). One might posit that the sum of all transportation needs funded out of VDOT revenue grows in proportion with the Gross State Product, so that the rate of growth of the GSP is a good measure of the rate of growth of total needs. Two observations about GSP may be useful: unlike the needs estimates that VDOT and other agencies in the transportation secretariat derive from engineering sufficiency standards, GSP is not mode-specific, and although GSP and state transportation revenues are correlated, they have not grown at the same average rate since 1986.

$Urb Mnt Allocation= $Rev × (($Urb Mnt Needs) ÷ ($Total Needs).

$Total Needs α $GSP

$\%\Delta(UrbMntAlloc) = \%\Delta(\mathrm{Re}v)*\%\Delta(UrbMntNeeds) \div \%\Delta(GSP)$
where %Δ(x) is the percent change in variable x.

One might further posit that urban maintenance needs equal urban system deficiencies (measured in terms of the number of units of work required to correct them), *times* the price of an index "basket" of labor, materials, and equipment (measured in dollars per basket), *divided* by technical productivity (measured in units of work per basket).

$Urb Mnt Needs = Deficiencies (units) × (Price Index ($/bskt) ÷ Productivity Factor (units/bskt).

Ignoring the issues raised by deferred maintenance or by possible past inequities in the meeting of maintenance needs, one might posit that urban system deficiencies equal the damage that the urban streets incur annually from weather and traffic, and that annual street damage is proportional to the number of lane-miles, and also dependent on the average traffic throughput (in vehicles per hour per lane, heavy vehicles being weighted more than passenger cars) and on weather conditions, roughly 65 percent of the damage being due to traffic and 35 percent to weather.

Deficiencies = Damage = Constant × LnMi × (0.65 × VPH/ln + 0.35×weather) = Constant × (0.65 × VMT/hr + 0.35 × Ln-Mi × weather).

Allowing the above postulates, urban street maintenance's fair share of the VDOT budget would depend directly on: (1) VDOT revenue; (2) a price index of labor, materials, and equipment; (3) lane mileage; (4) traffic volume; and (5) average weather conditions. It would depend inversely on: (6) total transportation needs (proxied by Gross State Product) and (7) the technical efficiency of maintenance operations. The annual percent change in urban street maintenance's fair share would depend on the annual percent changes in all of the above factors except weather. (Because climatic changes occur so slowly, the average weather damage in a given spot can probably be treated as a constant whose annual percent change is zero.) VDOT currently determines its payments to the cities and incorporated towns with reference to only two of these seven factors, (2) a price index and (3) lane mileage.

$\%\Delta(UrbMn) = \%\Delta(\mathrm{Re}v) + 0.65*\%\Delta(LnMi) + 0.35*\%\Delta(VMT) + \%\Delta(\mathrm{Pr}iceIndex) - \%\Delta(GSP) - \%\Delta(\mathrm{Pr}oductivityFactor)$

VDOT revenue rose at an annual rate of about 6.8 percent from FY 1985 to FY 1995, and traffic volume (average VPH per lane) appears to have risen at an annual rate of between 0.5 and 1.4 percent. On the other hand GSP rose at an annual rate of about 6.5 percent from 1985 to 1994 and productivity (proxied by the difference between the MCI and the FHWA composite construction cost index) appears to have risen at an annual rate of about 1.1 percent. In other words, overlooked pluses totaling 6.9 to 8.2 percent very closely matched (and offset) overlooked minuses of about 7.6 percent.

APPENDIX 3

Sample Lane Mile Allocations

Table 14. Lane Mile Rates Under Each Option for FY 1998

Basket Options	Combined Principal Arterials/Minor Arterials ($)		Combined Collectors/Locals ($)	
	Current Basket	Proposed Basket	Current Basket	Proposed Basket
Current MCI Formula - No Proxy	11,291.15	11,534.19	6,629.40	6,772.10
Current MCI Formula - ENR Proxy	11,450.02	11,433.70	6,722.68	6,713.09
Current MCI Formula - FHWA Proxy	11,519.65	11,473.65	6,763.56	6,736.55
Current MCI Formula - VDOT Proxy	11,460.57	11,392.09	6,728.87	6,688.66
Current MCI Formula - FHWA VA Proxy	11,001.30	10,969.36	6,459.22	6,440.47
Fisher Formula - No Proxy	11,050.17	11,432.63	6,487.91	6,712.47
Fisher Formula - ENR Proxy	11,248.90	11,402.99	6,604.59	6,695.07
Fisher Formula - FHWA Proxy	11,296.38	11,436.97	6,632.47	6,715.01
Fisher Formula - VDOT Proxy	11,234.08	11,596.12	6,595.89	6,808.46
Fisher Formula - FHWA VA Proxy	10,834.32	11,789.26	6,361.18	6,921.86
Törnqvist Formula - No Proxy	11,029.80	11,435.55	6,475.96	6,714.18
Törnqvist Formula - ENR Proxy	11,216.99	11,403.27	6,585.86	6,695.23
Törnqvist Formula - FHWA Proxy	11,266.80	11,437.95	6,615.10	6,715.59
Törnqvist Formula - VDOT Proxy	11,206.32	11,375.42	6,579.59	6,678.88
Törnqvist Formula - FHWA VA Proxy	10,834.32	10,992.11	6,361.18	6,453.82

Table 15. Allocations Based on Current Item Mix and Various Current Formula Options for Select Localities

In the following tables, FY 97 allocations under the current MCI formula and basket are the baseline. FY 97 allocations were calculated from the Urban Division's Urban Municipal Mileage and Payments Based on State Functional Classification for FY 96-97. Percentage change is measured from this baseline to the results from each option.

	Current MCI: No Proxy			Current MCI: FHWA Proxy	
Location	FY 97	FY 98	% Change	FY 98	% Change
Bristol	$1,758,465.15	$1,791,029.38	1.85	$1,839,076.23	4.58
Blacksburg	$1,608,334.98	$1,638,777.70	1.89	$1,682,737.01	4.63
Danville	$5,286,792.45	$5,389,145.51	1.94	$5,533,675.34	4.67
Petersburg	$3,009,739.32	$3,066,717.78	1.89	$3,148,970.72	4.63
Richmond	$14,373,197.27	$14,621,578.58	1.73	$15,013,736.71	4.46
Chincoteague	$326,628.56	$345,557.52	5.80	$354,827.65	8.63
Virginia Beach	$23,138,551.09	$23,732,484.65	2.57	$24,369,084.37	5.32
Fredericksburg	$1,213,870.88	$1,332,966.60	9.81	$1,368,717.78	12.76
Charlottesville	$2,196,731.62	$2,232,396.25	1.62	$2,292,274.09	4.35
Culpeper	$714,579.84	$728,107.94	1.89	$747,636.51	4.63
Staunton	$1,997,059.89	$2,034,863.04	1.89	$2,089,444.45	4.63
Alexandria	$4,118,191.93	$4,196,176.95	1.89	$4,308,700.66	4.63
Leesburg	$1,001,291.33	$1,054,785.90	5.34	$1,083,080.37	8.17
Harrisonburg	$2,178,979.81	$2,220,231.02	1.89	$2,279,780.04	4.63
Fairfax	$1,365,495.94	$1,391,351.85	1.89	$1,428,664.18	4.63
Statewide	$167,892,263.16	$172,146,472.75	2.53	$176,763,869.69	5.28

Table 16. Current Item Mix and Fisher Formula Options

	No Proxy		FHWA Proxy	
	FY 98	% Change	FY 98	% Change
Bristol	$1,752,886.08	-0.32	$1,791,942.70	1.90
Blacksburg	$1,603,873.86	-0.28	$1,639,610.28	1.94
Danville	$5,274,334.09	-0.24	$5,391,853.22	1.99
Petersburg	$3,001,391.05	-0.28	$3,068,266.00	1.94
Richmond	$14,310,102.88	-0.44	$14,628,950.86	1.78
Chincoteague	$338,198.29	3.54	$345,733.80	5.85
Virginia Beach	$23,227,002.79	0.38	$23,744,531.06	2.62
Fredericksburg	$1,304,571.45	7.47	$1,333,639.02	9.87
Charlottesville	$2,184,844.37	-0.54	$2,233,525.58	1.67
Culpeper	$712,597.77	-0.28	$728,475.39	1.94
Staunton	$1,991,520.54	-0.28	$2,035,894.24	1.94
Alexandria	$4,106,769.08	-0.28	$4,198,273.32	1.94
Leesburg	$1,032,320.72	3.10	$1,055,322.19	5.40
Harrisonburg	$2,172,935.86	-0.28	$2,221,351.74	1.94
Fairfax	$1,361,708.40	-0.28	$1,392,049.06	1.94
Statewide	$168,479,653.61	0.35	$172,233,602.65	2.59

Table 17. Current Item Mix and Tornqvist Options

Location	No Proxy		FHWA Proxy	
	FY 98	% Change	FY 98	% Change
Bristol	$1,749,656.30	-0.50	$1,832,645.47	4.22
Blacksburg	$1,600,918.63	-0.46	$1,676,852.92	4.26
Danville	$5,264,615.86	-0.42	$5,514,325.53	4.30
Petersburg	$2,995,860.83	-0.46	$3,137,959.59	4.26
Richmond	$14,283,735.76	-0.62	$14,961,237.61	4.09
Chincoteague	$337,575.14	3.35	$353,586.91	8.25
Virginia Beach	$23,184,205.81	0.20	$24,283,872.08	4.95
Fredericksburg	$1,302,167.71	7.27	$1,363,931.74	12.36
Charlottesville	$2,180,818.68	-0.72	$2,284,258.61	3.98
Culpeper	$711,284.78	-0.46	$745,022.22	4.26
Staunton	$1,987,851.06	-0.46	$2,082,138.21	4.26
Alexandria	$4,099,202.15	-0.46	$4,293,634.27	4.26
Leesburg	$1,030,418.62	2.91	$1,079,293.12	7.79
Harrisonburg	$2,168,932.11	-0.46	$2,271,808.24	4.26
Fairfax	$1,359,199.38	-0.46	$1,423,668.51	4.26
Statewide	$168,169,220.96	0.16	$176,145,772.82	4.92

Table 18: Proposed Item Mix and Current Formula Options

	Current MCI (No Proxy)		Current MCI: FHWA Proxy	
	FY 98	% Change	FY 98	% Change
Bristol	$1,828,284.16	3.97	$1,819,323.26	3.46
Blacksburg	$1,672,862.37	4.01	$1,664,663.23	3.50
Danville	$5,501,202.60	4.06	$5,474,239.76	3.55
Petersburg	$3,130,491.91	4.01	$3,115,148.55	3.50
Richmond	$14,925,633.02	3.84	$14,852,478.58	3.33
Chincoteague	$352,745.44	8.00	$351,016.55	7.47
Virginia Beach	$24,226,081.58	4.70	$24,107,343.20	4.19
Fredericksburg	$1,360,685.87	12.09	$1,354,016.79	11.55
Charlottesville	$2,278,822.56	3.74	$2,267,653.45	3.23
Culpeper	$743,249.23	4.01	$739,606.37	3.50
Staunton	$2,077,183.16	4.01	$2,067,002.34	3.50
Alexandria	$4,283,416.32	4.01	$4,262,422.18	3.50
Leesburg	$1,076,724.63	7.53	$1,071,447.32	7.01
Harrisonburg	$2,266,401.82	4.01	$2,255,293.59	3.50
Fairfax	$1,420,280.48	4.01	$1,413,319.32	3.50
Statewide	$175,726,582.99	4.67	$174,865,300.93	4.15

Table 19: Proposed Item Mix and Fisher Formula Options

	No Proxy		FHWA Proxy	
	FY 98	**% Change**	**FY 98**	**% Change**
Bristol	$1,816,886.45	3.32	$1,815,393.56	3.24
Blacksburg	$1,662,433.58	3.36	$1,661,067.60	3.28
Danville	$5,466,907.56	3.41	$5,462,415.54	3.32
Petersburg	$3,110,976.12	3.36	$3,108,419.91	3.28
Richmond	$14,832,585.15	3.20	$14,820,397.59	3.11
Chincoteague	$350,546.39	7.32	$350,258.36	7.23
Virginia Beach	$24,075,053.79	4.05	$24,055,271.93	3.96
Fredericksburg	$1,352,203.22	11.40	$1,351,092.14	11.30
Charlottesville	$2,264,616.15	3.09	$2,262,755.37	3.01
Culpeper	$738,615.74	3.36	$738,008.83	3.28
Staunton	$2,064,233.79	3.36	$2,062,537.67	3.28
Alexandria	$4,256,713.08	3.36	$4,253,215.45	3.28
Leesburg	$1,070,012.22	6.86	$1,069,133.02	6.78
Harrisonburg	$2,252,272.85	3.36	$2,250,422.21	3.28
Fairfax	$1,411,426.31	3.36	$1,410,266.58	3.28
Statewide	$174,631,086.10	4.01	$174,487,596.15	3.93

Table 20: Proposed Item Mix and Tornqvist Formula Options

	Tornqvist (No Proxy)		Tornqvist: FHWA Proxy	
	FY 98	% Change	FY 98	% Change
Bristol	$1,817,391.05	3.35	$1,815,647.02	3.25
Blacksburg	$1,662,895.29	3.39	$1,661,299.51	3.29
Danville	$5,468,425.88	3.44	$5,463,178.17	3.34
Petersburg	$3,111,840.12	3.39	$3,108,853.88	3.29
Richmond	$14,836,704.59	3.22	$14,822,466.72	3.13
Chincoteague	$350,643.75	7.35	$350,307.26	7.25
Virginia Beach	$24,081,740.14	4.08	$24,058,630.38	3.98
Fredericksburg	$1,352,578.76	11.43	$1,351,280.78	11.32
Charlottesville	$2,265,245.10	3.12	$2,263,071.29	3.02
Culpeper	$738,820.87	3.39	$738,111.87	3.29
Staunton	$2,064,807.09	3.39	$2,062,825.62	3.29
Alexandria	$4,257,895.30	3.39	$4,253,809.26	3.29
Leesburg	$1,070,309.40	6.89	$1,069,282.29	6.79
Harrisonburg	$2,252,898.37	3.39	$2,250,736.40	3.29
Fairfax	$1,411,818.31	3.39	$1,410,463.47	3.29
Statewide	$174,679,586.24	4.04	$174,511,957.06	3.94