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Value-Based Investing for Government Infrastructure: Financing Virginia's Roads

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Capital Markets and Economic Performance

One of the reasons that market economies create high standards of living is the efficiency of their capital markets. The main task of capital markets is to channel scarce capital resources into their most highly valued uses. This is a difficult and complex undertaking in modern economies. In 2007, U.S. business firms invested $2.1 trillion in plant and equipment.[1] This is a huge sum, but it only begins to tell the story. Investments are divided among tens of thousands of potential uses, from mundane items such as desks and chairs to sophisticated equipment such as magnetic resonance imagers or computerized farm equipment. Not only are there many thousands of goods to invest in, but the value of one capital good depends on the availability of complementary goods. The sawmill is dependent on roads, logging trucks, grappling machines, and well managed forests; crude oil production depends on drills, pipelines, refineries, and tankers; electrical power depends on the manufacture of turbines, the existence of transmission lines, and the installation of meters. Nor does the complexity end there; in deciding where to invest, each business firm has to anticipate the desires of consumers and the activities of competitors; a miscalculation can leave an investor facing takeover or bankruptcy. Given the difficulty of investing our scarce capital resources widely, we might think that such activity would be restricted to a few experts. Yet the opposite occurs in modern economies. Investing in the myriad of complementary capital goods is a widely distributed activity. There are approximately six million business

[1] http://www.bea.gov/newsreleases/national/gdp/2008/pdf/gdp407p.pdf. Accessed March 10, 2008. The figures measure gross investment in current dollars, meaning that they have not been adjusted for depreciation of the existing capital stock or the inflation of the currency. In 2000 dollars, private gross investment measures $1.8 trillion dollars, federal investment $36.9 billion, and state and local investment $257.3 billion.

establishments in the United States, all of which invest in capital goods.[2] Small, locally owned businesses invest in comparatively inexpensive goods such as ovens, dishwashers, steam irons, and cash registers, while large firms invest in relatively expensive goods such as automobile assembly lines, construction equipment, networks of cellular towers, and microchip plants. Besides the six million business owners, many other millions of investors choose to invest in stocks or mutual funds. In addition to the complexity of the capital structure, investment is made difficult by the changing landscape that efficient investment must serve. As populations grow or shrink, as goods improve, as new technologies emerge, as consumers alter their preferences, as markets open up or close down in different parts of the world, investors must adapt their actions to accommodate the new situation. An investment that was inappropriate when telephone signals could only be transmitted through wire can be highly profitable once the signals can be transmitted through the air. An investment in a Czech automobile plant might look unattractive in 1988 but promising in 1992, as Eastern Europe embraced markets. Change is an inescapable fact of economic life. Investors, if they are to use scarce capital resources efficiently, must correctly anticipate it.

Despite the complexity of investing properly, investors can be relied on to make correct decisions. Investment decisions are far from perfect, of course, as evidenced by bankruptcies, financial crises, and recurring cycles of booms and busts in capitalist economies. But in the main, investment is channeled into productive areas because investors have both the knowledge and the incentive to do so. The knowledge and the incentives to properly invest resources result from an economic system that relies on private property. Through a long developmental process, market economies have created

[2] http://factfinder.census.gov. Accessed March 11, 2008.

an extensive division of labor that is based on private ownership, specialization, and exchange. The exchange of economic goods by specialized producers creates market prices for thousands of goods and services used by consumers, and the tens of thousands of goods used by producers. Investors use the prices of consumers' and producers' goods to judge the relative value of alternative investments; business firms calculate the revenues and expenses that they believe will flow from their decisions. The calculations are demanding and complex; it takes years and a great deal of mental effort to master modern methods of accounting and finance. Discounting, options pricing, derivatives, income statements, and capital budgeting are just some of the techniques that investors use to judge the value of their prospective investments. Each of these techniques depends on prices that are established through the purchase and sale of goods and services. Not only do investors rely on monetary calculation to determine where resources should be invested, they also exert foresight and judgment in making their decisions. They have a strong incentive to be right, because correct decisions are rewarded with profits while incorrect ones are punished with losses. An increased demand in one area will create higher differential between revenues and costs, thus drawing investment into the growing area with the promise of profits. A decreased demand in another area will create a lower differential, or even a negative one, between revenue and cost, thus pushing investment out of the area.

Two other aspects of investment contribute to its reliability. First, investors with a record of success gain influence in the investment community. Warren Buffet, David Swenson, and Steve Ballmer have huge investment sums at their disposal; their past success has increased their capital and expanded their influence in decision making.

Investors who fail to invest successfully see their funds shrink, and their influence over investment decisions diminishes correspondingly, as evidenced by Jeffrey Skilling, Bernard Ebbers, and General Motors. There is a selection process in markets that puts persons of foresight and judgment in positions of authority. Second, business managers who receive funds from investors have an incentive to use those funds efficiently. A business manager who borrows from a bank, or floats corporate bonds, tries to put those funds to good use, because he must pay back a fixed amount. If the manager generates revenues above the cost of capital, he profits; if the cost of borrowing exceeds the revenue generated, he loses. Given the amounts that are borrowed, this incentive to use funds wisely is crucial. Federal Reserve data show that banks in the United States issued commercial and industrial loans worth $79.4 billion during the week of Nov. 5-9, 2007, a week that was not at all unusual. Some weeks, commercial banks issue business loans in excess of $100 billion.[3] Managers who finance their operations through the sale of securities or retained earnings, as is common in large corporations, also take care to put their funds to good use; investors have learned to align the incentives of shareholders and managers. The long-term growth of stock indexes, such as Standard & Poor's index of America's 500 largest firms, shows that managers of large firms usually succeed in putting investment funds to valuable use.[4]

Efficient investing is important to our well-being because investment is the main cause of economic growth. Since the end of World War II, America's gross domestic

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[3] http://www.federalreserve.gov/releases/e2/current/default.htm. Accessed March 10, 2008.
[4] Vanguard created its index fund in 1976. It has returned over 12% a year since then. For statistics and analysis of corporate securities, see Jeremy J. Siegel, *Stocks for the Long Run* (New York: McGraw Hill, 2002.)

product has increased from $1.6 trillion to $11.6 trillion, measured in constant dollars.[5] Of course, population has increased, too, from 150 million in 1950 to 300 million in 2007, but the increase in per capita income is still impressive; measured in constant 2000 dollars, it has risen from an average $11.1 thousand per capita in 1950 to $38.7 thousand per capita in 2007. In the space of two generations, income per person has more than tripled in the United States.[6] Nor is this the whole story. The increased income is spent on better goods than it was in 1946. Today's consumer buys safer cars, more energy efficient appliances, and smaller, faster computers than she did fifty or sixty years ago. Technical change is responsible about twenty-five and thirty per cent of the economic growth in America, but the increase in investment is responsible seventy or seventy-five per cent.[7]

While most investment in market economies is private, governments also invest large amounts. To the $2.1 trillion in private investment, the federal government added $38.8 billion while state and local governments added $348.3 billion in 2007. Sometimes governments can use prices to make its investment decisions. The United States Postal Service, for example, charges for its services. Because the Service generates revenues, the Postmaster General can calculate profit and loss for its various operations and use these calculations to decide where to invest. If population is shifting from rural areas to cities, or from northern States to southern States, the Service can increase its investment in cities or southern States and decrease investment in rural areas or northern States. The

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[5] http://www.bea.gov/national/nipaweb/TableView.asp#Mid. Accessed March 10, 2008. Gross domestic product is measured in constant 2000 dollars. 2007 gross domestic product in current dollars was $13.8 trillion.

[6] Hobbs, Frank and Nicole Stoops, *U.S. Census Bureau, Census 2000 Special Reports, Series CENSR-4, Demographic Trends in the 20th Century* (Washington, D.C.: U.S. Government Printing Office, 2002), p. 13.

[7] Reference Dale Jorgenson and others here.

Service may or may not do this; it does not operate under the discipline of profit and loss, but it has the ability to invest this way because of the guidance it receives from market prices.

Most government investment, however, does not result in goods or services for which the government charges. As the Bureau of Economic Analysis says in its introduction to the national income accounts, "Because governments primarily rely on tax receipts and transfer payments to cover their expenditures, sales are not a good measure of the value of their gross output. As a result, gross output for general government is measured by the expenditures that are made to provide goods and services for public consumption."[8] The lack of sales creates a substantial problem for government investment. Without market prices for its services, the government cannot compare revenues and costs when deciding on investments. Of course, there may be sound reasons for not charging market prices for government services. It would be awkward to negotiate prices for military services, for example. Because citizens benefit from military services whether or not they pay, there is an incentive for citizens to understate the amount that they are willing to pay for such services. If citizens did understate their willingness to pay, market prices signal that military services are less valuable than they really are. The false signal would result in too little investment in the military sector.[9] But whatever the reasons for the absence of market prices, the situation precludes the comparison of revenue and cost figures, which makes it difficult for government officials

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[8] McCulla, Sephanie and Charles Ian Mead, *An Introduction to the National Income and Product Accounts* (Washington, D.C. Bureau of Economic Affairs, September 2007), p. 19.

[9] Military services are an often cited example of "public goods," goods whose use by one person does not exclude their use by another. For the classic statement of underinvestment of public goods, see Paul Samuelson, "The Pure Theory of Public Expenditures," *Review of Economics and Sta*tistics, vol. 36 (November 1954), pp. 387-389.

to tell whether or not they are investing resources where they will produce the most value. Inefficiency and waste are a likely result of this situation; governments might be investing taxpayer funds in military services when they would have a higher value in social services, or vice-versa. If it were possible to accurately estimate prices for governmentally provided goods and services, efficiency could be improved.

Business firms sometimes face a problem similar to that of government bureaus. Firms that are introducing new goods or services onto the market do not have established market prices to guide them. They must somehow figure out what their product is worth without the benefit of established prices. Firms facing this problem have developed a technique called Economic Value Analysis, which helps them estimate what a novel product is worth to customers. This technique can also be used by government officials. It can help officials to reliably estimate market prices. Consequently, this technique has the potential of substantially improving the efficiency of government investment. This is particularly true, as we will show in this study, of investment in roads.

Economic Value Analysis

When a new product, such as a television set or a personal computer, or a new service, such as air travel or laser eye surgery, is offered to the public, the price to charge for the good or service is not readily apparent. Firms must somehow estimate what the price that will generate the most net revenue for the firm. As mentioned earlier, economic value analysis was developed by private industry to help them solve this problem. An historical example will illustrate the technique.

In 1955 E.I. du Pont de Nemours and Company introduced a new resin, Alathon 25, for the manufacture of pipe. The pipe had many uses, one of which was irrigation pipe used by farmers to carry water from wells to fields that required regular watering. The pipe was sometimes laid above ground and sometimes laid underground to protect it from damage by trucks, tractors, and other farm implements. Irrigation pipe was in common use in 1955, but Alathon 25 was a new material that was substantially more reliable than pipe made from existing resin; the failure rate of existing resin was 8%, that of Alathon25 was 2%. With this information, DuPont estimated the economic value of Alathon 25 as follows:

1. The price of pipe that used existing resin was $6.50 per 100 feet. DuPont used this as a reference value, i.e. as a starting point to figure out the value of their new pipe.
2. Since Alathon25 needed to be replaced 6 % less often (8% - 2%), DuPont added 6% to the price of the pipe. This added $.39--$ 650 x .06--to the price of the pipe.

3. When pipe needed to be replaced, the cost of the pipe was not the only expense. Farmers had to pay labor to replace the pipe at a rate of $60 per one hundred feet. This added $3.60 to the price of the pipe.
4. By adding together the reference value and the differentiating values of Alathon 25, DuPont arrived at a figure of $10.47 ($6.50 + $.39 + $3.60). This figure, $10.47, is the economic value of underground irrigation pipe made from Alathon 25.[10]
5. Using the economic value as an upper bound and the reference value as a lower bound, DuPont then decided on a price Alathon 25 irrigation pipe. A price of $8.50 per 100 feet would split the differentiation value between DuPont and its customers.

With the example to guide us, we can delve more deeply into economic value analysis. Economic value analysis consists of five steps. The first step is to decide on an appropriate reference value. A reference value is the market price of good that is comparable, but not identical, to the good being introduced to the market. When personal computers were introduced, the price of an electric typewriter served as a reference value. When commercial air travel between Chicago and New York was first offered, the reference the price of a train ticket was a logical reference value. For a new good or service, a reference value is the price of an established good or service with which the new good will compete. When a firm decides to calculate the economic value for an existing good or service, it often has the choice of several reference values; a grocery

[10] This example is taken from Thomas T. Nagle and Reed K. Holden, *The Strategy and Tactics of Pricing* (New York: Prentice Hall, 2002), pp. 77-78. As the authors explain in footnote 4, p. 115, the figures they use are for illustration, not the historical figures used by DuPont.

store that wanted to begin selling its own band of dishwashing detergent could use the prices of any of the name brands as a reference value. For Alathon 25, Dupont chose for a reference value a commonly used irrigation pipe. Choosing a commonly used good appeals to potential customers, because it is something whose value they readily understand. Choosing a reference value for a road will be a more difficult task than for most services, because most roads are not priced and substitute modes of transportation, such as rail, are usually subsidized, so that the price does not reflect the market value. Fortunately, we are able to solve this problem by relying on the prices for the few roads that do reflect market values.

The second step of economic value analysis is identifying the differentiating characteristics of the new good. The differentiating characteristic of Alathon 25 pipe was its reliability, which meant that it did not have to be replaced as often. This is a simple comparison. Often, identifying differentiating characteristics can be complicated. A personal computer differs from a typewriter in many respects. On the positive side, the computer will perform numerical computations and it will store data in electronic form, both of which add to its value as compared to a typewriter. On the negative side, computers crash, causing downtime among workers and sometimes losing hundreds of hours of work in the process. This subtracts from the value of a computer as compared to an electric typewriter. When we identify differentiating characteristics, we will usually find some that add value and some that subtract. A plane ride is shorter than a train, but it often leaves us farther from the city center that we wish to visit and it is less comfortable. A good economic value analysis will identify all the differentiating characteristics that add or subtract value to customers. Leaving out characteristics distorts the value.

The third step in economic value analysis is placing a monetary value on the distinguishing characteristics. For Alathon 25, this was comparatively simple; we could use the price of existing pipe and the price of labor to calculate the value of the differentiating characteristics. However, it is often difficult to assign monetary values to characteristics. For example, it takes eighteen hours to travel from New York to Chicago by train, but only four hours by plane (including a stop.) This is a savings of fourteen hours and raises the question, "what value do we put on the time savings?" This value will obviously differ for different travelers. For a business executive who wants to visit several clients in different cities in a short amount of time, the value of the time will be very high, perhaps $200 per hour, which would give a differentiation value of $2800. For a student traveling home for the holidays, the time savings may be worth little, especially if she plans on studying during the trip. The value of saving time may be worth $10 per hour, or $140 for a 14 hour savings. Which value do we assign to time? One practical solution to the problem is to calculate different values for different customer segments, one for business travelers and one for leisure travelers.

The fourth step is comparatively simple: Add the reference value and differentiation values. The sum of the two is the economic value of a good or service. It is the most that a fully informed, rational person would pay for the good. This is the value that we will use for comparing the values of different road investments.

The fifth and final step of economic value analysis is setting the price. Business firms will set the price below the full economic value of a product, so that customers receive more value than they pay for. Firms do this, not out of altruism, but to give customers an incentive to purchase its products rather than those of its competitors. Setting the price is usually a complex decision that requires managers to consider not only the economic value to the customer, but also competitor reactions and firm costs. In our study, we will not concern ourselves with this step, because we are not advocating that actual prices be charged for roads. We simply want to use the economic value as a basis for determining the value of investing in various road projects.

Virginia Department of Transportation Planning Process

In 2002, the Virginia General Assembly mandated that the Virginia Department of Transportation "provide a comprehensive review of the statewide construction needs of all systems—highways, airports, seaports, transit, rail, bicycle and pedestrian." As a part of this general review, the Department has developed a broad ranging and forward looking planning process for highways. The process consists of three steps. The Department first assesses highway needs throughout the state and, based on the assessment, develops a plan without regard to financial constraints. The purpose of the unconstrained plan is to identify all the productive uses to which highway funds could be put if resources were unlimited. They then prioritize the use of funds based on a set of goals and measures that the Department has developed. Highway projects are classified into three tiers. Tier 1 projects are those that address capacity and safety issues that require investment in the near term (0 to 7 years). Tier 2 projects address capacity and safety issues that require investment in the intermediate term (8 to 16 years). Tier 3 projects address capacity and safety issues that are expected to require investment in the longer term (17 to 25 years). The purpose of prioritizing the projects is precisely the purpose that we identified at the beginning of this study: to invest resources efficiently. The Department writes, "Why develop a prioritization process? The transportation needs of the Commonwealth continue to increase. Revenues to fund transportation improvements have not kept pace with growing traffic levels. Virginia must continue to find ways to more effectively and efficiently invest the limited funds that are available for transportation."[11]

[11] *2025 State Highway Plan, Technical Report* (Virginia Department of Transportation, December 2005), p. 2; *Prioritizing the State Highway Plan: Brochure* (Virginia Department of Transportation, n.d.), p. 3. As of

Choosing among the options is not easy. In 2004, the Department rated the level of service on twenty-nine percent of its interstate highways and thirty-six percent of its primary roads at F, which it defines as follows: "Level of Service F: Forced traffic flow in which the amount of traffic approaching a point exceeds the amount that can be served. LOS F is characterized by stop-and-go waves, poor travel times, low comfort and convenience, and increased accident exposure and is used to identify the point where the facility has reached maximum capacity and a complete breakdown of service occurs."[12] Considering that the State of Virginia is responsible for maintaining 1,100 miles of interstate and 8,500 miles of primary roads, the deficiencies are enormous. At an average rate of $1.75 million per mile to add two lanes in each direction to the deficient interstate roads, and an average cost of $800 thousand per mile to add one lane in each direction to the primary roads, Virginia will need to spend $2.1 billion just to correct its existing deficiencies. In addition, because of its growing population, the State will need to spend funds to build new roads.[13] Besides the additions to existing highways, the Department recommends the construction of 86 miles of new interstate highway construction. 70 of these miles are 4 lane with a median strip; 7.5 are 6 lane with a median strip; 8.75 miles are reversible high occupancy lanes. The cost of the new interstate highways would run into the hundreds of millions of dollars. That the Virginia Department of Transportation rates thirty percent of its interstate highways and primary roads as deficient illustrates

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March 19, 2008, both documents can be accessed at http://www.virginiadot.org/projects/pr-statehighwayplan.asp

[12] *2025 State Highway Plan, Technical Report*, pp. 10-11.

[13] For highway construction costs in 2002, see *2025 State Highway Plan, Technical Report*, p. 26.

that investment funds for highway construction are scarce and need to be allocated where they will add the most value.[14]

[14] I have used a cost of $3.5 million per mile for the 4 lane highway with a median strip, $4.5 million per mile for a 6 lane highway with a median strip, and $1million per mile for the reversible HOV lanes. The figures are adjusted from the 2002 figures given in appendix D of the *2025 Hig*hway *Plan Technical Report*.

Economic Value of Virginia Highway Segments:

I-66 and I-581[15]

We will illustrate the use of economic value analysis by calculating the value of two construction projects recommended in the *2025 Highway Plan*. The first project recommends widening I-581, a 6.75 mile segment road in southern Viginia. I-581 connects the city of Roanoke to I-81 to the north and to Route 220 to the south. (Route 220 is a four lane divided highway that runs from Roanoke south to the North Carolina border and has a high volume of freight; about 15% of the traffic on route 220 consists of commercial trucks.) The existing road is six lanes, three in each direction. In 2006, I-581 averaged about 75,000 vehicle trips per day, 7% of which were made by commercial trucks.[16] Virginia's Department of Transportation recommends widening I-581 to 10 lanes, 2 in each direction. The second project recommends widening I-66 from Route 50 in Fairfax County to the Beltway that girds Washington, D.C. The existing road segment is six lanes (three in each direction), with a shoulder added as a fourth lane during morning and evening rush hours. The segment is 6.9 miles long and the daily volume is 187,000 trips on the busiest segment and 174,000 on the other segment. Commercial trucks constitute 4% of the traffic. The Department of Transportation recommends widening I-66 to ten lanes.[17]

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[15] This section of the paper is based on an economic value analysis by G..M.U. graduate students Amy DePolo, Seniha Ormurdenal, and Olga Rines during the Fall Semester of 2007. See the "Economic Value Analysis: I-66 Corridor and I-581 Corridor (unpublished paper, George Mason University, 2007), 42 pp.

[16] See *Average Daily Traffic Volumes with Vehicle Classification Data* (Richmond: Virginia Department of Transportation, 2006), p. 495. Report can be found at http://www.virginiadot.org/info/resources/AADT_PrimaryInterstate_2006.pdf. See also De Polo et al., pp. 32-34.

[17] See *Daily Traffic Volume Estimates:Juridiction Report 29* (Richmond: Virginia Department of Transportation 2006). Although both projects are approximately equal in length and recommended width widening, the added lanes are not identical. The I-581 project proposes to "widen to 8 lanes + CD Roads:

Reference Value: California 91Express Lanes. For a reference point to calculate the economic values of I-581 and I-66, I have chosen California 91 Express Lanes. The Express Lanes are ten miles long and run from Route 55 in Anaheim to the border of Riverside County. These lanes were privately built and managed from 1995 to 2003, when they were purchased by the Orange County Transportation Authority. The reason for choosing these lanes as a reference value is that they are priced so that traffic flows smoothly, even during hours of heavy use. Pricing roads so that traffic flows smoothly at all times is an example of peak-load pricing (or dynamic pricing or value pricing.) In addition to providing a market price for a heavily travelled highway, the 91 Express contains 4 lanes, two in each direction, that match the width of the additions to 581 and 66. Also, the 91 Express Lanes run next to a freeway. The similarities between the Express Lanes and I-581 and I-66 make them suitable as a reference value.

In 2006, the latest year for which an annual report is available, 14.1 million trips were taken on the 91 Express Lanes. 2.9 million of these trips paid no tolls because they were in vehicles occupied by three or more persons. The remaining 11.2 million trips paid tolls worth a total of $44.2 million. Non-peak tolls were $1.20 per trip; heavier traffic tolls ranged from $1.90 to $9.50 per trip. The higher tolls were the amounts required to keep traffic flowing smoothly during times of heavy use. The highest toll, $9.50, kept eastbound traffic flowing at 65 miles per hour during the peak hour of 4:00 to 5:00 p.m. on Friday. The highest toll in the westerly direction was $4.20, which

I-73 overlap;" The I-66 project proposes to "widen to 8 lanes + 2 reversible HOV lanes." See *2025 State Highway Plan,Recommendations*, p.2. The differences between H.O.V. and CD roads may require separate estimates in value.

occurred Monday through Thursday from 7:00 a.m to 8:00 a.m. The average toll in 2006 was $3.95. The tolls increased in January 2008. The new toll schedule is given below.[18]

91 Express Lanes **Toll Schedule** *Effective January 1, 2008* — **Eastbound** *SR-55 to Riverside Co. Line*

	Sun	M	Tu	W	Th	F	Sat
Midnight	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20
1:00 am	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20
2:00 am	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20
3:00 am	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20
4:00 am	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20
5:00 am	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20
6:00 am	$1.20	$1.90	$1.90	$1.90	$1.90	$1.90	$1.20
7:00 am	$1.20	$1.90	$1.90	$1.90	$1.90	$1.90	$1.20
8:00 am	$1.55	$1.90	$1.90	$1.90	$1.90	$1.90	$1.90
9:00 am	$1.55	$1.90	$1.90	$1.90	$1.90	$1.90	$1.90
10:00 am	$2.35	$1.90	$1.90	$1.90	$1.90	$1.90	$2.35
11:00 am	$2.35	$1.90	$1.90	$1.90	$1.90	$1.90	$2.35
Noon	$2.80	$1.90	$1.90	$1.90	$1.90	$2.90	$2.80
1:00 pm	$2.80	$2.65	$2.65	$2.65	$2.90	$4.50	$2.80
2:00 pm	$2.80	$3.80	$3.80	$3.80	$3.90	$5.10	$2.80
3:00 pm	$2.35	$4.10	$4.70	$5.95	$5.70	$10.00	$2.80
4:00 pm	$2.35	$6.85	$8.00	$8.50	$9.25	$9.50	$2.80
5:00 pm	$2.35	$6.65	$8.50	$8.50	$9.25	$8.00	$2.80
6:00 pm	$2.35	$4.10	$5.45	$4.95	$5.75	$4.90	$2.35
7:00 pm	$2.35	$2.90	$2.90	$2.90	$4.15	$4.55	$1.90
8:00 pm	$2.35	$1.90	$1.90	$1.90	$2.65	$4.15	$1.90
9:00 pm	$1.90	$1.90	$1.90	$1.90	$1.90	$2.65	$1.90
10:00 pm	$1.20	$1.20	$1.20	$1.20	$1.20	$1.90	$1.20
11:00 pm	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20

91 Express Lanes **Toll Schedule** *Effective January 1, 2008* — **Westbound** *Riverside Co. Line to SR-55*

	Sun	M	Tu	W	Th	F	Sat
Midnight	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20
1:00 am	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20
2:00 am	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20
3:00 am	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20
4:00 am	$1.20	$2.25	$2.25	$2.25	$2.25	$2.25	$1.20
5:00 am	$1.20	$3.70	$3.70	$3.70	$3.70	$3.55	$1.20
6:00 am	$1.20	$3.80	$3.80	$3.80	$3.80	$3.70	$1.20
7:00 am	$1.20	$4.20	$4.20	$4.20	$4.20	$4.10	$1.65
8:00 am	$1.65	$3.80	$3.80	$3.80	$3.80	$3.70	$1.90
9:00 am	$1.65	$3.05	$3.05	$3.05	$3.05	$3.05	$2.35
10:00 am	$2.35	$1.90	$1.90	$1.90	$1.90	$1.90	$2.35
11:00 am	$2.35	$1.90	$1.90	$1.90	$1.90	$1.90	$2.70
Noon	$2.35	$1.90	$1.90	$1.90	$1.90	$1.90	$2.70
1:00 pm	$2.70	$1.90	$1.90	$1.90	$1.90	$1.90	$2.70
2:00 pm	$2.70	$1.90	$1.90	$1.90	$1.90	$1.90	$2.70
3:00 pm	$2.70	$1.90	$1.90	$1.90	$1.90	$2.35	$2.70
4:00 pm	$2.85	$1.90	$1.90	$1.90	$1.90	$2.35	$2.85
5:00 pm	$2.85	$1.90	$1.90	$1.90	$1.90	$2.35	$2.85
6:00 pm	$2.85	$1.90	$1.90	$1.90	$1.90	$2.80	$2.35
7:00 pm	$2.35	$1.20	$1.20	$1.20	$1.20	$1.90	$1.90
8:00 pm	$2.35	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20
9:00 pm	$2.35	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20
10:00 pm	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20
11:00 pm	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20

As can be seen from the schedule, elevated tolls are charged from 4:00 a.m. to 6:00 p.m. in the westerly direction, and from 6:00 a.m. to 9:00 p.m. in the easterly direction. Assuming that 80% of the $44.2 million in revenues was paid by users during the elevated toll periods, the average elevated toll was $4.60 per trip. The average non-peak toll was $1.20 per trip. These two figures will serve as our reference values for peak and

[18] The price table for 2007 is given in DePolo, et al., p. 15. With the exception of a few The updated toll schedule is found at http://www.octa.net/schedule_effective.aspx, accessed April 1, 2008. I arrived at an average toll by dividing the total toll revenue of $14.2 million

non-peak periods on the Virginia roads. For I-66 we will use both reference values. For I-581 we need use only the non-peak reference value. Even during rush hour, traffic flows at speed along I-581; there is no need for a higher toll to reduce congestion on I-581, although this may change in the coming years.[19]

Differentiating Characteristics and Differentiation Value. California's 91 Express Lanes, and the surrounding area and users, differ in important ways from 581 and 66, and from Fairfax and Roanoke, Virginia. One difference is the length of the road. The Express Lanes are ten miles in length, 581 and 66 are 7 miles. The shorter length of the Virginia roads, makes them less valuable than the Express Lanes simply because they do not carry the traveler as far. We reduce both the peak and non peak values by .3 for Fairfax and the non-peak value by .3 for Roanoke.

The differentiation value for length is -$.36 for non-peak hours and -$1.38 for peak.

In addition to the length of the roads, the incomes of the residents differ. It is common for business firms to charge lower prices to consumers in lower income brackets. Discounts for senior citizens and students exemplify this practice and it makes sense to adjust the value of roads to the height of income in a particular area. In 2005 Orange County, the primary users of I-91 had a per capita personal income of $44,453; Fairfax County, Fairfax City, Falls Church, Prince William County, Manassas, and Manassas Park had a per capita personal income of $48, 491, which is 9% higher than

[19] I drove Route 220 from Danville to Roanoke and arrived at 581 at the height of rush hour, 7:00 a.m. Congestion did not slow between 7 a.m. and 8 a.m. in either direction. Traffic in the center lane flowed at a consistent 60 miles per hour. Of course, this is one data point; more detailed estimates might reveal congestion, in which case a peak period toll could be calculated and revenue estimates could be derived from this toll.

Orange County; Roanoke had a per capita personal income of $32,512, which is 26% lower than Orange County. A 9% increase in income would increase the willingness to pay road tolls. In the absence of income elasticity data, we will be conservative and limit the price increase to 3%. A 26% decrease in income would lower the willingness to pay road tolls. Again we will be conservative and assume that road tolls would fall by 8%.[20]

The differentiation value for income in Fairfax is $.14 for peak periods.

The differentiation value for income in Fairfax is $.04 for non-peak periods.

The differentiation value for income in Roanoke is -$.10 for non-peak periods.

Other differentiating values could be added for the Virginia roads. I-66 is heavily congested during rush hours, which makes the road less safe and adds to pollution as compared to the 91Express Lanes and to I-581. The value of added safety, improved fuel economy, and reduced pollution could be estimated. We have not done so here because accident data by road segment is difficult to collect, and reduced pollution is difficult to measure. Nor are additional differentiating values necessary to illustrating economic value analysis. Nevertheless, these differentiating values exist; the perceived safety of the 91 Express Lanes is one of the reasons drivers use the lanes during non-peak hours even though there is a freeway running adjacent to the toll lanes.[21]

Economic Value Estimates and Revenues. The economic value estimates for I-581 and I-66 are obtained by summing the reference and differentiation values. Since there is no congestion on I-581, the reference value for all periods during the day is $1.20. From

[20] See Appendix A for a more complete explanation of these estimates.
[21] See Edward Sullivan, *Continuation Study to Evaluate the Impacts of the SR 91 Value-Priced Express Lanes:Final Report* (San Luis Obispo: Cal Poly State University), p. 108.

this reference value we subtract \$.36 for the shorter length of I-581 as compared to the 91 Express Lanes and we subtract \$.10 for the lower income of Roanoke County as compared to Orange County. *The economic value of I-581 is \$.74 per trip.*

For I-66, the reference value is \$4.60 during heavy traffic periods. We subtract \$1.38 to adjust for the shorter distance of I-66 as compared to the 91 Express Lanes and we add \$.14 to adjust for the higher income of Fairfax as compared to Orange County. *The economic value of I-66 during heavy traffic is \$3.36 per trip.* During light periods, we use \$1.20 as the reference value. We subtract \$.36 for the shorter distance and add \$.04 for the higher income. *The economic value of I-66 during light traffic is \$.88 per trip.*

Using these economic value estimates, we can estimate the revenues that each construction project would generate were it a commercial venture. We begin by estimating the number of vehicle trips that drivers would take on the additions to I-581. At present, the average volume is approximately 75,000 vehicle trips per day or 27,375,000 trips per year. Since congestion does not slow down traffic, this number will not increase as a result of improved traffic flow. However, it will increase because additional lanes will improve safety and will stimulate development in the area, increasing both population and income. These induced effects have been estimated for Virginia at .506, meaning that a 10% increase in lane miles will increase traffic by about 5%, a 20% increase in lane miles will increase traffic by 10%, etc. Adding two lanes in each direction will increase lane miles by 66% on I-581, so we should expect traffic to increase by 33%, or 9,033,750 vehicle trips per year. At a toll charge of \$.74 for each additional trip made by a vehicle, the added lanes would generate revenues of \$6.7

million per year. We are not, of course, advocating that a toll be charged; we are simply calculating the revenue that would be generated if there were a toll charge comparable to that charged on California's 91 Express Lanes.[22]

For the I-66 project, the calculations are similar, except that we have to perform two value calculations, one for peak periods of travel and the other for non-peak periods. At present, the average traffic volume on I-66 is approximately 180,000 vehicle trips per day, or 65,700,000 trips per year. Virginia's Department of Transportation estimates of traffic volume do not give the time of day that travel occurs, so we have to estimate what proportion of travel would take place during periods of elevated tolls. The proportion will depend, *inter alia,* on the hours that an elevated toll would be required to keep traffic flowing smoothly. On the eastward bound 91 Express Lanes, elevated tolls are charged from 6 a.m. in the morning to 10 p.m. in the evening during the week, and from 8:00 a.m. to 10:p.m. on Friday and Saturday. In the westbound direction, elevated tolls are charged from 4 a.m. to 7 p.m. during weekdays and 8:00 a.m to 8:00 p.m. on weekends. Elevated toll times would probably not be identical for I-66, but if elevated tolls were charged for from 6:00 a.m. to 9:00 p.m. hours per day during the week, the proportion of traffic during these times would be well over 50% of all traffic.[23] We will take a conservative

[22] For estimates of increases in traffic resulting from increased road construction in Virginia, see Lewis M. Fulton, Robert B. Noldand, Daniel J. Meszler, and John V. Thomas, "A Statistical Analysis of Induced Travel Effects in the Mid-Atlantic Region," *Journal of Transportation and Statistics* (April 2000), p. 8. North Carolina has a somewhat lower induced effect of .475. See also the discussion in "Build It and Will They Drive? Modelling Light Duty Travel Demand," a briefing from the Conference Board of Canada, December 2006. In that study, light truck traffic increased by 5% for every 10% increase in lane miles, and automobile traffic increase by 2.5%.

[23] *2006 Virginia Department of Transportation Jurisdiction Report Daily Traffic Volume Estimates: Jurisdiction Report 29* (Richmond: Virginia Department of Transportation) gives a great deal of information on traffic flows, but does not give information on traffic flows by hour of day. They give average flow per weekday (Monday through Thursday), which is 196,000, and average flow per day for all days, which is 187,000, which means that average daily flow per weekend (Friday through Sunday) is about 175,000 trips per day. Since the weekend calculation includes Friday, which is a day of heavy use,

approach and assume that 55% of the traffic would be during times of elevated tolls on I-66. This proportion of traffic moving during elevated toll periods means that 99,000 trips per day, or 36,135,000 trips per year, take place during the peak hours, while 81,000 trips per day, or 25,565,000 per year, take place during non-peak hours. The increase in lanes would draw additional traffic to I-66 in both peak and non-peak hours. During non-peak hours, when three lanes are in use in each direction, an additional two lanes each way increases lane mileage by 66%, so we expect traffic to increase by 33%, or 9,756,450 trips per year. At a rate of $.88 per trip, the non-peak use of the addition lanes would generate $8,585,676 in revenues if drivers were required to pay. During the peak hours, four lanes are in use in each direction, so the addition of two lanes would add 50% to lane mileage; traffic would increase by 25%, or 9,033,750 trips per year. If a peak rate toll of $3.36 per trip were charged, the peak-use of the additional lanes would generate $30,353,400 in revenues. The combined revenue estimate for peak and non-peak uses of the new lanes on I-66 is $38,939,076.[24]

To check our estimates, we can calculate the revenues another way. Using hourly k-factors and average daily traffic volume, we can calculate daily traffic volume by hour on the existing lanes of I-66.[25] These hourly flows are shown in figure 1. To calculate the

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these figures do not tell us what proportion of the trips are taken during peak periods, but they do indicate that a 55% to 45% split is a conservative estimate for peak non-peak use.

[24] This value may be too low. According to our induced traffic estimates, two additional lanes in each direction on I-66 would draw an additional 18,790,200 vehicle trips onto the two lanes each year. The 91 Express Lanes handle 14 million trips yearly. If 14 million trips is an upper limit for a four lane expressway, the I-66 tolls would have to be raised to insure that traffic flows at permitted highways speeds. If demand is inelastic for the roadways, which is likely, then an increase in price would also increase revenues; that is, a 25% reduction in traffic would require a rise in tolls of greater than 25%.

[25] The k-factors are taken from *Quickzone Delay Estimation Program: User Guide,* Version 1.0 (Washington, D.C.: Mitretek Systems, 2001), pp. 28-30. The k-factors were not calculated for I-66, but for a roadway that has a similar traffic pattern. The annual average daily traffic flows for I-66 are given in *Virginia Department of Transportation: Daily Traffic Volume Estimates, Jurisdiction Report 29* (Richmond: Virginia Department of Transportation, 2006), pp. 10-12.

increased traffic flow that would follow the addition of two lanes in each direction, we multiply the peak hour traffic flows by .25, and the off peak traffic flows by .33, as explained in the previous paragraph. This gives us the induced traffic on the new lanes. We then multiply the induced traffic flow by $3.36 for the hours of 6 a.m. to 9 p.m., Monday through Friday. For all other hours, we multiply the hourly traffic flow by $.88. Using this method, the additional lanes on I-66 would generate $6,135,065 during off-peak hours, and $35,052,676 during peak hours, or a total of $41,187,741. This higher figure is the result of a higher percentage of traffic occurring during peak hours than in our previous example. However, both methods result in revenues that are in the same ball park and both reveal a substantial difference in economic value between the I-66 and the I-581 projects.

Because the I-581 and I-66 projects are nearly identical in length, in lane width, and in construction costs, and because the economic values are so different, the decision between the two projects is clear. For a roughly equal expenditure in investment funds, I-581 would generate revenues of about $7 million, while I-66 would generate revenues of about $38 million. If scarce resource funds are to be invested efficiently, I-66 clearly ranks above I-581.

Caveats and Extensions

The economic value exercise conducted here illustrates a method that government officials can use to invest scarce capital funds efficiently. Although I have taken reasonable care in the analysis, this study contains shortcomings. Some of the shortcomings could be eliminated by a professional transportation staff, but there are also inherent limitations to the method advocated here.

The data that I have used to estimate the economic value of the roadways could be more accurate. The hourly traffic data, for example, were not calculated specifically for Virginia highways, and so the volume estimates for various times of the day are not as accurate as they would be with better hourly data. Although the volume estimates are reasonable, more accurate estimates would enable a more accurate calculation of economic value for I-66.

I could not find statistics on the safety effects traffic congestion, so I could not calculate whether or how much a reduction in congestion would reduce accidents on Virginia roadways. I also did not have data on pricing for trucks on the roadways; the 91 Express Lanes do not allow trucks. However, commercial truck traffic is important in both Roanoke and Fairfax, and commercial trucks have a higher value than automobile traffic. Hourly traffic flows, congestion, and safety are data that could be obtained at low costs by Virginia's Department of Transportation. Pricing for trucks may be obtainable from other roadways in the United States, Europe or Asia. A professional staff with modest resources should be able to obtain enough data to accurately estimate the economic value, not only of I-581 and I-66 additions, but of all of Virginia's recommended projects. Economic value analyses of all Virginia's suggested road improvements would enable officials to invest Virginia's scarce road funds efficiently.

This study made no attempt at comparison of different modes of transportation. Economic Value Analysis could be used to compare bus and rail transport if reliable market prices can be found for these methods of transportation. In the absence of reliable market pricing, economic value comparisons will be difficult to make. Total cost analysis, as developed by de Corla-Souza *et al*. may enable broader comparisons than economic value analysis.[26]

Yet another shortcoming of this study was that it made no use of cost data. I deliberately chose two projects, I-66 and I-581 that were similar in length and other characteristics so that economic value could be demonstrated without relying on cost estimates. However, to compare investment projects that differ in length, width, or other features, estimating costs is essential. (Costs should even play a role in the present study, because land values in Roanoke are considerably less than in Fairfax.) Fortunately, incorporating costs into the analysis can be done using capital budgeting, a well established technique in business and policy studies.[27] Capital budgeting models can be used to calculate net present values and rates of return, both of which enable managers to compare potential investments that have very different characteristics; for example, using capital budgeting techniques, a firm like General Electric can compare investments in medical imaging, financial services, and jet engines. Similarly, by combining economic value analysis and capital budgeting, Virginia's highway planners can compare rates of

[26] See Patrick de Corla-Souza, *et al*., "Total cost analysis: An alternative to benefit-cost analysis in evaluating transportation alternatives," *Transportation*, Volume 24, (May 1997), pp. 107-123.
[27] Most textbooks on managerial economics explain capital budgeting. See, for example, Mark Herschey, *Managerial Economics* (Mason, Ohio: South-Western Publishing, 2003), pp. 606-645.

return from widening I-95 from Route 58 to the North Carolina border, a four-lane addition of eleven miles, with widening I-264 between I-64 and Independence Avenue, a six lane addition of less than four miles. They can also compare the merits of building a new, four-lane highway seventy miles in length (I-73) with adding two lanes to I-81 between West Virginia and Tennessee, a distance of 35 miles. Comparing the economic value of these two projects using economic value analysis and capital budgeting would be a natural extension of the present study. It may also be possible to compare road maintenance with road construction using these techniques. I have included a comparison of I-581 and I-66 using capital budgeting in appendix B. Using a discount rate of 10%, the net present value of I-66 is about $76 million, the net present value of I-581 is a negative $15 million. The internal rate of return of the I-66 project is 28%, the internal rate of return for I-581 is 0%. (The meanings of terms and calculations of values are presented in Appendix B).

One difficulty of incorporating costs into economic value analysis is the reliability of the cost estimates. Over or under estimation of costs will distort the results and lead to bad investment decisions. It is of the utmost importance that these estimates be undertaken without biasing influences of any kind, including political pressures. This is of course difficult because delegates and senators know that bringing construction projects to a district is an important means of pleasing constituents and winning elections. This kind of pressure could be diminished by setting up a professional staff, a Bureau of Economic Value analysis, within Virginia's Department of Transportation. The bureau's sole task would be to determine the economic value of investment projects. A Bureau of Economic Value Analysis would require engineers, economists, accountants, and financial analysts to gather data, conduct the analysis, and present the results. The work of the bureau would necessarily require close examination by elected officials and the public, and the bureau should be held accountable for the accuracy of its results. Of course, even professional staff will make mistakes; sound investment decisions embody art as well as science and we cannot expect perfection. But a professional staff of dedicated and trained analysts could go a long way toward improving the allocation of scarce investment funds; on net, they would recommend investing Virginia's scarce transportation funds into those projects that produce the most value for its citizens.

A State that successfully instituted economic value analysis into its decisions would not only use its own resources more efficiently, thus spurring economic growth, it would also serve as a model to other States and to local jurisdictions. A State that became known for investing its highway funds with efficiency would produce a third kind of benefit for a State government—it would build trust with its voters. Taxpayers would be more willing to part with their hard earned income if they knew that officials were using it to serve the most urgent needs of its citizens rather than using it for political advantage.

Summary and Conclusions

Wise investment leads to economic growth. Capital resources in every society, no matter how wealthy, are scarce and have alternative uses. Investing those scarce resources where they will create the most value enables a community to prosper. Putting resources into less valuable projects contributes to waste and diminishes growth and prosperity. A society can depend on business firms to invest wisely; the price system gives entrepreneurs the means and the incentive to use resources where they will produce the most value. It is more difficult for government agencies to invest wisely; bureaus usually do not generate revenue from their investments, so they do not have the price system to guide them. Fortunately, this disadvantage can be overcome by using economic value estimates in place of actual prices. Value estimates can be calculated by finding the market prices of similar services and adjusting them to new circumstances. We did this for two construction projects proposed by the Virginia Department of Transportation. Using California's 91ExpressLanes as a reference value, we were able to calculate value estimates for I-81 in Roanoke and I-66 in Fairfax. Using these estimates, we were able discover how much revenue could be generated from each investment. $7 million in gross revenues could be generated yearly from the I-581 project; $38 million in gross revenues could be generated yearly from the I-66 project. Since the costs of these two projects are about equal, investing in I-66 generates considerably more value that investing in I-581. By creating a Bureau of Economic Value Estimation and giving it the power to prioritize road investments, the Virginia legislature could institutionalize the efficient investment of its scarce capital resources in roads, thus furthering growth at home and serving as a model for other States.

Appendix A

One way to approach the differentiation value of income on road travel is to calculate the income elasticity of demand for vehicle trips. Income elasticity of demand measures the effect that a rise in income will have on quantity demanded, holding prices constant. When income elasticity of demand is greater than zero, an increase in income increases expenditures on a good; when it is less than zero, it decreases expenditures. In our study, where quantity supplied is fixed for our reference value, a change in quantity demanded will change the price at which traffic flows smoothly, with increases in income requiring increases in tolls, and vice-versa. I have been unable to find data on income elasticity of demand for the use of roads. However, income elasticity of demand for the U.S. as a whole is estimated at .42.[28] Using this figure as a proxy for income elasticity of demand for road use, we can calculate the change in quantity demanded for Fairfax and Roanoke vis a vis Orange County. The formula is **N** = %ΔQd ÷%ΔI, where **N** is income elasticity of demand, %ΔQd is the percentage change in road use and %ΔI is the percentage change in income. Using the income figures from Fairfax and vehicle trip figures from I-66, we get ΔQd = (.42*$4038*180,000) ÷ $44,453, or 6,867 vehicle trips. In other words, Fairfax drivers would be willing to undertake an additional 6,867 vehicle trips if prices remained constant and their income increased by $4,000 per year. Or, to put it in percentage terms, a 9% increase in income between in Fairfax County will increase the number of vehicle trips on I-66 by 4% if prices are not raised. This implies that the value of each vehicle trip has risen. Income elasticity does not tell us by how

[28] For estimates of income elasticity, see Edwin Mansfield, *Managerial Economics* (New York: Norton Publishing Co., 1999), pp. 98-101. Income figures are for 2005 and come from the Bureau of Economic Analysis. See http://www.bea.gov/regional/bearfacts/. Accessed April 3, 2008.

much it has risen, but a 3% increase in value is a conservative estimate for a 9% increase in income. This is a conservative estimate because it is likely that price elasticity for commuting is inelastic. Our assumptions imply that price elasticity of demand is 4%÷3%, i.e., that a 4% fall in demand will cause toll charges to drop 3%. If demand were inelastic, a 4% drop in quantity demanded would cause a drop in price of more than 4%. We can cast this in a slightly different form by translating it into what it would mean for tolls in Orange County. We are saying that a 9% increase in income in Orange County would result in a 3% increase in fares in order to keep traffic flowing at speed. The $1.90 fare would increase to $1.95 if income increased from $44,500 per person to $48,500 in Orange County. Of course this assumes that Fairfax County drivers and Orange County drivers would respond similarly to changes in prices and income.

For Roanoke County, the analysis is the same. Using the income elasticity formula, $\mathbf{N} = \%\Delta Qd \div \%\Delta I$, we derive the formula for the change in quantity demanded: $\Delta Qd = (.42 * \Delta I * Qd) \div I = (.42 * -\$11{,}941 * 74{,}000) \div \$44{,}453 = -8{,}349$ vehicle trips. In other words, Roanoke drivers would reduce their number of daily trips by 8,349 if their income fell from $44,500 to $32,500 and prices remained constant. In percentage terms, a 26% drop in income in Roanoke City will reduce road trips by 11% on I-581. We are assuming that the 26% drop in income and the 11% drop in road trips will cause the value of trips to diminish by 8% in Roanoke. Again we see that our assumptions mean that demand for toll roads is elastic. To again cast our analysis into equivalent terms for Orange County: If income diminished from $44,500 to $32,500 in Orange County, the $1.90 toll would decrease to $1.75. Such a dramatic drop in income would probably decrease tolls by considerably more, but we are being conservative so as not to exaggerate the differentiation values between Roanoke and Fairfax.

Appendix B

Capital budgeting is used by business firms to help them determine where to invest their capital. Comparisons can be made on the basis of net present value, or internal rates of return, or payback periods. Using the economic value estimates derived earlier in this study, I will calculate the net present values and the internal rates of return of the I-581 and the I-66 projects. In addition to the gross revenue figures that we have calculated, we need cost estimates. Road construction costs for 2002 are given in 2025 State Highway Plan: Technical Report as $1.05 million per mile for two lanes 24 feet wide. This cost includes a 20% fee for engineering and contingencies, so the construction costs are $840,000 per mile and the engineering and contingency costs are $210,000 per mile. Assuming that these costs increase at a 10% annual rate and that the roads will be built in 2010, the constructions costs will amount $1.8 million dollars per mile and the engineering and contingency costs will amount to $450,000 per mile. The additions to I-581 and I-66 require two lanes in each direction, so the cost figures will be double: $3.6 million per mile for construction and $900,000 per mile for engineering and contingency costs.

In addition to these costs, the Department of Transportation will have to pay for right-of-way and utility costs. According to the *Tri-County Parkway Location Study*, the right of way costs for 10.46 miles of roadway in Prince William and Loudon Counties, just west of Fairfax are estimated $66 million and utility relocation costs are estimated at $9.89 million. Dividing the total costs by 10.46 miles, the right of way costs are $6.32 million per mile for four lanes; the utility costs are $94,551 per mile. If we use figures proportional to distance for the 6.91 miles of I-66, the right-of-way costs will be $43.6

million and the utility relocation costs $4.4 million. For utility relocation, we can also use figures proportional to distance for the 6.75 miles of I-581, which amounts to $6.4 million. However, right of way costs will not be proportional to distance in Roanoke, because land values are roughly one-fifth of the land values in Fairfax. Dividing the proportional rights of way costs by five, the right of way costs in Roanoke are $8.5 million.[29] Using these cost figures, and revenue figures from the main study, we can now use capital budgeting to compare the two projects.

Capital Budget for I-581:
Net Present Value
(In millions of US$)

Item/Year	1	2	3	4	5	6	7	8	9	10
Costs										
Right of Way	$ (8.54)									
Engineering&Contingency	$ (6.08)									
Construction		$ (24.31)								
Utility relocation		$ (6.38)								
Maintenance&Operation			$ (1.67)	$ (1.72)	$ (1.77)	$ (1.83)	$ (1.88)	$ (1.94)	$ (2.00)	$ (2.06)
Revenues										
Vehicle traffic			$ 6.68	$ 6.89	$ 7.09	$ 7.30	$ 7.52	$ 7.75	$ 7.98	$ 8.22
Net Revenues	$ (14.61)	$ (30.69)	$ 5.01	$ 5.16	$ 5.32	$ 5.48	$ 5.64	$ 5.81	$ 5.99	$ 6.17
Discounted Values @10%	$ (14.61)	$ (27.90)	$ 4.14	$ 3.88	$ 3.63	$ 3.40	$ 3.19	$ 2.98	$ 2.79	$ 2.62
Net Present Value	$ (15.88)									

The first column shows the cost and revenue items. Net revenues are revenues minus costs, and these are shown for a ten year period. The calculations have been cut

[29] For construction and engineering costs estimates, see 2025 State Highway Plan: Technical Report, p. 26. For acquisition and utility relocation costs in Fairfax, Prince William, and Loudon counties, see Tri-County Parkway Location Study: Capital Cost Estimate and Methodolgy Technical Report (Prepared for the Virginia Department of Transportation by Parsons, Brinckerhoff, Quade, and Douglas, Inc., March 2005), Table 3-2, p. 3-4. Although the Study was prepared in 2005, the costs were estimated for 2010. Even so, the report says that "It is important to note that the estimates contained in this report are order of magnitude in nature and are the products of the defined alternatives and conceptual design plans. Modifications to these cost estimates will be made in the future, as necessary, to reflect the increasing level of available information." P. S-3. I have attempted to be accurate in the cost estimates for the capital budgeting exercise, but these costs should be considered illustrative only. It will take a professional staff that is rewarded for correct estimates and punished for incorrect ones to infuse reliability into cost estimates.

off at ten years, although it would be a simple matter to continue them. The net revenues are negative for the first two years. In the first year, the State is incurring the costs of acquiring right of way and designing the roadways; in the second year, the State is incurring the costs of constructing the roads and relocating the utilities. Beginning in the third year, the I-581 projects starts delivering value to the road users. If a toll of $.74 were charged and the new traffic induced 9 million new users, the value of the additional lanes would equal $6.7 million in year three. I have assumed that usage would increase by 3% each year, so that the value would increase to $6.89 million in the fourth year, $7.09 million in the fifth year, etc. From the value delivered are subtracted the operating and maintenance costs. These costs begin at 25% of revenues, or $1.67 million, in the first year and increase at the rate of 1% per year for each year thereafter. The estimates for operating and maintenance expenses may be too high; the State of Virginia, for example, allocated only $7,201 per lane mile to the county of Arlington for maintenance and construction of its secondary roads in 2006.[30] I have estimated the maintenance and operation figures by taking the payments to suppliers figure from the 91ExpressLanes Annual Report for 2006. These payments were 30% of total revenues. The maintenance costs should be lower for new lanes than for lanes that have been in operation for 12 years, so I used a 25% figure for the first year of the I-581 lanes, and raised the costs 1% each year thereafter. These cost figures can easily be lowered if Department experts determine that they are too high. The discounted value row shows the net revenues discounted at a rate of 10% per year. Again, the discount may be high, given the low risks involved in road projects; if so, the discount rate is easily changed. Finally, the

[30] See "Local Assistance Division: Arlington and Henrico County SecondaryConstruction and Maintenance Payments" at http://www.virginiadot.org/business/local-assistance-special-federal-programs-Arl&Henrico.asp. The figures are for 2006. Accessed April 30, 2008.

discounted values are summed to obtain the net present value. For I-581, the net present value is a negative $15.9 million. The value to users is not enough to offset the costs of the I-581 project. Of course, this calculation would change if we carried the revenues out further, or if we lowered the estimates of maintenance and operation costs, or if we used a lower discount rate. We should not place too much emphasis on the present value being negative; the number mainly serves as a point of comparison with the same calculations for another project, I-66.

Capital Budget for I-66:
Net Present Value
(In millions of US$)

Item/Year	1	2	3	4	5	6	7	8	9	10
Costs (in millions)										
Right of Way	$(43.63)									
Engineering&Contingency	$ (6.21)									
Construction		$(24.85)								
Utility relocation		$ (6.52)								
Maintenance&Operation			$ (9.73)	$(10.03)	$(10.33)	$(10.64)	$(10.96)	$(11.29)	$(11.62)	$(11.97)
Revenues (in millions)										
Vehicle traffic, non-peak			$ 8.59	$ 8.84	$ 9.11	$ 9.38	$ 9.66	$ 9.95	$ 10.25	$ 10.56
Vehicle traffic, peak			$30.35	$ 31.26	$ 32.20	$ 33.17	$ 34.16	$ 35.19	$ 36.24	$ 37.33
Vehicle traffic, combined			$38.94	$ 40.11	$ 41.31	$ 42.55	$ 43.83	$ 45.14	$ 46.50	$ 47.89
Net Revenues	$(49.84)	$(31.37)	$29.20	$ 30.08	$ 30.98	$ 31.91	$ 32.87	$ 33.86	$ 34.87	$ 35.92
Discounted Values @10%	$(49.84)	$(28.52)	$24.14	$ 22.60	$ 21.16	$ 19.82	$ 18.55	$ 17.37	$ 16.27	$ 15.23
Net Present Value	$ 76.78									

The capital budgeting model for I-66 used the same assumptions as the model for I-581. Right of way expenses are five times higher than I-581, reflecting the higher land costs in Fairfax as compared to Roanoke. Maintenance and operating expenses are also higher than I-581, because revenues are higher. Like the I-581 project, maintenance and operating expenses begin at 25% of hypothetical revenues and increase by 1% per year thereafter. The discount rate is 10% and the revenue and cost streams extend to ten years.

The table for I-66 shows both peak and off-peak values and the combined values. Despite the substantially higher costs for I-66, the net present value is $77 million, as compared to a negative $15 million for I-581. Clearly, the net present value of investing in I-66 is much higher than that of investing in I-581. Based on economic efficiency, which means investing in projects that produce the most value, investment in the I-66 project ranks above the I-581 project.

Capital budgeting is also used to calculate the rate of return that will equate the expenses and revenues. This is called the internal rate of return of the project. The higher it is, the more attractive is the investment. Business firms often set a threshold rate of 15% or so. Projects whose internal rate of return is above the threshold receive investment funds; projects whose internal rate of return fall below the threshold are denied funding. The State of Virginia could adopt a threshold for its own investments in roads and other forms of transportation.

Capital Budget for I-581:
Internal Rate of Return

Item/Year	1	2	3	4	5	6	7	8	9	10
Costs										
Right of Way	$ (8.54)									
Engineering&Contingency	$ (6.08)									
Construction		$ (24.31)								
Utility relocation		$ (6.38)								
Maintenance&Operation			$ (1.67)	$ (1.72)	$ (1.77)	$ (1.83)	$ (1.88)	$ (1.94)	$ (2.00)	$ (2.06)
Revenues										
Vehicle traffic			$ 6.68	$ 6.89	$ 7.09	$ 7.30	$ 7.52	$ 7.75	$ 7.98	$ 8.22
Net Revenues	$ (14.61)	$ (30.69)	$ 5.01	$ 5.16	$ 5.32	$ 5.48	$ 5.64	$ 5.81	$ 5.99	$ 6.17
Internal Rate of Return	-0.321%									

In the table above, the cost, revenue, and net revenue figures are identical to the table in which we calculated the net present value. Using the figures in row labeled "Net Revenues," we calculate the internal rate of return. This can be done using the IRR function in Excel and entering the figures for the Net Revenues row. The internal rate of return for I-581 is slightly negative. This is not a project that would be chosen for investment by a firm that was trying to invest its resources efficiently. Even if revenue figures were extended for another 10 years, or costs were somewhat lower, the internal rate of return would not meet a 15% threshold.

Capital Budget I-66:
Internal Rate of Return

Item/Year	1	2	3	4	5	6	7	8	9	10
Costs (in millions)										
Right of Way	$(43.63)									
Engineering&Contingency	$ (6.21)									
Construction		$(24.85)								
Utility relocation		$ (6.52)								
Maintenance&Operation			$ (9.73)	$(10.03)	$(10.33)	$(10.64)	$(10.96)	$(11.29)	$(11.62)	$(11.97)
Revenues (in millions)										
Vehicle traffic, non-peak			$ 8.59	$ 8.84	$ 9.11	$ 9.38	$ 9.66	$ 9.95	$ 10.25	$ 10.56
Vehicle traffic, peak			$30.35	$ 31.26	$ 32.20	$ 33.17	$ 34.16	$ 35.19	$ 36.24	$ 37.33
Vehicle traffic, combined			$38.94	$ 40.11	$ 41.31	$ 42.55	$ 43.83	$ 45.14	$ 46.50	$ 47.89
Net Revenues	$(49.84)	$(31.37)	$29.20	$ 30.08	$ 30.98	$ 31.91	$ 32.87	$ 33.86	$ 34.87	$ 35.92
Internal Rate of Return	28%									

The table above shows the same information for the I-66 project. The cost and revenue figures are identical to the I-66 table that calculated net present value. However, instead of discounting net revenues at a specified rate, we calculate the rate that will equalize the present value of expenditures and net revenues. This is a simple calculation in Excel, and it shows an internal rate of return of 28%. A firm that was committed to investing its funds efficiently would invest in the I-66 project, which easily clears a 15% threshold.

Because the capital budgeting model includes revenues and costs, it can be used to calculate projects of different lengths. To illustrate this, we will analyze another project that has been recommended by the Virginia Department of Transportation—widening a 5.36 mile stretch of I-64 between Fort Eustis Boulevard and Jefferson Avenue near Newport News. Since this project is 20% shorter than the Roanoke or Fairfax projects, we cannot ignore costs. The Department recommends that the existing four lane highway be expanded to eight lanes, two for general use and two for automobiles with two or more persons traveling together. Using the same techniques explained earlier, we estimate the economic value of the new lanes to be $2.33 per trip for periods of peak use and $.60 for non-peak periods. These value estimates were obtained by using the reference values from the 91 Express Lanes and adjusting for the shorter length of I-64 compared to the Express Lanes and for the lower income of the Virginia Beach, Norfolk, Newport News region. Using the induced traffic formula, we calculate that the new lanes will increase traffic volume by about 12.29 million trips annually. 6.76 million of these trips will occur during peak hours, 5.53 million trips will occur during off-peak hours. Multiplying the volume of the new lanes by the economic value, we estimate that new lanes would generate $19 million annually, $15.3 million during peak hours and $3.7 million during off-peak hours.[31] Using these revenue figures and the costs figures used for I-66 and I-581, we arrive at the following capital budget for the I-64 recommendation.

Capital Budget for I-64:
Net Present Value
(In millions of US$)

Item/Year	1	2	3	4	5	6	7	8	9	10
Costs										
Right of Way	$ (16.95)									
Engineering&Contingency	$ (4.83)									
Construction		$ (19.30)								
Utility relocation		$ (5.07)								
Maintenance&Operation			$ (4.77)	$ (4.91)	$ (5.06)	$ (5.21)	$ (5.37)	$ (5.53)	$ (5.70)	$ (5.87)
Revenues										
Vehicle traffic, non-peak			$ 3.36	$ 3.46	$ 3.56	$ 3.67	$ 3.78	$ 3.89	$ 4.01	$ 4.13
Vehicle traffic, peak			$ 15.73	$ 16.20	$ 16.69	$ 17.19	$ 17.70	$ 18.23	$ 18.78	$ 19.34
Vehicle traffic, combined			$ 19.09	$ 19.66	$ 20.25	$ 20.85	$ 21.48	$ 22.12	$ 22.79	$ 23.47
Net Revenues	$ (21.77)	$ (24.37)	$ 14.31	$ 14.74	$ 15.19	$ 15.64	$ 16.11	$ 16.59	$ 17.09	$ 17.60
Discounted Values @10%	$ (21.77)	$ (22.16)	$ 11.83	$ 11.08	$ 10.37	$ 9.71	$ 9.09	$ 8.52	$ 7.97	$ 7.47
Net Present Value	$ 32.11									

The I-64 project has a net present value, at a 10% rate of discount, of $32.1 million dollars. This assumes that the acquisition costs for right-of-way are in Norfolk are one-half the acquisition costs in Northern Virginia. All other costs are calculated at the same rate as the Roanoke and Fairfax projects. Total construction costs are lower than in Roanoke and Fairfax because the highway is shorter. Maintenance costs in Norfolk are higher than in Roanoke because usage is heavier. Maintenance costs in Norfolk are lower than in Fairfax, because usage is lighter.

Projects whose costs differ substantially from one another should be compared using their internal rates of return rather than their net present values. This is because larger, more expensive projects have the potential to attain a higher net present values than smaller, cheaper projects. Internal rates of return compare projects on the basis of each dollar invested. The internal rate of return for I-64 is given in the table below.

Capital Budget for I-64:
Internal Rate of Return

[31] The recommendation is contained in *Prioritizing the State Highway Plan: Brochure* (Virginia Department of Transportation, n.d.), p. 3. As of March 19, 2008, the document can be accessed at http://www.virginiadot.org/projects/pr-statehighwayplan.asp The Bureau of Economic Analysis of the Department of Commerce reported that that per capital personal income in the Virginia Beach-Norfolk-Newport Metropolitan Statistical Area was $34,858 in 2006. See http://www.bea.gov/regional/bearfacts/lapipdf.cfm?yearin=2006&fips=47260&areatype=MSA

Item/Year	1	2	3	4	5	6	7	8	9	10
Costs										
Right of Way	$ (16.95)									
Engineering&Contingency	$ (4.83)									
Construction		$ (19.30)								
Utility relocation		$ (5.07)								
Maintenance&Operation			$ (4.77)	$ (4.91)	$ (5.06)	$ (5.21)	$ (5.37)	$ (5.53)	$ (5.70)	$ (5.87)
Revenues										
Vehicle traffic, non-peak			$ 3.36	$ 3.46	$ 3.56	$ 3.67	$ 3.78	$ 3.89	$ 4.01	$ 4.13
Vehicle traffic, peak			$ 15.73	$ 16.20	$ 16.69	$ 17.19	$ 17.70	$ 18.23	$ 18.78	$ 19.34
Vehicle traffic, combined			$ 19.09	$ 19.66	$ 20.25	$ 20.85	$ 21.48	$ 22.12	$ 22.79	$ 23.47
Net Revenues	$ (21.77)	$ (24.37)	$ 14.31	$ 14.74	$ 15.19	$ 15.64	$ 16.11	$ 16.59	$ 17.09	$ 17.60
Discounted Values @10%	$ (21.77)	$ (22.16)	$ 11.83	$ 11.08	$ 10.37	$ 9.71	$ 9.09	$ 8.52	$ 7.97	$ 7.47
Internal Rate of Return	13.4%									

Widening I-64 between Fort Eustis Boulevard and Jefferson Avenue has an internal rate of return of 13%. This internal rate of return on this project is much higher than the slightly negative rate of return for I-581. It is about half of the rate of return for I-66. The threshold rate of return for Virginia will be set by the funds available for new construction. Because of the low risk associated with interstate highway investment, a 13% rate of return would very likely be sufficient to justify the project if the decision were being made by a private, profit seeking organization.