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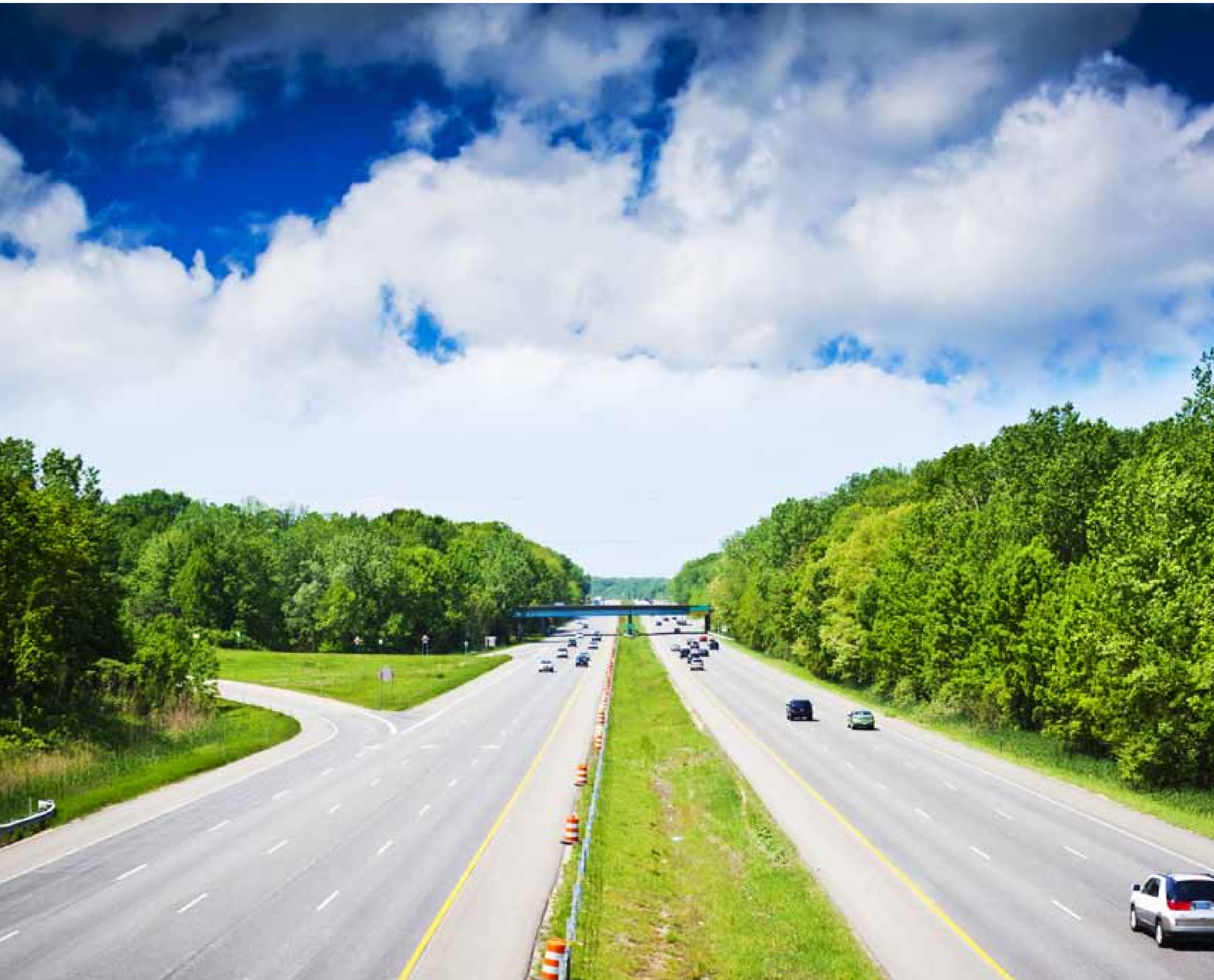

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By Robert W. Poole, Jr.

Executive Summary

The Interstate highway system is America's most important surface transportation system. With just 2.5% of the nation's lane-miles of highway, it handles some 25% of all vehicle miles of travel. It served to open the country to trade and travel, enabling the just-in-time logistics system at the heart of U.S. goods movement. Yet the first-generation Interstate system is wearing out. Most of the pavement has exceeded or is nearing its 50-year design life, meaning that nearly the entire system will need reconstruction over the next two decades. In addition, more than a hundred interchanges are major bottlenecks, needing redesign and reconstruction, and about 200 corridors need additional lanes to cope with current and projected traffic.

The need for massive investment to transform the first-generation Interstate into what this report calls Interstate 2.0 occurs just as our 20th-century highway funding system—based on fuel taxes and state and federal highway trust funds—is running out of gas. Steady increases in vehicle fuel economy, the lack of inflation indexing of fuel tax rates, and political gridlock over increasing fuel tax rates all make it very difficult even to maintain current pavement and bridge conditions and prevent congestion from getting even worse. The transportation community agrees that we need to phase out fuel taxes and replace them with a more sustainable funding source, generally agreed to be mileage-based user fees of some sort. But no consensus exists on how and when to do this.

This study seeks to address both problems: replacing the aging Interstate system with a 21st-century Interstate 2.0 and taking the first major step toward implementing mileage-based user fees. It proposes that the United States finance the Interstate 2.0 project based on per-mile tolls collected using all-electronic tolling (AET). Over several decades, the transformation of the Interstate system, state by state, would convert at least one-fourth of all travel from per-gallon fuel taxes to per-mile charging.

The study makes quantitative estimates for each state of the cost of reconstructing the existing Interstates, identifies specific corridors in each state that need widening, and estimates the cost of doing so. Reconstruction is estimated at $589 billion in 2010 dollars and lane additions at $394

billion, for a total 2010 cost of $983 billion. To get a handle on the feasibility of toll financing, the study models a tolling system based on 3.5¢/ mile for cars and 14¢/mile for trucks, indexed annually for inflation. Using state-by-state estimates of annual growth in travel by cars and by trucks, over a 35-year period, it calculates the net present value (NPV) of toll revenue and compares that with the net present value of construction and reconstruction costs. Overall, the NPV of revenue equals 99% of the NPV of cost, indicating that the overall system is likely to be toll-financeable.

Since the calculations were done state by state, using the latest cost data from the Federal Highway Administration and state-specific forecasts of vehicle miles of travel based on a recent FHWA forecasting model, the study provides toll-feasibility estimates for each of the states. While not all states could fully toll-finance their Interstate modernization based on the low toll rates used for the national analysis, all but five or six rural states could do this with somewhat higher toll rates than the baseline ones used in this study—rates comparable to those on recently financed toll roads.

The cost estimates include fitting the entire Interstate highway system, both rural and urban, with state-of-the-art all-electronic tolling (AET) equipment. Fully interoperable tolling already exists statewide in California, Florida and Texas, as well as the 15 E-ZPass states in the Northeast and Midwest. With AET there would be no toll booths or toll plazas, and by 2016 nationwide electronic tolling interoperability is expected to be in place. That will mean a motorist needs only one account and one transponder to travel throughout the United States.

To make the transition attractive to highway users, the study proposes it be implemented on the principle of "value-added tolling." That means tolls would only be introduced in a corridor once it was reconstructed and modernized, designed to operate at a higher "level of service" than today's design standards call for (technically, LOS C on rural Interstates and LOS D on urban Interstates). If a state has not yet replaced its per-gallon fuel taxes with a standard mileage-based user fee at the time Interstate tolls are introduced, the AET system will permit rebates of fuel taxes generated by the miles driven on the tolled Interstates, thereby avoiding "double taxation."

The study also explains why per-mile tolling is a better highway user fee than per-gallon taxes. The reasons include:

- Per-mile tolls can be tailored to the cost of each road and bridge, rather than being averaged across all types of roads, from neighborhood streets to massive Interstates; this ensures adequate funding for major highway projects like Interstate reconstruction and modernization.
- Per-mile tolling reflects greater fairness, since those who drive mostly on Interstates will pay higher rates than those who drive mostly on local streets.
- If per-mile tolling is implemented as a true user fee, it will be self-limiting, dedicated solely to the purpose for which it was implemented (and enforceable via bond covenants with those who buy toll revenue bonds).

- Per-mile tolling will guarantee proper ongoing maintenance of the tolled corridors, since bond-buyers and other investors legally require this as a condition of providing the funds.
- Per-mile tolling also provides a ready source of funding for future improvements to the tolled corridor.
- Toll financing means needed projects, such as reconstruction and widening, can be done when they are needed, and paid for over several decades as highway users enjoy the benefits of the improved facilities.
- Finally, a per-mile tolling system using AET can easily implement variable pricing on urban expressways to reduce and manage traffic congestion.

Converting from the 20^{th}-century Interstate 1.0 to a toll-financed Interstate 2.0 would be a major change, which elected officials may be leery of leading. That's why it is critically important that one pioneering state step forward to be a role model for the others. Currently, federal law prohibits tolling for reconstruction of Interstates—except for a three-state pilot program. However, all three slots are now occupied by states that have not solved the political problem of getting legislative approval to go forward. And the pilot program permits only a single facility in each (e.g., I-95 in North Carolina) to be rebuilt using tolls. This situation could be changed by Congress in the 2014 reauthorization of the federal surface transportation program. The one needed step is to "mainstream" the tolled-reconstruction pilot program, so that it is (1) available to all states, and (2) applicable to all of a state's Interstate facilities.

America needs a second-generation Interstate highway system. The 20^{th}-century fuel tax system is inadequate for this trillion-dollar task. This study shows that the alternative of financing this transformation via all-electronic tolling is feasible. The one needed enabler is permission from Congress to begin this transition.

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Part 1

Rationale and Overview

The Interstate highway system, begun as a federal-state partnership in 1956 and largely completed by the mid-1970s, is America's most valuable set of highways. With just 2.52% of total lane-miles,[1] the urban and rural Interstates account for 24.4% of all vehicle miles of travel (VMT).[2] But this system is not really prepared for the 21st century.

Its major corridors were mostly opened during the 1960s and 1970s. With a typical design life of 50 years, most will need reconstruction between 2010 and 2030. While some have been widened to accommodate traffic growth, many more will likely need widening when they are rebuilt for another 50-year period. In the most truck-heavy corridors, widening might take the form of truck-only lanes, while in the most-congested urban areas, a growing number of long-range transportation plans include networks of variably priced express lanes. Over 100 major interchanges constitute serious bottlenecks, mostly on urban Interstates.[3]

Moreover, there are routes that make sense today which were not contemplated when the original map was drawn up in the 1940s, given the patterns of settlement and commerce back then. And some current routes may no longer generate enough traffic volume to justify continued status as Interstates. Hence, a complete Interstate 2.0 would include new routes reflecting current economic and geographic realities, as well as reasonable projections of future development.

This policy study has a less ambitious agenda. It first develops a defensible cost estimate for reconstructing the existing Interstate system, both rural and urban, using construction cost figures from the Federal Highway Administration (FHWA). Next, it estimates traffic and potential toll revenue on the reconstructed Interstate systems of each state over a 35-year period. The net present value of toll revenues in 2010 is then compared with the 2010 reconstruction cost estimates as an initial indication of toll-finance feasibility.

Because some of the projected traffic volumes are well beyond the capacity of the existing lanes, the analysis next identifies specific Interstate corridors that will need widening. It also estimates the cost and time frame for these lane additions, using appropriate FHWA lane-addition cost factors. The widening analysis also uses data from FHWA's Freight Analysis Framework to identify corridors where truck volume may be high enough to implement truck-only lanes as part of the widening, and cost estimates for these additions are included.

Finally, this study compares the net present value of the reconstructed and widened system with the previously estimated net present value of toll revenue as an indication of the toll-feasibility of financing the project via per-mile tolls.

Part 2

Summary of Previous Research

A. Interstate Modernization

Given the large and vital role played by the Interstate system, it is surprising that its long-term existence is taken for granted. Politicians and reporters have endlessly repeated that the system was "finished" about 20 years ago, and the idea that highways and bridges eventually wear out and need to be replaced (even if well-maintained) seems to be understood only by highway engineers.

In the early 2000s, the National Cooperative Highway Research Program (NCHRP)—a joint effort of the membership organization for state DOTs (AASHTO) and the Transportation Research Board—launched a study of future options for the Interstate system. Task 10 of this project produced the first serious study that defined the need to modernize the system to meet the needs of 21st century America.[4] The need for a new vision sprang from recognizing not only that the network layout itself was 70 years old and the pavement beginning to exceed its 50-year design life, but also on new factors like global economic integration, metropolitan congestion and post-industrial geography.

The study foresaw a slowdown in the growth rate of vehicle miles of travel (VMT) and the likely topping out of VMT per capita, and therefore used a 2% annual growth rate for the first 20 years of its 30-year projection and 1.5% thereafter. Based on those VMT assumptions, it projected a revamped Interstate system widened by 88,600 lane-miles on the existing 46,800 route-miles plus an additional 84,000 lane-miles on 15,000 route-miles to be added to the system, mostly by upgrading existing National Highway System corridors. The widening was estimated to cost $1.4 trillion (in 2003 dollars) and the new routes another $1.74 trillion—a total of $3.14 trillion over 30 years.

Reconstruction of worn-out pavement and bridges was not explicitly dealt with in that project. As a result, a Task 14 was added to assess the extent to which reconstruction needs were or were not already being addressed via the investment needs identified every two years by FHWA in its biennial Conditions & Performance reports. The researchers concluded that such needs "appear to have been underrepresented in prior work" and "should be the subject of a follow-on effort to develop appropriate estimating methodologies."[5]

Prior to the passage of the surface transportation reauthorization bill designated as MAP-21, AASHTO produced a series of three reports in 2010, based on the Interstate vision from the 2007 NCHRP report. The series was called *Transportation Reboot: The Case for Capacity—To Unlock Gridlock, Generate Jobs, Deliver Freight, and Connect Communities*.[6] Its numbers came largely from the NCHRP report, but its planning horizon was extended to 50 years from the previous report's 30 years. Both the NCHRP and the AASHTO reports used a benefit/cost ratio screen of 1.0 in estimating which lane additions and new corridors should be included. Neither report identified a funding plan for the $3 trillion upgrade, though both mentioned that tolls and congestion pricing could help generate funding.

Several other experts have taken a look at the need for Interstate modernization and the possible use of tolls to pay for it. In 2011 the former vice chairman of the National Surface Transportation Policy & Revenue Study Commission co-authored a paper calling for a national inflation-adjusted toll on all Interstate system users to pay for restoration, expansion and modernization of the system.[7] The electronically collected toll revenues would be deposited in a new account in the Highway Trust Fund and would provide grants solely for the Interstate program. The modernization would be carried out on a cash basis, rather than using toll revenue bonds as is the normal practice for toll facilities. The study was not quantitative: there were no estimates of the investments needed or the toll rates contemplated.

Tolling experts Ed Regan and Steven Brown published an article that same year on the case for tolling as a way to pay for Interstate reconstruction and modernization. Their top-down estimate of the cost to reconstruction and modernization was between $1.3 and $2.5 trillion.[8] In 2012 an official of a global toll concession company suggested that about 10,000 route-miles of rural, inter-city Interstates with heavy truck traffic could be rebuilt and modernized via toll financing, based on an average toll (car + truck) rate of 15 cents per mile, yielding an estimated $22 billion per year in revenues.[9]

B. Highway Funding Problems

Although detailed cost estimates for Interstate reconstruction and modernization have been lacking, the likely trillion-dollar scale of such an undertaking contrasts sharply with the decreasing viability of the fuel tax system. For a variety of reasons, including political difficulties in increasing fuel tax rates and a sharp upward trend in vehicle fuel efficiency (i.e., going farther on a gallon of fuel, which means less fuel tax revenue per mile driven), there is a growing consensus that the 20th century system of paying for highways via fuel taxes is not sustainable long-term.

The first detailed assessment of this problem was carried out by a TRB special committee in 2005.[10] It concluded that fuel used per vehicle mile of travel (VMT) would likely decrease 20% by 2025 under then-current Corporate Average Fuel Economy (CAFE) standards, and that total fuel tax revenues could well decline due to this during that time period. It recommended retaining the users-pay principle as the basis for highway funding, and that in the near term states should strengthen the fuel-tax systems, as well as enabling alternative-fuel vehicles to pay their fair share of highway system costs. To begin the transition to a replacement system, it urged the federal government to encourage road-use charging and expanded use of tolling. Longer term, the country should transition to a users-pay system based on charging per mile driven.

Several years later Congress appointed the National Surface Transportation Infrastructure Financing Commission to explore options and recommend the best path forward for funding surface transportation, building on the TRB Committee's work. The Commission documented a serious long-term highway investment shortfall under status quo funding, and evaluated numerous alternatives. It concluded that the United States needs to begin transitioning from a user-fee system based on gallons of fuel consumed to one based on miles driven.[11]

Part 3

Why Consider Toll Financing?

This study carries out a detailed analysis of whether tolling is a feasible method of raising the revenues needed to rebuild and modernize the Interstate highway system. Because tolling is considered controversial, this section seeks to explain the case for 21st-century tolling, not merely as a feasible method of financing the second-generation Interstate system, but as a highly desirable approach compared with other alternatives.

A. Tolling Has a Long and Positive U.S. History

Tolling was the original highway user fee, dating back to the pre-auto era in Britain and the United States. In those days, most inter-city highways were developed as turnpikes, generally by companies incorporated specifically for the purpose of building, operating and maintaining the toll road. Researchers Daniel Klein and John Majewski found that 2,500 to 3,000 toll road companies financed, built and operated such toll roads in 19th-century America, with a total length of between 30,000 and 52,000 miles.[12]

When the Good Roads Movement early in the 20th century began to lobby for paved highways to serve the emerging population of motor vehicles, advocates came up with a different form of user fee—a per-gallon tax on motor fuel. By the time Oregon enacted the first such tax in 1919, the internal combustion engine had become the overwhelming mode of propulsion for motor vehicles, displacing early electric and steam-powered cars. Hence, nearly everyone who drove used gasoline, and since fuel economy was not very different among different vehicles, early per-gallon fuel taxes were pretty much equivalent to a per-mile charge for using the highway. By 1930, all 48 states had enacted motor fuel taxes to build, operate and maintain their highway systems.

When the idea for super-highways (multi-lane, divided highways with limited access and higher speeds) came along in the 1930s, their much higher cost led early adopters such as Pennsylvania to revive the tolling concept, producing the Pennsylvania Turnpike prior to World War II. The Turnpike, thanks to tunnels through mountains and numerous bridges, provided a vastly superior east-west corridor and was hailed as "America's Superhighway" when it opened in 1940. Within a year, the Maine Turnpike was authorized, and a dozen other states began planning similar turnpikes. Soon after the war's end, superhighways such as the Connecticut Turnpike, Florida

Turnpike, Indiana Toll Road, Massachusetts Turnpike, New York Thruway, Ohio Turnpike and a number of others were financed, built and put into operation.

Early plans for the Interstate system also assumed toll finance, but officials of the Bureau of Public Roads (predecessor of the Federal Highway Administration) were skeptical and produced forecasts of low traffic and revenue. There was also congressional opposition. Members from southern, mountain and western states objected on the grounds that traffic in those less-developed parts of the country would not be sufficient to finance their portions of the national super highway system.[13] After several years of debate, such considerations led to enactment in 1956 of a system to be funded by a new federal tax on gasoline and diesel fuel, dedicated to the new Interstate system and safeguarded in a federal Highway Trust Fund. A basic premise of this system was that funding would be redistributed from states producing higher amounts of federal fuel tax revenues to those producing lower amounts. Hence, from the outset, there were "donor" states and "donee" states, a distinction that remains a source of controversy to this day.

The various state turnpikes that already existed or were under construction using toll finance were, in nearly all cases, included as part of the Interstate system and were allowed to retain tolling (which they needed, at the very least, to service the toll revenue bonds they had issued to finance the initial construction). But in all the other states, the new Interstates were built on a cash basis, with federal grants from the new Highway Trust Fund paying 90% of the construction costs and states providing 10% match. Over the years, Congress periodically increased the gasoline and diesel tax rates while also expanding the uses to which federal highway funds could be put: initially to non-Interstate highways, then to facilities for buses, and by 1982 to urban transit, with the creation of a transit account in the Highway Trust Fund. Subsequent reauthorizations of the program expanded the uses still further to include bikeways, sidewalks, recreational trails and other non-highway purposes. Thus, what had begun as a federal user fee to build and maintain the Interstate system evolved into a general-purpose transportation tax.[14]

Nevertheless, states have continued to expand the use of tolling during the Interstate era. Today toll bridges, tunnels, highways and express lanes exist in 35 states, not only traditional tolled bridges, tunnels and long-distance turnpikes but also key portions of urban expressway systems in California, Colorado, Florida, Georgia, Maryland, Texas and Virginia.

B. All-Electronic Tolling Is a Game-Changer

While toll booths and toll plazas had always created congested bottlenecks and led to rear-end collisions, these problems were even greater in the denser traffic of urban areas. But technology came to the rescue by the late 1980s with the introduction of small, windshield-mounted radio-frequency transponders that allowed tollway users to pay electronically, as the system at the toll plaza recognized the transponder number and debited the account of the owner. This new electronic toll collection (ETC) system spread rapidly to urban toll bridges and tunnels, and by the mid-2000s had been embraced by nearly all the long-distance toll roads of the Interstate system, as well. Early that decade, toll road systems began offering customers a way to bypass the toll booths in separate lanes, without having to slow down or queue up. This open road tolling (ORT) also spread rapidly since it further reduced toll plaza congestion and accidents, in addition to reducing toll collection costs. The International Bridge, Tunnel & Turnpike Association (IBTTA) estimates that some 31 million toll transponders were already in use by 2009.

By the beginning of the 21st century's second decade, toll operators began dispensing with toll booths and plazas altogether. The new paradigm became all-electronic tolling (AET), in which all tolls on the highway are paid either via transponder or by license-plate imaging. The latter had been introduced early in the ETC transition as a verification/enforcement mechanism, but it is now marketed by some operators to toll road users who either do not want a transponder or are from out of state. To better deal with out-of-state customers, toll road operators took steps toward interoperability (in which a customer with a toll account with one operator could use the facility of any other operator). The most extensive example is the E-ZPass system in the Northeast and Midwest, which as of 2013 encompasses 25 toll operators in 15 states. No matter which of the toll operators in E-ZPass territory provides the toll account for a customer, the customer can use the toll facilities in all member states but will pay only via his or her home-state toll account. Interoperable statewide systems exist within California, Florida and Texas.

The toll industry has created an Alliance for Toll Interoperability, which is working along with industry trade association IBTTA to extend the E-ZPass principle nationwide. IBTTA has been working through its membership to identify a transition path for both toll operator technology and business practices that would help to meet the congressional mandate for a nationally interoperable electronic tolling system by 2016. Thus, America is on the verge of having a nationwide system for all-electronic tolling (AET), suitable for use on any and all limited-access highways—such as the Interstate system.

C. 21st-Century Tolls Cost No More to Collect Than Fuel Taxes

Those who favor retaining fuel taxes typically maintain that while tolling may be a good user fee in principle, it is inefficient in that the cost of collecting and enforcing toll payments consumes 20 to 30% of the revenue, compared to using about 1% of the revenue to collect fuel taxes. That conventional wisdom was challenged by a team of researchers headed by Daryl Fleming in 2012.[15] Theirs was the first attempt to accurately quantify the current cost of collection in early AET systems and to spell out a simplified business model aimed at reducing collection/enforcement costs to a minimum. In addition, they reviewed recent research aimed at getting a more complete picture of the costs of collecting and enforcing the payment of fuel taxes.

Their most important finding was that instead of the 20-30% of revenue needed for 20th-century (largely) cash toll collection, early adopters of AET are already achieving collection costs close to 5% of the revenue collected, especially for urban toll systems where the revenue collected (the denominator in the measure of collection cost divided by revenue collected) tends to be larger.

They also spelled out the kinds of business methods that can reduce collection costs (such as minimizing billing in favor of maximizing the use of pre-paid accounts that can be debited).

Their second-most-important finding was that the cost of collecting motor fuel taxes is significantly higher than the 1% of conventional wisdom. Indirect costs, taxes hidden in the revenue collection, evasion and exemptions taken together make 5% (and in some cases up to 15%)—a more plausible number for the true cost of fuel tax collection in America today. Thus, the 20th-century argument that toll collection is grossly inefficient compared with fuel tax collection no longer holds true as AET with streamlined business models becomes the prevailing way of collecting per-mile charges.

D. Motorists Prefer Tolling to New Taxes

If you ask people in a public opinion poll if they want to pay tolls, they generally say no. They say the same thing if you ask them if they want to pay any kind of new tax. It's only when you give them a realistic situation and ask them to pick the best (or least bad) option that you learn something useful. When it comes to transportation funding, the most relevant question to ask is along the following lines:

> *A new [highway/bridge/set of express lanes] between A and B would save travelers X minutes getting from A to B. Its cost is $XXX million, but there are no funds in the transportation budget for such a project during the next 10 years, unless voters approve a new funding source. Which of the following would you prefer:*
>
> *a) Increase the gasoline tax*
>
> *b) Implement a transportation sales tax*
>
> *c) Increase the property tax*
>
> *d) Issue bonds to be paid off from future state income tax revenue*
>
> *e) Put tolls on the new facility.*

In numerous surveys of this type over a recent 10-year period, the most popular choice was nearly always tolling. And the explanation is pretty obvious. Under all four tax alternatives, the only thing the voter can be sure of, if the measure passes, is that she will pay higher taxes; she has no confidence that the road/bridge/lanes will actually be built. However, if she opts for tolling, then she knows that she will only pay tolls if three conditions hold true: that the facility actually gets built, that the route is one she would actually use, and that the toll is worth paying due to the time savings and/or other benefits to her.

The National Cooperative Highway Research Program commissioned a special study of what could be learned from 10 years of public opinion data concerning transportation funding, with an emphasis on surveys that included tolling or pricing.[16] One of its major conclusions was that "the public favors tolls if the alternative is taxes," as summarized by lead researcher Johanna Zmud.

Other, more-recent surveys, are consistent with this finding. Among the most recent was a statewide 2013 survey of public opinion in Wisconsin, a state with no toll roads where many motorists dislike having to pay tolls when they drive into nearby Illinois. Marquette University asked the "which-kind-of-additional funding for transportation" question. Only 28% favored increasing the state fuel tax and just 24% favored highway bonds backed by general tax revenue. But 53% supported tolls, with majority support in nearly every region of the state.[17]

E. The Value-Added Tolling Principle

The public opinion results noted above are encouraging to those favoring increased use of tolling as the replacement highway user fee. But making the transition is likely to be very difficult. While much of the public and a growing number of elected officials are comfortable with tolling to pay for new capacity (e.g., new express lanes on a congested freeway, a new bridge or a brand new tollway between two cities), they tend to view tolling to rebuild an existing but worn-out highway as "tolling existing capacity" or, as some campaigns have put it, "setting up toll booths on the Interstate"—with the implication that this would be forcing people to pay tolls for something that was already paid for with fuel taxes. And framing of the issue that way has been exacerbated by several attempts by state officials to do just that.

The most recent example occurred in Pennsylvania, where legislators sought to put tolls on I-80 (which is parallel to the tolled Pennsylvania Turnpike), with a significant fraction of the revenue used for statewide transportation funding, including mass transit in Philadelphia and Pittsburgh. Current federal law only permits tolling to be used on currently non-tolled Interstates for new lanes, except for a three-state pilot program that permits toll financing of reconstruction. Pennsylvania had to file for permission under that pilot program. It applied twice, and was turned down twice, since its proposal violated the clearly stated intent of Congress that toll revenues be used only for reconstruction.

Instead of trying to use tolling as a general statewide funding source, the more productive way forward would be to adopt the principle of "value-added tolling." That means asking highway users to pay tolls only in circumstances where those paying the new tolls would personally get significant added value. That is obviously the case if the tolls finance a new bridge, new lanes or a new toll road. But it would also be the case if a major highway or bridge has reached the end of its original design life, or is significantly undersized for the travel demand, and needs to be replaced with a state-of-the-art facility with a new, long design life. In the case of the SR 520 floating bridge in the Seattle area, the bridge has reached the end of its useful life and needs to be replaced. After several years of study and debate, elected officials approved tolling to pay the majority of costs for the replacement span—and in this case, they even approved the start of tolling to take place on the existing bridge during construction of its replacement (since doing so would reduce the amount of state funding for the bridge, leaving more state highway funds for other needed projects).

In general, however, value-added tolling would likely gain greater acceptance if toll collection began only after the replacement facility was completed and opened to traffic.

That value-added tolling approach is employed in this study, including all 50 states and the District of Columbia.

F. Why Tolling Is a Better User Fee than Fuel Taxes

One very important difference is that toll rates can be *tailored to the cost of each highway*. Under the fuel tax system, every driver pays an average rate based on gallons consumed, regardless of whether the driving takes place mostly on inexpensive local streets and/or two-lane country roads or mostly on multi-billion-dollar expressways and Interstates. In other words, under a fuel tax system, operators of cars and trucks pay a single *average price* to use all roads, regardless of their cost. It's as if everyone paid a standard price for a car, regardless of its cost to produce and its various features. Under such a system, nearly everybody would want a Jaguar or a Rolls Royce, but nobody would call that an efficient system of paying for automobiles. This problem helps to explain why it is so difficult to expand major highways such as expressways and Interstates. Those who use them are paying only average costs, but the costs of building, operating and maintaining those highways are far above average.

That leads to a second advantage of a toll-based system: *greater fairness*. Because the toll rates are directly related to the costs of specific highways or bridges, people pay specifically for what they use and can avoid paying for what they do not use. Someone who drives only around town on ordinary streets and roads would avoid having to pay for costly freeways and Interstates. On the other hand, those who extensively use Interstates (such as trucking companies) would pay rates that fully cover the cost of building, operating and maintaining those specific facilities—as do users of the toll road portions of the Interstate system today. If a reconstructed and modernized toll-financed 21st-century Interstate system cost truckers more than their cost of using the largely fuel-tax-funded 20th-century Interstate system, they would be getting better service (including truck-only lanes in major truck corridors). But from a resource allocation perspective, if a higher cost of using the 21st-century Interstate resulted in slightly higher freight rates, those rates would get factored into the prices of goods transported that way. Those, in fact, would be the real costs to shippers choosing that mode, rather than rail freight. And that is part of the greater fairness (and greater economic efficiency) of tolling.

Another advantage over today's fuel tax system is the *self-limiting nature* of a toll-financed system. We have seen how the federal fuel tax over the past six decades has morphed from an Interstate highway user fee to a general-purpose federal transportation tax. Because most voters no longer have trust in the federal highway program as directly benefiting them, most of them do not support increasing the federal fuel tax rate. By contrast, under the system of toll finance that has evolved in this country, toll roads and bridges are financed by issuing long-term revenue bonds. Bond buyers impose stringent conditions on the use of toll revenues (including reserve funds, coverage ratios, etc.) to ensure a very high probability that the toll revenues will cover the contractually called-for (and legally enforceable) debt service payments. Hence, those paying tolls to use such facilities can generally count on their toll dollars being used only for the construction, operation, maintenance, improvement and reconstruction of those specific facilities.[18] This is a far more sustainable model of users-pay/users-benefit than what the federal Highway Trust Fund has become. To retain long-term user support, replacing fuel taxes with per-mile charges must reflect the principle of users-pay/users-benefit.

Related to the self-limiting nature of tolling is the *guarantee that toll roads and bridges will be well-maintained*. Historically, toll roads in America have been the exception rather than the rule. They are premium facilities that motorists or truckers in most cases have the option to use—or not. As such, they must offer performance superior to what is available from their non-tolled competition—such as less (or no) congestion, smoother pavement, less-steep grades, service patrols, etc. When it comes to proper maintenance, those who buy toll revenue bonds understand this, and require funds to be set aside to ensure proper ongoing maintenance—in many cases even before the toll operator makes the scheduled payments to bondholders. It's as if every toll road comes equipped with an endowment fund to ensure that it is properly maintained over its lifetime. Nothing approaching this exists with fuel-tax-funded highways. In those cases, what gets spent on maintenance each year is whatever the state legislature appropriates—and legislators are known for favoring new projects (highly publicized ribbon-cuttings) over maintenance (boring, unseen by voters). Moreover, since federal grants focus primarily on capital expenditures, this creates a subtle incentive for states to let highways and bridges wear out completely so that they can be reconstructed largely with federal funds.

On the other hand, legislators also face constraints on putting money into major highway projects, since there are typically far more projects around the state seeking funds than the amount of funds available. What often get short-changed in that decision process are the big-ticket items, such as a new interchange on the Interstate. The same $400 million it would take for that one interchange could fund 20 smaller projects in numerous members' districts, so choices like that are often made. But if the Interstate is tolled, and a new Interstate project makes financial sense, it is more likely to get financed and built, serving current and new customers. In short, a toll-based system *facilitates needed expansions*.

The preceding paragraph used the term "finance" deliberately, even though popular writing often fails to distinguish between "funding" and "financing." When highway projects are done using federal and/or state fuel tax money, they are not *financed*. Instead, they are paid for in cash, out of available (or saved-up) federal and state funds. When you buy a house or a car, you can either pay cash or finance the purchase over time. The vast majority of people finance a long-term asset such as a house, because they can obtain it much sooner than if they first had to save up the entire purchase price and only then buy it and enjoy its benefits. The same differences apply to major highways and bridges. It makes far better sense to finance such big-ticket items, to get them into service as soon as they are needed, and have the users pay for them over time. This is especially the case when a state or country has a huge backlog of infrastructure needs (such as reconstructing worn-out Interstates). Instead of waiting decades to save up enough money to do each billion-dollar project, *using toll financing means the project can be done when needed*, with users paying to use it over the 50 or more years of its useful life.

One more advantage of tolling over fuel taxes is that in cases of heavy urban freeway congestion, all-electronic tolling makes it feasible to *vary the toll amount to reduce congestion*. Even very modest peak/off-peak differentials, such as those now used on a number of toll bridges and tunnels in the New York metro area and on the San Francisco-Oakland Bay Bridge, have reduced peak-period congestion—by encouraging less-critical trips to be made at other times of day, encouraging some to carpool instead of driving alone, and encouraging others to use transit for peak-period trips. Far more dramatic results have been achieved on tolled express lanes in urban areas of California and a number of other major metro areas.

Part 4

The Cost of Reconstructing the Interstates

The starting point for this analysis is construction cost data from FHWA's Highway Economic Requirements System (HERS). It provides "improvement costs" data in the U.S. DOT's *2010 Conditions & Performance Report*'s Appendix A. Exhibit A-4 provides typical costs per lane-mile for various types of improvements. The data used for this portion of the analysis came from the column headed "Reconstruct Existing Lane." These costs are national averages in 2008 dollars. Using the Bureau of Labor Statistics CPI calculator, they were adjusted for inflation to provide costs as of 2010—the base year for all calculations.

Second, they were adjusted for state-specific variations, using data from R. S. Means Company's *Heavy Construction Cost Data* volume. This volume lists tables of cost factors for several cities in each state. This research used an average of the "site construction" (which includes labor) and "concrete" (as a proxy for material) to give a highway construction cost index for each locale. The rural index reflects the figure for a randomly selected small city in each state; the urban index reflects the figure for the state's largest city. As an example, the state adjustment factor for rural Interstates in Alabama was 0.812 (meaning its cost is 81.2% of the national average). Hence, the 2010 national HERS unit costs were multiplied by this factor for Alabama.

A. Rural Interstates Reconstruction

State-specific data on lane-miles of rural Interstates were obtained from FHWA Highway Statistics Table HM-60, available online. This table does not break down lane-miles by individual Interstate routes, so the reconstruction calculations dealt with each state's rural Interstate system as a whole. The spreadsheet for rural Interstates included 49 states, excluding Delaware and the District of Columbia (which have no rural Interstate miles in HM-60).

The HERS rural cost estimates are given separately for flat, rolling and mountainous terrain. But HM-60 and other online tables did not provide a breakdown into those three categories. A query to FHWA produced a listing of the fraction of rural Interstate route-miles in each category for each state. Those fractions were entered in the spreadsheet for each state and used to create a weighted average reconstruction cost per lane-mile. This composite unit cost was multiplied by the state's adjustment factor (from R. S. Means), and that unit cost was multiplied by the number of lane-miles to provide the estimated rural Interstate reconstruction cost, in 2010 dollars. Those numbers ranged from a low of $101 million for Rhode Island to a high of $7.84 billion in California.

Since the premise of this study is the use of all-electronic tolling to provide the revenue stream, the reconstruction cost must also include outfitting each reconstructed corridor with the gantries and tolling equipment needed for AET. Electronic tolling expert Daryl S. Fleming estimates the cost of equipping rural highways for AET at $250,000 per mile. After including this cost for each state, the total reconstruction cost is $148 billion, which is 5.4% more than reconstruction cost alone.

B. Urban Interstates Reconstruction

For urban Interstates, the HERS reconstruction unit costs are presented for four different-sized urban areas: small urban, small urbanized, large urbanized and major urbanized. Table HM-60 provides lane-mile data only for the total of urban Interstate lane-miles in each state. Therefore, it was necessary to estimate the fraction of urban lane-miles in each of the four size groups for each state.

The database for the *Urban Mobility Reports* of the Texas Transportation Institute provides freeway lane-mile data for 101 urban areas, listed in four size groups as small, medium, large and very large. We took those four size groups as proxies for the four HERS urban categories and used TTI data as follows. These urban areas were grouped by state, and the fraction of TTI-reported freeway lane-miles in each TTI group was used to produce a weighted average urban HERS reconstruction unit cost for each state. After adjustment by the state cost adjustment factor, this number was multiplied by the urban Interstate lane-mile total from HM-60 to yield a total urban reconstruction cost figure for each state. These ranged from a low of $315 million in Vermont to a high of $59.2 billion in California.

For urban Interstates, Fleming estimates a typical AET equipment and installation cost of $2.5 million per route-mile. After adding those costs, the total cost of reconstruction is $441 billion, which is 10.4% higher than the cost of reconstruction alone.

C. Initial Conclusions on Reconstruction Costs

The estimated cost of reconstructing the rural Interstate system is $148 billion, or $1.20 million per lane-mile. While the overall cost is large, the unit cost seems surprisingly modest. This is probably due to the relatively small fraction of rural Interstate miles in mountainous terrain, as well as the lack of need to acquire new right of way for reconstruction.

Reconstructing urban Interstates is estimated to cost $441 billion or $4.78 million per lane-mile, which also seems low, given the high cost of new expressway lanes in urban areas. But as with the rural Interstates, this baseline cost is only for reconstructing existing lane-miles and does not include any costs for new lanes or right of way. Moreover, it is an average of states with mostly small and medium urban areas where costs average less than $2 million per lane-mile, and the small number of states with large and very large metro areas whose typical reconstruction costs average $4 to $7 million per lane-mile.

Overall, reconstructing the entire existing Interstate highway system, without adding any new lanes or new routes, is estimated to cost $589 billion in 2010 dollars.

Part 5

Estimating Traffic and Revenue

A. Traffic and Revenue, Rural Interstates

The basic approach to projecting toll revenues was adapted from a more detailed analysis of toll-financed reconstruction of Wisconsin's Interstates.[19] That study used the principle of "value-added tolling," under which tolls would be applied to a specific Interstate corridor only when it was reconstructed and modernized. In that study, some of the reconstruction also involved lane additions, using detailed corridor-by-corridor data provided by the Wisconsin DOT. The present 50-state study had to be carried out at a higher level of abstraction, treating each state's rural (or urban) Interstate system as a whole. In this more aggregated look at basic toll feasibility, the calculation is done as if the entire set of rural Interstates were reconstructed by 2020 and tolling began that year. Since the estimated costs and projected toll revenues are discounted to 2010 for this analysis, reconstruction over a longer period would not have a significant impact on the results. This analysis is presented as an exercise to test basic feasibility, not as a proposed reconstruction plan. The reader may prefer to think of this model and time frame being applied to the state's first Interstate reconstruction project (e.g., the proposed toll-financed reconstruction and widening of I-95 in North Carolina).

Traffic (VMT) is projected starting with 2010 FHWA data (from FHWA Highway Statistics Table VM-4) for light vehicles and heavy vehicles. As in the Wisconsin study, once tolling begins, some diversion of traffic off the Interstate is assumed, because we know that some fraction of vehicles that previously used the Interstate will decline to do so when it is tolled. A diversion rate of 10% was used for light vehicles (cars, vans, pickup trucks, etc.) and 20% for heavy vehicles. The 10% diversion rate in the Wisconsin study drew upon recent traffic and revenue modeling for the proposed toll-financed reconstruction and widening of I-70 in the Midwest.[20] In that analysis, 10% was selected as a reasonable light-vehicle diversion rate for "modest" tolls of around 5¢/mile (higher than the 3.5¢/mile used in this study). The I-70 study assumed 30% diversion for trucks, based on national average truck tolls of 20¢/mile. Since this study's baseline rate for trucks is 14¢/mile, a diversion rate of 20% was used.

Notably, the traditional approach of assuming a diversion rate for a tolled versus non-tolled highway will be less relevant in future decades during which Interstate reconstruction takes place if, as expected, states proceed to phase in some form of mileage-based user fees for all their roadways (to replace fuel taxes). In that environment, all roads will be "tolled" via some form of charge per mile, with the charge being higher for premium facilities such as Interstates. This change, over several decades, will likely reduce the extent that "diversion" in the traditional sense is a problem for rebuilt, tolled Interstates. But in order to make our analysis conservative, we have retained the traditional approach of assuming diversion rates.

The assumed baseline toll rates—3.5¢/mile for light vehicles and 14.0¢/mile for trucks, both in 2010 dollars—were selected as potentially being in the right ballpark to pay for reconstruction only. Those rates are below the national average tolls of 4.9¢/mile for cars and 19.9¢/mile for trucks on long-distance toll roads.[21] For a 45-year projection to 2054 (10 years' construction from 2010 through 2019, followed by 35 years of tolling), both toll rates were adjusted annually by an assumed CPI increase averaging 2.5% per year.

State-specific annual VMT growth rates for 2011 through 2041 for light vehicles and trucks were based on a methodology devised by the US DOT's Volpe Center.[22] For light vehicles, these annual growth rates ranged from a low of 0.3% (Connecticut) to a high of 2.2% (Arizona). The truck VMT growth rate (average of single-unit trucks and combination trucks) ranged from a low of 1.8% (Wisconsin) to a high of 3.4% (Arizona). Car and truck VMT is projected year by year for each state, using these rates from 2010 through 2019. Starting with 2020, the projected VMT number for each year is adjusted downward by the selected diversion rates, and these adjusted volumes are used from 2021 through 2054, the last year in the projection.

The gross toll revenue in each year, for cars and for trucks, is calculated by multiplying the CPI-adjusted toll rate for that year by the adjusted VMT for that year. The net toll revenue for that year is then defined as 85% of the gross toll revenue. This reflects an estimated 10% of revenue devoted to highway maintenance and 5% of revenue for the cost of toll collection based on all-electronic tolling, as derived in the previously cited policy study by Fleming, et al.[23]

Each state's spreadsheet then totals the net toll revenue collected from cars and trucks for each year. The final step is to compute the net present value (NPV), as of 2010, of the net toll revenue stream from 2020 through 2054. A 6% discount rate was used, to be conservative. (The higher the discount rate, the lower the NPV.) The sum of each year's discounted revenue number is the NPV of total revenue, as of 2010. The NPV of toll revenue is not an estimate of bonding capacity. But comparing the NPV of revenue to the 2010 reconstruction cost estimate, provides a general estimate of whether the assumed toll rates would be sufficient to support the reconstruction and maintenance of the Interstates in question. The large majority of states had an NPV of revenue greater than the 2010 cost of reconstructing their rural Interstates.

B. Traffic and Revenue, Urban Interstates

The traffic and revenue projections for urban Interstates were carried out via a similar set of state-specific spreadsheets, but the tolling assumptions were more complex. Although the focus of this study is on paying for reconstruction, America's urban congestion problem suggests that if urban

Interstates are to be tolled for reconstruction, the toll rates should be higher during peak periods than at other times of day, to manage peak-period congestion. Moreover, rebuilding urban Interstates will be far more costly than rebuilding rural Interstates, so higher toll rates are justified on that basis, as well.

Therefore, a peak/off-peak toll regime was assumed, with rates in all cases higher during peak periods, and with higher rates in larger, more congested urban areas than in smaller, less congested ones. Table 1 shows the toll rates used for this exercise and the fraction of the VMT charged the peak and off-peak rates. This set of assumptions is intended as a proxy for the kind of variable pricing system that would be tailored to the specifics of each urban area. Note that the peak periods are assumed to be longer in duration the larger the size of the urban area, and that toll rates also increase with the size of the urban area, since congestion is more intense, on average, the larger the urban area. Since some trucks (but by no means all) have the ability to shift their trips to off-peak times of day, this behavior was assumed for the larger urban areas.

Table 1: 2010 Urban Per-Mile Toll Rates, by Urban Area Size

	Peak rate	% of VMT	Off-peak rate	% of VMT
Cars				
▪ Small urban areas	$.05	30%	$.035	70%
▪ Medium urban areas	$.06	40%	$.045	60%
▪ Large urban areas	$.075	50%	$.055	50%
▪ Very large urban areas	$.10	60%	$.070	40%
Trucks				
▪ Small urban areas	$.20	35%	$.14	65%
▪ Medium urban areas	$.24	40%	$.16	60%
▪ Large urban areas	$.30	40%	$.18	60%
▪ Very large urban areas	$.40	35%	$.20	65%

As with the urban cost spreadsheets, it was necessary to compute a weighted-average car toll and truck toll for each state, depending on how many lane-miles of urban Interstate each state has in each of the four urban-area size categories. The same urban freeway lane-mile data from TTI were used for this purpose. Maine, Montana, North Dakota, South Dakota and West Virginia have no urban areas listed in the TTI database, so their urban Interstates were assumed to be in the "small urban" category.

Using the derived car and truck toll rates, the last step was to create a traffic and revenue spreadsheet for each state with urban Interstates. Even though the toll rates are higher than for the rural case, this analysis applied the same diversion rates of 10% for cars and 20% for trucks. The rationale is that drivers in urban areas generally have higher values of time and trip-time reliability, that variable tolling offers drivers a value proposition of less congestion in exchange for the toll, and there are typically few or no uncongested expressway alternatives. Gross toll revenue was first calculated and then reduced by 15% to cover maintenance and other operating costs, including all-electronic toll collection. The total net toll revenue for each year was discounted using the 6%

discount rate, enabling the total NPV of net toll revenue to be calculated, base-lined to 2010. Only seven states had an NPV of revenues less than 100% of urban Interstate reconstruction costs.

C. Initial Conclusions on Toll-Financed Reconstruction

These results suggest that modest toll rates (lower than those charged on most established toll roads and much lower than on new toll facilities) would be sufficient to pay for the capital and operating costs of a completely rebuilt Interstate system in most states. The vast majority of states have percentages between 150% and 250%, with a small number of outliers. The seven most problematic states were Alaska (24%), Montana (43%), New York (85%), North Dakota (69%), South Dakota (60%), Vermont (43%) and Wyoming (77%).

This is a surprisingly positive result. When the Interstate system was being planned, many advocated a toll-finance model similar to what had already been used to construct many eastern superhighways that were later incorporated into the Interstate system (e.g., Pennsylvania Turnpike, New York State Thruway, Ohio Turnpike, etc.). But concerns over low traffic and hence insufficient toll revenue in the southern, mountain and western states led to the federal fuel tax/Highway Trust Fund model being adopted instead. But massive economic and demographic shifts over the last 50 years have dramatically altered the prospects for toll finance of the system's reconstruction.

Of the seven problem states noted above, New York and Wyoming could resolve their reconstruction financing problem by using somewhat higher toll rates than our assumed 3.5¢/mile for cars and 14¢/mile for trucks. Montana, North and South Dakota, and Vermont might have to use a mix of fuel taxes and toll revenue—or scale back the scope or time frame of reconstruction. Alaska, as always, remains a special case, with very low traffic for Interstate-quality highways.

The tables of costs and revenues include existing tolled Interstates for those states that have them. Because the tolling mechanism is already in place on those Interstates, some of these facilities may have been partially reconstructed already and may therefore need less-extensive reconstruction than is assumed in the numbers for those states.

Part 6

Interstates Widening Needs

A. Which Interstates Need Widening?

Some of the traffic projected for high-growth states cannot be accommodated with the existing number of lanes. In such cases, the ratios of NPV of revenue to reconstruction costs derived in Part 5 are unrealistically high, because those revenues are based on more traffic than those Interstates can handle. Hence, the next step in the research was a preliminary analysis of where additional lanes are needed to accommodate the projected traffic.

At this point, the simplified analysis used for the reconstruction analysis, which treated each state's rural Interstates as a single project (and did likewise for urban Interstates), was no longer suitable, since it is highly likely that some corridors carry significantly more traffic than others. FHWA provided a spreadsheet listing each Interstate highway within each of the 50 states, giving for each (e.g., I-10 in Alabama) the number of route-miles, lane-miles and 2010 average daily VMT. From this information the average number of lanes of each and the 2010 daily VMT per lane-mile were computed. In the initial analysis, only one-digit (I-5) and two-digit (I-95) Interstates were included; the three-digit facilities that are solely urban in nature were addressed at a later step. The initial set included 237 state-specific one- and two-digit, mostly rural Interstates.

This information was scanned for Interstates whose 2010 traffic was at or above Level of Service C. Although many state DOTs use LOS D or even LOS E as the threshold for rural lane additions, the "value-added tolling" premise of this study was interpreted to mean that toll-paying customers are entitled to receive better service than provided on non-tolled highways. Whereas LOS A and B are described by traffic engineers as providing drivers with a high level of comfort, LOS C is described as offering drivers "some tension," with LOS D's driver comfort defined as "poor."[24]

Florida DOT's LOS C standards were used for initial screening of these mostly rural Interstates.[25] LOS C for rural expressways equates to about 12,500 daily VMT per lane-mile. This analysis used 12,000 DVMT per lane-mile to identify one-digit and two-digit Interstates as widening candidates. The next step was to estimate traffic volume growth for each of the 237 corridors, at 10-year intervals: 2010, 2020, 2030 and 2040. Since the rural Interstate traffic growth rates used in the previous traffic and revenue analysis were on a statewide basis, and no comparable rates were available for individual Interstate facilities, this research used the statewide annual growth figure for light vehicles (which is consistently lower than the growth rate for trucks) and applied that rate to the 2010 VMT for each of the one-digit and two-digit Interstates in that state. This produced daily VMT per lane-mile estimates for 2020, 2030 and 2040 for each facility, used for screening purposes.

A review of that spreadsheet identified 96 corridors where DVMT/lane-mile exceeds the 12,000 threshold. Using this threshold, 41 need more capacity as of 2010, 5 more need widening by 2020, another 27 by 2030, and another 23 by 2040.

A similar analysis was carried out for the shorter urban Interstates with three-digit designations. Most state DOTs use a different standard for urban Interstate congestion than for rural Interstates, often accepting LOS E conditions as a threshold for lane additions. Based on the premise of value-added tolling, this study opted for a higher level of service than current practice, using LOS D as the urban lane-addition threshold. The previously cited FDOT handbook's Table 1 provides LOS D volumes for urbanized area freeways, which average 18,676 daily VMT per lane-mile. This analysis used 18,000 as the threshold at which lane additions are needed. Following a similar procedure to that used for rural Interstates, DVMT per lane-mile were projected at 10-year intervals following the actual values for 2010. This analysis identified 97 three-digit urban Interstates, in 30 states, that exceed or will exceed the LOS D standard during the 30-year period.

B. Estimated Widening Cost

The data on the 96 major (one- and two-digit) Interstates and on the 97 urban (three-digit) Interstates make it possible to produce a very preliminary cost estimate for those widening projects. FHWA's table of HERS representative construction costs provides unit costs for lane additions. Because portions of the long-distance Interstates pass through urban areas, accurate cost estimation requires the use of unit costs for both rural and urban lane-additions. The rural lane-addition costs are given for flat, rolling and mountainous terrain. Adjusted to 2010 dollars, they are, respectively, $2.251 million (flat), $2.462 million (rolling) and $7.597 million (mountainous) per lane-mile.

The urban lane-addition costs are more complex, since the table lists both "normal" and "high" costs for each of the four size categories of metro areas. This study used the midpoint of those two figures for each size category, and after adjusting for inflation, those 2010 unit costs per urban lane-mile are:

- Small $4.448 million
- Medium $5.725 million
- Large $11.178 million
- Very Large $29.717 million.

For the three-digit urban Interstates, the costing is straightforward. A spreadsheet was used to identify how many lanes need to be added to reduce the 2040 DVMT/lane-mile to 18,000 or below.

The results are that 48 require two new lanes, 23 require four, 10 require six, and 16 require eight or more lanes, with California and Texas accounting for most of those cases. In two California cases (I-405 and I-605), even eight lanes would not suffice. Because six-lane and eight-lane additions are highly unlikely to be possible in major metro areas, calculations for those cases were based on adding just four lanes, and assuming that more-aggressive congestion pricing would be used there to deal with congestion.

Since it's possible to extrapolate approximately in which decade in the future the various lane addition projects would be carried out, this research used the 4% annual construction cost inflation factor from the Wisconsin study to estimate the build-year cost and the 6% discount rate to obtain the NPV of that cost as of the base year 2010 (to make it comparable with the 2010 reconstruction costs estimated previously).[26] For each long-distance Interstate, it was necessary to estimate what fraction is rural and what fraction is urban, to use the correct construction cost for each portion. Spreadsheets were produced for each state listing Interstates that need widening, with the final result of each being the net present value of the state's widening costs.

C. Truck-Only Lane Candidates

FHWA's Freight Analysis Framework (FAF) provided a separate data set focused on truck traffic on one-digit and two-digit Interstates. It was organized by Interstate route, breaking down each one (e.g., I-10) into separate segments in each of the states through which it is routed. For each segment, the database gives the length in miles, daily truck VMT in 2007, and projected daily truck VMT in 2040. The previously provided FHWA data were added on lane-miles for each.

The FAF uses sophisticated modeling techniques driven by historical data and forecasts about goods movement not only via highway truck but also via other modes. For purposes of this project, it provides a more detailed look into future truck traffic on specific Interstate corridors in individual states. Those 2040 truck daily VMT figures offered a cross-check on the overall 2040 traffic projections used in the above widening analysis.

For each of the 96 corridors in the previous lane-additions spreadsheet, this research compared the projected 2040 total traffic with the FAF 2040 truck projection to yield an estimate of the fraction of traffic constituted by trucks in that year. Interstates with a projected 2040 truck fraction of 40% or greater were selected for truck-only lanes. Evaluating the larger 237-corridor spreadsheet for corridors with a high fraction of truck trips in 2040 led to adding 16 more corridors.

In several multi-state corridors a particular Interstate serves multiple contiguous states that all have high projected 2040 truck volumes and percentages:

- I-40, from California through Tennessee, encompassing seven states;
- I-70, from Missouri to Pennsylvania;
- I-80, from Nebraska through Ohio;
- I-81, from Tennessee north through Pennsylvania.

Other possible multi-state truck-lane corridors include I-10 from California to Mississippi, I-30 in Arkansas and Texas, and I-65 in Tennessee, Kentucky and Indiana. Single-state truck-only lanes might be warranted for I-76 in Colorado, I-84 in Idaho, I-69 in Indiana and I-71 in Kentucky.

Some would argue that, on both safety and capacity grounds, a lower threshold than the 40% truck traffic used here should define corridors warranting truck-only lanes. Mannering and Washburn estimate that an expressway with just 20% heavy trucks can accommodate much lower traffic flows than one used only by cars; they estimate reduced vehicle throughput up to 40% due to that volume of trucks.[27]

The identified truck-only corridors were included in the individual widening spreadsheets for each of the 42 states with Interstate corridors needing lane additions. The truck-only lane cases were modeled as two lanes in each direction, for operational reasons. From these 42 spreadsheets, the NPV of widening cost was determined, and that NPV was added to the NPV of reconstruction cost for each state.

Part 7

Overall Financial Feasibility Estimate

A. Feasibility Results

Table 2 provides a state-by-state summary comparing the previously estimated NPV of revenue with the NPV of both reconstruction and widening derived previously.

Table 2: Estimated Toll Feasibility of Interstate Reconstruction and Widening

State	NPV of Reconstruction Cost ($M)	NPV of Widening Cost ($M)	NPV of Total Cost ($M)	NPV of Net Toll Revenue ($M)	Revenue/Cost Ratio
Alabama	$6,368	$ 411	$ 6,779	$ 13,743	203%
Alaska	$4,772	$ 0	$ 4,772	$ 1,140	24%
Arizona	$11,301	$ 8,332	$ 19,633	$ 22,329	114%
Arkansas	$ 3,858	$ 1,998	$ 5,856	$ 11,321	193%
California	$70,275	$117,509	$187,784	$124,438	66%
Colorado	$ 8,670	$ 2,275	$ 10,945	$ 13,646	125%
Connecticut	$ 6,045	$ 3,866	$ 9,911	$ 9,649	97%
Delaware	$ 1,824	$ 299	$ 2,053	$ 2,298	112%
D. C.	$ 578	$ 544	$ 1,132	$ 819	72%
Florida	$22,006	$ 13,914	$ 35,920	$ 49,190	137%
Georgia	$25,646	$ 19,250	$ 44,896	$ 46,556	104%
Hawaii	$ 1,049	$ 666	$ 1,715	$ 1,631	95%
Idaho	$ 3,537	$ 1,904	$ 5,441	$ 4,649	85%
Illinois	$36,610	$ 20,465	$ 57,075	$ 47,295	83%
Indiana	$12,024	$ 4,650	$ 16,674	$ 25,076	150%
Iowa	$ 4,439	$ 1,405	$ 5,844	$ 8,331	143%
Kansas	$ 6,079	$ 0	$ 6,079	$ 7,720	127%
Kentucky	$ 7,091	$ 3,183	$ 10,274	$ 15,337	149%
Louisiana	$ 7,183	$ 1,665	$ 8,848	$ 15,545	176%
Maine	$ 2,175	$ 0	$ 2,175	$ 2,430	112%
Maryland	$ 9,700	$ 7,547	$ 17,247	$ 20,872	121%
Massachusetts	$17,812	$ 20,070	$ 37,882	$ 20,387	54%
Michigan	$23,498	$ 4,227	$ 27,725	$ 26,501	96%
Minnesota	$ 9,265	$ 3,950	$ 13,215	$ 13,150	100%
Mississippi	$ 3,922	$ 191	$ 4,113	$ 7,293	177%
Missouri	$12,676	$ 6,358	$ 19,034	$ 24,595	129%

Table 2: Estimated Toll Feasibility of Interstate Reconstruction and Widening					
State	**NPV of Reconstruction Cost ($M)**	**NPV of Widening Cost ($M)**	**NPV of Total Cost ($M)**	**NPV of Net Toll Revenue ($M)**	**Revenue/Cost Ratio**
Montana	$ 6,905	$ 0	$ 6,905	$ 2,940	43%
Nebraska	$ 2,564	$ 2,490	$ 5,054	$ 4,788	95%
Nevada	$ 4,803	$ 2,304	$ 7,107	$ 7,478	105%
New Hampshire	$ 3,331	$ 0	$ 3,331	$ 3,211	96%
New Jersey	$19,075	$ 12,714	$ 31,789	$ 22,693	71%
New Mexico	$ 5,605	$ 2,787	$ 8,392	$ 10,591	126%
New York	$37,480	$ 12,924	$ 50,404	$ 31,790	63%
North Carolina	$11,266	$ 9,407	$ 20,673	$ 29,607	143%
North Dakota	$ 3,080	$ 0	$ 3,080	$ 2,118	69%
Ohio	$20,549	$ 9,610	$ 30,159	$ 36,854	122%
Oklahoma	$ 5,469	$ 1,861	$ 7,330	$ 11,761	160%
Oregon	$ 6,176	$ 1,930	$ 8,106	$ 11,144	137%
Pennsylvania	$24,154	$ 10,013	$ 34,167	$ 31,032	91%
Rhode Island	$ 1,328	$ 386	$ 1,714	$ 2,197	128%
South Carolina	$ 5,301	$ 2,493	$ 7,794	$ 13,281	170%
South Dakota	$ 3,946	$ 0	$ 3,946	$ 2,370	60%
Tennessee	$10,364	$ 7,065	$ 17,429	$ 29,396	169%
Texas	$42,149	$ 47,419	$ 89,568	$ 95,648	107%
Utah	$ 8,013	$ 1,890	$ 9,903	$ 15,163	153%
Vermont	$ 2,913	$ 0	$ 2,913	$ 1,260	43%
Virginia	$13,605	$ 9,605	$ 23,210	$ 29,966	129%
Washington	$15,805	$ 12,872	$ 28,677	$ 22,673	79%
West Virginia	$ 5,336	$ 180	$ 5,516	$ 5,456	99%
Wisconsin	$ 6,500	$ 1,174	$ 7,674	$ 10,704	139%
Wyoming	$ 5,058	$ 0	$ 5,058	$ 3,888	77%
TOTALS	$589,178	$393,743	$982,921	$973,950	99%

Overall, for all 50 states plus DC, the NPV of construction and widening cost is $982.9 billion, and the NPV of toll revenue is $973.95 billion. Hence, the NPV of revenue equals 99% of the NPV of cost, a surprisingly positive result. Thirty states have NPV of revenue greater than NPV of cost, once widening costs are included. Another nine have ratios in the 80–90% ranges, which suggests that with somewhat higher toll rates than the modest levels assumed here, their revenue/cost ratios could exceed 100%. And another nine have ratios ranging from 54% to 79%. Only three have ratios less than 45%. Options for the states with ratios less than 80% are discussed in Appendix A.

Part 8

Policy Implications

This study has found that, contrary to the situation when the Interstate highway system began in 1956, the country's economic growth and shifts in population and goods-movement trends since then make it feasible for most Interstates to be reconstructed and widened using toll finance. The alternative to toll finance would be massive increases in fuel taxes. Just to pay for the $589 billion reconstruction cost estimated in this study (and ignoring the needed widening) would require an additional 40 to 50 cents per gallon over a period of 10 years. And that increase would apply to all gallons used, whether on the Interstates or on local streets and roads. Thus, a motorist driving 15,000 miles per year, in a vehicle getting 25 miles/gallon, would pay an additional $270 per year based on a 45¢/gallon increase. By contrast, assuming the same motorist drives 5,000 of her 15,000 annual miles on Interstates, she would pay $175/year at our baseline toll rate of 3.5¢/mile.

Shifting the 21st-century Interstate system from fuel taxes to per-mile tolls would be a major change. This concluding section of the report considers the implications of this change.

A. Political Feasibility

The plan outlined in this report is based on the "value-added tolling" principle of only introducing tolling when a corridor is reconstructed (and in some cases also widened). While there is a growing consensus in transportation circles on the need to transition from a highway funding system based on per-gallon fuel taxes to one based on per-mile user fees, there is no consensus on how to make the transition. This report has assumed that one major part of that transition would be to convert the entire Interstate system to per-mile all-electronic tolling over several decades, using existing, well-accepted AET technology, thereby avoiding Big Brother privacy concerns and the need to equip all motor vehicles with costly new technology.

Given long-standing opposition to tolling by trucking organizations, and to a lesser extent by auto clubs, it is not certain that this value-added tolling concept will gain these user groups' acceptance. A major argument raised by user groups is that charging fuel taxes and tolls on the same highway represents "double taxation." If fuel taxes remain in place for some years after the reconstruction and modernization of Interstates, the average amount that motorists and truckers pay in fuel taxes for the miles they drive could be rebated. Electronic toll collection makes it feasible to give fuel tax rebates, since the vehicle's identity is known. That makes it possible to (1) identify the owner to whom a fuel-tax rebate is owed, and (2) estimate the number of gallons consumed by that category of vehicle driving the number of miles charged for on the tolled facility, and thereby (3) calculate the fuel tax payment to be reimbursed.

Many state DOTs would prefer to retain fuel taxes as long as possible to help pay for the rest of the streets and roads in their state, during the period when total fuel tax revenues will be declining. They will face the difficult challenge of gaining political support for implementing some kind of mileage-based user fee (or other replacement funding mechanism) for all these other roads. Since inflation-adjusted toll rates for Interstates will be significantly higher per mile driven (because Interstates are far more costly than other roads to build/rebuild and maintain) than the per-mile yield of current fuel taxes, state DOTs would be better off even if they provide fuel-tax rebates on their toll-financed Interstates during the transition to mileage-based user fees overall.

B. Transition to Mileage-Based User Fees

Much of the policy discussion on replacing per-gallon fuel taxes with mileage-based user fees (MBUFs) in recent years has assumed that a single system must be used to keep track of all miles that a vehicle drives on any category of road or highway. But since many state DOTs and transportation planners envision the per-mile fees on urban expressways being variable, as a powerful tool for congestion-reduction, this means the equipment on the vehicle must be able to distinguish between congested expressways and ordinary streets and roads. And that, in turn, implies knowing where the vehicle goes, raising potential privacy concerns.

That conflict can be avoided by implementing MBUFs via a two-level system, as proposed in this study. Basic per-mile charges could be levied via a simple, low-tech system intended to record all miles driven in a state, without regard to location or type of roadway. This could be as simple as annual odometer readings or a mileage-only device that plugs into the vehicle's diagnostic port (which is already being used by some car insurance companies that offer pay-as-you-drive insurance). Some estimates are that a basic rate of 1.0–1.5¢/mile would suffice to replace gas tax revenues.

Premium charges would apply to premium (limited-access) highways, namely expressways and Interstates. And this can be done, as proposed in this study, with current state-of-the-art all-electronic tolling (AET). Such a system is based on low-cost transponders supplemented by license-plate imaging, and is already widely used statewide in California, Florida and Texas as well as in the 15 E-ZPass states. This kind of AET handles variable pricing very well; it does not require the use of costly GPS equipment.

Implementing this study's proposal for a toll-financed Interstate 2.0 using AET would be the first major step toward replacing fuel taxes with MBUFs, since the Interstate system already handles 25% of all vehicle miles of travel. It would be logical to extend the AET system to all other *limited-access* highways in the state, such as other urban expressways and other limited-access inter-city highways. The remaining highways, arterials and local streets would be covered by the basic annual per-mile charge, as described above.

C. Project Procurement and Public-Private Partnerships

Reconstructing and widening of a state's Interstate highways would be carried out as a large set of projects over a period of several decades. Each of those projects would likely be a "megaproject"—i.e., costing a half billion dollars or more. Tolled megaprojects lend themselves to being developed as long-term concessions—a form of public-private partnership (PPP).

Transportation megaprojects have a poor track record, in terms of cost overruns, schedule slippage, and over-optimistic projections of traffic and revenue.[28] Under a toll concession model, firms compete for the right to detail-design, finance, build, operate and maintain a toll facility for a long enough period to have a reasonable prospect of making a return on their equity investment. In such agreements, the risks of cost overruns, late completion, and traffic and revenue shortfalls can be shifted to the concession company.[29]

Many states have state toll agencies that already operate various tolled facilities and are experienced in financing toll projects. Toll agencies increasingly use design-build procurement, so as to limit bond-buyers' exposure to cost overruns and late completion. But traffic and revenue risk remains with the toll agency. State PPP enabling legislation often permits state toll agencies, in addition to state DOTs, to make use of toll concessions, and this makes sense in cases where the toll agency has reached the limits of its bonding capacity or where the risks of a particular project are higher than the agency and its bond-buyers are comfortable with.

States without an experienced toll agency should make use of toll concessions for their Interstate 2.0 reconstruction and widening projects, both for risk-transfer reasons and to take advantage of the experience of toll concession companies.

D. Federal or State Program?

This study's initial feasibility results suggest that most states could toll-finance the reconstruction and modernization of their existing Interstate highways. Just a handful of states had some combination of high costs and low traffic that would appear to make toll financing difficult (see Appendix A for more details).

Thus, one key question is whether the toll-financed reconstruction and modernization of the Interstates should be a federal program like the original 1956 program, with a federal toll providing funds for redistribution to the small number of problem states. The case for such redistribution is far weaker than it was in 1956, given the changes in population distribution and goods movement since then. Perhaps in the new era of fiscal constraint, the federal role should be more limited, such as ensuring nationwide all-electronic tolling interoperability and setting uniform design and performance standards.

E. Federal Permission

The largest obstacle to launching this much-needed effort is permission from Congress, which could occur as early as the next reauthorization of the federal surface transportation program in 2014. Current federal law prohibits tolling “existing” lanes on Interstate highways, which has been interpreted as banning tolling to pay for reconstruction (i.e., replacement) of worn-out existing lanes.

Only three states have permission, under a pilot program, to use toll finance to reconstruct a single Interstate highway each: Missouri, North Carolina and Virginia. None of them has reached political agreement on actually doing this, to date. But as the reality of the cost of Interstate reconstruction and modernization sinks in, and the low cost and convenience of all-electronic toll collection becomes better understood, elected officials may catch up with public sentiment that is already receptive to tolling as better than (or less bad than) increases in transportation taxes to pay for major new investments in highway infrastructure.

Expanding the pilot program to all states would increase the likelihood of one state developing the political consensus to adopt the toll-financed, value-added tolling model for reconstruction and modernization of their Interstates. The demonstration value of this first mover could be very large, just as the successful implementation of the first priced managed lanes (on SR 91 in Orange County, California in 1995) became the role model for dozens of subsequent managed lanes projects across the country.

Thus, the one thing all states need from Congress in the next reauthorization is permission to use toll financing for the specific purpose of replacing worn-out Interstate pavement and bridges with new and better ones.

About the Author

Robert Poole is Director of Transportation Policy and the Searle Freedom Trust Transportation Fellow at Reason Foundation. He received his B.S. and M.S. in mechanical engineering from MIT and did graduate work in operations research at New York University. He has advised the US DOT Office of the Secretary, the Federal Highway Administration, the Federal Transit Administration, and the state DOTs of a half dozen states, including California and Florida. He has also testified before House and Senate committees on transportation policy issues, as well as before a number of state legislatures. He is a member of the Transportation Research Board's standing committees on Congestion Pricing and on Managed Lanes. In 1995–96 he was a member of California's Commission on Transportation Investment. In 2008 he was a member of the Texas Study Committee on Private Participation in Toll Roads, and in 2010 he served as a member of Washington State DOT's Expert Review Panel on a proposed $1.5 billion managed lanes project on I-405. And in 2010 he was a member of the transportation policy transition team for Florida Gov.-elect Rick Scott. He received the American Road & Transportation Builders Association's 2007 Private Sector Entrepreneur of the Year award, and he received the TRB Managed Lanes Committee's 2012 Leadership Award.

Appendix

Appendix A: Options for Outlier States

Table 2 in Part 7 provides the ratio of NPV of toll revenue to NPV of reconstruction and widening costs for each state. Three groups of states are outliers: those with ratios of 150% or higher, rural states with low traffic but high costs, and urbanized states with high traffic but very high costs. These ratios were all based on applying the same toll rate schedule nationwide, which is not a realistic situation but was useful on an analytical basis.

Nine states have ratios that range from 150% to 203%, which suggests that the standard toll rates used in our calculations may be higher than needed. As can be seen in Table A-1, these are mostly southern and western states with flat or rolling terrain (lower construction costs than for mountainous terrain) and mostly small or medium-size urban areas (again, lower construction costs than in large or very large metro areas). Since toll financing plans generally require reserve funds to ensure that debt service payments can be maintained during recessions (when fewer miles are driven), a safer ratio than NPV of revenue at 100% of NPV of costs might be 120%. On that basis, Table A-1 shows potentially lower per-mile toll rates for cars and trucks in those states.

Table A-1: States Needing Lower Toll Rates

	Rev/Cost (%)	Needed (%)	Ratio	Car Toll	Truck Toll
Alabama	203	120	.59	2.1¢/mi.	8.3¢/mi.
Arkansas	193	120	.62	2.2	8.7
Illinois	150	120	.80	2.8	11.2
Louisiana	176	120	.68	2.4	9.5
Mississippi	177	120	.68	2.4	9.5
Oklahoma	160	120	.75	2.6	10.5
S. Carolina	170	120	.71	2.5	9.9
Tennessee	169	120	.71	2.5	9.9
Utah	153	120	.78	2.7	10.9

A second group consists of urbanized states with very large metro areas and in most cases considerable rolling terrain in their rural portions. For these five states plus the District of Columbia, toll rates higher than this study's basic levels would be needed, but as Table A-2 shows, the resulting toll rates are not out of line with toll rates on newer toll facilities, especially in urban areas. For simplicity, Table A-2 (like the previous table) uses only the basic rural rates, but in practice most of the additional revenue would likely be generated by more-aggressive congestion pricing on the urban Interstates, which constitute the majority of lane-miles for all those in this group except Washington State.

Table A-2: High-Cost Urbanized States					
	Rev/Cost	**Needed**	**Ratio**	**Car Toll**	**Truck Toll**
California	66%	120%	1.8	6.3¢/mi.	25¢/mi.
D.C.	72	120	1.7	6.0	24
Massachusetts	54	120	2.2	7.7	31
New Jersey	71	120	1.7	6.0	24
New York	63	120	1.9	6.6	27
Washington	79	120	1.5	5.2	21

The above toll rates are higher than those on most long-distance toll roads, but they are in the same ballpark as the urban/suburban toll rates in Illinois, which as of 2010 ranged from 2.2 to 6.2¢/mi. for cars and from 22 to 49¢/mi. for trucks.

A third group consists of rural states with low traffic but high costs, generally due to high fractions of rolling and mountainous terrain, which leads to higher construction costs. Given significantly lower traffic levels, which led to none of the Interstates in these states meeting our criteria for lane additions, it might be the case that portions of these Interstates will not need full reconstruction during the several decade period of concern in this study—in which the costs assumed would be significantly lower. However, following the same method as used above to estimate what toll rates might be required if the full reconstruction of all Interstate lane-miles in these states were to be carried out on a fully toll-financed basis produces the data for Table A-3.

Table A-3: Rural States Needing Higher Toll Rates					
	Rev/Cost	**Needed**	**Ratio**	**Car Toll**	**Truck Toll**
Alaska	24%	120%	5.0	17.5¢/mi.	70¢/mi.
Montana	43	120	2.8	9.8	39
N. Dakota	69	120	1.7	6.0	24
S. Dakota	60	120	2.0	7.0	28
Vermont	43	120	2.8	9.8	39
Wyoming	77	120	1.56	5.5	22

These rates, especially those for Alaska, are probably far from being acceptable in those states. This leaves them with several choices. As noted above, some of the Interstates in question may not need full reconstruction during the next few decades due to their lower traffic levels, thereby reducing the costs assumed in our calculations. These states might be expected to argue for federal aid, analogous to what they received in the original Interstate construction program, to cover part of the costs, leaving a smaller amount to be financed by tolls. Or, they could decide to use one or more sources of state funds (e.g., in Alaska, a portion of the revenues from the Alaska Permanent Fund) to supplement the amount raised via tolling. Such funding would be a departure from the users-pay/users-benefit principle advocated in this study.

Appendix

Appendix B: Caveats and Limitations

The cost and revenue estimates in this study are the first bottom-up, corridor-by corridor estimates of reconstruction and widening for all U.S. Interstates. They are intended as a first-cut, 50,000-foot view of the situation, to gain a reasonable estimate of the cost of reconstructing existing Interstate lane-miles and adding lanes in corridors where plausible estimates of VMT growth warrant (including freight corridors where high fractions of truck traffic justify truck-only lanes). In addition, this study is the first detailed effort to estimate the extent to which moderate, inflation-adjusted tolling could finance the costs of reconstructing and widening the Interstates.

The results are heavily dependent on assumptions, approximations and choices. Such choices include the selection of 2.5% as the average inflation rate for the next 40 years, 4% as the average construction cost inflation, and 6% as the most appropriate discount rate for the net present value calculations. Changes in any of those numbers would affect the quantitative results.

The revenue estimates also depend critically on the state-by-state projections of traffic growth (VMT). The author believes the rates used, derived from recent analytical work at the Volpe Center, are reasonable. For light vehicles they range from a low of 0.3% per year in Connecticut to a high of 2.2% in Arizona, while truck VMT growth ranges, from a low of 1.8% per year (Wisconsin) to a high of 3.4% (Arizona). If significantly lower VMT growth rates were used, traffic and revenue would be less, but so would widening needs and costs. The revenue projections depend critically on the toll rates being indexed to inflation. The finding that most states could finance Interstate reconstruction and widening via tolling depends on inflation-indexed toll rates.

Data limitations in some cases required the use of simplifying assumptions. Since the VMT projections were available by state but not by individual Interstates, the statewide VMT growth rate was applied to every Interstate within that state. That is unlikely to be the case, but no better data were available.

The estimated reconstruction and widening costs are likely overstated to some extent, since they do not reflect reconstruction and widening projects that may already have been completed or are currently under way. (Thus, a small portion of this study's estimated reconstruction and widening costs may already have been incurred in a few states and should be omitted from the totals.) But in some other cases, urban widening costs may be understated for very large urban areas, where calculations used the average of the HERS "normal" and "high cost" lane addition costs. In addition, there is some question within the highway community about whether the "reconstruction" cost figures in HERS reflect total (or extreme) reconstruction or more moderate heavy repaving. If the HERS numbers do not reflect total reconstruction, this study's reconstruction cost estimates will understate the true cost of replacing all Interstates over the next several decades.

Somewhat higher unit costs would be required for truck-only lanes (due to the more durable pavement and higher-weight bridges needed) but were not explicitly estimated in the widening calculations. On the other hand, the likely higher toll rates that could be charged to longer combination vehicles (LCVs) were also not modeled, somewhat underestimating the revenues from the truck-only lanes. And for the very large urban areas where lane additions were held to just four, and higher congestion tolls were assumed necessary, the resulting higher toll revenues were not estimated.

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