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In recent years there has been concern over the deterioration and lack of adequate funding for the US road and highway system. The main goals of this study are to examine how increasing use of general financing methods effects road quality, to determine if capital outlay and maintenance expenditure impact road quality differently, and to determine the effect diverting user fees to mass transit purpose has on road quality. An empirical model is constructed to estimate road quality. Results indicate that states that have large user fee gaps do not systematically observe lower road quality. Increased state spending on capital outlay and maintenance results in improved quality with maintenance expenditure having a larger effect. Diversion of user fees away from highway purposes towards mass transit results in lower road quality.

Highway Finance and the Impacts on Road Quality

by
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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Rachel L. Knutson, Author

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Chapter 1. Introduction

In recent years there has been much concern over the deterioration and lack of adequate funding for the road and highway system in the United States. Current federal tax levels and user fees are too low to effectively pay for all the road maintenance and expansion required by individual states. The burden of funding for roads and highways has increasingly shifted away from the federal government and towards state and local governments. The Highway Trust Fund (HTF) was created by the Highway Revenue Act of 1956 with the purpose of providing a reliable source of funding to build and maintain the national highway system. The HTF is a financing mechanism used to account for tax receipts collected by the Federal Government earmarked for expenditure for special purposes.[1]

Over the roughly half century since the creation of the HTF there has been a changing definition of what is considered acceptable use "for highway purposes." The federal HTF is mainly funded through user fees. In 1956 there was a very narrow definition of what HTF money could be used for; it was limited to strictly highway projects. There was a shift in preferences in the 1970's to federal funding for financing mass transit. This was done through a series of transportation assistance and highway acts. Significant amounts of federal funding for mass transit were not available until 1970, with the Urban Mass Transportation Act of 1970. This act appropriated $3.1 billion of $10 billion already marked to be spent over 12 years, to be awarded during

[1] Federal Highway Administration, Office of Policy Development (1998).

fiscal year 1971.[2] The Federal Highway Act of 1973 allowed for another $3 billion of the previously allocated $10 billion to be awarded for transit, as well as shifted some funding from the HTF towards mass transit projects.[3] The National Mass Transportation Assistance Act of 1974 significantly increased federal level transit funding by authorizing an additional $11.8 billion over six years.[4] The Surface Transportation Act of 1982 established the Mass Transit Account, a more stable source of transportation funding, which pulls its funds from the main Federal Highway Trust Fund. Since the Federal HTF is almost exclusively funded through user fees, the creation of the Mass Transit Account resulted in a diversion of user fees to non-direct road and highway use. One of the main arguments in favor of this type of diversion is that better funded mass transit may effectively reduce highway usage by causing road users to switch modes of transport. A reduction in the number of highway users results in fewer cars on the roads, less need for highway maintenance due to less road damage, and less money needed for the road system as a whole. Other arguments for the creation of the Mass Transit Account deal with environmental concerns; some believe that encouraging the use of mass transit may significantly reduce air pollution levels.

More recently HTF money has been used for intermodal projects under the Intermodal Surface Transportation Efficiency Act of 1991 as well as environmental

[2] Lieb (1994), p. 445.
[3] Lieb (1994), p. 446.
[4] Lieb (1994), p. 446.

projects under the Congestion Mitigation and Air Quality Improvement program.[5] It can be seen that the definition of what is considered acceptable use of highway user revenues has expanded considerably over the past fifty years. Uses that were once considered an inappropriate diversion of funding away from highway purposes have become more acceptable.

At the state level, how funds are collected, the tax rate, the type of tax, etc. are all at the discretion of individual states. Each state chooses what it considers to be the optimal mix of taxes and user fees and individually decides how these revenues should be used and for what purpose. Some states divert a significant portion of user fees to non-road uses and some states mandate that user fees be used exclusively for highways and roads. States also individually determine if debt financing is acceptable and which types, if any, are best suited for their specific needs.

The following table summarizes how states distribute user fees to non-highway purposes. On average states divert 4.3% of total user fees to mass transit, 4.3% to general purposes, and 8.9% are diverted for expenses incurred in collecting user fees. On average, 17.5% of user fees are diverted to non-highway purposes. It should be noted that not all states pay for collection expenses through diversion of user fees; states that do not divert user fees for collection expenses appear to be financing this expense through other revenue sources. States in the northeast US tend to have higher diversions to mass transit and diversions to general purposes appear to be a personal state preference that is not regionally correlated.

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[5] Kulash (2001).

Table 1. Percentage of Total User Fees Distributed to Non-Highway Purposes, 2005[6]

State	Mass Transit	General	Collection	Total Non-Highway
Alabama	0.6%	1.0%	0.0%	1.6%
Arizona	0.0%	7.0%	1.4%	8.4%
Arkansas	0.0%	4.1%	2.9%	6.9%
California	0.0%	29.3%	3.6%	33.0%
Colorado	3.1%	0.0%	0.0%	3.1%
Connecticut	33.7%	0.0%	7.9%	41.6%
Delaware	0.0%	0.0%	7.3%	7.3%
Florida	8.4%	7.8%	1.9%	18.2%
Georgia	1.3%	11.8%	12.2%	25.3%
Idaho	0.1%	2.9%	5.3%	8.4%
Illinois	7.5%	1.8%	5.5%	14.9%
Indiana	0.0%	0.0%	13.4%	13.5%
Iowa	0.0%	1.0%	4.4%	5.4%
Kansas	0.6%	4.7%	6.9%	12.2%
Kentucky	0.0%	3.8%	4.4%	8.2%
Louisiana	0.8%	0.0%	0.0%	0.8%
Maine	0.0%	4.1%	0.0%	4.1%
Maryland	26.9%	16.0%	6.8%	49.7%
Massachusetts	0.0%	0.8%	5.1%	5.9%
Michigan	11.5%	0.7%	0.0%	12.2%
Minnesota	1.5%	0.0%	0.0%	1.5%
Mississippi	0.3%	4.3%	0.4%	5.0%
Missouri	0.0%	0.0%	5.5%	5.5%
Montana	0.3%	33.0%	3.7%	37.1%
Nebraska	0.0%	0.0%	6.6%	6.6%
Nevada	0.0%	34.5%	10.3%	44.8%
New Hampshire	0.0%	4.6%	7.9%	12.5%
New Jersey	47.6%	0.0%	10.4%	58.0%
New Mexico	0.5%	20.3%	1.9%	22.6%
New York	11.1%	1.4%	4.7%	17.2%
North Carolina	3.8%	7.6%	1.3%	12.6%
North Dakota	1.4%	2.3%	2.7%	6.4%
Ohio	0.0%	1.7%	7.0%	8.7%
Oklahoma	0.4%	36.1%	0.0%	36.6%
Oregon	1.9%	0.6%	13.1%	15.6%
Pennsylvania	0.0%	0.0%	3.3%	3.3%
Rhode Island	0.0%	55.2%	0.0%	55.2%
South Carolina	1.0%	13.1%	8.5%	22.7%
South Dakota	2.5%	0.0%	0.0%	2.5%
Tennessee	3.2%	16.2%	1.0%	20.4%
Texas	1.3%	49.2%	3.4%	53.8%
Utah	0.0%	0.5%	3.9%	4.4%
Vermont	1.3%	29.5%	1.0%	31.7%
Virginia	0.0%	3.4%	6.0%	9.4%
Washington	0.8%	2.2%	8.3%	11.4%
West Virginia	0.0%	1.4%	3.1%	4.5%
Wisconsin	7.1%	0.5%	5.6%	13.1%
Wyoming	25.4%	12.7%	0.0%	38.1%
Average	**4.3%**	**4.3%**	**8.9%**	**17.5%**

The main objectives of this paper are to try to answer the following three questions. First, has a shift in preference away from optimal user fee financing

[6] Data compiled from US Department of Transportation, FHWA: Federal Highway Statistics, (2005): Table SDF.

towards other more general financing methods had a discernable impact on road quality? Second, which type of state level expenditure, capital outlay spending or maintenance spending, impacts road quality to a greater extent? Third, what effect, if any, does diverting user fees to non-highway mass transit purposes have on road quality?

Chapter 2. Issues in Highway Finance

2.1 Federal Highway Funding

Funds for the HTF are raised through a variety of federal taxes, the largest being levied on motor fuel, with different rates for gasoline, diesel, and other special fuels. There are also special taxes placed on trucks such as the tire tax, truck and trailer sales tax, and the heavy vehicle use tax. The proceeds from these truck taxes go directly into the Highway Account, where portions of revenue from fuel taxes are diverted into the Mass Transit Account.[7] The HTF is primarily funded through taxes that are equivalent to user fees, which will be discussed in more detail later. Funds from the HTF are distributed back to states based on specific allocation formulas. These formulas do not always allocate money to states based on how much they have contributed, but rather by miles of state highway, vehicle miles of travel on interstate highways, whether or not they have maintained federal air quality standards, etc.[8] The following table shows the relationship between the amount of funds states received from the federal HTF compared to the amount states paid into the federal HTF for fiscal year 2005. Not all states are allocated the same amount of funds that they have contributed to the federal HTF.

[7] Federal Highway Administration, Office of Policy Development (1998).
[8] Wachs (2003).

Table 2. Ratio of Payments out of vs. into the Federal HTF, Fiscal Year 2005[9]

State	Ratio of Payments out of the Federal HTF vs. Payments into Federal HTF
Alabama	1.20
Arizona	0.96
Arkansas	1.13
California	1.15
Colorado	0.99
Connecticut	1.66
Delaware	1.94
Florida	1.46
Georgia	1.02
Idaho	1.57
Illinois	0.93
Indiana	0.93
Iowa	1.00
Kansas	1.18
Kentucky	1.01
Louisiana	1.05
Maine	1.11
Maryland	1.00
Massachusetts	1.10
Michigan	1.01
Minnesota	0.87
Mississippi	1.03
Missouri	1.04
Montana	2.44
Nebraska	1.08
Nevada	0.94
New Hampshire	1.19
New Jersey	0.96
New Mexico	1.17
New York	1.34
North Carolina	1.03
North Dakota	2.60
Ohio	1.05
Oklahoma	1.29
Oregon	1.10
Pennsylvania	1.34
Rhode Island	2.68
South Carolina	0.96
South Dakota	2.22
Tennessee	1.00
Texas	0.96
Utah	1.01
Vermont	2.30
Virginia	0.98
Washington	1.05
West Virginia	1.99
Wisconsin	1.14
Wyoming	1.60
Average	**1.29**

[9] Data compiled from US Department of Transportation, FHWA: Federal Highway Statistics, (2005):Table FE-221.

It should be noted that the average is higher than 1.0 because the federal HTF has historically run a surplus and thus there have been more than just current year payments into the fund available for distribution.

In recent years there has been growing concern that revenues coming into the HTF will not be adequate to maintain and expand the aging highway system in the United States. Currently, the largest source of funding to the HTF are federal fuel tax user fees on gasoline and diesel, these tax rates are fixed amounts which are not tied to inflation or any other index, so revenue from these sources are solely a function of the amount of fuel purchased. Current projections by the Congressional Budget Office (CBO) estimate that funds in the HTF highway account will be exhausted during fiscal year 2009 and funds in the mass transit account will be exhausted by 2012, if current tax rates and obligations to states are maintained.[10] It is likely that current fuel tax rates will continue to be too low to cover the costs of maintenance and expansion of the highway system. As technology improves the efficiency of vehicles and average gas mileage increases more miles are traveled on the roads with fewer gallons of gasoline purchased, which leads to lower tax revenues. Other factors such as inflation and increasing costs of materials used to build and maintain the road system may also impact the ability to maintain adequate road quality.

In the future, a tax system that better links the amount an individual pays to the cost they impose on the road system may be a solution to the problem of projected budget shortfalls associated with the HTF. Financing mechanisms such as tolls,

[10] CBO Testimony (2007).

congestion pricing, and fees for vehicle miles traveled are potential directly linked financing mechanisms that are being explored.[11] It is thought that these methods of taxation may lead to more sustainable funding than current methods are able to provide.

2.2 Transit Financing

Financing for mass transit has become an increasingly important issue when discussing transportation finance. There is concern over how much investment in transit is appropriate and where the funding should come from. At the federal level a portion of the HTF, 10-15%, is dedicated to financing transit projects. The revenues received by the Mass Transit Account are solely from user fees on motor fuel and do not include non-fuel revenues such as those collected from heavy vehicle use taxes.[12] In 2004, approximately 72 percent of revenue sources for transit financing came from funds allocated by federal, state, and local governments. The other 28 percent were system generated revenues which go directly back into supporting the transit system. Of that 72 percent, the majority, approximately 35 percent was from local governments, with another 20 percent coming from state governments, and the remaining 17 percent from the federal government.[13] It can be observed that the burden of financing mass transit in the United States falls most heavily on local governments, despite growing federal contributions to transit since the 1970's.

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[11] McMullen and Zhang (2008).
[12] U.S. Department of Transportation, Report to Congress (2007), Chapter 6: Finance, p. 6-25.
[13] U.S. Department of Transportation, Report to Congress (2007), Chapter 6: Finance, p. 6-25.

Since 1973, there have been flexible funding provisions that allow transfers of highway funds to transit at the federal level. Also, the majority of states participate in flexible funding programs which allow money to be “flexed” from highway programs to transit projects. Since the beginning of this program in 1992 approximately $10.9 billion was transferred from highways to transit.[14]

Diversion of funds that would otherwise be used for highways and roads to finance transit, whether it is through the use of earmarking user charges or through flexible funding provisions, has the potential to be problematic for states and local governments. Currently, it is unknown if diverting funds from roads to transit has a significant impact on the overall transportation system. Some believe that diverting funds from roads to transit shifts some of the travel demand burden away from roads on to transit and improves overall conditions, but others feel that diverting funding to transit takes much needed money away from road and highway maintenance and expansion making an already tight budget even tighter. If shifting funds from highway maintenance to developing more extensive transit networks effectively reduces the burden placed on the highway system, then the investment in transit can be viewed as money well spent. This will be examined in more detail in the empirical section where the effects user fees diverted to mass transit purposes have on road quality are estimated.

[14] U.S. Department of Transportation, Report to Congress (2007), Chapter 6: Finance, p.6-26.

2.3 Tolling

Tolls are a method of financing transportation that directly link a user fee to the use of roads and bridges. Tolls have been used in the United States as a method to build and maintain road infrastructure since the first turnpikes were introduced in the late eighteenth century. Currently, there are over 300 toll facilities in operation in the US.[15] Tolls can serve a variety of different purposes; they can be used to raise revenue to build and maintain roads and bridges or they can be used to mitigate congestion or pollution during peak driving hours. New technology that allows tolls to be collected electronically has helped renew interest in tolls as a method of road financing at both the state and local level. While tolls may be a method to maintain a steady stream of revenue, they may also be politically unpopular and not feasible in less densely populated areas. In addition, they may not always mitigate congestion, but rather shift traffic to different roads, non-toll roads, or other surrounding areas. Tolls may be most effective in states or areas that import a significant number of workers during the workday, in these areas the tax is being imposed on out of state residents who do not vote in the state elections.[16] More directly linked financing mechanisms such as tolling may become more popular in the future as technology continues to reduce the transactions costs of collection and the burden of financing roads and highways is increasingly placed in the hands of state and local governments.

[15] Holguin-Veras, Cetin, and Xia (2006).
[16] Levinson (2001).

2.4 State and Local Option Taxes

At the state level, individual states have chosen to finance roads in several different ways. States levy motor fuel taxes in addition to those imposed by the federal government. Some states maintain their own highway trust funds that are used to finance transportation projects within their borders and some states impose additional taxes on trucks and other heavy vehicles, or use other non-user revenue sources such as income, property, or special sales taxes to finance transportation and transit projects. There is much variation between states when it comes to how to pay for roads and highways. States have widely varying preferences on what is considered the optimal mix of funding sources and methods.

When needs for transportation funding are not entirely met by the federal and state governments; counties, metropolitan areas, cities, and special transportation districts may turn to local option taxes. Local option taxes add an additional layer of motor fuel taxes, property taxes, sales taxes, income taxes, etc. that are collected by local governments in addition to federal and state taxes.

Over the last two decades local option taxes of many kinds have shown up in communities all over the country, this signifies a shift in transportation planning away from planning bureaucracies towards mechanisms of direct democracy, meaning the decision to undertake transportation projects is put directly in the hands of the voters. Use of local option taxes was rarely seen before the late 1960’s and the use of these taxes continued to spread through the 1980’s and 1990’s. Increased use through the 1990’s can be attributed to intense competition between local governments to enhance both political and economic development through improvements in transportation infrastructure.[17]

A troublesome result of extensive use of local option taxes is that in most states there is no connection between metropolitan planning organizations and local option transportation taxes. This makes it easy for politicians to push their transportation infrastructure agendas and produce highly visible results without much concern for regional transportation planning. While some argue that local option taxes are becoming increasingly prevalent in transportation finance, others maintain that there is no overwhelming trend towards increasing local option financing despite a steady increase in local option taxes passed on ballot measures since the year 2000.[18]

In states that authorize the use of local option taxes for transportation related projects, there are a wide variety of different types of taxes used, the most common being gasoline taxes, sales taxes, property taxes, vehicle taxes, and severance taxes. Each state has its own unique mix of these taxes with laws stipulating where and for how long they can be enforced, as well as how revenues collected may be used.

For example, the state of Oregon allows the use of local option gasoline taxes at both the city and county level, but only two counties and three cities have actually put them to use. Oregon also allows the use of local option property taxes at the county and transit district level with nearly 70% of districts receiving revenues from these types of taxes. In addition to gasoline and property taxes, some Oregon counties

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[17] Goldman and Wachs (2003).
[18] Perrotta (2007).

and jurisdictions also levy income and hotel taxes to support transportation projects.[19] In contrast, the state of New Jersey for the most part is not dependent on local option taxes. New Jersey has no local option gasoline taxes, jurisdictions are allowed by law to adapt property, sales, and payroll taxes, but none have done so.[20]

Even though local option taxes have been shown to generate revenues to supplement those generated at the state and federal level, they are not completely without drawbacks. In the case of local option gasoline taxes, they are somewhat easy for drivers to circumvent. When a tax is only enforced in a fairly small area like a county or within a city's limits, drivers can easily plan to buy their gasoline in a nearby or adjacent area where the tax is not enforced.

Another issue that is of concern is equity, when local option sales and property taxes are used to raise revenue specifically for road projects, the link between the tax and the road user is weakened, individuals who do not use the roads extensively may still bear the burden of the tax. The use of local option taxes and other creative financing measures may become more prevalent in the coming decades if state and federal funds fall below what is required to maintain and operate the road and highway system in the United States.

2.5 Debt Financing

Another interesting factor to consider when discussing transportation is debt financing. Borrowing against future tax revenue is an accepted and cost effective method to pay for transportation projects in the United States. Current trends indicate

[19] Goldman, Corbett, and Wachs (2001).
[20] Goldman, Corbett, and Wachs (2001).

that debt loads for transportation are increasing faster than the inflation rate. At the state level debt is used more heavily to finance roads and at the local level debt is used more heavily to finance transit.[21] Overall trends in data do not necessarily indicate increased reliance on debt, but do indicate larger municipalities are increasing their use of debt financing. The use of debt to pay for roads and highways is becoming a large problem for some states but is not a problem for others; it seems to be dependent on the specific conditions in each state.

States have a variety of debt financing mechanisms at their disposal to assist with funding transportation projects. One of the more common methods of debt financing is called pay-as-you-go. This type of funding structure allows for projects that do not have the ability to generate their own revenue to be completed more efficiently. This also allows for large projects to be split up into many phases and for each phase to be paid for as funding becomes available. Pay-as-you go financing can sometimes be used to skirt restrictions placed on other methods of debt financing.[22] One of the more popular pay-as-you-go financing plans include flexible or tapered match which allows for matching federal funds to be accelerated so that more federal funding is used early in a project and more state and local funds are used towards the end of a project.[23]

Another method of debt financing is short-term borrowing. One program states have at their disposal for short-term borrowing is the State Infrastructure Bank (SIB)

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[21] Perrotta (2007).
[22] Cambridge Systematics, Inc. and HDR, Inc. (2005), p. 38.
[23] Cambridge Systematics, Inc. and HDR, Inc. (2005), p. 38.

Pilot Program introduced in 1995. This allows states to use federal assistance funds to finance state and local transportation projects through two main mechanisms. First, SIB programs can loan money to public or private transportation projects and repayments and interest are used to replenish the SIB equity fund for future loans. Second, SIB programs are allowed to borrow from the credit market using federal funds as collateral.[24]

Another short-term borrowing plan available to states are Section 129 loans. These loans are only applicable to projects that are able to generate their own revenue with which to repay the loan and allow a state to loan funds to a public or private sponsor and then obtain federal-aid reimbursement for the loaned funds, then recycle the repaid principal to use as matching funds for different federal-aid projects.[25]

In addition to pay-as-you-go and short-term debt financing, more long-term debt financing mechanisms such as revenue bonds are commonly issued to pay for transportation related projects. Revenue bonds allow states to redistribute the cost of a project over the project's lifetime rather than having it paid for up front and generally funds are repaid through the use of dedicated revenue streams.[26] Over reliance on debt to finance transportation can become problematic when large portions of tax revenues, especially those generated from user fees, are needed to service debt, taking away from already strapped current year budgets for maintenance and capital outlay.

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[24] Ryu (2007).
[25] Cambridge Systematics, Inc. and HDR, Inc. (2005), p. 39.
[26] Cambridge Systematics, Inc. and HDR, Inc. (2005), p. 40.

2.6 Fungibility and Highway Funding

Confounding the analysis of alternative funding sources, is the issue of fungibility of funding from different levels of govenrment. Fungibility is defined as "the ability to use funds for any purpose, even though they might be granted for a specific purpose."[27] Fungibility is an important thing to consider when discussing highway finance; as mentioned previously there are three levels of government that finance roads, federal, state and local. The higher levels of government give aid to lower levels of government in the form of grants.

One of the more common types of grants used in financing roads are called categorical grants-in-aid. Categorical grants are given from federal to state governments or from state to local governments with a set of specific conditions attached to the use of the funds; in the case of roads the condition is often that the jurisdiction match the amount of aid with their own local funds.[28] These categorical matching grant-in-aid programs function to lower tax prices and help to promote regional planning.[29] Matching grants are designed to promote road construction and maintenance by making these activities less expensive for states relative to other programs.[30] Grants can indirectly fund other unassisted government activities because they effectively increase the amount of services a state can provide using their own funding, this can lead to more spending on road construction and maintenance or more

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[27] Hyman (1983), p. 657.
[28] Hyman (1983), p. 635.
[29] Hyman (1983), p. 636.
[30] Meyers (1987), p. 221.

spending on other programs because resources have been freed due to the lower cost of road construction.[31]

[31] Meyers (1987), p. 251.

Chapter 3. Conceptual Issues: The Benefit Principle, User Fees, and Earmarking

3.1 The Benefit Principal

The benefit principal is commonly applied to the discussion of user charges for highway and transit financing. This principal of taxation attempts to directly relate government expenditures on a good or service to the revenues collected from the users of the good or service. It assumes that similar to a market, exchange of purchasing power for a good is voluntary and payments by users are equal to the benefits they receive.[32]

Most public services are difficult to price using the benefit principal because it is nearly impossible to determine each individuals benefit from the use or consumption of the service in question. There is an incentive for people to lie about the true amount of benefit they receive from a government service if they know they will be charged accordingly.[33] This is sometimes referred to as the free rider problem; people do not pay or do not pay enough to cover the cost of the good or service they consume and occurs frequently in the discussion of highway finance.

3.2 Optimal User Fees

User fees or user charges are defined as, "prices for the use of government services, determined by political as well as market considerations."[34] These fees serve several purposes, they force users to pay for some of the cost of using the government

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[32] Herber (1983), p. 124.
[33] Hyman (1983), p. 357.
[34] Hyman (1983), p. 377.

services they consume and function to ration the service to prevent negative externalities such as congestion.[35]

User fees for roads are optimal when the fee paid by the user is equal to the marginal cost that user places upon the road system, meaning the fee they pay is exactly the cost of the wear they inflict upon the road and the additional congestion they create. Individuals generally ignore their own contributions to road wear and congestion, so the social cost of the use of a road will be higher than the private cost of the use of a road. Optimal user charges for road wear and congestion should effectively close the gap between social and private costs leading to an efficient pricing mechanism for roads.[36] Optimal users fees would thus constitute a good example of the benefit principle in practice however, it is often difficult to implement such fees.

If optimal user fees for roads are not imposed several potential problems may occur. If fees are too low this can lead to congestion and overuse of roads. If individuals are charged a price lower than the true marginal cost of using a road, they have no incentive to curb usage, especially during peak hours, which places a larger burden on the road and highway system, increasing travel times for all users of the road. Congestion problems can be mitigated through the use of peak load pricing schemes. Higher user fees are charged to reflect increased marginal social cost during peak road travel times.[37]

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[35] Hyman (1983), p. 354.
[36] Winston (1991).
[37] Hyman (1983), p. 446.

If marginal cost pricing is not used for competing modes of travel additional congestion problems may be created, shifting users to the suboptimal priced mode of transport. If a competing mode of transport such as bus service were to be priced at zero, there might eventually be a shift to this mode and congestion on the bus system may be observed. In addition to congestion, suboptimal user fees lead to difficulty with long term financing. If vehicles such as heavy trucks are not charged an optimal user fee they will overuse roads and the damage and wear they cause may become difficult to repair due to insufficient funding from user fees.

As mentioned previously, current user fees for roads and highways in the United States, especially at the federal level, are too low to provide for adequate maintenance and expansion of the highway system. State and local level taxes and user fees have made up some of the slack, but there is still concern that in the long term user fees need to be increased or different types of user fees that are more directly linked to the cost of using roads will need to be implemented, instead of, or in addition to the gasoline tax, in order to maintain a functional road and highway system in the United States. The portion of financing for roads that comes from tax payers in the form of user fees can be observed in the following table.

Table 3. The Relationship Between User Fees and Total Highway Expenditures[38]

State	Total User Fees ($1000's)	Total Highway Expenditures by States ($1,000's)	User Fees as a % of Total Expenditures
Alabama	710,155	1,518,996	46.8%
Arizona	995,375	2,457,999	40.5%
Arkansas	586,687	1,078,033	54.4%
California	8,229,549	8,307,510	99.1%
Colorado	1,232,568	1,651,948	74.6%
Connecticut	807,121	1,344,613	60.0%
Delaware	226,146	857,657	26.4%
Florida	3,112,633	6,790,577	45.8%
Georgia	822,488	2,029,673	40.5%
Idaho	351,643	608,258	57.8%
Illinois	2,800,899	4,200,962	66.7%
Indiana	1,168,117	2,234,580	52.3%
Iowa	825,434	1,392,206	59.3%
Kansas	599,208	1,394,269	43.0%
Kentucky	1,161,476	1,649,503	70.4%
Louisiana	624,933	1,387,132	45.1%
Maine	272,027	543,547	50.0%
Maryland	2,064,362	2,049,308	100.7%
Massachusetts	1,039,626	3,196,486	32.5%
Michigan	1,937,856	3,276,173	59.1%
Minnesota	1,196,863	2,130,536	56.2%
Mississippi	540,670	1,081,143	50.0%
Missouri	1,014,342	2,068,907	49.0%
Montana	319,798	664,491	48.1%
Nebraska	413,031	875,927	47.2%
Nevada	844,588	864,601	97.7%
New Hampshire	272,634	389,212	70.0%
New Jersey	1,377,910	3,825,050	36.0%
New Mexico	611,372	911,059	67.1%
New York	2,495,371	6,332,847	39.4%
North Carolina	1,920,639	3,697,793	51.9%
North Dakota	173,653	455,550	38.1%
Ohio	2,627,620	4,040,127	65.0%
Oklahoma	722,107	1,162,696	62.1%
Oregon	859,322	1,520,218	56.5%
Pennsylvania	2,800,017	4,566,683	61.3%
Rhode Island	214,422	406,986	52.7%
South Carolina	752,798	1,353,711	55.6%
South Dakota	127,836	466,426	27.4%
Tennessee	1,163,922	1,718,454	67.7%
Texas	7,268,679	8,585,542	84.7%
Utah	444,870	986,237	45.1%
Vermont	227,800	309,574	73.6%
Virginia	1,743,260	3,070,041	56.8%
Washington	1,344,688	2,534,290	53.1%
West Virginia	578,024	1,104,784	52.3%
Wisconsin	1,417,237	2,086,087	67.9%
Wyoming	118,458	428,893	27.6%
Average	**1,315,838**	**2,200,152**	**55.9%**

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[38] Data compiled from US Department of Transportation, FHWA: Federal Highway Statistics, (2005): Table SDF and Table SF-21. User fee data includes motor vehicle and motor fuel taxes.

It can be seen that in some states user fees make up a significant portion of the funds states have available to spend on roads and highways, on average 55.9% of road infrastructure funding comes from user fees. States with user fee levels falling below the level of expenditure required to adequately maintain the road system attempt to solve this problem, the free rider problem, by making up the user fee gap with funds from non-user fee sources such as the general fund, bonding, etc. Data suggests that trends towards increased use of general fund financing is occurring, it is observed that many states presently have large user fee gaps. The correlation between large user fee gaps and road quality is tested in the empirical portion of this paper. The benefit principal of taxation helps shed light on some of the complexities associated with user fees as a primary highway financing method.

From a political standpoint suboptimal user fees are preferred by users of roads, people prefer to pay lower taxes and fees. This is one of the reasons they are also, in many cases, chosen by politicians. Also, suboptimal user fees can be used in conjunction with general taxation to subsidize part of the cost of the government service in question. For example, a service like public mass transit may be funded by users paying a fee lower than the marginal cost of the government provided service, with the difference subsidized with other taxes such as property or sales taxes that are placed on all residents of the community. The political popularity of suboptimal user fees contrasts with optimal user fees such as peak load pricing schemes, discussed earlier. Congestion pricing tends to be politically unpopular because the times of day that the user fees are the highest directly coincide with the commute to and from work.

This means individuals do not have the option to travel during off peak hours so they do not have the option to not pay the congestion fee which can place hardships on low income users. User fees play an important role in US road and highway financing.

3.3 Optimal Investment

Road user charges and optimal investment are generally treated separately, but are each part of the solution to the same problem: minimizing the total cost of building and maintaining the road system.[39] As mentioned previously, in order for optimal user fees to be truly optimal they must be set equal to the marginal cost of the use of a road, where marginal cost includes pavement wear and congestion factors. If optimal user fees are charged but infrastructure investment is suboptimal, user fees alone may still not be an effective form of highway finance.

In order for investment to be optimal there must be investment in both the width or number of lanes of roadway and the depth or thickness of a roadway. To determine if highways can be financially self-sufficient from optimal user fees, the degree of scale economies must be determined.

Previous studies have generally found constant returns to scale in highways.[40] This indicates that in the long run congested urban roads could be self financing, but additional taxes or funding sources may be needed to finance uncongested rural roads.[41] It is observed that optimal user fees may not be a completely effective method

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[39] Small, Winston, and Evans (1989), p. 9.
[40] Winston (1991).
[41] Winston (1991).

of finance in all cases; use in conjunction with other financing methods may be desirable.

3.4 Earmarking vs. User Fees

Earmarking taxes refers to designating funds from a single tax base or from a wider pool of revenues to a particular end use. Examples of earmarking are property taxes for education and payroll taxes for social security.[42]

The issue becomes slightly more complex when discussing the gasoline tax and highway user fees. Federal and state fuel taxes could be considered an earmarked tax because they are collected and placed in the HTF to specifically be used for highway related projects. However, these taxes are clearly user fees because the consumption of gasoline is directly correlated with the use of highway services.[43] The exact distinction between user fees and earmarked taxes is a gray area, earmarked taxes do not necessarily approximate individual "prices" but are collected from the group that benefits from the government provided service.[44] User fees are "prices" which are based on the marginal cost of providing the government service, but may also reflect other considerations and externalities.[45] Because user fees rarely reflect just marginal cost, these fees and earmarked taxes become difficult to distinguish in real world situations such as with federal gasoline taxes in the US.[46]

[42] Teja (1988).
[43] Wagner (1991), p. 9.
[44] Anderson (1991), p. 19.
[45] Anderson (1991), p. 19 – 20.
[46] Anderson (1991), p. 20.

Additionally, the issue of earmarked taxes can become confusing because funds can be earmarked in a manner that is different than normally expected. For example, when revenues from a tax on motor fuel, which is considered to be a user fee, are earmarked for expenditure on highways, this is a practical application of the benefit principal. If the revenues from a gasoline tax were earmarked to pay for some non-transportation related purpose such as education, the connection between the tax base and the service provided is broken and the benefit principal no longer directly applies. Earmarking just means that revenues are dedicated to a specific purpose in advance, not that the specific purpose has any necessary relation to the tax base.

At the state level, as far as highways and roads are concerned, many states mimic the federal government and place revenues generated from state fuel taxes, vehicle fees, and other types of non-user fees into a fund earmarked specifically for future road construction or transit projects rather than using pure general fund financing methods to deal with transportation funding. Advantages to using earmarked taxes are stable and reliable revenue streams which can make long term budgeting for government services easier. Earmarks tend to remove some of the funding decisions from the political process guaranteeing at least a certain level of funding for a particular program.[47] Disadvantages to using earmarked taxes are budgetary inflexibility, problems with revenue fluctuations from year to year, and issues with overall spending levels when earmarked taxes become the sole funding source for

[47] Michael (2008), p. 2.

certain programs or services.[48] Despite the disadvantages associated with using earmarked taxes as a method of finance, this type of tax remains common at both the state and federal level. For the most part, earmarked taxes appear to be a relatively simple and effective way to ensure funds are readily available for road and transit projects in the short term.

[48] Michael (2008), p. 3.

Chapter 4. Previous Studies of State Highway Expenditures

Previous studies including those by Goel and Nelson (2003), Congleton and Bennett (1995), Ryu (2007), and Meyers (1987) use state highway expenditure as the dependent variable in their empirical models and sometimes as a proxy for road quality. The studies by Congleton and Bennett (1995) and Goel and Nelson (2003) use similar empirical methods to develop models of state highway expenditure.

The goal of the Congleton and Bennett (1995) study was to “explore the extent to which the public demand for roads and/or the power of special interest groups determines road expenditure at the state level”[49] They develop a model of the median voter’s demand for roads, special interest group demand for roads, and a combined model. Some of the independent variables Congleton and Bennett use include state land area, median income, average value of farm land, average wage of highway construction labor, FHA grants per mile, state population, etc.

The performance of the Congelton and Bennett model was tested by comparing the actual state road expenditure per mile with estimates from the model. The actual mean state road expenditure per mile was calculated as $37.358 which is very close to the estimate from the model which was $37.862.[50] This result is consistent with previous studies. Additionally, it was determined that voting does play at least some role in determining state level road expenditures.

The study by Goel and Nelson (2003) uses state level data to look at the consequences of diverting highway levies or earmarks to non-highway purposes. They

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[49] Congleton and Bennett (1995), p. 2.
[50] Congleton and Bennett (1995), p. 16.

examine the extent to which state imposed user fees, such as gasoline taxes, are earmarked for highway purposes as well as to what extent they are diverted to non-highway related purposes.[51] They develop both a theoretical and empirical model that builds upon the model used by Congleton and Bennett (1995).

The theoretical model from Goel and Nelson (2003) is based directly on the Congleton and Bennett (1995) median voter model, but it expands on and derives unique comparative statics. The empirical portion of Goel and Nelson (2003) differs from this model mainly in that it looks at the demand for highway services by an average consumer rather than a median voter or special interest group.[52] Another slight difference is the way the dependent variable is specified. This variable is still representative of total state highway expenditures but computed differently.

The empirical model from Goel and Nelson (2003) is used to examine if there is a statistically significant link between an individual state's policy on diverting user fee revenues or earmarked taxes to non-highway purposes and the total amount the state spends on highways. Their model uses state highway expenditure as a proxy for road quality and sets this as the dependent variable. The independent variables used include a variety of factors expected to impact state highway spending, including federal grant dollars, per capita personal income, road density measured as miles of road divided by state land area, annual payroll for highway construction workers, and the price per acre of farm land, with the most important variable being state motor fuel revenues used for general purposes. Clearly, Goel and Nelson borrowed several of

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[51] Goel and Nelson (2003).
[52] Goel and Nelson (2003), p. 816.

these variables for their study from Congleton and Bennett (2005) but framed them to be used in a slightly different context.

The variable for motor fuel revenues diverted to general purposes was found to be negative and statistically significant indicating that a $1 increase in the motor fuel taxes diverted to general funds reduces state highway spending by $2.52.[53] The Goel and Nelson (2003) study concludes that there is no evidence that states that divert larger amounts of user fees to non-highway purposes impose higher tax rates to recover lost revenues for highways. Also, it was found that states that divert funds to non-highway purposes do systematically spend less on highways than those that do not.[54] Because expenditure is used as a proxy for road quality, it can be inferred that states that divert highway funds to other purposes appear to have lower road quality as a result.

Another study that builds an empirical model based on Congelton and Bennett (1995), but with a different purpose, is Ryu (2007). This study examines whether the State Infrastructure Bank Program (SIB) is an effective method of expanding funds available to state and local governments to help alleviate the problems associated with diminishing funding for transportation infrastructure.[55] The model is similar to Congleton and Bennett (1995) in that it takes a similar approach and uses the same dependent variable, state highway expenditure as well as many similar independent variables, including labor cost for construction and maintenance for state roads, gas

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[53] Goel and Nelson (2003).
[54] Goel and Nelson (2003).
[55] Ryu (2007).

prices, median income for families, the farm value of land per acre, local highway grants to state governments, population, etc. It differs in that it takes a logarithmic form which was then estimated using OLS. The relevant explanatory variable to the primary research question is total SIB funds calculated as the sum of federal assistance funds and appropriated general funds for the Federal Department of Transportation deposited into the SIB program.[56] This model is estimated for individual years from 1997 to 2003 and as a full sample. Results indicate that one dollar of federal funds placed in the SIB program can stretch state highway expenditures by $5.24 in six years.[57]

The purpose of a study by Meyers (1987) is to "assess the degree to which certain Federal highway grants to States are shifted to other programs or tax relief by recipients."[58] An empirical model similar to those discussed previously is used to estimate three separate regressions each with different dependent variables. The first regression uses own source per capita state highway expenditures as the dependent variable, similar to Goel and Nelson (2003). The other regressions use per capita expenditures except highways and per capita own source expenditures on unaided highway construction and major repair as dependent variables. The independent variables used are similar to the previously discussed studies with highway grants being the variable of interest. This study uses pooled data from 1976 to 1982 and two-stage least squares to estimate the previously discussed regressions. Results indicate

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[56] Ryu (2007).
[57] Ryu (2007).
[58] Meyers (1987), p. 221.

that states are able to convert approximately 63 percent of their matching federal grants to unrestricted resources.[59] The hypothesis that non-highway programs and activities benefit from diversion of state resources by federal assistance dollars can not be supported statistically but there was found to be a strong link between spending on non-Federal aid highways and outlays for highways that are included in the Federal-aid system.[60]

These four studies all use empirical models with some variation of highway expenditure as the dependent variable but with different purposes. Goel and Nelson (2003) are using state highway expenditure as a proxy for road quality in order to determine how diverting funds from collected user fees will impact road quality. Congleton and Bennett (1995) are attempting to determine how demand for roads and special interest groups affect state highway expenditures. Ryu (2007) examines the effects SIB programs have on state highway expenditures and Meyers (1987) looks at how federal grants to states can be shifted to alternative purposes. It is important to note that using state highway expenditure as the dependent variable is an indirect method of measuring road quality and may not be as accurate as using a physical measure of pavement quality. The International Roughness Index (IRI) is a measure of physical road quality and is available at the state level from the Federal Highway Administration.

A recent study by Oh and Sinha (2009) takes a different approach to examining the relationships between road quality and investment. The main purpose of this study

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[59] Meyers (1987), p. 229.
[60] Meyers (1987), p. 232.

is to investigate the effectiveness of current and historical highway expenditures by developing econometric models to explain the correlation between highway investment and performance.[61]

The empirical model developed by Oh and Sinha differs from the previously discussed models in the way it uses highway expenditures. Rather than using state highway expenditures as a proxy for road quality, highway expenditures are used as an explanatory variable and the international roughness index (IRI), a measure of physical pavement quality, is used to measure road quality. This model sets the dependent variable as the percentage of roads with IRI values meeting defined levels and uses variables representing capital outlay expenditures, maintenance expenditures, vehicle miles traveled, and variables to account for past expenditures as independent variables. Two-way fixed effects models were estimated using ten years of data from 1996 to 2005. Urban and rural roads were treated separately and roads were categorized by functional class; interstate, principal arterial, etc.

Results indicate that across functional class, maintenance expenditures tend to have a larger influence on pavement quality than capital investment.[62] It was also found that past expenditures affect current pavement performance levels, maintenance expenditures paid out in the last year have more impact on present road quality than those paid out two years ago. As anticipated, in both urban and rural estimations, it was observed that variables for capital outlay and maintenance have positive signs indicating that spending improves pavement quality. The variables for vehicle miles

[61] Oh and Sinha (2009).
[62] Oh and Sinha (2009).

traveled, the demand for roads, have negative signs, indicating demand is a main cause of pavement distress.[63]

It is important to note that the median voter and average consumer type models used by Congleton and Bennett (1995) and Goel and Nelson (2003) are not the best way to approach the questions this paper is addressing. The approach used by Oh and Sinha (2009) is preferable when physical pavement quality data is available. The IRI data is thought to measure road quality better than using expenditure as a proxy.

This study uses an empirical framework that builds on previous studies, especially Oh and Sinha (2009) to examine several different questions. First, has a shift in preference away from optimal user fee financing towards other more general financing methods had a discernable impact on road quality? Second, which type of state level expenditure, capital outlay spending or maintenance spending, impacts road quality to a greater extent? Third, what effect, if any, does diverting user fees to non-highway mass transit purposes have on road quality?

[63] Oh and Sinha (2009).

Chapter 5. Data, Model, and Results

An empirical model was developed to examine the determinants of road quality and answer some of the primary research questions about how diversion of user fees and different types of spending impact road quality. The model takes the following functional form and is estimated using OLS:

Road Quality = f(Capital Outlay Expenditures, Maintenance Expenditures, Vehicle Miles Traveled, User Fees Diverted to Transit Purposes)

Due to concern over potential endogeneity problems with vehicle miles traveled, the variable representing the demand for roads, we test for endogeneity and specify a 2SLS model to deal with it. Accordingly, an additional model to estimate vehicle miles traveled was developed that takes the following functional form:

Vehicle Miles Traveled = f(Urban Population, Per Capita Income, Motor Vehicle Registrations)

Detailed descriptions of all variables are included in the following sections.

5.1 Measures of Road Quality: IRI vs. Expenditure

The empirical model developed in this paper uses the International Roughness Index (IRI) as a measure of road quality at the state level as reported by the US Department of Transportation, Federal Highway Administration in their annual publication, Federal Highway Statistics.[64] The IRI is a rating that classifies ride quality on roads and highways into three main categories; good, acceptable, and not acceptable. For a road to be classified as “good” its IRI value must be less than 95 inches per mile, to be classified as “acceptable” its IRI value must be less than or

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[64] All data from the US Department of Transportation, Federal Highway Administration is from the year 2005.

equal to 170 inches per mile, and to be classified as "not acceptable" its IRI value must be greater than 170 inches per mile.[65]

The following table summarizes the available IRI data for all roads and highways. The number of miles of roads and highways is reported along with the percentage of total road miles that fall into each quality category in each state. It can be observed that road quality varies a great deal from state to state. States like California, Massachusetts, and New Jersey have large percentages of highway considered to be unacceptable based on IRI measurements, where as states such as Georgia, Kentucky, and Nevada, among others have less than 1% of highways falling into the unacceptable category. Possible reasons for this wide variability are related to some of the previously discussed highway financing issues. It should be noted that this study is only using data pertaining to urban roads that fall within the category of other freeways and expressways or other principal arterials. This is due to the availability of data and because the effects of diverting user fees to transit purposes are likely to be most apparent on urban rather than rural roads and highways.

[65] U.S. Department of Transportation, Report to Congress (2007), Chapter 3: System Conditions, p. 3-6.

Table 4. Summary of 2005 State Level IRI Data, All Roads and Highways[66]

State	IRI – Good		IRI – Acceptable		IRI - Unacceptable	
	Miles	Percent	Miles	Percent	Miles	Percent
Alabama	4702	42.9%	2899	26.5%	343	3.1%
Arizona	3317	48.8%	1168	17.2%	195	2.9%
Arkansas	2647	16.1%	3360	20.4%	519	3.2%
California	6420	42.2%	9880	64.9%	4105	27.0%
Colorado	3889	42.7%	4106	45.1%	534	5.9%
Connecticut	408	11.0%	1010	27.2%	260	7.0%
Delaware	278	5.3%	220	4.2%	34	0.6%
Florida	8924	74.1%	1741	14.5%	126	1.0%
Georgia	10263	57.2%	846	4.7%	9	0.1%
Idaho	2550	51.4%	1299	26.2%	81	1.6%
Illinois	5495	34.1%	5434	33.7%	1424	8.8%
Indiana	3642	32.6%	2663	23.8%	512	4.6%
Iowa	3807	42.8%	3827	43.0%	1193	13.4%
Kansas	7211	69.5%	1403	13.5%	273	2.6%
Kentucky	3417	12.4%	2187	7.9%	67	0.2%
Louisiana	2027	12.1%	1767	10.6%	644	3.9%
Maine	1194	14.0%	890	10.4%	248	2.9%
Maryland	1477	28.7%	1110	21.6%	497	9.7%
Massachusetts	785	27.6%	1606	56.4%	886	31.1%
Michigan	5341	55.1%	4263	44.0%	1093	11.3%
Minnesota	6083	51.2%	5512	46.4%	201	1.7%
Mississippi	3325	30.5%	3102	28.5%	821	7.5%
Missouri	3818	11.8%	5284	16.3%	805	2.5%
Montana	5435	50.4%	1405	13.0%	131	1.2%
Nebraska	3840	38.5%	2684	26.9%	760	7.6%
Nevada	2709	50.2%	195	3.6%	20	0.4%
New Hampshire	892	22.4%	363	9.1%	64	1.6%
New Jersey	359	15.5%	1729	74.5%	901	38.8%
New Mexico	3821	31.9%	1252	10.4%	349	2.9%
New York	4694	31.2%	3998	26.6%	2014	13.4%
North Carolina	3529	4.5%	3548	4.5%	759	1.0%
North Dakota	3196	43.3%	2797	37.9%	190	2.6%
Ohio	5481	28.4%	3059	15.9%	552	2.9%
Oklahoma	3541	28.8%	2829	23.0%	776	6.3%
Oregon	3134	41.6%	3210	42.6%	321	4.3%
Pennsylvania	4493	11.3%	5915	14.8%	1172	2.9%
Rhode Island	101	9.2%	309	28.1%	215	19.5%
South Carolina	3782	9.1%	2631	6.4%	180	0.4%
South Dakota	2622	33.3%	2635	33.5%	1152	14.6%
Tennessee	6116	44.3%	1491	10.8%	243	1.8%
Texas	12510	15.7%	11630	14.6%	1725	2.2%
Utah	2049	35.0%	1627	27.8%	48	0.8%
Vermont	698	26.5%	628	23.8%	165	6.3%
Virginia	3551	6.1%	3503	6.1%	413	0.7%
Washington	3395	48.2%	2317	32.9%	544	7.7%
West Virginia	1691	5.0%	1486	4.4%	130	0.4%
Wisconsin	5935	50.4%	3761	31.9%	950	8.1%
Wyoming	3085	45.6%	1184	17.5%	101	1.5%
Average	**3785**	**32.1%**	**2745**	**23.9%**	**599**	**6.3%**

Several different ways of describing the dependent variable for road quality using the IRI were explored. Unlike some previous studies, state expenditure on

[66] Data compiled from US Department of Transportation, FHWA: Federal Highway Statistics, (2005): Table HM-64 and Table HM-80.

highways in the form of capital outlay and maintenance expenditures, is included in the model as an independent variable rather than as the dependent variable, or as a proxy for road quality. The dependent variable using IRI can be described in terms of the number of miles or percentage of highway that is considered to be unacceptable, acceptable, good, or some combination of these quality categories.

This study uses the IRI to measure road quality rather than state road and highway expenditures because this physical pavement quality measurement is thought to better represent actual road quality. The following table shows the results of a Spearman rank order correlation test used to show the correlation between the percentage of roads and highways that fall into the unacceptable IRI category and the level of state capital outlay and maintenance expenditures.

Table 5. Expenditure vs. IRI Correlation

Spearman's ρ	0.2197
P-Value	0.1336
Null Hypothesis: State Expenditure and % Unacceptable IRI are independent	

The Spearman's $\rho = 0.2197$ implies a weak positive relationship between IRI and expenditure and the p-value = 0.1336 suggests that this relationship is not statistically significant at conventional levels. This result suggests that using expenditure as a proxy for road quality is not the best way to model road quality when IRI data is available.

5.2 Data

This study uses state level data from the lower 48 United States for the year 2005. The main source for the highway data used in this study is the annual publication from the US Department of Transportation and the Federal Highway Administration, Federal Highway Statistics. Specifically, data for urban areas with populations greater than 5,000 residents were used and road and expenditure data pertaining to roads and highways that fit into the functional class of other freeways and express ways and other principal arterials.

The variable used as an indicator for road quality is based on Federal Highway Administration measurements of the International Roughness Index (IRI) as discussed previously. A variety ways of describing the dependent variable were explored. It was determined that looking at the number of miles of highway that have IRI values below 170, or the number of miles of road in each state that fall into the quality category of “good” and “acceptable” was preferable to using the percentage of total roads that fall into these quality categories or using data for “unacceptable” roads. Using the number of miles rather than a percentage is preferred for this study because it is likely that mile counts for the IRI data sets are less complete than those for total miles of roads which makes determining a true percentage more difficult. The variable representing road quality (*RoadQuality*) is defined as the number of miles of urban other freeways and expressways and other principal arterials with IRI values that are “good” and “acceptable.”

There are two variables included in the model that measure the effects of road and highway expenditure by states, capital outlay (*CapitalOutlay*) and maintenance (*Maintenance*) which are included separately. The variable representing capital outlay was calculated in $1,000’s and represents capital outlay expenditures in urban areas for roads that fall into the categories of other freeways and expressways and other principal arterials. The variable representing maintenance was calculated in $1,000's and represents maintenance expenditures in urban areas for roads that fall into the categories of other freeways and expressway and other principal arterials.

The variable that represents user fees diverted to mass transit purposes (*MassTransUserFees*) was calculated in $1,000's and is meant to approximate the amount of collected user fees that are being diverted away from road and highway projects towards mass transit purposes. It was not possible to separate urban from rural spending for this variable, but it is assumed that the majority of transit spending occurs in urban areas where transit services are more prevalent. The number of vehicle miles traveled (*VMT*) for each state was calculated as the number of vehicle miles traveled in urban areas on roads classified as other freeways and expressways and other principal arterials. For the OLS regressions this variable was measured by the Federal Highway Administration. For the 2SLS regressions, vehicle miles traveled (*VMT*), or the demand for roads, was estimated using variables representing urban population (*UrbanPopulation*), per capita income (*Income*), and motor vehicle registrations (*MVRegistrations*).

The variable representing urban population (*UrbanPopulation*), is defined as the population (1,000's of people) living in urban areas. The variable representing per capita state personal income (*Income*) was measured and calculated by the Bureau of Economic Analysis. The variable representing motor vehicle registrations (*MVRegistrations*) includes registrations of all motor vehicles owned privately, commercially, and publically as calculated at the state level by the Federal Highway Administration.

Table 6. Descriptive Statistics

Variable	**Mean**	**Standard Deviation**
RoadQuality	1,099 miles	1,059 miles
CapitalOutlay	$274,227,000	$414,914,000
Maintenance	$38,978,000	$63,184,000
VMT	14,010 million mi.	19,169 million mi.
MassTransUserFees	$60,886,000	$137,211,000
UrbanPopulation	4,680,000	6,007,000
Income	$31,895	$4,480
MVRegistrations	4,986,175	5,509,925

5.3 Model

The models used to examine the determinants of road quality are specified as:

$$RoadQuality = \beta_0 + \beta_1 CapitalOutlay + \beta_2 Maintenance + \beta_3 VMT + \beta_4 MassTransUserFees + \varepsilon$$

$$VMT = \alpha_0 + \alpha_1 UrbanPopulation + \alpha_2 Income + \alpha_3 MVRegistrations + e$$

The regression was estimated with both OLS and 2SLS. These models are primarily based on the empirical model used by Goel and Nelson (2003) and Oh and Sinha (2009). As discussed previously, Goel and Nelson used state highway expenditure as a proxy for road quality. This study attempts to better approximate road quality by using the IRI, a measure that is more closely connected to the physical condition of the road as a proxy for overall road quality. This use of IRI data more closely resembles models in the Oh and Sinha study as this is a direct measure of road quality.

The independent variables include *CapitalOutlay* and *Maintenance* as measures of state expenditure on roads and highways similar to the Oh and Sinha paper, the Goel and Nelson paper combined these two types of spending into one state highway expenditure variable. It is preferable to include them separately in order to examine if different types of spending impact road quality in different ways. Other independent variables in this model are *VMT*, which is included to measure the demand for roads, and is similar to the variable used in the Oh and Sinha study. Finally, *MassTransUserFees* is included to represent the amount of user fees diverted to non-highway purposes, specifically mass transit purposes, in order to examine the impact diversion of user fees has on road quality.

As mentioned previously, in the two stage estimation, *VMT* is estimated using variables thought to impact the demand for roads in urban areas. These variables include *UrbanPopulation*, *Income*, and *MVRegistrations* at the state level.

The following table summarizes the expected signs on the coefficients from the regression models.

Table 7. Summary of Expected Signs for Coefficients in Regression Models

Variable	**Expected Sign on Coefficient**
CapitalOutlay	Positive
Maintenance	Positive
VMT	Negative
MassTransUserFees	Uncertain

It is anticipated that the coefficient on *CapitalOutlay* will have a positive sign. This indicates that more state level spending directed towards building road infrastructure will lead to improved road quality. A positive coefficient is consistent with the results of previous studies and the generally accepted theory that more investment should lead to better roads and highways overall. The expected sign for the coefficient on *Maintenance* is also positive. Similar to increasing investment in capital outlay, increasing investment in maintaining roads and highways is expected to result in better overall road quality. It can be noted that previous studies have found that maintenance expenditures have a larger impact on pavement quality than capital outlay expenditures. Also, for the functional class of roads and highways examined in this study, there are significantly lower maintenance expenditures compared to capital outlay expenditures. It is unclear which type of expenditure will have a larger magnitude impact on road quality.

The variable *VMT* is included in the model because it is representative of the total demand for roads in each state. How heavily roads and highways are utilized is expected to significantly impact overall road quality. The expected sign for the coefficient on *VMT* is negative indicating that as the number of vehicle miles traveled increases or the demand for roads increases, lower road quality can be expected. This is consistent with the results of previous studies.

The expected sign on the coefficient for *MassTransUserFees* is somewhat uncertain. If the sign is positive, as previously discussed in the transit financing section of this study, shifting funds from highway to transit purposes should lead to better road quality if improving the transit system effectively reduces the demand for roads (vehicle miles traveled). A negative sign would indicate that improving transit systems by diverting a portion of user fees away from highways needs does not reduce demand for the road system enough to improve road quality.

5.4 Regression Results

The results of the OLS and 2SLS regressions are shown in the following table:

Table 8. OLS and 2SLS Regression Results[67]

Variables	**OLS - Dependent Variable: *RoadQuality***		**[68]2SLS - Dependent Variable: *RoadQuality***	
	Parameter (Standard Error)	t Value (Significance)	Parameter (Standard Error)	t Value (Significance)
Intercept	356.4507*** (69.87596)	5.10 (0.000)	344.9598*** (70.30109)	4.91 (0.000)
CapitalOutlay	.0006563** (.0002876)	2.28 (0.028)	.0005996** (.0002897)	2.07 (0.044)
Maintenance	.0029908* (.0017415)	1.72 (0.093)	.0029242 (.001748)	1.67 (0.102)
VMT	.0351648*** (.003848)	9.14 (0.000)	.0373031*** (.0039702)	9.40 (0.000)
MassTransUserFees	-.0007735* (.0004283)	-1.81 (0.078)	-.000779* (.0004298)	-1.81 (0.077)
	R^2 = 0.8854	N = 48	R^2 = 0.8846	N = 48
	Adj. R^2 = 0.8748	F Value = 83.09 Sig. = 0.0000	Adj. R^2 = 0.8736	F Value = 83.84 Sig. = 0.0000
	Wu-Hausman F Value = 6.05894, p = 0.0180			

A Wu-Hausman F test was conducted to determine if the variable *VMT* was endogenous to the model, the low p-value for the Wu-Hausman F statistic indicates that it is endogenous and a 2SLS model is preferred to the OLS model. Upon closer inspection, the signs on the coefficients are the same in both models and the coefficient values are very similar. Looking at the two stage regression, the majority of the coefficients were found to be statistically significant at conventional levels. The variable VMT is statistically significant at the 1% level, *CapitalOutlay* is significant at the 5% level, and *MassTransUserFees* is significant at the 10% level. The variable

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[67] The (*) symbols are used to indicate statistical significance at the following levels: *=significant at the 10% level, **=significant at the 5% level, ***=significant at the 1% level.

[68] Results from the first stage VMT estimation are included in Appendix B.

Maintenance is nearly statistically significant at the 10% level, just missing the mark with a t-value of 1.67.

The variables representing state highway expenditure, *CapitalOutlay* and *Maintenance*, took the expected positive sign indicating that as anticipated, increased spending on capital outlay and maintenance improves overall road quality. The coefficient on *Maintenance* was larger than the coefficient on *CapitalOutlay* which is consistent with the finding in the Oh and Sinha (2009) study. Even though significantly less is expended on maintenance relative to capital outlay, maintenance spending appears to have a greater impact on road quality.

The sign on the coefficient for *VMT* was also positive, which was unexpected. This indicates that more demand for roads does not necessarily reduce road quality. The unexpected positive sign may be explained by the cross sectional nature of the data. It is possible that the number of vehicle miles traveled or demand level for roads and highways in a single year is not large enough to significantly negatively impact road quality. It might take several years before deteriorating road quality is observed. This theory seems to be supported by the findings of Oh and Sinha (2009).

The coefficient on *MassTransUserFees* was found to be negative. This indicates that diverting user fees to a non-highway purpose such as mass transit reduces overall road quality. This suggests that spending funds collected as user fees for purposes that are not related to the capital outlay and maintenance of the road system may negatively impact road quality. Additionally, investment in transit does not significantly shift users preferred mode of transportation in favor of transit strongly enough to reduce the demand on roads; therefore investment based solely to control road quality may not be worthwhile.

5.5 Spearman Rank Order Correlation Results

A Spearman rank order correlation test was used to examine the relationship between state user fee gaps and the percentage of roads and highway that fall into the unacceptable IRI category. This test is used to determine if a shift in preference from optimal user fee financing towards more general financing methods impacts road quality. Results are as follows:

Table 9. Spearman Correlation Results

Spearman's ρ	0.0430
P-Value	0.7718
Null Hypothesis: User Fee Gap and % Unacceptable IRI are independent	

Spearman's $\rho = 0.0430$ indicating that there is only a slight positive correlation between user fee gaps and road quality. The null hypothesis that user fee gaps and miles of unacceptable IRI are independent is accepted. This indicates that states that have large user fee gaps, meaning that they likely use more general financing methods as opposed to marginal cost pricing through user fees, do not necessarily observe lower road quality.

Chapter 6. Conclusion

Results indicate that state expenditure on roads and highways is indeed a significant factor in determining road quality. There is evidence that both expenditures on capital outlay and maintenance have measurable impacts on road quality. Even though less funding goes towards maintenance relative to capital outlay, results indicate that maintenance expenditures have a larger relative impact on road quality. This implies that states that desire to see improvement in urban road quality may be best served by maintaining adequate investment levels in road maintenance budgets.

It seems that a shift in preference from optimal user fees to supplementing user fees with other sources of financing does not impact road quality significantly. There is no evidence to support the theory that where funding comes from plays an important role in determining road quality. States that have large user fee gaps do not seem to have systematically lower road quality.

It was also found that diverting road user fees to mass transit purposes has a statistically significant negative impact on road quality. Results indicate that diverting user fee revenues to mass transit leads to lower overall road quality. Although investing user fees in mass transit reduces road quality, from a policy stand point there are other factors to consider, such as the impacts transit may have on environmental factors or other cost savings.

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APPENDICES

Appendix A Definition of Variables

Table 10. Variables: Definitions and Sources

Variable	Definition	Source
RoadQuality	Road quality is defined as number of miles of road in the functional categories other freeways and expressways and other principal arterials that have IRI values below 170, or fall into the quality category of "good" or "acceptable."	US Department of Transportation, FHWA: Federal Highway Statistics, (2005): Table HM-64.
CapitalOutlay	Total state expenditure on capital outlay in thousands of dollars in urban areas with populations greater the 5,000 on roads that fall into the functional class of other freeways and expressways or other principal arterials.	US Department of Transportation, FHWA: Federal Highway Statistics, (2005): Table SF-12.
Maintenance	Total state expenditure on maintenance in thousands of dollars in urban areas with populations greater the 5,000 on roads that fall into the functional class of other freeways and expressways or other principal arterials.	US Department of Transportation, FHWA: Federal Highway Statistics, (2005): Table SF-12.
VMT	Total annual vehicle miles traveled on urban roads that fall into the functional class of other freeways and expressways and other principal arterials in millions of miles.	US Department of Transportation, FHWA: Federal Highway Statistics, (2005): Table VM-2.
MassTransUserFees	State expenditure of revenues collected from motor fuel and motor vehicle taxes used for mass transit purposes in thousands of dollars.	US Department of Transportation, FHWA: Federal Highway Statistics, (2005): Table SDF (also reference tables MF-3, MV-3).
UrbanPopulation	Total urban population in each state in thousands of residents.	US Department of Transportation, FHWA: Federal Highway Statistics, (2005): Table PS-1.
Income	State personal income, in per capita dollars.	US Bureau of Economic Analysis, Table 1. Per Capita Personal Income, Personal Income, and Population, by State and Region, 2005-2006.
MVRegistrations	Total number of motor vehicle registrations in each state, includes all private, public, and commercial vehicle registrations.	US Department of Transportation, FHWA: Federal Highway Statistics, (2005): Table MV-1.

Appendix B Results of VMT Estimation

Table 11. First Stage Results of 2SLS Regression[69]

Variables	**Dependent Variable: *VMT***	
	Parameter (Standard Error)	t Value (Significance)
Intercept	-2299.402 (5063.733)	-0.45 (0.652)
UrbanPopulation	1.551898*** (.5763549)	2.69 (0.010)
Income	.0146823 (.1547777)	0.09 (0.925)
MVRegistrations	.0017205*** (.0006172)	2.79 (0.008)
	R^2 = 0.9542	N = 48
	Adj. R^2 = 0.9511	F Value = 305.76 Sig. = 0.0000

[69] The (*) symbols are used to indicate statistical significance at the following levels: *=significant at the 10% level, **=significant at the 5% level, ***=significant at the 1% level.