Policies for highway financing: Gasoline taxes and other alternatives

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POLICIES FOR HIGHWAY FINANCING: GASOLINE TAXES AND OTHER

ALTERNATIVES

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ABSTRACT

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The development and maintenance of highway infrastructure in the US is becoming an important challenge due to increasing costs and revenues that are not adequate to meet the costs. Traditionally, fuel taxes have provided a significant portion of the revenues for the highway network. This research evaluates the impacts of changes in automobile and light truck fleet fuel economies, as well as hybrid and alternative fuel vehicles in the fleet, on gasoline tax based revenues. Vehicle sales, vehicle survivability, and fuel consumption data from 1980 to 2005 were used to estimate the fleet mix, Vehicle Miles Travel (VMT) by fleet mix, and revenue projections through the year 2025.

Six options were identified and evaluated to help address the revenue needs for highway financing: 1) gasoline tax as a fixed amount per gallon, 2) gasoline tax as a percent of the gasoline price, 3) toll based options, 4) user fee based on vehicle miles traveled (VMT), 5) tiered system of user fee based on VMT, and 6) user fees based on
axle load and VMT. The results indicate that increasing the existing gasoline tax by 10 cents per gallon would not generate enough revenues to maintain the transportation infrastructure over time, unless they are indexed to the Producer Price Index (PPI). However in this scenario, hybrid vehicles and alternative fuel vehicles would not be paying their fair share for using the system. Tolling, when implemented for urban interstates at a rate of 10 cents per vehicle mile and indexed to the PPI, would generate enough revenues to maintain the system. A VMT based system, when implemented using the 1993 gasoline tax rate adjusted by the Consumer Price Index (CPI) would generate enough revenues to maintain the system. A tiered structure based on VMT, or an axle load and VMT based method would generate enough funds to maintain the system over the years provided the 2009 rate required to maintain the system is indexed to the CPI. Sensitivity analyses show that even with the revised user fee structures, there would be savings for the users of hybrid and alternative fuel vehicles.

The results indicate that the existing gasoline tax policy would not be able to generate revenues required to maintain and improve the US highway network in the years to come. Among the six options explored herein, the best alternative is a VMT based user fee. Further, it is important to index user fees based on either CPI or PPI. The implementation of the proposed options requires overcoming various challenges. Such challenges include political, behavioral, social, equity, economic, and technological considerations. In the meantime, it is important to continue with the existing gasoline tax policy and revise it to meet, at least partially, the increased need for revenues to maintain the highway system.
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CHAPTER 1

INTRODUCTION

The global economy is pressuring countries to upgrade their transport infrastructure so as to remain competitive, gain advantage, or to keep from falling behind. International trade in the US increased from 13 percent in 1990 to 30 percent in 2007. The volume of international containers coming into the US ports annually is estimated to increase from 40 million in 2007 to 110 million in 2020. Providing mobility in the US is getting tougher because of the inability to keep the system capacity on pace with the increases in demand. Economic forces in Asia are investing heavily in their infrastructure development. This, along with the eroding quality of the transport and civil infrastructure in the US, is challenging the economic vitality and global leadership role of the US (AASHTO, 2007a).

Highway programs derive a portion of their funding from user fees such as taxes and charges levied on vehicles and their operators in relation to their use of roads. The motor fuel excise tax, also known as gasoline tax or fuel tax is one of the major contributors of such road user fees. The federal excise tax revenue generated from this tax increased from $125 Million in 1933 to $21 Billion in the year 2002 (Talley and Jackson, 2004). More than one-third of the $133 billion in total U.S. revenue available for highway spending in 2001 came from federal and state gas taxes. State gas taxes alone made up 21.6 percent of all highway revenues that year (Puentes and Prince, 2003). In 2004, fuel
tax accounted for about 64 percent of the highway user fee revenue (TRB, 2006). Other major contributors of highway user fees include vehicle registration fees, excise taxes on truck sales, and tolls. About 80 percent of the highway user fee is dedicated to highway spending (TRB, 2006).

When gas tax revenues over time are considered, it is seen that after years of steady growth, federal and state gas tax receipts stabilized in the late 1990s. When accounting for inflation, federal and state gas tax revenues are actually declining (Puentes and Prince, 2003). The federal fuel tax on gasoline has been based on a fixed amount per gallon of fuel sold, and not as a percentage of the sale price of gasoline. Thus, changes in automotive technologies, fuel prices, and new energy regulations could cause significant reductions in fuel consumption and hence a severe reduction in fuel tax revenues. This will affect the current system of highway financing. Boarnet (1999) explains that in the current system travel on most of the highways is essentially free to the drivers. The author emphasizes that similar to the use of any free good, the lack of a price will encourage inefficient consumption. A decrease in revenues coupled with increases in construction, operations, and maintenance costs for highways will make the future for highway funding one of the most critical issues in infrastructure development and maintenance in the US.

Much of the research identified in the literature review focuses on identifying alternatives for highway funding. Potential alternatives identified include charging tolls, road use metering, and mileage based charges. However, making these modifications throughout the US would require significant time for policy development and implementation. Delays in developing the alternative finance arrangements would be
costly. In the interim, it will be necessary to depend on fuel tax and other existing fees as the primary funding sources. Even after the deployment of various modifications to generate revenues from road users, fuel taxes are expected to continue to serve a major part of the highway funds.

1.1. Motivation for the Study

Several studies (AASHTO 2007b, AASHTO 2007c, and NCHRP 2006) state that the gasoline tax based system needs to be restructured, and they identified potential alternatives. However, these studies do not document any detailed analysis of revenue generated for the various options. Typically these estimates rely on projected gasoline consumption based on historical data. Changes in automotive technologies over the years have improved the fuel efficiency of vehicles. The existing studies identified in the literature do not document the impacts of these changes on the revenues derived from the gasoline-based user fee structure. The introduction of hybrid vehicles and alternate fuel vehicles is expected to cause significant challenges the gasoline tax based revenue system in the years to come. Therefore, it is important to study these impacts and evaluate alternatives to generate the necessary revenues to maintain and enhance the highway network.

1.2. Objective

The objective of this research is to identify the impacts of changes in automotive fleet fuel efficiencies on fuel tax revenues. The projected fuel tax revenues will be estimated for various projected combinations of vehicle fleets and travel demand. The research
studies current practices in the US to generate fuel taxes and to estimate future fuel tax revenues considering the historical growth patterns together with projected changes in technologies as well as under varying policies. This is to help identify changes in fuel tax revenues for different scenarios and their effects on highway funds. The study also identifies alternative means to generate user based revenues for highway maintenance and improvement programs. These results can be used to enhance awareness among decision makers, elected officials, and the general public of the seriousness of the issue and the importance of policy changes needed to address the financial needs for the future of the road infrastructure development in the US.

Chapter 2 of this report summarizes the literature review related to present highway financing scenarios. In Chapter 3, future financing requirements for a future year is estimated. Chapter 4 summarizes the methodology followed in this study to estimate revenues based on gasoline tax and other alternatives. Chapter 5 explores various options discussed in Chapter 4 for various scenarios. Implementation strategies for each of the options considered are discussed in Chapter 6. Conclusion, discussions and recommendations for future work are documented in Chapter 7.
CHAPTER 2

LITERATURE REVIEW

Several previous studies have analyzed the transportation funding scenarios for the US infrastructure. This chapter summarizes a review of the literature identified in this research effort. This section is divided into several sub-sections as follows.


In a research paper, Roth (1996) discusses the radical changes road financing in the United States since the nation's formation in 1776. This paper indicates that the passage of the Federal-Aid Highway Act in 1956 resulted in a major role for federal financing, which enabled the Interstate Highway System to be rapidly completed.

Hecker (2002) states that the Highway Trust Fund (HTF) is the principle mechanism for funding federal highway programs authorized by the Transportation Equity Act for the 21st Century (TEA-21). Federal highway user taxes directed to the Highway Trust Fund include excise taxes on motor fuels (gasoline, gasohol, diesel, and special fuels); and truck-related taxes on truck tires, sales of trucks and trailers, and the use of heavy vehicles. Oil companies typically pay a per-gallon tax on the motor fuels at the point where their fuel is loaded into tanker trucks or rail cars at a terminal. Tire manufacturers pay taxes on truck tires, by weight; and retailers pay taxes on the sales price of new
trucks and trailers. Owners of heavy highway vehicles pay taxes on the use of these vehicles, making this the only highway tax directly paid by the highway user.

Talley and Jackson (2004) list historical revenues of the gasoline excise tax. The federal government first imposed a gasoline excise tax with the passage of the Revenue Act of 1932. The rate was one cent per gallon. During the early years of the tax, the proceeds went into the general fund of the Treasury. The gasoline tax rate stands at 18.4 cents per gallon. This rate has provided a reliable and steady source of receipts. Since the fiscal year 1997, gasoline taxes have generated over $20 billion per year for the Highway Trust Fund with the vast majority of receipts disbursed through the Highway and Mass Transit Accounts.

Jackson (2006) describes the history of the Federal excise tax on gasoline and the Highway Trust Fund. Starting with the state of Oregon, which enacted the first tax on motor fuels in 1919, all states and the District of Columbia had followed suit with tax rates that ranged between two and seven cents per gallon by the year 1932. The federal government first imposed its excise tax on gasoline at a one-cent per gallon rate in 1932. This report illustrates different phases of the Highway Trust Fund. In the short run, any increase in the gasoline tax is generally passed forward to the retailer, translating into a higher retail gas sales price. As recently as 1990 and 1993, Congress passed legislation dedicating a portion of gasoline tax revenue for deficit reduction. Out of the current 18.4-cent per gallon tax imposed on gasoline 15.44 cents per gallon, is earmarked to the Highway Account, also within the Highway Trust Fund the remaining portions are assigned to transits and other transportation related operations. The author indicates that Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
(SAFETEA-LU) signed by President Bush in 2005 provides a six-year extension of the Highway Trust Fund excise taxes that were scheduled to expire in 2005. Thus, the gasoline excise tax is now scheduled to expire after September 30, 2011. The act also established a Motor Fuel Tax Enforcement Advisory Commission. Among the Commission’s duties will be to review motor fuel revenue collections, investigations related to motor fuel taxes and to help develop and review legislative proposals with respect to motor fuel taxes.

The congressional authorizing acts that provided for these and other revisions to the fund's funding levels and administrative procedures from 1956 to 2003 are documented in this report (McDaniel and Coley 2004). The fund's history is an important subject because of the proposed extensions to the fund, the fund's supporting revenues, and the transportation programs it finances. Here the author indicates that the fund, whose principal purpose was to finance the construction of the Interstate highway system, with an original intention was to terminate the fund when that effort was accomplished. However this has morphed into an ongoing method of financing a broad range of federal transportation programs and now comprises both a highway account and a mass transit account. This report analyzes significant changes in the fund tax levels. The congressional authorizing acts that provided for these and other revisions to the fund's funding levels and administrative procedures from 1956 to 2003 are documented.

More than one-third of the $133 billion in total U.S. revenue available for highway spending in 2001 came from federal and state gas taxes (Puentes and Prince 2003). State gas taxes alone made up 21.6 percent of all highway revenues that year. This report points out that the state gas tax is also the largest single source of highway funding for
the states. When accounting for inflation, federal and state gas tax revenues are actually declining from late 1990's. Only three states raised fuel taxes enough to keep pace with inflation. Although the average state gas tax rate increased by 8.7 percent, in real terms, the average gas tax rate declined by about 14 percent. This report also identifies that the existing distribution of the gas tax within some states appears to penalize cities and urban areas, which contribute significantly more in tax receipts than they receive in allocations from their state's highway fund or through direct local transfers.

Siggerud (2006) reviews the two different estimates for future Highway Trust Fund estimates. These two are the semiannual estimates prepared by the Department of Treasury and the Congressional Budget Office (CBO). The agencies' most recent estimates show that the Highway Account within the Highway Trust Fund could have a negative balance as early as 2009, raising concerns about whether funding for federal highway programs—which were recently authorized by the SAFETY-LU will continue to be met. The Government Accountability Office (GAO) reviewed and compared recent estimates made by these two agencies. This report documents information on how (1) estimates are used to provide key information about the Highway Trust Fund, (2) the most recent Highway Trust Fund estimates-based on receipt estimates made by Treasury and CBO-compare, and (3) Treasury's and CBO's estimates compare to actual receipts for recent years. In this report the author indicates that due to the complexities associated with the process of the receipts and disbursement of the Highway Trust Fund, estimates are used regularly not only to project the Highway Trust Fund's future balance, but also to determine its current balance. This report also shows that even though Treasury and CBO use different assumptions to estimate receipts for the fund, the Highway Trust Fund
estimates from the President’s Budget and CBO show similar trends. The Highway Trust Fund balance is projected to steadily decline because estimated outlays of the Highway Account exceed estimated revenues each year from 2006 through 2011. Treasury projects lower receipts levels than CBO, and therefore the President’s Budget contains estimates of negative Highway Trust Fund balances occurring one year earlier than CBO is projecting. Here, the author mentions that the differences in receipts estimates developed by Treasury and CBO are caused in part by the use of different economic assumptions, such as economic growth and fuel prices.

An article by Forkenbrock (2006) discusses the long term impacts of how the local governments are changing the ways that they finance streets and roads. The author finds that since the motor fuel tax becomes less productive, the states and the federal government have been devolving the responsibility for financing these vital facilities to local governments, the local governments are forced to utilize general fund revenue and have increasingly adopted local option taxes. In general, since these local taxes have no direct relationship to actual road use, this system would affect local government’s overall budget. The author states that without policy innovations, the dependence on non-use-related financing of local roads will increase as people tend get attracted more towards alternate and fuel efficient vehicles such as, hybrids and hydrogen fuel cells. This paper also discusses several possible policy directions to increase the role of direct road user charges. These options would help local agencies to assign more of the financing burden for local roads from those paying property and sales taxes to actual users of the roads within a community.
The California Department of Transportation, (Caltrans, 2005) uses a series of charts to show sources and uses of transportation funds in California. The charts cover these types of funding sources: state fuel taxes, truck weight fees, Federal Highway Trust Fund, gasoline sales tax, diesel fuel sales tax, general sales tax, local sales tax measures, and toll bridge revenues. This document shows the significance of gasoline taxes on the overall transportation funds for the state of California.

Hecker (2002) explains how tax revenues are distributed into the Highway Trust Fund, the General Accounting Office (GAO) review of the fiscal year 2003 Revenue Aligned Budget Authority (RABA) calculation and ways to reduce fluctuations in the RABA adjustment, the impact of gasohol on the Highway Trust Fund, and industry proposals of ways to increase revenues into the trust fund. The GAO believes that the fiscal year 2003 RABA appears reasonable. Although the fiscal year 2003 RABA adjustment of a negative $4.369 billion is severe, it is largely a reflection of the multiple ways a downturn in the economy affects the calculation. One way that the RABA adjustment could be changed to help reduce fluctuations in highway funding is that the RABA adjustment could be distributed over 2 years. The use of ethanol-blended fuel (gasohol) instead of gasoline reduces Highway Trust Fund revenue because gasohol is partially exempt from the standard excise tax on gasoline (18.4 cents), and 2.5 cents on each gallon of gasohol soled is transferred to the General Fund. Industry groups have proposed a number of ways to increase Highway Trust Fund revenues in order to address future transportation needs. One proposal is that the trust fund be paid interest on its balance. Other proposals are aimed at altering the current user tax structure to increase Highway Trust Fund revenue.
2.2. Issues Associated with the Existing System

Lemer (2006) provides a history of highway spending and transportation spending from the early years of the automobile. In this article the author examines the gas tax and whether it will continue to play such a key role in transportation funding. With the expected sales of fuel are headed down, the tax revenues are also expected to fall. The author points out that currently, gasoline taxes cover about 87 percent of federal highway spending. On the other hand, on the state level, the gas tax covers only six percent of expenditures. The author winds up the report by exploring some alternatives, including tolls, area charging schemes and mileage charges.

Increased fuel efficiency and the use of alternative fuels were seen as potential threats to future road finance due to the heavy reliance on fuel taxes (Rufolo, Bertini, and Kimpel 2001). Giving primary focus passenger vehicles, this report mentions that the technological progress in vehicle fuel-efficiency, alternative fuel vehicles, and methods of collecting alternative types of revenue has been substantial.

An article by Wachs (2003) presents 12 reasons for supporting higher motor fuel taxes. They are: (1) motor fuel taxes are lower now than in the past; (2) fuel taxes are below levels in other countries; (3) fuel taxes are below their theoretical optimum; (4) drivers show high tolerance for fuel price changes; (5) the cost of transportation projects continues to rise faster than revenue; (6) congestion is growing in part because not enough is being spent on new capacity; (7) relative declines in fuel tax revenues increase reliance on non-transportation related taxes to support transportation projects; (8) the relative decline in fuel tax revenues is increasing borrowing for transportation projects and programs; (9) fuel taxes have low collection costs and are relatively fraud-proof; (10)
fuel taxes are user fees that send price signals to motorists to use the transportation system more efficiently; (11) fuel taxes are fairer for lower income groups than other alternatives; and (12) fuel taxes make it easier to transition to better user fees in the future.

The fuel tax-based system that has worked for more than 50 years can no longer meet future transportation needs (Innovation Briefs 2006). In this commentary, the author discusses some viable ways to raise money for new highways in order to supplement eroding resources of the Highway Trust Fund. According to the author, one of the most feasible way is a mileage-based revenue system could in the distant future provide a solution. On the other hand for the short term, the author suggests that states and other localities may need to raise private investment capital in exchange for long-term toll concessions. In this report, the author suggests that the creation of express toll lane networks in all urban areas of the country in order to provide congestion-free travel to anyone for a fee would be one of the final options.

Delucchi (2007) investigates whether the motor vehicle users in the US pay their share for road use. This study concludes than while the European users pay excess of what is necessary to maintain and improve the roadway system, their US counterparts do not even pay their fair share for roadway use. The author suggests, after considering several factors, such as reduction in fuel consumption, a raise in gasoline tax by $1 may be necessary to make the users pay for their use.

A study by the American Trucking Association, (McNally 2005), the study panel identifies that due to the expected reduction in tax revenues and increases in construction and maintenance costs associated with highways, fuel tax would be required to be
increased. Here, the group identifies that it might consume some more years to implement and efficient mile-based charging system.

Levinson and Yerra (2002) relate highway expenditures with the share of expenditure by state governments to determine how governments should allocate expenditure on all roads in a state. Using regression models to predict different highway expenditures on each highway class as a function of utilization, capacity, and funding shares are estimated. Both governments and transportation networks are both hierarchically organized. This paper discusses the financing scheme between state agencies and local agencies for different states for financing for their highways. In this paper, highways are divided into two hierarchical classes (higher and lower), governments into two layers (state and local), and costs into capital and operations and maintenance. The results can be applied in formulation of efficient network financing arrangements.

A report by CBO (2004), the issue of increasing corporate average fuel economy (CAFE) standards for passenger vehicles is discussed. While proponents of CAFE standards see the policy as a relatively low cost and proven way to decrease the United States' dependence on oil and emissions of carbon dioxide, the opponents argue that CAFE standards are a costly and cumbersome way to reduce gasoline consumption, that they interfere with the market and unduly burden U.S. business, and that they may compromise the safety of motorists by altering vehicle designs. This report discusses CAFE standards for different vehicle classes. All major auto makers currently meet or exceed the standards. In this report also focuses on the economic costs of CAFE standards and compares them with the costs of a gasoline tax that would reduce gasoline consumption by the same amount. The Congressional Budget Office (CBO) estimates
that a 10 percent reduction in gasoline consumption could be achieved at a lower cost by an increase in the gasoline tax than by an increase in CAFE standards. Furthermore, an increase in the gasoline tax would reduce driving, leading to less traffic congestion and fewer accidents. Since this report does not perform a cost analysis of the value of less congestion and fewer accidents, it does not draw any conclusions about whether an increase in the gasoline tax would be warranted. However, CBO does find that, given current estimates of the value of decreasing dependence on oil and reducing carbon emissions, increasing CAFE standards would not pass a benefit-cost test.

In another study by the CBO, Dinan and Austin (2002) compares three methods of reducing gasoline consumption: increasing the corporate average fuel economy (CAFE) standards that govern passenger vehicles; raising the federal tax on gasoline; and setting a limit on carbon emissions from gasoline combustion and requiring gasoline producers to hold allowances for those emissions. The study weighs the relative merits of those policies against several major criteria: whether they would minimize costs to producers and consumers; how reliably they would achieve a given reduction in gasoline use; their implications for automobile safety; and their effects on such factors as traffic congestion, requirements for highway construction, and emissions of air pollutants other than carbon dioxide. In addition, the analysis examines two more policy implications that lawmakers may be concerned about: the impact on people at different income levels and in different regions, and the effects on federal revenue.

DOTs have been searching elsewhere for potential sources of revenue because of the speculation regarding instability of the Highway Trust Fund (Ichniowski and Buckley 2006). This report indicates that such efforts have crystallized in the National Surface
Transportation Policy and Revenue Study Commission, which was inaugurated by the SAFETEA-LU. This report summarizes different options available including increasing the existing U.S. federal gasoline tax from 18.4 US cents/gallon which has been used since 1993. Reservations about these different options are also described.

Orski and Woof (2006) looks at funding challenges that await the U.S. Interstate Highway system in the coming future. The author estimates that at the current rate of spending, there will be a $23 billion deficit at the end of 2009. With the anticipated change in vehicle fleet mix, income from fuel taxation is expected to decrease. The author also points out that in order to compensate for the loss in revenue and increase in costs, the Highway Trust Fund would require gas taxes of 10 to 15 cents per gallon. The author reports, however, that raising gas taxes is a hot political issue, and raising funds through tolling may be less difficult.

Considering the seriousness of the taxation issues, Laurio (2002) points out that increasing fuel taxes and limiting road projects are the two major solutions for accommodating reduction in tax revenues.

2.3. Alternate Funding Options

The Oregon Dept. of Transportation (ODOT) is trying out a pay-as-you-go approach in an attempt to maintain fuel tax revenue levels for transportation funding (McFall and Cho 2005). As the gas prices increases, the motorists are considering switching to fuel-efficient cars, thus impacting the availability of fuel tax revenues. This paper discusses an in-vehicle system that uses a smart odometer paired with wireless technology developed by researchers at Oregon State University for calculating how many miles a vehicle
travels before needing to be refueled. A fee, rather than a gasoline tax, would then be added to the cost of gas when refueling. In an effort to halt privacy concerns, the system only receives location data and logs only the number of miles since the last refueling.

Analyzing the revenue associated with vehicle miles traveled (VMT), Minnesota state and local agencies spend averages 5 cents per VMT statewide (Ryan and Stinson 2003). However, travel on local government roads, especially low volume networks, costs more. State road aid reduces the local tax effort significantly in most high cost areas. The average like most of the other states, Minnesota’s local road funding is supported primarily with motor fuels excise taxes, vehicle registration and sales taxes, and local property taxes. On an average, a household pays about $600 annually for roads, but this estimate varies widely with household characteristics. This paper indicates that substituting travel-dependent taxes for fixed or hidden charges could improve the tax system efficiency, and potentially distribute the road tax burden more fairly. The author also mentions that compared to current law, even radical tax reform may not change the road tax bill for some households.

Ryan (2006) compares twelve different options for financing local roads are examined in this report related to property access, vehicle use or local economic activity. The authors identify property taxes, special assessments, vehicle registration taxes, motor fuel taxes and local sales taxes as the most frequent levied taxes. This report also recommends that the benefits of any individual road tax must be judged in the context of the larger state and local tax system.

A briefing (Innovation Briefs 2006) analyzes the impending highway transportation funding crisis and illustrates solutions recommended by several organizations. Per the
estimates by the Chamber Foundation, between 2006 and 2015 annual Highway Trust Fund revenues will fall an average $23 billion short of the amount required to maintain the present system and $48 billion short of that needed to improve the system. Looking at solutions to recover the issue, this article suggests indexing federal motor fuel taxes to help narrow the revenue gap in the short term. In the long run, it recommends various alternatives, such as, a two-tier mileage-based revenue system, state vehicle-miles of travel (VMT) fee, and expansion of tolling.

In another briefing, (Innovation Briefs 2006a) the author takes note of the growing acceptance of tolls and variable road pricing, and the private sector’s willingness to finance, construct and operate toll roads. Looking at the feasibility of implementation, the author suggests that for the immediate and near future, tolls are the most practical and logical ways to supplement the gas tax. In the long term, a mileage-based tax may replace the fuel tax. The article describes the advantages of tolls and their growing importance.

An article by Forkenbock (2005) explores a series of issues related to implementing a mileage-based road user charge. The article first presents an overview of a mileage-based road user charge approach, then examines a variety of issues related to its implementation, and concludes that substantial benefits from implementing this new form of user charge are possible. This user charge is intended to eventually replace the motor fuel tax, which is certain to become increasingly less productive as gains in fuel mileage occur and as electric hybrid and eventually hydrogen fuel-cell vehicles enter the market. The author also cautions that before so great a change can occur as to how roads in the United States are financed, a series of policy and operational considerations must be addressed.
An article (Innovative Briefs, 2002) points out that long-term growth of trust fund revenues may be seriously impaired by the prospect of more fuel efficient cars and increased market penetration by hybrids and fuel-cell-powered vehicles that do not use petroleum-based fuels. Every 1-mile-per-gallon increase in fuel efficiency is estimated to result in a $3.5 billion loss of income to the trust fund. In order to keep pace with the future highway and transit needs, entirely new funding mechanisms may need to be devised to supplement or replace the gasoline tax in the very long term. In this article, some tentative thoughts are offered on what these alternative funding concepts might involve.

Kriger (2006) points out that the traditional public sector funding sources are less able to meet the growing demand for highway infrastructure in the United States. Therefore, some state departments of transportation (DOTs) and metropolitan planning organizations (MPOs) are considering alternative methods such as, tolling, to finance new highway projects.

Critics predict that sales of fuel are headed down, which will cause tax revenues to fall (Lemer, 2006). This article examines the gas tax and whether it will continue to play such a key role in transportation funding. Currently, they cover about 87 percent of federal highway spending. However, on the state level, the gas tax covers only six percent of expenditures. The author explores some alternatives, including tolls, area charging schemes and mileage charges. Utility districts are another alternative. Local communities that take the initiative in starting such arrangements could help steer the debate when and if the gas tax is abolished or loses its importance.
In a study identifying the role of fuel tax and identifying alternatives for transportation funding (Morris, 2006), the committee has assessed the future of traditional transportation finance. The committee stressed the need for methods of charging fees that relate directly to the cost of providing services, and recommended immediate changes to strengthen the highway and transit finance system.

All states rely on gasoline taxes as one source of funds for road improvement and maintenance (Rufolo, Bertini, and Kimpel, 2001). Increasing fuel efficiency and alternative fuel vehicles reduce both the equity of the revenue source and its growth over time, threatening the existing financing systems. On the other hand, improved technology has made more direct pricing of road usage more feasible. This paper summarizes some of the economic issues that arise in moving toward the more extensive use of road pricing as a substitute for fuel taxes.

Samuels (2005) illustrates by using miles traveled, the cost of funding highways in the U.S. may require the country to adopt road user charging (RUC). It is predicted that by 2012 or 2015, enough U.S. vehicles will be installed with the equipment necessary to make road user charging practical. An increase in fuel tax is considered to be unlikely, while its buying power is also viewed as being far less than it once was.

Declining transportation funding is a reality that is faced by most states across the country and is a concern of the Federal Highway Administration (Sisiopiku et al., 2006). To address such issues this study investigated both traditional and innovative highway financing options for the state of Alabama are analyzed in detail. Options considered include: (a) vehicle mileage road user fee, (b) heavy truck road user fee, (c) public toll roads, (d) private toll roads, (e) privatization of highway projects, (f) private funding
using bonds, (g) inspection fees, and (h) increase in the fuels tax. For each option, implementation requirements, institutional issues, and anticipated costs and benefits from adoption were identified and assessed. The review and evaluation of available options indicated that, for the immediate future, the most desirable solution to funding Alabama's highways with respect to efficiency and effectiveness is to increase the fuel tax to at least $0.27 per gallon. However, as the gasoline tax revenue declines, additional options should be considered and future plans made to implement alternative financing solutions to complement or replace the fuel tax revenue. The most promising options include inspection fees, toll collection, and reallocation of funds generated from vehicle registration fees and title fees.

Because of the numerous merits that the fuel tax has, many believe that it will remain the mainstay of the transportation finance for years to come. On the other hand, the growing political resistance to fuels tax increases, and the rise of alternative propulsion vehicles, makes this conventional system's existence challenging. This article (Sorensen and Taylor, 2005) summarizes an extensive review of innovative electronic tolling applications around the world. The review included projects already in operation as well as those that have been proposed or are in the advanced stages of planning; each was evaluated in terms of policy, technology, and political acceptance issues.

A report by the TRB (2006) examines the different existing revenue sources, the merits of present transportation finance arrangements, and potential directions for reform of transportation finance. This report summarizes that that fuel taxes can remain the primary funding source for the nation's highways for at least another decade. However, it
needs to be replaced by a system using metered road use technology, which would benefit both the public and the agencies.

The literature review shows that the revenue stream for the highway trust fund is declining. Most of the documented research efforts aimed to identify alternate arrangements to the gasoline tax, such as charging based on usage. Adapting to a newer technique for user fee collection requires considerable time and in the interim, the fuel tax would be the primary source of revenue for transportation infrastructure. Further, the literature review points to the need to evaluate the impacts of high fuel efficient vehicles on the gasoline tax revenues and potential alternatives for highway financing. Such concerns are addressed in this research through the identification of alternative policies for highway financing and an evaluation of these strategies.
CHAPTER 3

ESTIMATE TRANSPORTATION FINANCING NEEDS FOR A FUTURE YEAR

The American Association of State Highway and Transportation Officials published a report (AASHTO, 2007d), with information on future revenue requirements for the highway infrastructure and transportation infrastructure in the US for the years from 2005 to 2021. This report shows the required funding for two scenarios:

a) to maintain the existing systems; and
b) to improve the system for future demands.

These estimates are based on an assumption that the historic split between the federal and state/local share of surface transportation capital costs is maintained. Since the analysis horizon for this study is 2025, the values obtained from AASHTO are projected to the year 2025. The data are shown in Table 1. This table shows that in the year 2025 $84.1Billion is required to maintain the US highway system, as compared to $119.1Billion to improve the highway facilities. Similar figures for the overall road transportation systems (including public transportation systems) are $98.5B and $139.8B, respectively. Since the public transportation systems are integral part of the transportation infrastructure, it is important to include their needs also in the planning process.

Although table 1 provides information regarding the required revenues for the future years, only a portion of it is expected from gasoline taxes, the remaining coming from
other sources, such as diesel tax, sales tax on trucks, heavy vehicle use tax, and tax on truck tires.

Table 1. Estimated Total Revenues Required for the Future Road Transportation Needs (in $Billions)

<table>
<thead>
<tr>
<th>Year</th>
<th>Requirement to Maintain Highway</th>
<th>Requirement to Maintain Total</th>
<th>Requirement to Improve Highway</th>
<th>Requirement to Improve Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>$46.6</td>
<td>$55.4</td>
<td>$65.6</td>
<td>$78.6</td>
</tr>
<tr>
<td>2006</td>
<td>$48.0</td>
<td>$57.1</td>
<td>$67.6</td>
<td>$81.0</td>
</tr>
<tr>
<td>2007</td>
<td>$49.4</td>
<td>$58.8</td>
<td>$69.6</td>
<td>$83.4</td>
</tr>
<tr>
<td>2008</td>
<td>$50.7</td>
<td>$60.3</td>
<td>$71.5</td>
<td>$85.6</td>
</tr>
<tr>
<td>2009</td>
<td>$52.0</td>
<td>$61.9</td>
<td>$73.3</td>
<td>$87.8</td>
</tr>
<tr>
<td>2010</td>
<td>$53.2</td>
<td>$63.4</td>
<td>$75.1</td>
<td>$89.9</td>
</tr>
<tr>
<td>2011</td>
<td>$54.5</td>
<td>$64.8</td>
<td>$76.8</td>
<td>$92.0</td>
</tr>
<tr>
<td>2012</td>
<td>$55.7</td>
<td>$66.3</td>
<td>$78.6</td>
<td>$94.1</td>
</tr>
<tr>
<td>2013</td>
<td>$57.6</td>
<td>$68.5</td>
<td>$81.2</td>
<td>$97.1</td>
</tr>
<tr>
<td>2014</td>
<td>$59.5</td>
<td>$70.6</td>
<td>$83.9</td>
<td>$100.2</td>
</tr>
<tr>
<td>2015</td>
<td>$61.5</td>
<td>$72.9</td>
<td>$86.7</td>
<td>$103.3</td>
</tr>
<tr>
<td>2016</td>
<td>$63.5</td>
<td>$75.2</td>
<td>$89.6</td>
<td>$106.6</td>
</tr>
<tr>
<td>2017</td>
<td>$65.7</td>
<td>$77.6</td>
<td>$92.6</td>
<td>$110.0</td>
</tr>
<tr>
<td>2018</td>
<td>$67.8</td>
<td>$80.0</td>
<td>$95.7</td>
<td>$113.5</td>
</tr>
<tr>
<td>2019</td>
<td>$70.1</td>
<td>$82.6</td>
<td>$98.9</td>
<td>$117.1</td>
</tr>
<tr>
<td>2020</td>
<td>$72.4</td>
<td>$85.2</td>
<td>$102.2</td>
<td>$120.8</td>
</tr>
<tr>
<td>2021</td>
<td>$74.8</td>
<td>$87.9</td>
<td>$105.6</td>
<td>$124.6</td>
</tr>
<tr>
<td>2022</td>
<td>$77.0</td>
<td>$90.4</td>
<td>$108.9</td>
<td>$128.2</td>
</tr>
<tr>
<td>2023</td>
<td>$79.3</td>
<td>$93.0</td>
<td>$112.2</td>
<td>$132.0</td>
</tr>
<tr>
<td>2024</td>
<td>$81.7</td>
<td>$95.8</td>
<td>$115.6</td>
<td>$135.8</td>
</tr>
<tr>
<td>2025</td>
<td>$84.1</td>
<td>$98.5</td>
<td>$119.1</td>
<td>$139.8</td>
</tr>
</tbody>
</table>

Source: Adapted from AASHTO (2007d)
A report by Congressional Budget Office (CBO, 2006) projects the Highway Trust Fund revenues for five years 2005-09. Table 2 shows the sources of revenue for each year from 2005 to 2009. This table shows that for each of the years considered, about 65 percent of Highway Trust Fund revenues are generated from Gasoline taxes. Therefore, assuming that the revenue structure remains the same, revenues from gasoline taxes or similar user fee should account for 65 percent of required funding in a future year. Figure 1 shows the required revenues from gasoline taxes in order to serve the transportation needs of the future years assuming that its proportional contribution to the Highway Trust Fund would remain the same.

Table 2. Sources of Highway Trust Fund

<table>
<thead>
<tr>
<th>Revenue Source</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$</td>
<td>%</td>
<td>$</td>
<td>%</td>
<td>$</td>
</tr>
<tr>
<td>Gasoline and Gasohol Tax</td>
<td>$25.5</td>
<td>66.9%</td>
<td>$26.3</td>
<td>65.6%</td>
<td>$27.0</td>
</tr>
<tr>
<td>Diesel Tax</td>
<td>$9.3</td>
<td>24.4%</td>
<td>$10.0</td>
<td>24.9%</td>
<td>$10.4</td>
</tr>
<tr>
<td>Retail Sales tax on Trucks</td>
<td>$2.6</td>
<td>6.8%</td>
<td>$3.1</td>
<td>7.7%</td>
<td>$3.1</td>
</tr>
<tr>
<td>Heavy Vehicle Use Tax</td>
<td>$1.2</td>
<td>3.1%</td>
<td>$1.2</td>
<td>3.0%</td>
<td>$1.2</td>
</tr>
<tr>
<td>Tax on Truck Tires</td>
<td>$0.5</td>
<td>1.3%</td>
<td>$0.5</td>
<td>1.2%</td>
<td>$0.5</td>
</tr>
<tr>
<td>Refunds</td>
<td>-$1.0</td>
<td>-2.6%</td>
<td>-$1.0</td>
<td>-2.5%</td>
<td>-$1.0</td>
</tr>
<tr>
<td>Total</td>
<td>$38.1</td>
<td>100%</td>
<td>$40.1</td>
<td>100%</td>
<td>$41.2</td>
</tr>
</tbody>
</table>

Source: Adapted from CBO (2006)
Figure 1. Funding Required from Gasoline Taxes for Future Transportation Needs
CHAPTER 4

METHODOLOGY

A review of the literature showed that the future of the existing financing system for the roadway infrastructure in the US is under threat due to several challenges that the revenue generation policies face. Due to political and public pressures, changing the existing structure of gasoline taxes is not easy. This study aims to illustrate the impact of high fuel efficiency and alternative fuel vehicles on the existing fuel tax system, and to explore alternate options to overcome the fiscal shortage.

Figure 2 shows a causal diagram, illustrating the fuel tax mechanism. As is evident from this diagram, gasoline consumption and driving behaviors of motorists are based on several factors. Some of them include land use and socio economic related, whereas the others are dependent on the gasoline price and fuel efficiency. In this figure, arrows with a “+” sign illustrate positive relationship, and a “-” sign negative relationship. This means that if the value of item on the tail of a “+” arrow increases, the corresponding value on the head of the arrow also increases. On the other hand, if it is a “-” arrow, as the value on the tail increases, corresponding value on the head decreases.

In this study, factors related to gasoline price and fuel efficiency are analyzed in detail. Land use and socio economic related factors are difficult to evaluate because of
Figure 2. Causal Diagram for Fuel Tax Revenues
the lack of data and thus they are beyond the scope of this study. Figure 3 shows the causal diagram illustrating the focus of this study.

![Figure 3. Causal Diagram for the Study Scope](image)

The entire process in the study could be divided into three major steps as follows:

Step I - Estimate transportation financing needs for a future year: Here the data would be obtained from existing studies and reports on the requirements, specifically from the gasoline tax, for maintaining and improving the transportation infrastructure of the country. This step is discussed in detail in Chapter 3.

Step II - Develop models to estimate vehicle fleet mix and VMT by vehicle fleet mix for a future year: Here the models should be able to provide estimates based on fuel prices and vehicle classifications based on statistical analysis of historical data.

Step III - Estimate revenues generated for highway funds for alternate scenarios: Using the results from the model for a future year (e.g. 2025, 2030, etc), the revenue generated would be estimated for different scenarios.

Step II and III are illustrated in this chapter.
4.1. Step I: Develop Models to Estimate Fleet Mix and Distribution of VMT by Vehicle Fleet

Figure 4 shows flow diagram for developing models to estimate fleet mix and distribution of VMT by vehicle fleet, and fuel consumption based on available data.

![Figure 4: Flow Diagram of Estimating Fuel Consumption based on Historical Data](image)

The steps involved in this study are summarized as follows.

4.1.1. Step 1: Develop Inventories of the Vehicle Fleet

Vehicle fleet data such as the year of manufacture, make, model, vehicle type, and fuel efficiency are the critical data that need to be collected. In a technical report by the United States Environmental Protection Agency (EPA), Heavenrich (2006) lists historical data of the total number of vehicles sold by year for the years 1975 to 2006. The data
provided include the proportion of vehicles in five major types: cars, station wagons, vans, SUVs, and trucks. Each of these categories is again categorized into three other categories based on size: small, medium, and large. For each of these categories, the information provided includes average fuel economy, and key engine properties. This report also provides fuel efficiency based on lab tests as well as based on-road data. Using these data, vehicle fleet inventories could be developed. A report by the US Department of Energy (Davis and Diegel 2007) also lists vehicle inventory for the US for the past few years. This inventory again categorizes vehicles into two basic types: cars and light trucks. This report lists the average age of vehicles for each the two types. This information could be used along with EPA data for verification purposes.

4.1.2. Step 2: Estimate Fleet Mix for Registered Vehicles using Vehicle Sales Information

This is the key step in identifying fuel consumption by each vehicle type and vehicle category. This step could be divided into the following steps.

4.1.2.1. Step 2a: Categorize Vehicle Sales in to Vehicle Categories

As indicated in Step 1, the vehicle sales information obtained from the EPA report (Heavenrich 2006) divides vehicles into five different types (sedans, station wagons, vans, SUVs, and trucks), each of which is again divided into three categories, (small, medium, and large vehicles) based on their size. This results in a total of 15 categories. Although these different classifications would be good for detailed study, the 15 categories become too complicated for the task at hand. Such a large number of categories make it difficult to perform statistical analysis with too many variables, especially since they all belong to two basic types: cars and trucks. For illustrative
purposes, this study uses the following types: cars and trucks, each of which is further classified as small, medium, or large. This results in a total of six categories. Cars type includes sedans and station wagons, whereas trucks include vans, SUVs, and pick-up trucks.

4.1.2.2. Step 2b: Summarize Registration Data

Highway Statistics are reports published by Federal Highway Administration (FHWA 2006). They provide registration information of all vehicles (both commercial and private) by state for each year. In this step, the registration data are summarized for the years from 1981 to 2005 from the Highway Statistics report for these years.

4.1.2.3. Step 2c: Identify Fleet Mix for Registered Vehicles by Year

The registered vehicle information provided by in the Highway Statistics does not contain information on the fleet mix. However, such information is very important from the point of view of fuel consumption, since fuel efficiency is dependent to some extent on size and type. A study by NHTSA (NHTSA, 2006) estimated the survivability and mileage information based on vehicle age. The information is divided into two types: cars and light trucks. Using this information, the fleet mix of registered vehicles in any year for each category $N_{ivk}$ could be estimated using the following equation:

$$N_{ivk} = \sum_{j=1975}^{i} Sales_{jkv} \times S_{(i-j+1)vk}$$

$$\text{......(4.1)}$$

where, $i$ – year considered

$j$ – vehicle model year (starting from 1981 to $i$)

$k$ – vehicle category

$= 1 \text{ to } 3 \ (1 = \text{ small, 2 = medium, and 3 = large})$

$v$ – vehicle type ($1 = \text{ cars, 2 = light trucks}$)
S – survivability

The total number of vehicles for a particular year is,

\[ N_i = \sum_{v=1}^{2} \sum_{k=1}^{3} N_{ijvk} \] ........(4.2)

The next step in finalizing the fleet mix is to compare the sum of estimated vehicle fleet mix with the vehicle registration data obtained in step 1. Figure 5 compares registered vehicle data and vehicle fleet data obtained in the previous step for each of the years from 1981 to 2005. It is seen that the vehicle estimate obtained based on vehicle sales data under estimated vehicle registration data between -8 to -21 percent for cars and -6 to -24 percent for light trucks for various years. Table A2 to A7 in the appendix shows the calculations in estimating the vehicle registration data.

4.1.2.4. Step 2d: Adjust Vehicle Fleet Mix based on Registration Data

Figure 5 shows that although the vehicle registration data from the model and from FHWA shows similar pattern, there is a notable difference between these two. In this step, first, the percent of vehicle fleet in the year i is calculated using the following equation:

\[ \text{Perc. Adj. } V_{ijvk} = \frac{\sum_{i=1982}^{S_{ij}} S_{ij} x S_{i+1} x S_{i+1}}{\sum_{v=1}^{3} \sum_{k=1}^{2} S_{ij} x S_{i+1} x S_{i+1}} \] ........(4.3)

Here Perc. Adj. \( V_{ijvk} \) is the percent of adjusted vehicle in the year i of the vehicle manufactured in the year j belonging to vehicle type v and vehicle category k.

Using these calculated values of all vehicle types and categories, adjusted vehicle fleet could be estimated by multiplying the percent of cars or light trucks with the total
number of vehicles registered in these categories respectively for the year 2005 using the equation 4.4.

\[
\text{Adj. Fleet Mix}_{iv} = \sum_{j=1981}^{i} \sum_{k=1}^{3} \text{Perc. Adj. Veh}_{ijk} x R_{iv}
\]  \hspace{1cm} ......(4.4)

where, \( R_{iv} \) – Total reported vehicles registered in the year \( i \) for vehicle type \( v \) from Highway Statistics.

![Figure 5. Comparison of Vehicle Registration Data from Model and FHWA](image)

Using this process, adjusted fleet mixes for both cars and light trucks are estimated separately for each of the years from 1981 to 2005.
4.1.3. Step 3: Estimate Vehicle Miles Traveled (VMT) by Vehicle Category by Year

In the previous step, the vehicle registration data were estimated based on vehicle type and category. This step is to estimate the vehicle miles traveled by these vehicles. FHWA (FHWA 2006) provides a summary of total VMT by state for each year.

4.1.3.1. Step 3a: Distribute VMT by Fleet Mix

The next step is to distribute the VMT by different fleet mix identified in step 2. Using the estimated VMT data by year for cars and light trucks based on their age, the distribution of VMT for any particular year by vehicle category and model year is estimated by multiplying VMT values and final adjusted number of vehicles by fleet obtained from previous step using the equation 4.5.

\[ VMT_{ivk} = \sum_{j=1981}^{i} AFM_{jvk} \times EVMT_{(i-j+1)vk} \]  

where, $AFM$ – Adjusted fleet mix estimated previous step

$EVMT$ – EPA Estimated VMT based on age of vehicle

Total vehicle miles traveled by different vehicle fleet mix could be estimated using equation 4.6

\[ VMT_i = \sum_{v=1}^{2} \sum_{k=1}^{3} VMT_{ivk} \]  

The same process is performed for all the years from 1981 to 2005. This activity provides estimates of VMT based on sales data and survivability data. Similar to the comparison made for registered vehicles, it is important to compare the VMT estimates from the model with similar estimated published on Highway Statistics. Figure 6 compares VMT data from model and highway statistics for each of the years from 1981 to 2005. It is seen that the total VMT estimates obtained based on vehicle sales data and
that reported by Highway Statistics follow very similar trends over the years. However, when the cars and light trucks are considered separately, there are some notable changes especially for light trucks. Tables A8 to A12 in the appendix summarize the calculations for estimating VMT from the model.

![Comparison of Vehicle Miles Traveled Data from Model and FHWA](image)

**Figure 6.** Comparison of Vehicle Miles Traveled Data from Model and FHWA

4.1.3.2. Step 3b: Adjust Vehicle Fleet Mix based on VMT Data by FHWA

Figure showed that the VMTs based on the registration data and the fleet mix data, although show similar trend, are off by a notable difference. Therefore, the next step is to make these counts comparable. This step is very similar to the adjustments made in the
vehicle fleet estimates. Here, first, the percent of vehicle fleet is calculated using an
equation similar to equation 4.3

\[
\text{Perc. Adj. VMT}_{ijk} = \frac{\sum_{j=1981}^{i} \text{AFM}_{jvk} \times \text{EVMT}_{(i-j+1)vk}}{\sum_{j=1981}^{i} \text{AFM}_{jvk} \times \text{EVMT}_{(i-j+1)vk}} \tag{4.7}
\]

Table 4.12 summarizes the calculation for the year 2005. In this table, the percent of
VMT for each fleet is calculated. Using the values in Table 4.12, the vehicle fleet could
be estimated by multiplying the percent with the total number of vehicles registered for
the year from Table 4.9.

\[
\text{Adj. VMT}_i = \sum_{j=1981}^{i} \sum_{v=1}^{2} \sum_{k=1}^{3} \text{Perc. Adj. VMT}_{ijkv} \times \text{RVMT}_{iv} \tag{4.8}
\]

where, RVMT$_{iv}$ – Reported VMT (from Transportation Statistics) for cars (=1) and light
trucks (2)

The same calculations are performed on the available data and adjusted VMTs by
vehicle fleet are estimated for all the years from 1981 to 2005.

4.1.4. Step 4: Estimate Fuel Consumption by Vehicle Category

The first step in identifying the impact of fuel efficient vehicles on fuel tax revenue is
estimating the historical fuel consumption rate by each of the vehicle categories. The
distribution of VMT by fleet mix estimated in previous step is used to estimate fuel
consumption by vehicle category. The US EPA (Heavenrich 2006, 8-8-20) publishes fuel
efficiency by vehicle category for each year. This report categorizes vehicles into over 30
categories. The first step is to consolidate these into the six categories identified in step 2.
In the consolidated vehicle category, fuel efficiency (or gas mileage) for each of the
categories is estimated by calculating the weighted average.
\[ FE_{ivk} = \sum_{j=1981}^{i} \sum_{m=1}^{n} N_{ijvm} \times FE_{ijvm} \]  \hspace{1cm} \ldots (4.9)

Where, \( FE_{ivk} \) – Fuel efficiency of vehicle category \( k \) for vehicle type \( v \) for the year \( i \),

\( m \) – Vehicle sub-categories within each of categories \( k \)

\( N_{ijvm} \) – Number of vehicles for each of the sub-categories for cars and light trucks

The existing literature shows that the fuel efficiency reported by the EPA is off from the on-road performance by about 15 percent. Corresponding adjustments are made on the actual values of fuel efficiency.

Fuel Consumption by each of the vehicle categories is estimated based on adjusted VMT values estimated in previous step using the equation,

\[ \text{Fuel Consumption, } FC_{ivk} = \frac{VMT_{ivk}}{FE_{ivk}} \]  \hspace{1cm} \ldots (4.10)

Table 4.16 shows the fuel consumption by different vehicle categories for the year 2005. The same procedure is conducted to identify fuel efficiency by different categories of vehicles for the years 1981 to 2005. The summary from each year is compared with the gasoline sales data published by highway statistics. Figure 7 compares the gasoline sales data from estimates and the one published by Highway Statistics. It is evident that the estimated fuel consumption and reported fuel consumption do not match and the change increases with the year. This could because of the fuel efficiency data used for estimation. For this estimation, it is assumed that the fuel efficiency of vehicles would remain the same, irrespective of the age of vehicle. On the other hand, both the model estimates and the reported values from Highway Statistics show very similar trends, which validate the estimation process. Tables A13 to A18 in Appendix illustrate the calculations used to estimate fuel consumption.
These steps estimate the distribution of vehicle mileage and fuel consumption by various vehicle classifications. These steps also compare the accuracy of these estimates by comparing with the Highway Statistics data. The next step in this methodology is to develop mathematical models to identify relationships among different parameters of the system. These relations would help estimating future demands and requirements for future.

4.1.5. Step 5: Develop Mathematical Models to Establish relationship of Fuel Consumption

The major objective here is to establish relationships among variables such as gasoline price, fleet mix, VMT, and gasoline consumption. Once the relationships are
established, they could be used to estimate future fleet mix and VMT as a function of gasoline price and hence fuel consumption. Several models, including regression models and time series models, were developed to study the relationships among vehicle sales data, VMT data by fleet, and fuel consumption.

Mathematical models developed here are expected to provide an indication of the new vehicle sales information for any future year. The financial reports from auto manufacturers and industry analysts show that in the past couple of years, the sales of large vehicles, especially SUVs and pick-up trucks, have shown a clear reduction (New York Times 2008 and US News 2008). However, the models developed using the values obtained from estimates do not show that trend. These have positive correlation to gasoline price. The reason for that is because of limitations of the data that are used to develop these models. All the mathematical models represented previously are derived from vehicle sales data for the years 1975 to 2005. Figure 8 shows the average gasoline prices of regular and premium gasoline for the years 1976 to 2008. Gasoline prices for the years 1976 to 2007 in this figure were obtained from Energy Information Administration website (EIA, 2008) and these values were adjusted for inflation using inflation calculator from Bureau of Labor Statistics, U.S. Department of Labor (BLS, 2008). The gasoline prices shown are based on the average gasoline prices and not peak gasoline prices for the respective years. These indicate that when changes in gasoline prices over the years are considered, for years from 1990 to 2003 the gasoline price remained relatively the same, with significant and continuous increase from the year 2004 onwards. Since the sales data considered in the models used the vehicle sales until the year 2005, during this time, the sales of large vehicles especially that of SUVs and
pick-up trucks increased each of these years. Therefore, to show the impact of high gasoline prices on new vehicle sales, the models developed here could not be used. Using these models would overestimate proportion of large vehicles, especially SUVs and pick-up trucks in both the vehicle fleet mix and the VMT estimates for a future year.

Figure 8. Change in Average Gasoline Sales Price

4.2. Developing a Model to Account for Fleet Distribution Based on Gasoline Price

The Congressional Budget Office of the U.S. Congress (CBO, 2008) published a report which analyzes the impact of high gasoline prices on new vehicles sales and VMTs. Using data for the three years 2005 to 2007, this report identifies that for a 20 percent increase in gasoline price, there is a +2.6 percent shift in new vehicle sales
towards sedans from light trucks. This report also shows that the prices of used SUVs and pickups decreased and the prices of used sedans increased. These data show a clear consumer trend over the most recent 3 years towards purchasing sedans which have relatively better fuel efficiency. This was the relationship which could not be established from the historical vehicle sales data for the years 1976 to 2005. While accounting for vehicle miles traveled, the report shows that a 20 percent increase in gasoline price results in a significant decrease (-0.40 percent) for weekday traffic and an insignificant increase (+0.12 percent) for weekend traffic. These findings could be used to estimate various scenarios of fuel consumption and hence revenues for various policy options.

Thus models to estimate vehicle fleet mixes for a future year are:

$$PC_i = PC_{(i-1)} \times \left[1 + \left( \frac{GP_i - GP_{i-1}}{GP_{i-1}} \times \frac{RC}{0.20} \right) \right]$$ \hspace{1cm} \ldots \ldots (4.11)

Where, $PC_i$ – Proportion of cars for the year $i$

$PC_{(i-1)}$ – Proportion of cars for the year $i-1$

$GP_i$ - Price of gasoline for the year $i$

$GP_{i-1}$ – Price of gasoline for the year $i-1$

$RC$ - Change in proportion of cars for a 20 percent increase in gasoline price

= 0.026 based on CBO, 2008

$$PT_i = PT_{(i-1)} \times \left[1 + \left( \frac{GP_i - GP_{i-1}}{GP_{i-1}} \times \frac{RT}{0.20} \right) \right]$$ \hspace{1cm} \ldots \ldots (4.12)

where, $PT_i$ – Proportion of light trucks for the year $i$

$PT_{(i-1)}$ – Proportion of light trucks for the year $i-1$

$GP_i$ - Price of gasoline for the year $i$
GP_{i-1} – Price of gasoline for the year i-1

R_T - Change in proportion of light trucks for a 20 percent increase in gasoline price

= -0.026 based on CBO, 2008

In order to develop mathematical models, the vehicle fleet mix needs to be further divided into six categories: small cars, medium cars, large cars, small light trucks, medium light trucks, and large light trucks. The same CBO report (CBO, 2008) provided the percent changes for four types of cars (subcompact, compact, midsize, and large), and four types of light trucks (minivan, SUV, pickup truck, and passenger or cargo van). The values are shown in Table 3.

These categories identified in the CBO report are different from the one identified for this study. Therefore, the first step is to reclassify these categories into the ones used in this study. For cars, the reclassification is simple, add subcompact and compact cars together to small cars, and the other two categories remain the same. On the other hand for light trucks, the categories are quite different. Using the four categories, it is practically impossible to reclassify into the three categories such as small light trucks, medium light trucks, and large light trucks. New vehicle sales data for the months of April through June 2008 (New York Times 2008 and USA Today 2008) show that the new vehicle sales trend is strongly shifting towards more small and compact vehicles from large models for both pick-up trucks and SUVs. These factors are considered for estimating the fleet mix. Therefore, in order identify change in fleet mix based on gasoline price for each of the category, it is assumed that the predominant decreases among light trucks are for the large (1.3 percent) and medium (1.1 percent) categories,
Table 3. Changes in Fleet Mix for a Change in 20 Percent Gasoline Price (Source: CBO, 2008)

<table>
<thead>
<tr>
<th>Vehicle Category</th>
<th>Average Market Share</th>
<th>Average Effect of Increase</th>
<th>Statistical Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cars (versus light trucks trucks)</td>
<td>46.4%</td>
<td>+2.6%</td>
<td>**</td>
</tr>
<tr>
<td><strong>Cars</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subcompact or two wheeler</td>
<td>1.4%</td>
<td>+0.1%</td>
<td>*</td>
</tr>
<tr>
<td>Compact</td>
<td>19.7%</td>
<td>+0.9%</td>
<td>*</td>
</tr>
<tr>
<td>Midsize</td>
<td>16.6%</td>
<td>+0.8%</td>
<td>*</td>
</tr>
<tr>
<td>Large</td>
<td>8.7%</td>
<td>+0.8%</td>
<td>**</td>
</tr>
<tr>
<td><strong>Light Trucks</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minivan</td>
<td>6.2%</td>
<td>-0.3%</td>
<td>*</td>
</tr>
<tr>
<td>Suv</td>
<td>26.9%</td>
<td>-1.2%</td>
<td>**</td>
</tr>
<tr>
<td>Pickup truck</td>
<td>18.2%</td>
<td>-1.0%</td>
<td>*</td>
</tr>
<tr>
<td>Passenger or cargo van</td>
<td>2.3%</td>
<td>-0.1%</td>
<td>*</td>
</tr>
</tbody>
</table>

** significant at 1 percent; * significant at 5 percent confidence level

with the small category showing the lowest decrease. The revised equations for the changes in proportions for each of the vehicle categories are as follows:

\[
P_{Si} = P_{S(i-1)} \times \left[ 1 + \frac{(GP_i - GP_{i-1}) \times R_{CS}}{GP_{i-1}} \right]
\]

\[
P_{Mi} = P_{M(i-1)} \times \left[ 1 + \frac{(GP_i - GP_{i-1}) \times R_{CM}}{GP_{i-1}} \right]
\]

\[
P_{Li} = P_{L(i-1)} \times \left[ 1 + \frac{(GP_i - GP_{i-1}) \times R_{CL}}{GP_{i-1}} \right]
\]

\[
P_{Ti} = P_{T(i-1)} \times \left[ 1 + \frac{(GP_i - GP_{i-1}) \times R_{TS}}{GP_{i-1}} \right]
\]

\[
P_{Mi} = P_{M(i-1)} \times \left[ 1 + \frac{(GP_i - GP_{i-1}) \times R_{TM}}{GP_{i-1}} \right]
\]

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The variables in these equations are the same as those for the equations 4.11 and 4.12 except for the suffix S, M, and L, which stand for small, medium, and large vehicles for each of the cars and light trucks. Here, based on the CBO report, the values of $R_{cs}$, $R_{cm}$, $R_{cl}$, $R_{ts}$, $R_{tm}$, $R_{tl}$ are 0.08, 0.08, 0.1, -0.01, -0.11, and -0.13 respectively. The overall proportion of fleet mix for any year $i$ could be estimated using the equation:

$$P_{i} = \sum_{v=1}^{2} \sum_{k=1}^{3} P_{vk(i-1)} \left[ 1 + \left( \frac{GP_{i} \cdot R_{TL}}{GP_{i-1} \cdot 0.20} \right) \right]$$

where $v$ is vehicle type (car or light truck); and $k$ is vehicle category (small, medium, or large).

The next step is estimate fleet mix for a future year based on these equations. The first step here is to identify the existing fleet mix in terms of the six categories considered in this study. Using the new vehicle sales data, proportion of each of these categories are calculated.

Once the fleet mix distribution is determined, the next step is to estimate gasoline price for future years. Figure 4 showed the gasoline sales price over the past thirty years. This figure shows that the gasoline price has increased dramatically over the past five years. Although the gasoline price is not expected to increase at the same rate, the current trend shows that there would not be a sudden decrease in fuel price in the coming years. Therefore for illustration purposes, it is assumed that the gasoline price increases based on the Consumer Price Index (CPI) percent every year after 2008.
The next step is to estimate the proportion of the six categories of vehicles for future years based on the relationship established between fleet mix proportion and gasoline price. Equations 4.13 through 4.19 are used to estimate the fleet mix for the years considered. It is important to note that the new vehicle sales data are available only up to the year 2005.

Once the proportions are estimated, to convert these to the number of vehicles, the total numbers of new vehicles sold for each of the years needs to be estimated. Comparing the total number of registered vehicles and new vehicle sold in each of the years from 1981 to 2005, provides a relationship between total vehicles registered and new vehicles sold per year. The data shows (Table A40 in Appendix) that for each of the past 10 years, new vehicle sold account for about 7.1 percent of total vehicles registered. For illustration purposes, it is assumed that for any future year, this proportion would remain at 7.1 percent, average over the last 10 years (1996 to 2005). In order to estimate number of vehicles in each category, the total number of registered vehicles needs to be estimated. Historical data do not show a consistent trend for the change. However for illustration purposes, it is assumed that the total number of registered vehicles would increase by 0.5 percent every year. Once the total number of registered vehicles is estimated for a year, the corresponding number of new vehicles for that year is estimated by multiplying the total number of registered vehicles with the proportion of new vehicles (i.e. 7.1 percent).

Once the total number of new vehicles sold is estimated, the fleet mix for these new vehicles is estimated using the information on the proportions estimated represented by equation 4.20.
\[ N_{ivk} = P_{ivk} \times NV_i \]  

where \( N_{ivk} \) is the total number of vehicles in the year \( i \), vehicle type \( v \) and category \( k \)

\( P_{ivk} \) is the proportion of vehicles in corresponding vehicle type and category; and

\( NV_i \) is the total number of estimated new vehicles sales for the year \( i \)

Once the number of new vehicles in each category of vehicles is estimated, the actual fleet mix is calculated using the equations 4.1 through 4.5, using the vehicle survivability data obtained from the EPA. Tables A19 to A25 summarize the calculations and hence the estimates of number of vehicles by fleet for years 2006 to 2025.

4.3. Estimating the Distribution of Hybrid Vehicles in the Vehicle Fleet

The vehicle fleet mix estimated so far accounts for six major categories of vehicles, without considering alternate fuel vehicles and hybrid vehicles. When considering the fuel consumption and hence revenues from fuel taxes, it is important include these vehicle categories in the fleet composition. The U.S. Department of Energy - Energy Efficiency and Renewable Energy website (USDoE, 2008) lists the vehicle sales information of hybrid vehicles in various categories for the years 1999 to 2007. Although hybrid vehicles were available in 1999, only from the year 2000 did their sales show any notable numbers. The total numbers of hybrid vehicles sold per year are shown in Figure 8. These vehicle types are summarized into six vehicle categories. Table 4 summarizes the vehicle sales into the six vehicle categories. Data in this table show that of all hybrid vehicles sold in the US, a predominant portion of it has been cars and within the cars type, small cars and medium cars account for more than 70 percent of all vehicles sold in all the years and over 80 percent for most of the years. This provides a sense of the
consumer's buying trend. Although one could argue that in the previous years, there were no other vehicles available as a choice, still even after they became available, their sales were not comparable with those of small/medium cars category. Therefore, it could be indicated that the sales of hybrid vehicles are also very similar to the sales of non-hybrid vehicles, with more cars being sold than light trucks with higher gasoline prices.

![Figure 9. Total Number of Hybrid Vehicles Sold per Year](image)

Using the trend of historical vehicle sales data, sales data for a future year could be estimated. The historical data show that for all years cars accounted for over 70 percent of all the hybrid vehicles sold. Hybrid vehicle sales grew well over 30 percent for most of the years. Although, to sustain that percent growth is difficult, with the gas prices
Table 4. Percent of Hybrid Vehicle Sales by Vehicle Category

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Cars</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>95.2%</td>
<td>64.1%</td>
<td>55.0%</td>
<td>60.7%</td>
<td></td>
</tr>
<tr>
<td>Medium Cars</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>1.3%</td>
<td>8.0%</td>
<td>15.3%</td>
<td>19.5%</td>
<td></td>
</tr>
<tr>
<td>Large Cars</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.3%</td>
<td></td>
</tr>
<tr>
<td>Small Light Trucks</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>3.6%</td>
<td>9.4%</td>
<td>9.2%</td>
<td>7.1%</td>
</tr>
<tr>
<td>Medium Light Trucks</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>18.4%</td>
<td>20.4%</td>
<td>12.4%</td>
</tr>
<tr>
<td>Large Light Trucks</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

remaining historically high, the growth of hybrid vehicles into the future is expected to increase. For illustrations purposes, it is assumed that the over the future years the sales of new hybrid vehicles will increase annually by 20 percent, with the proportion of six categories of, small cars, medium cars, large cars, small light trucks, medium light trucks, and large light trucks being 60 percent, 18 percent, 2 percent, 7 percent, 12 percent, and 1 percent respectively. Therefore, the fleets mix of new alternate fuel vehicles for a particular year i could be represented mathematically as follows:

\[ HV_i = \sum_{v=1}^{6} \sum_{k=1}^{3} HV_{2007} \times (1 + r)^{i-2007} \times PH_{vk} \]

where \( HV_{2007} \) is the total new hybrid vehicles sold in the year 2007

\( r \) is the average rate of change in annual sales of hybrid vehicles; and

\( PH_{vk} \) is the proportion of hybrid vehicles in type v and category k.
Fleet mix of new hybrid vehicles for the years from 2000 to 2025 is estimated assuming an average annual growth rate of 20 percent. For these estimates, it is assumed that 70 percent of the new vehicles sold are cars, with distribution of vehicles as 70 percent, 25 percent, and 5 percent each for small, medium, and large vehicle categories of both cars and light trucks.

Once the new vehicles sales data are estimated, the next step is to estimate for a future year the fleet mix of this vehicle group by year of manufacture. This is done using equation 4.1. Here, survivability of each of the vehicle categories needs to be estimated. Since the hybrid vehicles are relatively new, their survivability data are not readily available. Therefore, it is assumed that the survivability of the hybrid vehicles remain the same as that of regular vehicles. Using these values, the fleet mix of hybrid vehicles for a future year could be estimated.

In order to estimate fuel consumption by hybrid vehicles, the next step is to estimate vehicle miles traveled by them. This could be estimated using steps illustrated in Figure 4. Here, similar to having survivability data, it is important to have VMT estimates by vehicle category for hybrid vehicles. Since VMT data for hybrid vehicles are not available, the values for used in previous steps are used as proxy. The distribution of VMT could be calculated using the equations 4.5 and 4.6. Using the estimated VMT by model year of hybrid vehicles, and fuel efficiency of the vehicles, fuel consumption by each of the vehicle categories for a year could be estimated using equation 4.10. Average fuel efficiency of hybrid vehicles is available for several years. Based on historical data, it is assumed that that for a future year, average fuel efficiency would improve by 2 percent every year, because of advances in energy related research. Using the equation
4.10 and estimated values of VMT and fuel efficiencies, fuel consumption by individual vehicle categories is estimated. Table 5 shows the estimated fuel consumed by hybrid vehicles. Tables A26 to A31 illustrate the calculations to estimate fuel consumed.

Table 5. Estimated Fuel Consumption by Hybrid Vehicle Categories (in Thousands of Gallons)

<table>
<thead>
<tr>
<th>Model Year</th>
<th>Small Cars</th>
<th>Medium Cars</th>
<th>Large Cars</th>
<th>Small Lt. Trucks</th>
<th>Medium Lt. Trucks</th>
<th>Large Lt. Trucks</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2001</td>
<td>63</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2002</td>
<td>150</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2003</td>
<td>268</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2004</td>
<td>609</td>
<td>9</td>
<td>-</td>
<td>117</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2005</td>
<td>1,378</td>
<td>190</td>
<td>-</td>
<td>895</td>
<td>1,982</td>
<td>-</td>
</tr>
<tr>
<td>2006</td>
<td>1,918</td>
<td>588</td>
<td>-</td>
<td>1,220</td>
<td>3,062</td>
<td>-</td>
</tr>
<tr>
<td>2007</td>
<td>3,959</td>
<td>1,399</td>
<td>21</td>
<td>1,521</td>
<td>3,003</td>
<td>-</td>
</tr>
<tr>
<td>2008</td>
<td>5,853</td>
<td>2,299</td>
<td>511</td>
<td>4,144</td>
<td>1,677</td>
<td>387</td>
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<tr>
<td>2009</td>
<td>9,315</td>
<td>3,659</td>
<td>813</td>
<td>5,735</td>
<td>2,321</td>
<td>536</td>
</tr>
<tr>
<td>2010</td>
<td>14,682</td>
<td>5,768</td>
<td>1,282</td>
<td>7,908</td>
<td>3,201</td>
<td>739</td>
</tr>
<tr>
<td>2011</td>
<td>22,877</td>
<td>8,987</td>
<td>1,997</td>
<td>10,856</td>
<td>4,394</td>
<td>1,014</td>
</tr>
<tr>
<td>2012</td>
<td>35,099</td>
<td>13,789</td>
<td>3,064</td>
<td>14,820</td>
<td>5,999</td>
<td>1,384</td>
</tr>
<tr>
<td>2013</td>
<td>52,834</td>
<td>20,756</td>
<td>4,612</td>
<td>20,069</td>
<td>8,134</td>
<td>1,877</td>
</tr>
<tr>
<td>2014</td>
<td>77,654</td>
<td>30,507</td>
<td>6,779</td>
<td>27,049</td>
<td>10,948</td>
<td>2,527</td>
</tr>
<tr>
<td>2015</td>
<td>110,960</td>
<td>43,592</td>
<td>9,687</td>
<td>35,740</td>
<td>14,466</td>
<td>3,338</td>
</tr>
<tr>
<td>2016</td>
<td>148,369</td>
<td>58,288</td>
<td>12,953</td>
<td>46,859</td>
<td>18,967</td>
<td>4,377</td>
</tr>
<tr>
<td>2017</td>
<td>189,417</td>
<td>74,414</td>
<td>16,536</td>
<td>60,972</td>
<td>24,679</td>
<td>5,695</td>
</tr>
<tr>
<td>2018</td>
<td>239,935</td>
<td>94,260</td>
<td>20,947</td>
<td>78,690</td>
<td>31,851</td>
<td>7,350</td>
</tr>
<tr>
<td>2019</td>
<td>301,607</td>
<td>118,489</td>
<td>26,331</td>
<td>100,706</td>
<td>40,762</td>
<td>9,407</td>
</tr>
<tr>
<td>2020</td>
<td>376,194</td>
<td>147,790</td>
<td>32,842</td>
<td>127,748</td>
<td>51,708</td>
<td>11,933</td>
</tr>
<tr>
<td>2021</td>
<td>465,753</td>
<td>182,974</td>
<td>40,661</td>
<td>160,631</td>
<td>65,017</td>
<td>15,004</td>
</tr>
<tr>
<td>2022</td>
<td>572,525</td>
<td>224,920</td>
<td>49,982</td>
<td>200,191</td>
<td>81,030</td>
<td>18,699</td>
</tr>
<tr>
<td>2023</td>
<td>699,208</td>
<td>274,689</td>
<td>61,042</td>
<td>247,389</td>
<td>100,134</td>
<td>23,108</td>
</tr>
<tr>
<td>2024</td>
<td>848,804</td>
<td>333,459</td>
<td>74,102</td>
<td>303,233</td>
<td>122,737</td>
<td>28,324</td>
</tr>
<tr>
<td>2025</td>
<td>1,025,049</td>
<td>402,698</td>
<td>89,488</td>
<td>368,818</td>
<td>149,283</td>
<td>34,450</td>
</tr>
</tbody>
</table>

Hybrid vehicles are considered, in broader terms as an alternative vehicle category. However, they use gasoline as the major fuel, with electric batteries improving its fuel mileage. In this study alternative fuel vehicles represent vehicles which do not use gasoline at all for operation. Several models of alternative fuel vehicles have emerged during the past decade. Because of the availability of cheap gasoline, higher price tag, and other technology related concerns, most of them did not last long to make an impression as the hybrid has done within a few years of its introduction. Examples of alternative fuel vehicles include, methanol fuel vehicles, ethanol fuel vehicles, electric vehicles, compressed natural gas internal combustion engine vehicles, compressed natural gas bi-fuel vehicles, liquefied petroleum gas internal combustion engine vehicles, liquefied petroleum gases bi-fuel vehicles, gasoline fuel cell, methanol fuel cell, and hydrogen fuel cell. As the name suggests, most of the existing alternative vehicles use some alternative petroleum based fuels. However, they do not pay road user fee in any form as the gasoline vehicle owners do. Most of the environmentalists and policy makers support these concepts of tax breaks on alternative fuel vehicles because of its benefits on environment, but in the existing scenario, there are no way to recoup the costs associated with driving those on the roadway infrastructure. With the gas prices riding at historical highs, popularity of alternative fuel vehicles is expected to be increasing in the years to come. Therefore, it is important to consider the impact alternative fuel vehicles cause to the HTF.

Energy Information Administration (EIA, 2007) publishes data on the vehicle sales data by fuel type. Table 4.34 shows a summary extracted from EIA’s report. It shows that
over the last three years, on an average about 3 percent of all new cars, 7 percent of all new trucks sold were alternative fuel vehicles, excluding hybrid vehicles.

Table 6. Alternative Fuel Vehicle Sales Data (in Thousands) (Source EIA, 2007)

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Alternate Fuel Cars (Excl. Hybrids)</td>
<td>138.0</td>
<td>248.5</td>
<td>278.5</td>
</tr>
<tr>
<td>Percent of New Alternate Fuel Cars</td>
<td>1.8%</td>
<td>3.1%</td>
<td>3.1%</td>
</tr>
<tr>
<td>New Alternate Fuel Lt. Trucks (Excl. Hybrids)</td>
<td>680.1</td>
<td>565.5</td>
<td>511.4</td>
</tr>
<tr>
<td>Percent of New Alternate Fuel Lt. Trucks</td>
<td>8.1%</td>
<td>7.0%</td>
<td>7.2%</td>
</tr>
<tr>
<td>Total New Alternate Fuel Vehicles (Excl. Hybrid)</td>
<td>818.1</td>
<td>813.7</td>
<td>789.9</td>
</tr>
<tr>
<td>Percent of Total New Alternate Fuel Vehicles</td>
<td>5.1%</td>
<td>5.0%</td>
<td>5.0%</td>
</tr>
</tbody>
</table>

This table shows that the total numbers of alternative fuel vehicles have been decreasing over the past three years. As indicated in the previous paragraph, most of the existing alternative fuel vehicles are predominantly petroleum based fuels, which in turn means that as the petroleum price goes up those vehicles also become expensive to operate. That might be the reason why the vehicle sales of this category of vehicles decreased. However, since the fuel prices remain at high levels as that of the years 2007 and 2008, the demand for newer version of vehicles in this category are expected to be increasing. Introduction of Honda's hydrogen fuel vehicles in California (Sabatini, 2007), and all electric cars developed by Tesla motors (Copeland, 2008) are only a few of the new fleet mix entering the market in the coming years. Reports indicate that all the major (U.S. based as well as foreign) automobile manufacturers are currently working on some alternative fuel vehicles. All these ensure that the growth in this segment of vehicles would show similar trend, if not more dramatic, as that of hybrid vehicles.
In order to show the impact of alternative vehicles on the fuel tax, it is assumed that from the year 2009 onwards, the sales of older technology based alternative fuel vehicles would increase at the rate of 0.5 percent and the newer version, such as, electric and hydrogen cell fuel, would grow at the rate same as hybrid vehicles. Table 4.35 shows the estimated new vehicle sales based on this assumption. Here, the growth rate for older technology based alternative vehicles were estimated to be 0.5 percent each year starting from 2009, with equal distribution of sedans and light trucks, each further categorized into small, medium, and large divisions by 70, 25, and 5 percent each. The sales of new older technology alternative fuel vehicles could be estimated as follows,

\[ AFV_{Oi} = \sum_{v=1}^{2} \sum_{k=1}^{3} AFV_{O,2006} \times (1 + r)^{i-2006} \times P_{AFVv} \] 

Where \( AFV_{O,2006} \) is the total new older technology alternative fuel vehicles sold in the year 2006

\( r \) is the average rate of change in annual sales of new alternative fuel vehicles; and

\( P_{AFVv} \) is the proportion of alternative fuel vehicles in type v and category k.

The sales of new newer technology alternative fuel vehicles could be mathematically represented as:

\[ AFV_{Ni} = HV_{(i-9)} \] 

Where \( HV_{(i-9)} \) is the total number of new hybrid vehicles sold in the year i-9. This means that the number of new newer technology based vehicles sold will be equal to the number of hybrid vehicles sold in the year 2000. Therefore the total number of alternative fuel vehicles could be estimated as:

\[ AFVi = AFV_{Oi} + AFV_{Ni} \]
Similar to hybrid vehicle fleet mix, the new vehicles sales data are estimated, the next step is to estimate fleet mix of this vehicle group by year for a future year. In order to estimate fleet mix by vehicle category by year, equation (1) could be used. Here, survivability of each of these categories needs to be estimated. Like hybrid vehicles, since the alternative fuel vehicles are relatively newer vehicle categories, their survivability data are also not readily available. Therefore, it could be assumed that the survivability of the alternative fuel vehicles remain the same as that of regular vehicles. Using these values, fleet mix of hybrid vehicles for a future year could be estimated.

Since the alternative fuel vehicles do not use gasoline it is important to estimate the revenue lost due to their operation as compared to the regular gasoline vehicles, the next step is to estimate vehicle miles traveled by them. This could be estimated using steps illustrated in Figure 4. Here, similar to having survivability data, it is important to have VMT estimates by vehicle category for alternative fuel vehicles. Since VMT data for alternative fuel vehicles are not available, values for regular gasoline fuel vehicles are used. Distribution of VMT could be calculated using the equations 4.5 and 4.6. Table 7 shows the VMT estimate for alternative fuel vehicles for the years 2006 to 2025. Tables A32 and A33 show the calculations of the VMT by fleet mix for alternative fuel vehicles.

The VMT estimates of alternative fuel vehicles are very important, since they do not pay any user fee for their usage. Therefore, if the existing user fee structure continues, predominantly the regular gasoline fuel vehicles, and partially hybrid vehicles would be covering expense for the use of facility by alternative fuel vehicles.
Table 7. Estimated VMT by Fleet Mix of Alternative Fuel Vehicles by Model Year for the Year 2025 (in Millions)

<table>
<thead>
<tr>
<th>Model Year</th>
<th>Small Cars</th>
<th>Medium Cars</th>
<th>Large Cars</th>
<th>Small Lt. Trucks</th>
<th>Medium Lt. Trucks</th>
<th>Large Lt. Trucks</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>103.61</td>
<td>37.00</td>
<td>7.40</td>
<td>412.14</td>
<td>147.20</td>
<td>29.44</td>
</tr>
<tr>
<td>2005</td>
<td>141.87</td>
<td>50.67</td>
<td>10.13</td>
<td>483.47</td>
<td>172.67</td>
<td>34.53</td>
</tr>
<tr>
<td>2006</td>
<td>189.15</td>
<td>67.55</td>
<td>13.51</td>
<td>553.85</td>
<td>197.80</td>
<td>39.56</td>
</tr>
<tr>
<td>2007</td>
<td>261.32</td>
<td>93.33</td>
<td>18.67</td>
<td>660.55</td>
<td>235.91</td>
<td>47.18</td>
</tr>
<tr>
<td>2008</td>
<td>359.44</td>
<td>128.37</td>
<td>25.67</td>
<td>786.58</td>
<td>280.92</td>
<td>56.18</td>
</tr>
<tr>
<td>2009</td>
<td>496.76</td>
<td>177.42</td>
<td>35.48</td>
<td>945.39</td>
<td>337.64</td>
<td>67.53</td>
</tr>
<tr>
<td>2010</td>
<td>680.96</td>
<td>243.20</td>
<td>48.64</td>
<td>1,133.72</td>
<td>404.90</td>
<td>80.98</td>
</tr>
<tr>
<td>2011</td>
<td>927.59</td>
<td>331.28</td>
<td>66.26</td>
<td>1,360.55</td>
<td>485.91</td>
<td>97.18</td>
</tr>
<tr>
<td>2012</td>
<td>1,237.42</td>
<td>441.94</td>
<td>88.39</td>
<td>1,614.96</td>
<td>576.77</td>
<td>115.35</td>
</tr>
<tr>
<td>2013</td>
<td>1,663.66</td>
<td>594.16</td>
<td>118.83</td>
<td>1,955.88</td>
<td>698.53</td>
<td>139.71</td>
</tr>
<tr>
<td>2014</td>
<td>2,377.50</td>
<td>849.11</td>
<td>169.82</td>
<td>2,559.75</td>
<td>914.20</td>
<td>182.84</td>
</tr>
<tr>
<td>2015</td>
<td>3,027.21</td>
<td>1,081.14</td>
<td>216.23</td>
<td>3,013.79</td>
<td>1,076.35</td>
<td>215.27</td>
</tr>
<tr>
<td>2016</td>
<td>3,774.30</td>
<td>1,347.96</td>
<td>269.59</td>
<td>3,684.46</td>
<td>1,315.88</td>
<td>263.17</td>
</tr>
<tr>
<td>2017</td>
<td>4,360.48</td>
<td>1,557.32</td>
<td>311.47</td>
<td>4,338.43</td>
<td>1,549.44</td>
<td>309.89</td>
</tr>
<tr>
<td>2018</td>
<td>5,031.05</td>
<td>1,796.80</td>
<td>359.36</td>
<td>5,099.99</td>
<td>1,821.42</td>
<td>364.29</td>
</tr>
<tr>
<td>2019</td>
<td>5,800.13</td>
<td>2,071.48</td>
<td>414.30</td>
<td>5,985.99</td>
<td>2,137.86</td>
<td>427.58</td>
</tr>
<tr>
<td>2020</td>
<td>6,682.53</td>
<td>2,386.62</td>
<td>477.32</td>
<td>7,014.08</td>
<td>2,505.03</td>
<td>501.01</td>
</tr>
<tr>
<td>2021</td>
<td>7,698.43</td>
<td>2,749.45</td>
<td>549.88</td>
<td>8,206.57</td>
<td>2,930.92</td>
<td>586.18</td>
</tr>
<tr>
<td>2022</td>
<td>8,871.13</td>
<td>3,168.26</td>
<td>633.65</td>
<td>9,587.73</td>
<td>3,424.19</td>
<td>684.83</td>
</tr>
<tr>
<td>2023</td>
<td>10,231.46</td>
<td>3,654.09</td>
<td>730.81</td>
<td>11,189.17</td>
<td>3,996.13</td>
<td>799.22</td>
</tr>
<tr>
<td>2024</td>
<td>11,815.08</td>
<td>4,219.62</td>
<td>843.94</td>
<td>13,046.42</td>
<td>4,659.44</td>
<td>931.89</td>
</tr>
<tr>
<td>2025</td>
<td>13,668.52</td>
<td>4,881.62</td>
<td>976.32</td>
<td>15,201.12</td>
<td>5,428.97</td>
<td>1,085.79</td>
</tr>
<tr>
<td>Total</td>
<td>89,399.60</td>
<td>31,928.45</td>
<td>6,385.68</td>
<td>98,834.60</td>
<td>35,298.10</td>
<td>7,059.61</td>
</tr>
</tbody>
</table>

4.5. Revenue Generation Scenarios
The previous chapter estimated required revenue that needs to be generated from the users in order to maintain and (or) to improve the roadway infrastructure. The previous sections in this chapter illustrated how the price of gasoline affects the fleet mix and the fuel consumption for a year. The next step is to estimate revenue generated, considering several user fee options, and check how these would impact the HTF. Various options are explained and the revenue generated for these scenarios are provided in this section. The various options include:

I. Charge gasoline tax as a fixed amount/gallon
a) Charge fuel tax based on existing rate

b) Charge fuel tax based on existing rate adjusted for inflation from the year 2009 based on consumer price index (CPI)

c) Charge fuel tax based on existing rate adjusted for inflation from the year 2009 based on producer price index (PPI)

d) Charge fuel tax based on existing rate, adjusted for inflation from the year 1993 based on CPI

e) Charge fuel tax based on existing rate adjusted for inflation from the year 1993 based on PPI

f) Increase fuel tax by a fixed amount

g) Increase fuel tax by a fixed amount and adjust it for inflation from the year 2009 based on CPI

h) Increase fuel tax by a fixed amount and adjust it for inflation from the year 2009 based on PPI

II. Charge gasoline tax as a percent value of the gasoline price

a) Charge fuel tax as a percent value based on gasoline price of the year 2009

b) Charge fuel tax as a percent value based on gasoline price of the year 1993

III. Convert some road segments to toll roads

a) Convert some of the roads to toll roads at the existing standard toll rates

b) Convert some of the roads to toll roads at the existing standard toll rates and adjust for inflation based on CPI

c) Convert some of the roads to toll roads at the existing standard toll rates and adjust for inflation based on PPI
IV. Charge based on VMT
   a) Charge based on VMT with the year 2009 as the base year
   b) Charge based on VMT adjusted for inflation from the year 2009 based on CPI
   c) Charge based on VMT adjusted for inflation from the year 1993 based on CPI
   d) Charge based on VMT adjusted for inflation from the year 2009 based on PPI
   e) Charge based on VMT adjusted for inflation from the year 1993 based on PPI

V. Tier system for charging based on VMT
   a) Tier system based on 2009 rates to maintain the system
   b) Tier system based on 2009 rates to maintain the system and adjust for inflation based on CPI
   c) Tier system based on 2009 rates to maintain the system and adjust for inflation based on PPI
   d) Tier system based on 2009 rates to improve the system
   e) Tier system based on 2009 rates to improve the system and adjust for inflation based on CPI
   f) Tier system based on 2009 rates to improve the system and adjust for inflation based on PPI

VI. Charge based on axle load and VMT
   a) Charge based on VMT and axle load

57
b) Charge based on VMT and axle load and adjust for inflation based on CPI

c) Charge based on VMT and axle load and adjust for inflation based on PPI

Discussions on the aforementioned alternatives to estimate revenues for these various scenarios are discussed as follows.

4.6. Charge Gasoline Tax as a Fixed Amount Per Gallon

It is the present scenario of generating revenues. Here, the gasoline taxes are collected as a fixed amount irrespective of the gasoline price. Since it has been used over the years, it has a proven record and since the taxes are collected even before it reaches the distributors, it is relatively fraud-proof. The advantage of this system is illustrated in several studies (Hecker 2002, McDaniel & Coley 2004, and Pruentes & Prince 2003). The procedure to estimate revenue based on charging gasoline as a fixed amount per gallon for any year could be illustrated using Figure 10. It shows that as the gasoline tax rate changes, the corresponding gasoline price also changes. As illustrated in previous steps, the new vehicle fleet is dependent on the price of gasoline and total number of estimated vehicles registered. Using the new vehicle sales data and historical vehicles sales data, the vehicle fleet mix for that particular year could be estimated by multiplying the number of vehicles with corresponding EPA estimated survivability. The vehicle fleet mix is adjusted to make the total number equal to the vehicle registration data for that particular year. Using the adjusted fleet mix and EPA estimated vehicle miles travelled (VMT) by vehicle categories, total VMT by each of the vehicle categories is estimated. This estimated VMT based on vehicle fleet mix is adjusted to match with the total VMT estimated based on highway statistics report. Using the adjusted VMT and weighted
average fuel efficiency of vehicle categories, fuel consumption by each vehicle categories and hence total fuel consumption for that particular year could be estimated. By multiplying the total fuel consumption with the gasoline tax rate, revenue generated from gasoline taxes could be estimated.

4.7. Charge Gasoline Tax as Percent Value of Gasoline Price

In the U.S., the gasoline tax has been collected as a fixed value per gallon. Therefore, the revenue generated depends only on the quantity of gasoline sales. One of the major issues with the existing scenario is that it does not take into consideration depreciation of dollar value. By following the percent charging of gasoline, this issue could be adjusted a certain extent. An AASHTO publication (AASHTO 2007c) discusses the option of changing the gasoline tax to a 5 percent tax. The procedure to estimate revenue based on charging gasoline as a percent value of gasoline price for any year could be illustrated using Figure 11. Here the process is very similar to that of charging as a fixed amount per gallon, with the only difference of tax as a percent instead of tax rate.

4.8. Revenue Generated by Tolling

Toll roads make the users pay for their use. Therefore, it could be considered as a direct user fee. In the U.S. very small proportion of roads are currently tolled. This option evaluates the feasibility of using tolling as a replacement or as way to produce additional income to maintain and improve the existing infrastructure. Davis (2008) iden-
-tifies tolling as one of the potential sources for funding for transportation projects. Szeto & Lo (2007) discuss the viability of charging time-dependent tolling strategies. These show that because of the proven technologies, tolling is a viable option to charge user fee either in its primitive version or for advanced charging, such as, congestion pricing. One
of the drawbacks in using tolling is that as of now, it could be used only on freeways. However since the funds from highway trust funds are used mainly for roadways in National Highway Systems (NHS), which are predominantly freeways, tolling could easily be justified. Figure 12 illustrates the process for this option. The first step in this option is to define roadway functional classes. Then estimate VMT of passenger vehicles on these classes of roadways. Historical data of major functional classes for both urban
and rural areas are published on "Highway Statistics" by the US Department of Transportation. The next step is to identify which of the functional classes needs to be selected for tolling. The options include; all interstates, all freeways, all urban interstates, all rural interstates, and all urban freeways. Once the selection is made, one needs to define what proportion of the roadways needs to be tolled. Because of public protests and political involvement, it is impossible to toll the entire road segments selected. Sometimes 25, 50, or 75 percent of the selected functional class may be selected. Using this proportion multiplied by the total VMT by passenger vehicles in that functional class, VMT that needs to be tolled is estimated. Now multiplying that with the toll rate obtained from existing toll roads would provide the estimate of revenue generated.

Figure 12. Flow Diagram of Estimating Revenue based on Tolling Roads
4.9. Charge based on VMT

Strictly speaking, the first two options of revenue generation could not be considered as a user fee since the tax is collected based on gasoline consumption. By using gasoline based taxes, the fuel efficient vehicles would not be paying a fair share for their use. However, the roadway deterioration caused is based on the vehicle miles traveled and axle loads of each of the vehicles. With more fuel efficient vehicles introduced into the market, would make big impact on the revenues. To avoid the shortcomings of this procedure, one option is to charge user fees based on vehicle miles traveled (VMT). Forkenbrock (2005) and Sorensen & Taylor (2006) discuss the advantages of adapting a VMT based user fee structure and its feasibility. Bertini & Rufolo (2004) describes the technology considerations for a statewide road user fee system. Figure 13 illustrates the procedure for this option. Here the procedure is quite simpler than the ones used for gasoline tax based systems. Since the charge is levied based on VMT, the fleet mix or VMT distribution need not be considered. In this case, analyzing historical data, the charge per VMT could be estimated by dividing the total revenue generated from fuel tax by total VMT, assuming that the VMT based charge would replace the existing gasoline based tax system. Now the total revenue could be estimated by multiplying this charge with the estimated VMT from Highway Statistics or other reliable models.

4.10. Tier System for Charging based on VMT

This option is very similar to the previous option, with the difference that instead of charging everyone the same rate for the usage, charging more to the users who use the sy-
Figure 13. Flow Diagram of Estimating Revenue based on VMT based Charge

-stem more. This is very similar to the systems used by utility agencies such as electricity and water. Figure 14 illustrates the process for this option. Here the first step is to define tiers, identify the proportion of VMT based charge for each of these tiers, and identify the average VMT by vehicles in each of these tiers. Similar to the previous option, based on historical revenue data and VMT data, the required charge per VMT (not considering tiers) could be estimated. Multiplying this value with the proportion of VMT based charge for each of the tiers, the charge per VMT for each of the tiers is estimated. In order to estimate revenue based on the tier system, the next step is to estimate the total VMT by vehicles in each category. The number of vehicles belonging to each tier is estimated by multiplying proportion of vehicles in each tier by the total number of vehicles estimated for that year. Multiplying this value with the average VMT by vehicles belonging to each tier would provide estimate of total VMT by vehicles in each tier. Multiplying this with the Total VMT by vehicles in each tier would provide total revenue generated.
Figure 14. Flow Diagram of Estimating Revenue based on Tier System based VMT Charge.
4.11. Charge based on Axle Load and VMT

As indicated in previous sections, the real user fee is that collected based on the usage. Charging based on VMT is one way to access user fees. However, this process does not consider the deterioration caused by that particular vehicle because of its weight. Deteriorations caused to the pavements are dependent on their weight and their axle configurations. Therefore, a mechanism to charge heavier vehicles a higher usage rate compared to smaller vehicle would ensure a fair usage fee based on their relative impacts on the pavement. Figure 15 illustrates the process for this option. The first step is to categorize vehicles based on their axle loads and estimate weight of the vehicle categories considered. Then using the Equivalent Single Axle Load (ESAL) method (AASHTO, 1993), the weights of these vehicles are converted into corresponding truck equivalent loads. Percent truck equivalent for each of these categories are also estimated. Estimated overall charge per VMT, without considering axle loads could be estimated based on historical revenue and VMT data. Now per VMT charge based on axle load could be calculated by multiplying this estimated overall charge per VMT and percent truck equivalent for the vehicle categories considered. Finally, revenue generated is estimated by multiplying the calculated per VMT charge based on axle load and total VMT by the corresponding vehicle categories.
Figure 15. Flow Diagram of Estimating Revenue based on Axle Load and VMT
CHAPTER 5

EVALUATING ALTERNATIVE FINANCING STRATEGIES

Chapter 3 estimated required revenue that needs to be generated from user fee in order to maintain and (or) to improve the roadway infrastructure. The previous chapter illustrated how the price of gasoline affects the fleet mix and the fuel consumption for a year. The previous chapter introduced several options to generate revenues from road users. In this chapter each of these options will be implemented and evaluated for their effectiveness in generating the revenues required for the Highway Trust Fund (HTF). The options as discussed in previous chapter are:

- 5.1 Charge gasoline tax as a fixed amount per gallon
- 5.2 Charge gasoline tax as a percent value of the gasoline price
- 5.3 Convert some of the roads to toll roads
- 5.4 Charge based on VMT
- 5.5 Tier system for charging based on VMT, and
- 5.6 Charge based on axle load and VMT

Each of these options is discussed in detail in this chapter. Similar to the previous chapters, in this chapter also, for demonstration purpose, the target year considered is 2025. In this chapter, unless otherwise specified, the base price of gasoline is taken as $4.00 for the year 2008, with an annual increase based on estimated average
Consumer Price Index (CPI) rate. The fleet mix and corresponding fuel consumptions are estimated based on the methodology explained in Chapter 4. The process of estimating revenue for a fixed tax rate is provided in figures 4.4 to 4.9. The step by step calculation for each of the options is explained in this chapter.

In this chapter, as discussed in the methodology, two indices are used to adjust for inflation over the years. The Consumer Price Index (CPI) is defined by the Bureau of Labor Statistics (BLS, 2008a.) as “is a measure the average change over time in the prices paid by urban consumers for a market basket of consumer goods and services”. CPI is generally used as an economic indicator and as a means of adjusting dollar values for consumers. The BLS releases average CPI of various consumer items, as well as average of all items for various metro cities by month and annually. For this study, the CPI of the US for all items is considered.

In order to estimate the future CPI, the average annual rate of change of CPI over the past 10 years is estimated using the equation:

\[ \text{CPI Annual Change} = \left[ \frac{\text{CPI}_{2007}}{\text{CPI}_{1997}} \right]^{\frac{1}{10}} - 1 \]  

Using the values in over the last 10 years, the CPI is calculated to be 0.026. This value is used as the default CPI for all the estimations in this chapter.

Although CPI provides inflation information on consumer goods, highway and street construction costs are typically not estimated using CPI. Therefore, a separate index, the Producer Price Index (PPI) is used for this purpose. Similar to CPI for consumer goods, PPI is a group of indices that measures the average change over time in selling prices received by producers of goods and services. The major difference between CPI and PPI is that CPI measure price change from the purchasers’ point of view whereas PPI is based
on the expenses for producers. In construction, PPI is used as a basis for contract escalation. Similar to CPI, BLS generates several monthly and annual tables for PPIs of various products. The average annual rate of change in PPI is calculated using the equation same as 5.1 and the value is 0.046 for the last 10 years.

Figure 16 compares CPI and PPI over the years 1987 to 2007 after both indexed value of the year 1987 to 100. It can be seen that that values of both CPI and PPI show different trends and hence it is important to use PPI for construction related estimates. Figure 16 also shows that the PPI has been lower than the CPI for most of the time over the last 20 years. However, over the last five years, the PPI showed a rapid increase and it went over CPI for the years 2006 and 2007. The calculated average PPI for the last five years is 0.078. This is quite high compared to the rate estimated for the last 10 years. Therefore, it is important to decide which value to be used for this study as the default PPI. In order to understand the sudden increase in the last five years, the indexed gasoline price for the same time period also is drawn. As seen in Figure 16, it is seen that the CPI rate does not affect by gasoline price. On the other hand, the PPI and gasoline price show very similar trend except for a couple of instances. As the gasoline price increases, the PPI also increases. As the graph shows, the average gasoline price over the last four years increased. That might be the reason for the sudden increase in PPI along the same time frame. Most of the construction equipments and materials require petroleum products. Therefore, this relationship is understandable. However, in the coming years, it is unlikely that the gasoline price will increase the way it did over the past four years. Therefore, the average PPI value also would not be increasing at the higher rates. Therefore, the default value of PPI for this study is selected as 0.046.
5.1. Option I: Charge Gasoline Tax as a Fixed Amount/Gallon

Currently, the user fee is collected as a federal fuel tax on gasoline, at a rate of 18.4 cents per gallon. Using the same rate, the revenue generated could be calculated based on the estimated fuel consumption developed in Chapter 3. Here the revenue generated for a year $i$ is represented as:

$$R_i = FC_i \times \left(\frac{FTR_i}{1,000,000,000}\right) \quad \text{(5.2)}$$

where $R_i$ is the revenue in Billion of Dollars for the year $i$

$FC_i$ is the fuel consumed for the year $i$

$FTR_i$ is the fixed tax rate in Dollars
Here, as seen in equation (5.2), estimated revenues are directly proportional to the fuel consumption, which in turn is strongly correlated with the fleet mix. As the fleet mix consist of more hybrid and alternate fuel vehicles, the fuel consumption is expected to go down because of their higher fuel efficiency. The process of estimating revenue for fixed tax rate is provided in previous chapter. Step by step calculations for each of the processes are explained in this chapter. Unless specified otherwise, it is assumed that the average price of gasoline (without considering federal or state taxes) increases based on Consumer Price Index. To estimate gasoline price, federal and state taxes are added to the gasoline price. Another assumption is made that the same changes applied to the federal portion of the gasoline taxes are applied to the state and local portions as well. The gasoline price for any year could be estimated using the equation;

\[ GP_i = ((GP_{2008} - FT_{2008} - SLT_{2008}) \times (1+r)^{(i-2008)}) + FT_i + SLT_i \]

where, \( GP_i \) – Average gasoline sales price for the year \( i \)

\( FT_i \) – Federal gasoline tax for the year \( i \)

\( SLT_i \) – state and local gasoline tax for the year \( i \), and

\( r \) – annual rate of change (= 2.3 percent for CPI)

For this option various rates for \( FT_i \) are used and corresponding revenue generated are estimated:

5.1.1. Charge fuel tax based on existing rate

5.1.2. Charge fuel tax based on existing rate adjusted for inflation from the year 2009 based on Consumer Price Index (CPI)

5.1.3. Charge fuel tax based on existing rate adjusted for inflation from the year 2009 based on Producer Price Index (PPI) for Streets and Highways
5.1.4. Charge fuel tax based on existing rate, adjusted for inflation from the year 1993 based on CPI

5.1.5. Charge fuel tax based on existing rate adjusted for inflation from the year 1993 based on PPI

5.1.6. Increase fuel tax by a fixed amount

5.1.7. Increase fuel tax by a fixed amount and adjust it for inflation from the year 2009 based on CPI

5.1.8. Increase fuel tax by a fixed amount and adjust it for inflation from the year 2009 based on PPI

Each of the various rates adopted are discussed in the following sections.

5.1.1. Charge Fuel Tax Based on Existing Rate

Currently, the user fee is collected as a federal fuel tax on gasoline, at a rate of 18.4 cents per gallon. Using the same rate, the revenue generated could be calculated based on the estimated fuel consumption developed in Chapter 3. Here the revenue generated for a year i could be represented as:

\[ R_i = FC_i \times \frac{0.184}{1,000,000,000} \]  

where \( R_i \) is the revenue in Billions of Dollars for the year i

\( FC_i \) is the fuel consumed for the year i

In order to show the impact of hybrid vehicles and alternate fuel vehicles on the fuel consumption, as illustrated in previous chapter, revenue generated for three scenarios are considered:

5.1.1.1) fleet contains only regular gasoline vehicles

5.1.1.2) fleet contains both regular gasoline and hybrid vehicles, and
5.1.1.3) fleet contains regular gasoline, hybrid, and alternate fuel vehicles.

Calculations for estimating fleet mix and VMT are provided in chapter 4. Using these equations, estimated revenues for these three scenarios are estimated below.

5.1.1.1. Fleet contains only regular gasoline vehicles

In this case, it is assumed that either hybrid vehicles or alternate vehicles do not exist and all the vehicles available in market will be regular gasoline fuel based vehicles. In order to estimate fuel consumption, Vehicle Miles of Travel (VMT) needs to be estimated for each of the future years considered. To do this, estimated number of vehicles registered, estimated number new vehicles introduced each year, and estimated fuel efficiency of these vehicles needs to be estimated.

Highway Statistics published by the U.S. Department of Transportation (FHWA, 2005) publishes total number of vehicles registered and estimated VMTs for each of the years. From these average VMT per vehicle registered is estimated for each of the years from 1981 to 2005. Looking at the change in the number of vehicles registered and in the VMT per registered vehicles, it is seen that overall, there is a 1.86 percent increase in the number of vehicle registered per year, where as the increase in the average VMT per vehicle is 1.04 percent. Assuming the trend would continue, the number of vehicles registered and average VMT per registered vehicles could be estimated using equations:

\[ RV_i = RV_{2005} \times (1+r_{rv})^{(i-2005)} \quad \ldots 5.5 \]

and \( (VMT/RV)_i = (VMT/RV)_{2005} \times (1+r_{rv})^{(i-2005)} \) \( \ldots 5.6 \)

where \( RV_i \) is the total registered vehicles registered for the year \( i \)

\( RV_{2005} \) is the total registered vehicles registered for the year 2005

\( r_{rv} \) is the rate of annual change in registered vehicles (= 1.86 percent)
(VMT/RV), is the average VMT per registered vehicles for the year i

(VMT/RV)_{2005} is the average VMT per registered vehicles for the year 2005

r_v is the rate of annual change in VMT per registered vehicles (= 1.04 percent)

Using these equations total registered vehicles and average VMT per registered vehicles could be estimated for a future year. Using these estimated values, total VMT for a year i could be calculated using the equation,

\[ VMT_i = (VMT/RV)_i \times RV_i \] ..........................................(5.7)

Once the total number of vehicles registered for a future year is estimated, the next step is to estimate new vehicles sales for that year using the relationships established in chapter 4. The total number of new vehicles for sold for a future year is determined based on the estimate of total number of vehicles registered in that particular year. In order to estimate fleet mix of new vehicles sold, as indicated previous chapter, gasoline price needs to be estimated. Assuming the federal tax and state remain the same, the gasoline sales tax for years from 2009 to 2025 is estimated to be $0.184. Gasoline sales price is estimated based on the assumption that it increases based on CPI over the years.

Based on the number of new vehicles sold and average gasoline price, fleet mix of new vehicles sold are estimated based on equations developed in Chapter 4. Using the estimates of new vehicles sold and vehicle survivability data from EPA, fleet mix of all registered vehicles for a particular year is estimated using the procedure explained in Figure 4 of Chapter 4. Adjusting the estimated fleet mix to match the estimated vehicle registration data, adjusted fleet of all vehicles registered, and Vehicle Miles Travelled (VMT) for a year is estimated. In this study in order to estimate fuel consumed, it is assumed that the average fuel efficiency of the regular fuel automobiles increase by 3.0
percent annually even without considering hybrid or alternate fuel vehicles. This value is selected based on the revised CAFE standard of average fuel efficiency improvement of 4.5 percent each year till 2015. Although the 3 percent used in this study is lower than the CAFE recommended rate, since all the major car manufacturers in the U.S. are developing hybrid and alternative fuel vehicles, a 3 percent improvement in regular fuel vehicles would be sufficient to comply with the revised CAFE standards, once hybrid and alternative fuel vehicles are added to the fleet by each of the automobile manufacturers.

Using this fuel efficiency data and VMT data by vehicle class, fuel consumption for each of the vehicle class for all the study years are estimated. The generated revenue for a particular year is estimated by multiplying the fuel consumed with the fuel tax rate, which is $0.184 in this case, the existing federal fuel tax.

Tables A36 to A45 in the Appendix illustrate each of these estimations.

5.1.1.2. Fleet contains both regular gasoline and hybrid vehicles

Previous section showed the impacts of improving average fuel efficiency of vehicles on gasoline tax revenues. However, in order to provide accurate estimation, it is important to consider both hybrid and alternate fuel vehicles in the vehicle fleet mix. As discussed in the previous chapter, the numbers of these categories of vehicles are expected to increase in the years to come, as demonstrated in Chapter 4. When these two categories are considered, it is assumed that the total number of new vehicles sold each year and total estimated VMT remain the same as estimated in Chapter 4. This could be mathematically represented as:

\[ \text{Total New Vehicles}_i = \text{RG}_i + \text{HV}_i + \text{AFV}_i \]  

\[ \text{......(5.8)} \]

where \( i \) is the year considered,
RG\textsubscript{i} is the number of new regular gasoline vehicles sold in the year \textit{i}.

HV\textsubscript{i} is the number of new hybrid vehicles sold in the year \textit{i}, and

AFV\textsubscript{i} is the number of new alternate fuel vehicles sold in the year \textit{i}.

\[ VMT\textsubscript{i} = VMT_{RGi} + VMT_{HVi} + VMT_{AFVi} \]  

\text{......(5.9)}

where, \( VMT_{RGi} \) is the VMT by regular gasoline vehicles for the year \textit{i},

\( VMT_{HVi} \) is the VMT by hybrid vehicles for the year \textit{i}, and

\( VMT_{AFVi} \) is the VMT by alternate fuel vehicles for the year \textit{i}.

In the present scenario, it is assumed that only hybrid vehicles are introduced to the fleet mix other than the regular gasoline vehicles. Here, the in the equations 5.8 and 5.9, AFV\textsubscript{i} and VMT\textsubscript{AFVi} are given a value of zero respectively. Results from Chapter 4 shows the estimated number of hybrid vehicles sold each year and hence the total registered hybrid vehicle per year. As explained in the equations 5.8 and 5.9, when hybrid vehicles are considered, the total number of new regular gasoline vehicles are equal to the difference between the total number of new vehicles sold and total number of hybrid vehicles sold, so that the total number of new vehicles sold each year would remain the same. Similarly, the VMT by regular gasoline vehicles are equal to the difference between the total VMT and the estimated VMT by hybrid vehicles. Using the equations developed and values estimated in Chapter 4, revised number of new regular gasoline vehicles, total registered regular gasoline vehicles and their VMT, fuel consumption for each of the year are estimated. As expected, these estimates show that in each year, the VMT by hybrid vehicles increase and hence, the total fuel consumption reduces because of the better gasoline mileage of hybrid vehicles. The revised estimates of revenue
estimated considering hybrids show a notable decrease in the estimated revenue for the years considered.

5.1.1.3. Fleet contains regular gasoline, hybrid, and alternative fuel vehicles (AFVs)

Although previous case considered hybrid vehicles into the fleet mix, they did not include alternative fuel vehicles (AFV), which do not use gasoline at all. Based on estimates from Chapter 4, the vehicles in this category are expected to increase notably in the future years. Using the equations 5.8 and 5.9, fleet mix and corresponding VMT are estimated in the same way as explained in the previous case. As expected, it shows that in each year, the number of registered AFVs, and corresponding VMT by AFVs increase. By making this change, the total fuel consumption reduces, since AFVs do not use gasoline as its fuel. Figure 17 compares the estimated revenue for these three scenarios for the years 1981 to 2025 and Figure 18 shows the same comparison for the years 2005 to 2025 along with the information on required funding needs for infrastructure maintenance and improvement. Figure 5.2 shows that the estimated revenue decreases as the hybrid vehicles and AFVs are considered. It shows that it is important to consider the presence of these categories of vehicles on the fleet mix when estimating revenue based on gasoline taxes. On the other hand, comparing these estimates with the required funds or maintenance and improvements, all these estimated revenues are lower than the required funding. This also shows the significance of changing the fuel tax rate or even changing the existing user fee structure.

Tables A46 to A53 in the Appendix shows the calculations of each of the steps explained here.
Figure 17. Comparison of Revenue Generated Assuming No Change in Gasoline Tax Rate, 1981-2025

Figure 18. Comparison of Revenue Generated Assuming No Change in Gasoline Tax Rate, 2005-2025
5.1.2. Charge Fuel Tax Based on Existing Rate Adjusted for Inflation based on Consumer Price Index (CPI) from the year 2009

Analysis in the previous sections showed that the existing gas tax rate would not be able to generate required revenue to even maintain the existing transportation infrastructure. Therefore, it is necessary to change it. One of the options would be to adjust the tax rate for the inflation. In this case the existing rate could be adjusted based on the some national index, such as Consumer Price Index (CPI). Both federal and state & local tax rates are adjusted for inflation and revised gasoline price based on these calculations are estimated.

Based on the estimated gasoline price, fleet mix of new vehicles sold, fleet mix of registered vehicles, VMT by vehicle categories, fuel consumption, and revenue generated are estimated for the three criteria as described in the previous section.

5.1.2.1) fleet contains only regular gasoline vehicles

5.1.2.2) fleet contains both regular gasoline and hybrid vehicles, and

5.1.2.3) fleet contains regular gasoline, hybrid, and alternate fuel vehicles respectively.

Figures 19 and 20 show the comparison of revenues generated for these scenarios. Tables A 54 to A 57 in Appendix shows the calculations in developing these estimates.

Figure 20 shows that by adjusting the gasoline tax rate based on CPI, the revenue increases notably. However, comparing it with the revenue required even to maintain the transportation network, it is seen that even if the hybrid vehicles and AFVs are not considered, the estimated revenue generated are off by over 30 Billion Dollars. This shows that using CPI adjustment for gasoline tax rate alone would help generate required funding and it is important to explore for other options to generate revenue.
Figure 19. Comparison of Revenue Generated for Gasoline Tax Rate Adjusted for Inflation Based on CPI from 2009, 1981-2025

Figure 20. Comparison of Revenue Generated for Gasoline Tax Rate Adjusted for Inflation Based on CPI from 2009, 2005-2025
5.1.3. Charge Fuel Tax Based on Existing Rate Adjusted for Inflation based on Producer Price Index (PPI) from the year 2009

Analysis in the previous sections showed that the existing gas tax rate would not be able to provide the revenue that is required to even maintain the existing transportation infrastructure, even by adjusting it with inflation based on CPI. Most of the transportation infrastructure maintenance and improvements are construction related. Therefore, instead of using CPI to index the taxes, Producer Price Index (PPI) for Street and Highway Construction would provide a more realistic adjustment. This case is very similar to the previous option, with replacing CPI with PPI. Based on the estimated gasoline price, fleet mix of new vehicles sold, fleet mix of registered vehicles, VMT by vehicle categories, fuel consumption, and revenue generated are estimated for the three scenarios as described in the previous sections. Figure 21 shows the comparison of revenue generated for three scenarios. Tables A58 to A61 in Appendix show the calculations in developing these estimates.

Figure 21 shows that by adjusting the gasoline tax rate based on PPI, the revenue increases notably. It also follows the trend of the funds required for maintenance over the years. However, comparing it with the required revenue to maintain the transportation system, the estimated revenue without considering hybrid vehicles or AFVs are off by over 10 Billion Dollars. This shows that this option is not viable to generate required revenue.

5.1.4. Charge Fuel Tax Based on Existing Rate Adjusted for Inflation based on CPI from the Year 1993

Analysis in the previous sections showed that the existing gas tax rate would not be
able to provide the revenue that is required to even maintain the existing transportation infrastructure, even with adjusting it for inflation based on CPI or with PPI. The existing gasoline tax rate of $0.184 was fixed in the year 1993. Therefore, in order to estimate its inflated value in the year 2009, it needs to be converted to the current value by adjusting it for inflation. This case is very similar to the previous two options, with the exception that instead of indexing the federal tax based on CPI from the year 2009, it is applied from the year 1993.

Based on the estimated gasoline price, fleet mix of new vehicles sold, fleet mix of registered vehicles, VMT by vehicle categories, fuel consumption, and revenue generated are estimated for the three scenarios described in the previous sections. Figure 22 shows
the comparison of revenue generated for these scenarios. Tables A62 to A65 in Appendix show the calculations in developing these estimates.

This figure shows that by indexing the gasoline tax rate from the year 1993 based on CPI, the revenue increases notably. In initial three to four (2009-2012) years the estimated revenues generated were very close to the required funding to maintain the transportation system. However, after each year, the gap between the estimated revenue and the required funds increases. This shows that adjusting the gasoline tax rate to prorate based on 1993 rate using CPI is not a sustainable option for a longer period there for it is necessary to explore other options.

![Figure 22. Comparison of Revenue Generated for Gasoline Tax Rate Adjusted for Inflation Based on CPI from 1993, 2005-2025](image-url)
5.1.5. Charge Fuel Tax Based on Existing Rate Adjusted for Inflation based on PPI from the year 1993

This case is very similar to the previous option, with replacing CPI with PPI. Based on the estimated gasoline price, fleet mix of new vehicles sold, fleet mix of registered vehicles, VMT by vehicle categories, fuel consumption, and revenue generated are estimated for the three scenarios described in the previous sections. Figure 23 shows the comparison of revenue generated for these scenarios. Tables A66 to A69 in Appendix show the calculations in developing these estimates.

Figure 23 shows that by adjusting the gasoline tax rate based on PPI from the year 1993, there is a significant increase in the estimated revenue generated. Among all the options discussed so far, this is the only option providing revenue more than the required fund to maintain or even improve the transportation system. Even after considering the impact of hybrid vehicles and alternate fuel vehicles, the estimated revenue generated is higher than the projected required funds to improve the system.

5.1.6. Increase Fuel Tax by a Fixed Amount

Analysis in the previous sections showed that at the existing gas tax rate, even with prorating for inflation would not be able to generate required revenue to even maintain the existing transportation system. Therefore, it is important to explore other options to charge gasoline taxes. One of the options is to increase the tax rate by a fixed amount. In the months of June – August 2008, there were several reports from media discussing the gasoline tax rates. Based on these reports, (Fox News, 2008, and CNN, 2008) the U.S. Congress is debating on raising the gasoline tax by 10 cents. Assuming that a decision is
made on the issue, the revenue generated (in Billions of Dollars) for a year $i$ could be represented as:

$$ R_i = FC_i \times \left( \frac{0.284}{1,000,000,000} \right) $$

In this section, three scenarios illustrated in the previous sections are performed to check if the proposed changes would generate more revenue to offset the requirements. Figure 24 shows the comparison of revenue generated for these scenarios. Tables A70 to A73 in Appendix show the calculations in developing these estimates.

Figure 24 shows that by increasing the gasoline tax rate by 10 cents in the year 2009, there is a notable increase in the estimated revenue generated. It is seen that the new tax structure would provide enough funds to maintain the infrastructure till the year 2012, assuming that there would not be any alternative fuel vehicles on the market. Once the
alternative fuel vehicles are included in the fleet mix, the estimated revenues would not
be sufficient to maintain the existing transportation infrastructure, even if alternative fuel
vehicles are not considered, from the year 2013 onwards, the revenue would not be
sufficient to sustain the infrastructure needs. These results show that by increasing the tax
rate by 10 cents a gallon, although short term needs would be satisfied, this may not work
for long term.

![Graph showing revenue comparison](image)

Figure 24. Comparison of Revenue Generated for Gasoline Tax Rate Increased by 10
Cents, 2005-2025

5.1.7. Increase Fuel Tax by a Fixed Amount and Adjust it for Inflation from the Year
2009 based on CPI

Estimates from previous section showed that although increasing the existing gas tax rate
by 10 cents would provide enough funds to maintain the system for a while, it would not
be able to provide sustainable revenue over time. One of the options would be to prorate
the increased tax rate based on CPI. Figure 25 shows the comparison of revenue generated for the three scenarios discussed in previous sections. Tables A74 to A77 in Appendix show the calculations in developing these estimates.

Figure 25 shows that by increasing the gasoline tax rate by 10 cents in the year 2009 and adjusting it for inflation based on CPI, there is a notable increase in the estimated revenue generated. It is seen that the new tax structure would provide enough funds to maintain the infrastructure till the year 2015, assuming that there would not be any alternative fuel vehicles on the market. Once the alternative fuel vehicles are included in the fleet mix, the estimated revenues would not be sufficient to maintain the existing transportation infrastructure. Even if alternative fuel vehicles are not considered, from the year 2016 onwards, the revenue would not be sufficient to sustain the transportation infrastructure needs. These results show that by increasing the tax rate by 10 cents a gallon and adjusting it for CPI would not be an effective long term option.

5.1.8. Increase Fuel Tax by a Fixed Amount and Adjust it for Inflation from the Year 2009 based on PPI

Estimates from previous section showed that increasing the existing gas tax rate by 10 cents and adjusting it for inflation based on CPI also provide only a short term solution for maintaining transportation infrastructure. One of the options would be to prorate the increased tax rate using PPI, instead of using CPI. Figure 26 shows the comparison of revenues generated for three scenarios considered in the previous sections. Tables A78 to A81 in Appendix show the calculations in developing these estimates.
Figure 25. Comparison of Revenue Generated for Gasoline Tax Rate Increased by 10 cents and Adjusted for Inflation based on CPI from 2009, 2005-2025

Figure 26 shows that by increasing the gasoline tax rate by 10 cents in the year 2009 and adjusting it for inflation based on PPI, there is a notable increase in the estimated revenue generated. It is observed that the new tax structure would provide more than the required funds to maintain the infrastructure till the year 2025 for all the three scenarios. This result shows that this could be an effective long term viable option to maintain the transportation infrastructure.

5.2. Charge Gasoline Tax as a Percent Value of the Gasoline Price

As discussed in the previous sections, in the U.S., the gasoline tax has been collected as a fixed value per gallon. Therefore, the revenue generated depends only on the quantity of
gasoline sales. One of the major issues with the existing scenario is that it does not take into consideration depreciation of dollar value, unless adjustments are made to the rates based on some standard indices. By following the percent charging of Gasoline sales price, this issue could be adjusted to an extent. Three options are considered for this option.

5.2.1. Charge fuel tax as a percent value based on gasoline price of the year 2009
5.2.2. Charge fuel tax as a percent value based on gasoline price of the year 1993
5.2.3. Charge fuel tax as a percent value based on gasoline price of the year 2004

Each of these options are discussed in detail as follows.
5.2.1. Charge Fuel Tax as a Percent Value based on Gasoline Price Starting 2009

Considering the year 2008 as base year, assuming the gasoline price to be $4.00 per gallon, out of which 18.4 cents is federal gasoline tax and another 19.3 cents is state and local taxes. Tax rate tax could be calculated as:

\[
\text{Tax rate} = \frac{0.184}{4.00 - 0.184 - 0.193} = 5.08\%
\]

Replacing the existing tax system with this rate is one option. It would help generate more revenues when the gasoline prices are higher. This methodology would help the gasoline tax to be prorated based on gasoline prices, which is assumed to change based on the depreciation of dollar value. Figure 5.27 shows the comparison of revenue generated for these scenarios. Tables A82 to A85 in Appendix show the calculations in developing these estimates.

Figure 27 shows that by charging the gasoline tax as a percent value of gasoline price from the year 2009, there is a notable increase in the estimated revenue generated. However, the projected revenue generated is very less than the required funding to maintain the transportation system. Therefore, this could not be considered as a solution for the existing system.

5.2.2. Charge Fuel Tax as a Percent Value based on Gasoline Price of the Year 1993

Previous option considered the year 2008 as base year. Instead of that by considering the year 1993 as the base year, tax rate as a percent value of the gasoline price for the years from 2009 to 2025 are estimated. This methodology would help the gasoline tax to be prorated based on gasoline prices of the year in which the existing tax rate was finalized.

\[
\text{Tax rate (for 1993)} = \frac{0.184}{1.224 - 0.184 - 0.155} = 20.8\%
\]
Figure 28 shows the comparison of revenues generated for the three scenarios considered. Tables A86 to A89 in Appendix show the calculations in developing these estimates.

Figure 28 shows that by charging the gasoline tax as a percent value from the year 1993, there is a significant increase in the estimated revenue generated. The estimated

![Figure 27. Comparison of Revenue Generated Considering Fuel Tax as a Percent Value based on Gasoline Price Starting 2009, 2005-2025](image)

revenues for each of the scenarios are more than the required funding to either maintain or to improve the transportation system. This shows that had the policy makers changed the tax rate from fixed rate to a percent value as used for any other commodity in the year 1993, the current issue of deficit would not have occurred. One of the issues with this option is that it will create more funds than what is required. Although from maintenance point of view, this is good, it would cause uproar from public and elected officials.
Therefore, generating user fee based revenue on this option might not be feasible. On the other hand, as discussed previously, converting the user fee to a percent based system starting 2009 would not generate enough funds to even maintain the system. To make the user fee appealing to public and elected officials as well as to generate enough funds, a different percent needs to be identified.

Figure 28. Comparison of Revenue Generated Considering Fuel Tax as a Percent Value based on Gasoline Price of the Year 1993, 2005-2025

5.2.3. Charge fuel tax as a percent value based on gasoline price of the year 2004

Previous options considered the years 1993 and 2008 as base years and each of those showed that they would not provide good solution for the gasoline tax based revenue. Instead of that by considering the year 2004 as the base year, tax rate as a percent value of the gasoline price for the years from 2009 to 2025 are estimated.
Tax rate (for 2004) = $0.184/(1.75-0.184-0.193) = 10.5\%$

Figure 29 shows the comparison of revenue generated for these scenarios. Tables A90 to A93 in Appendix show the calculations in developing these estimates.

Figure 29 shows that by using 2004 based percent gasoline tax, the estimated revenue for the first few years of implementation would yield revenue to even improve the system. As the year increases, as fuel efficiency improves, the estimated revenue decreases over the years and by the year 2025, the estimated revenue would be enough to maintain the system.

Figure 29. Comparison of Revenue Generated Considering Fuel Tax as a Percent Value based on Gasoline Price of the Year 2004, 2005-2025

The analysis shows that by collecting gasoline taxes as a percent value has several advantages. By making it a percent based system eliminates the need to index the rates. On the other hand, this option is vulnerable to gasoline prices. These estimated revenues
are calculated based on the assumption that the gasoline price would increase based CPI. However, in reality, the gasoline price varies based on several factors, including, its demand, season, availability, and major events, and not by CPI. If the gasoline price decreases over the years, the revenue generated would be significantly reduced over the years.

The two options considered here: one based on gasoline tax as a fixed rate; and considering gasoline tax as a percentage value have their own advantages and drawbacks. By adapting a combination of these two options would help to utilize the advantages of each of these options. Here, the fixed rate needs to be fixed based on the required funding for a base year and instead of indexing this rate to either CPI or PPI, that portion could be generated as a percent based system. The percent portion needs to be fixed such a way that that portion would generate enough funds even at the low gasoline prices. Such a system would ensure a minimum level of funding for any gasoline price.

5.3. Converting Some Road Segments to Toll Roads

Previous two sections showed various options to generate revenue from gasoline taxes. However, as explained previously, with the introduction of hybrid vehicles and alternate fuel vehicles, this concept is not valid anymore. Therefore, a more efficient way to generate user fee would be to charge it directly from the user. The following sections discuss some of the viable options to generate user fee based revenues.

Tolling could be considered as a direct user fee, since users pay their fee based on its use. Historically, only very low percent of the US roads have some kind of tolling implemented. Some of the states even do not have any kind of toll roads (USGAO, 2006).
Therefore, by converting more road segments into toll roads, additional revenue could be
generated. This section compares various scenarios for toll roads. They are:

5.3.1. Converting some of the roads to toll roads at the existing standard toll rates

5.3.2. Converting some of the roads to toll roads at the existing standard toll rates
    and adjust for inflation based on CPI

5.3.3. Converting some of the roads to toll roads at the existing standard toll rates
    and adjust for inflation based on PPI

Each of these options is discussed in detail in this section.

5.3.1. Converting Some of the Roads to Toll Roads at the Existing Standard Toll Rates

The flow diagram for estimating revenue based on tolling is provided in chapter 4. The first step is to define roadway functional classes. In the U.S., because of implementation logistics and policy reason, among public roads, tolls were implemented only on freeways, with very few exceptions. In this study, it is assumed that tolls would be implemented only on interstate freeway segments. Interstate segments could be further classified into two major groups, urban and rural interstates. The remaining road categories are divided into ‘other urban’ and ‘other rural’ roadways. Next step is to estimate VMT on each of the considered road segments. Highway Statistics lists VMTs by various roadway functional classes. They need to be converted to the VMT by selected categories. In order to estimate revenues based on tolling VMTs on the road segments selected for future years needs to be estimated. Overall projected VMTs for all years from 2006 to 2025 are estimated. Multiplying these estimates with the average proportion of VMTs by roadway categories, estimated VMTs by roadway classes for all years considered is estimated.
Once VMTs by roadway classes are estimated, the next step is to select roadways to be tolled. Here, there are major three classes that could be tolled they are:

i) Rural interstates

ii) Urban interstates, and

iii) All interstates.

Historically, urban interstates have been tolled. Therefore, tolling rural interstates alone would not be a viable option. Therefore the other two are considered in this study.

The next step is to identify what extend of these categories would be tolled. In this study, for illustration purposes, five different proportions, 10 percent, 25 percent, 50 percent, and 100 percent are considered for each of the roadway classes considered. Holguin-Veras, et al (2006) summarizes the U.S. toll policy by comparing various toll rates for various vehicle classes in various transportation infrastructures, such as, highways, and bridges. In this paper, the authors summarize that the average toll fee for passenger vehicles on highways as 6 cents and maximum as one dollar. Since it is based on the national study, these are the ranges that would be considered in this study. Toll rates of 5 cents, 10 cents, 15 cents, 20 cents, and 25 cents per mile are considered for estimating revenue.

Figures 30, and 31 compares the estimated revenue generated for a toll rate of 10 and 15 cents for urban interstates. This shows that toll rates of 5 cents and 10 cents would not be enough to generate required fund even to maintain the system even if all the urban interstates are tolled. On the other hand, a toll rate of 15 cents would generate enough funds to maintain the transportation system for some higher proportion of toll road conversion.
Figures 32 and 33 show the estimated revenues for toll rates of 5 and 10 cents for all interstates. These figures show that a toll rate of 5 cents would not be enough to even maintain the transportation infrastructure. On the other hand, the toll rates of 10 cents would generate enough funds required to maintain and in some cases improve the transportation systems. Tables A94 to A98 in Appendix show the calculations in developing these estimates.

5.3.2. Converting some of the Roads to Toll Roads at the Existing Standard Toll Rates and Adjust for Inflation based on CPI

In this option, the steps explained in the previous steps are followed in the same order. However, instead of using a fixed toll rate over the study period, the toll rate is prorated based on Consumer Price Index (CPI). Here also revenues are estimated for various toll rates with various proportion of roadways tolled for two scenarios: 1) all interstates; and 2) all urban interstates.

Figures 34 and 35 compare the estimated revenue generated for a toll rate of 10 adjusted for inflation based on CPI for urban interstates and all interstates respectively. This shows that toll rate of 10 cents would not be enough to generate required fund even to maintain the system unless all the urban interstates are tolled. On the other hand, the rate would generate enough funds to even improve the system, if all the interstates are tolled. Tables A99 to A100 in Appendix show the estimates of revenue generated for various scenarios considered.
5.3.3. Converting some of the Roads to Toll Roads at the Existing Standard Toll Rates and Adjust for Inflation based on PPI

In this option, the steps explained in the previous steps are followed in the same order. However, instead of using a fixed toll rate over the study period, the toll rate is prorated based on PPI. Here also revenues are estimated for various toll rates with various proportion of roadways tolled for two scenarios: 1) all interstates; and 2) all urban interstates.

![Figure 30. Comparison of Revenue Considering Urban Interstates Tolled at Fixed 10 cents per Mile](image-url)
Figure 31. Comparison of Revenue Considering Urban Interstates Tolled at Fixed 15 cents per Mile

Figure 32. Comparison of Revenue Considering All Interstates Tolled at Fixed 5 cents per Mile
Figures 36 and 37 compare the estimated revenue generated for a toll rate of 10 adjusted for inflation based on PPI for urban interstates and all interstates respectively. This shows that toll rate of 10 cents would generate funds to even improve the transportation system for both these cases. Tables A101 and A102 in Appendix show the estimates of revenue generated for various scenarios considered.
Figure 34. Comparison of Revenue Considering Urban Interstates Tolled at 10 cents per Mile and Adjusted for Inflation base on CPI

Figure 35. Comparison of Revenue Considering All Interstates Tolled at 10 cents per Mile and Adjusted for Inflation based on CPI
Figure 36. Comparison of Revenue Considering Urban Interstates Tolled at 10 cents per Mile and Adjusted for Inflation based on PPI

Figure 37. Comparison of Revenue Considering All Interstates Tolled at 10 cents per Mile and Adjusted for Inflation based on PPI
5.4. Charge based on VMT

As discussed previously converting interstates to toll roads is one way to generate revenue based on their use. Since predominant portion of federal funds generated are spent on improvements and maintenance roadways in the National Highway Systems, tolling is justifiable to an extent. Also for the quality of service the interstates provide in most of the places, these additional tolls are justifiable. However, some argue that, this is not a perfect system because of the fact that the interstate users pay the user fee for all the other users, some of whom might not even use interstates and this might cause some diversion of traffic from interstates to other classes of roadways, causing detrimental impacts on other roadway classes. One way to overcome these concerns of tolling is a system to charge based on the VMT, irrespective of where the users travelled. As illustrated in the previous chapter, the VMT based user fee generation is theoretically straightforward. The first step is estimate charge per mile based on historical revenue generated data from gasoline and VMT data. Estimated revenue for a future year could be estimated by multiplying this value with the estimated VMT in that particular year.

The tax rate based on VMT could be estimated by using the fees generated from gasoline tax for a base year (e.g. 2005). In the year 2005, a total of just over 2.7 Trillion VMT for a fuel consumption of 139 Billion gallons of gasoline, which in turn means about $26 Billion income for the Highway Trust Fund. This number would yield an average rate of $0.00933 per mile. Once the user fee is estimated, the next step is to estimate revenue generated. The revenue generated for a future year is estimated by multiplying this estimated rate per mile with the estimated VMT for that year. The rates per mile for various scenarios are estimated. The following scenarios are considered:
5.4.1 Charge based on VMT for the year 2009
5.4.2 Charge based on VMT adjusted for inflation from the year 2009 based on CPI
5.4.3 Charge based on VMT adjusted for inflation from the year 1993 based on CPI
5.4.4 Charge based on VMT adjusted for inflation from the year 2009 based on PPI
5.4.5 Charge based on VMT adjusted for inflation from the year 1993 based on PPI

Similar to adjusting the gasoline tax rate for inflation, the rate per VMT also adjusted for inflation based on either consumer price index (CPI) or Producer Price Index (PPI) from the years 2009 or 1993 as explained in the previous sections.

Figure 38 shows the revenue generated over the years from 2006 to 2025, comparing with the required funding to maintain and to improve the existing transportation systems. This figure shows that the 2005 rate and 2005 rate adjusted for CPI would not generate enough revenue to even to maintain the transportation system. Two options charging based on 1993 rate adjusted for CPI and CCI generate enough revenue to at least maintain the transportation system. Tables A103 to A105 Appendix show the calculations and estimates of revenue generated for various scenarios of VMT based charge.

5.5. Tier System for Charging based on VMT

Previous section showed that when users are charged based on VMT, the system could easily generate enough funds to maintain as well as improve the system, depending on the rate that is chosen. However, in order to encourage people to drive less, this section discusses how a tier based system to charge user fee based on VMT could be adopted. This option is very similar to the previous option, with the difference that instead of charging all users the same rate for the usage, charging more to the users who
use the system more. This is very similar to the systems used by utility agencies, such as, electricity and water. Previous chapter illustrated the process for estimating revenue for this option.

The first step in this option is to identify and define tiers. Since the purpose of this system is to discourage people to drive more distance, selection of tiers is the key to the revenue generated. Table 8 shows a sample tier system that is considered in this study.

Table 8 shows a five-tier system. The average annual VMT of the base year is shown as X and average cost per VMT at the base year is shown as C. Tier 1 consists of vehicles drive less than or equal to 80 percent of the average VMT per vehicle for that year. It is assumed that the average VMT recorded by vehicles within this tier would be equal to 60 percent of the average VMT per vehicle for that year. In order to estimate revenues, it is

Figure 38. Comparison of Revenue Generated based on VMT Charge for Various Rates
necessary to determine the percent of registered vehicles that would fit into each of the 
tiers. Although when implemented in real world, this has to be determined based on real 
data, for illustration purposes percent of vehicle registered in various tiers are assumed as 
shown in the table. In this case for tier 1, it is assumed that 50 percent of all registered 
vehicles drive less than 80 percent of the average VMT. The next item to be defined is 
the proportion of charge that VMT at these tiers are subjected to. In this study, the 
estimated VMTs within tier 1 are charged at 80 percent of the actual charge per VMT 
estimated. For any user with a particular VMT, first 80 percent of the average VMT will 
be charged at 80 percent of the estimated charge per mile, the next 40 percent (i.e. from 
proportions 0.8 to 1.2) charged at 120 percent of the estimated charge per mile, the next 
30 percent (from proportions 1.2 to 1.5) charged at 145 percent of the estimated charge 
per mile, and so on.

Table 8. Definition of Tier System for Generating VMT based User Fee

Average Annual VMT = X
Average Cost per VMT = C

<table>
<thead>
<tr>
<th>Tier</th>
<th>Range of VMT (Percent of X)</th>
<th>Average Range (Percent of X)</th>
<th>% of Total Registered Vehicles</th>
<th>% Charge per Tier (Percent of C)</th>
<th>Total Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tier 1</td>
<td>≤80%</td>
<td>60%</td>
<td>50%</td>
<td>80%</td>
<td>0.24C</td>
</tr>
<tr>
<td>Tier 2</td>
<td>80-120%</td>
<td>100%</td>
<td>20%</td>
<td>120%</td>
<td>0.176C</td>
</tr>
<tr>
<td>Tier 3</td>
<td>120-150%</td>
<td>135%</td>
<td>15%</td>
<td>145%</td>
<td>0.201C</td>
</tr>
<tr>
<td>Tier 4</td>
<td>150-200%</td>
<td>175%</td>
<td>10%</td>
<td>190%</td>
<td>0.203C</td>
</tr>
<tr>
<td>Tier 5</td>
<td>&gt;200%</td>
<td>245%</td>
<td>5%</td>
<td>250%</td>
<td>0.224C</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>5%</td>
<td>107%</td>
<td>1.044C</td>
</tr>
</tbody>
</table>
For example, estimates of overall charge to a user who drove over twice the average VMT could be calculated as follows:

Revenue Generated =

\[ \text{Revenue Generated} = VMT_1 \times C_1 + (VMT_2 - VMT_1) \times C_2 + (VMT_3 - VMT_2) \times C_3 + (VMT_4 - VMT_3) \times C_4 + (VMT_5 - VMT_4) \times C_5 \]

\[ \ldots (5.11) \]

Where, \( VMT_1 \) to \( VMT_5 \) represent upper range of VMT for tiers 1 to 5 respectively and \( C_1 \) to \( C_5 \) represent estimated charge per mile for tiers 1 to 5 respectively.

Once the tier is defined, the next step is to estimate charge per VMT that needs to be charged each year. The charges are calculated based on two different estimates of funding required for the base year considered, 1) to maintain the system and 2) to improve the system. For this option the year 2009 is considered as the base year. Each of these estimates is again subdivided into to three scenarios each; a) keeping the charge the same over the years, b) adjusting the charge for inflation based on CPI, and c) adjusting the charge for inflation based on CCI. For example, for the year 2009, based on the NCHRP estimates, the funding required from user fee to maintain the transportation infrastructure is $40.2 Billion. The estimated VMT for the year 2009 is about 2,923 Billion. The estimated rate per VMT could be calculated by dividing the required funding with the estimated VMT. In this case it is equal to $0.0138. The same process is repeated for funding required for improvements and these rates adjusted for inflation based on CPI and PPI. As discussed previously, in this study CPI and PPI rated used are 2.6 percent 4.6 percent respectively.

Using the VMT estimates and number of registered vehicle estimates determined in the previous sections, tier definition from Table 8, and estimated charge per VMT,
revenue generated is estimated for various scenarios of VMT charge system. Figure 39 shows the revenue generated for various scenarios considered. From this figure, it is clear that other than for the case of maintaining the 2009 charge per VMT, all the other options would generate more than enough funds to maintain the transportation systems. On the other hand by using the estimated charge per VMT for improving the system, adjusting based on either CPI or PPI would ensure enough funding to sustain improved transportation facility. Tables A106 and A107 in Appendix summarizes the charge per VMT and estimated revenue in Billions for the years 2009 to 2025.

It is important to note that the total charge adds up to a value of at least 1.000C, for the tier system to generate sufficient revenue for the scenario considered. Otherwise, this would mean that the tier based system would generate lesser revenue than the previous option, the VMT based usage fee without tier. Therefore once the average annual VMT (X), average cost per VMT (C), and percent of total registered vehicles within each of the tiers are identified from real data, the percent charge per tier needs to be adjusted so that the total charge is over 1.000C.

5.6. Charge based on Axle Load and VMT

As indicated in the previous sections, the real user fee is that generated based on the usage. Charging based on VMT is one way to access user fee. However, this process does not consider the deterioration caused by that particular vehicle because of its weight. Deteriorations caused to the pavements are dependent on their weight. Therefore, a mechanism to charge heavier vehicles a higher usage rate compared to smaller vehicle would ensure a fair usage fee based on the deterioration they cause to the pavement. The
process to generate user fee based on axle load and VMT is provided in previous chapter.

In this process, the first step is to categorize vehicles based on axle loads. For this study, the six categories selected before, small cars, medium cars, large cars, small light trucks, medium light trucks, and large light trucks are considered. The axle loads vehicles in each of the categories are also estimated. EPA (Heavenrich 2006) provides the weight of vehicles by category. The weights of the vehicles are converted to axle loads $W_A$ and $W_B$, where $W_A$ is the front axle load weight and $W_B$ is the back axle load weight using the equations,

$$W_A = 0.6 \times W_V$$  
$$W_B = 0.4 \times W_V$$

where, $W_V$ is the weight of the vehicle.
The next step is to normalize the weights of these vehicles for comparative analysis. The Equivalent Single Axle Load (ESAL) is one of the standards adopted by pavement designers and engineers to estimate the impacts on the pavement by passenger vehicles relative to a standard 18,000 lb single axle load (Garber and Hoel, 2001). The front axle load and rear axle load weights are converted into ESALs and the corresponding truck equivalent loads of each are calculated. These truck equivalency factor values show the relative impacts of these vehicle classes on the pavement. Percent truck equivalency factor values are calculated for each of the vehicle classes using the formula;

\[
\%TFE_{vk} = \frac{\text{TEF}_{vk}}{\frac{1}{2} \sum_{v=1}^{2} \sum_{k=1}^{3} \text{TEF}_{vk}}
\]

where, TEF\(_{vk}\) is the truck equivalency factor for vehicle class \(v\) and vehicle category \(k\).

The results of these calculations are provided in Table 9.

The next step is to estimate the charge for each vehicle class based on axle loads. To estimate the charge per vehicle class, it is required to estimate the overall charge per VMT. This could be calculated either using historical data, as illustrated in the Figure 15 or by matching the funding required to maintain or to improve the system for a base year.

Table 9. Estimating Truck Equivalency Factor

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Vehicle Category</th>
<th>Vehicle Weight (W(_v))</th>
<th>Axle Loads</th>
<th>ESAL</th>
<th>Truck Equivalency Factor (TEF)</th>
<th>% TEF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td>Small</td>
<td>3,198</td>
<td>1,919</td>
<td>1,279</td>
<td>0.000167 0.000065 0.0002317</td>
<td>5.2%</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>3,693</td>
<td>2,216</td>
<td>1,477</td>
<td>0.000386 0.000096 0.0004824</td>
<td>10.9%</td>
</tr>
<tr>
<td></td>
<td>Large</td>
<td>4,323</td>
<td>2,594</td>
<td>1,729</td>
<td>0.000747 0.000137 0.0008838</td>
<td>19.9%</td>
</tr>
<tr>
<td>Lt. Truck</td>
<td>Small</td>
<td>3,755</td>
<td>2,253</td>
<td>1,502</td>
<td>0.000422 0.000100 0.0005219</td>
<td>11.7%</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>4,154</td>
<td>2,492</td>
<td>1,662</td>
<td>0.000650 0.000126 0.0007761</td>
<td>17.5%</td>
</tr>
<tr>
<td></td>
<td>Large</td>
<td>5,245</td>
<td>3,147</td>
<td>2,098</td>
<td>0.001275 0.000274 0.0015490</td>
<td>34.8%</td>
</tr>
</tbody>
</table>
In this study, the latter option is selected. Similar to the previous section, here also, the year 2009 is considered as the base year and estimated charge per VMT is estimated based on funding required to maintain the system. The estimation of the overall charge per VMT and the charge per vehicle class based on weight are illustrated as follows:

Let the required funding for the base year = RF_B

The initial assumption is that all the vehicles are charged C dollars per VMT. Therefore, the total charge for all vehicle classes = 6C

Now, the total charge could be estimated using the following equation,

\[ 6C = \frac{RF_B}{2 \sum_{v=1}^{3} \sum_{k=1}^{3} \%TEF_{vk} \times VMT_{vk}} \] ...... (5.15)

where \( \%TEF_{vk} \) is the proportion of Truck Equivalency Factor for vehicle type \( v \), category \( k \); and

\( VMT_{vk} \) is the vehicle miles travelled by vehicle type \( v \), category \( k \).

Once the total charge is calculated, the charge for each vehicle class based on weight could be estimated proportional to the corresponding percent Truck Equivalency Factors.

\[ C_{vk} = 6C \times TEF_{vk} \] ......(5.16)

Using equations 5.15 and 5.16, the charge per vehicle type for the year 2009 based on the funding required to maintain the system yields the following results as shown in Table 10.

\[ RF_B = \$40.2 \text{ Billion} \]

\[ 6C = \$0.0801 \]
Table 10. Estimating Charge per Mile for Vehicle Categories based on Axle Load

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Vehicle Category</th>
<th>% TEF</th>
<th>VMT (Billions)</th>
<th>Charge per Mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td>Small</td>
<td>5.2%</td>
<td>728.3</td>
<td>$ 0.0042</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>10.9%</td>
<td>478.2</td>
<td>$ 0.0087</td>
</tr>
<tr>
<td></td>
<td>Large</td>
<td>19.9%</td>
<td>216.8</td>
<td>$ 0.0159</td>
</tr>
<tr>
<td>Lt. Truck</td>
<td>Small</td>
<td>11.7%</td>
<td>99.4</td>
<td>$ 0.0094</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>17.5%</td>
<td>682.5</td>
<td>$ 0.0140</td>
</tr>
<tr>
<td></td>
<td>Large</td>
<td>34.8%</td>
<td>544.3</td>
<td>$ 0.0279</td>
</tr>
</tbody>
</table>

The total revenue generated for a particular year is estimated by multiplying the VMT of the vehicle class with the corresponding charges per VMT based on its axle loads. The same process is repeated for the funding required for improvements and these rates are adjusted for inflation based on CPI and PPI. Figure 40 shows the revenue generated for various scenarios considered. Figure 40 looks very similar to Figure 39. Similar to previous option, it is clear that other than for the case of maintaining the 2009 charge per VMT, all the other options would generate more than enough funds to maintain the transportation systems. On the other hand by using the estimated charge per VMT for improving the system, adjusting based on either CPI or PPI would ensure enough funding to sustain improved transportation facility. Table A108 in Appendix shows the estimates of revenue generated for various scenarios.
As indicated in the previous sections, VMT based user fee systems are the most equitable mechanisms than the existing fuel tax based user fee structure. The estimates show that by adopting a VMT based user fee system, such as charge/VMT, tier based VMT charge, or axle load and VMT based, would generate adequate revenues to maintain or improve the transportation infrastructure. Under this concept, the transportation infrastructure is considered as a utility, similar to electricity or water. An electricity or water utility typically charges its users a flat fee irrespective of their usage and additionally based on their actual usage fee. This flat fee is charged to cover their basic operations and essential fixed costs (e.g. maintenance expenses) even if the consumer does not use the facilities. Transportation infrastructure operations and maintenance is similar. Therefore transportation (road) infrastructure systems also need
some minimum to cover essential fixed costs. Even if a user does not drive transportation agencies are responsible for the maintenance of the system. In order to generate revenues for such regular maintenance, it is important to consider a regular maintenance portion for the road user fee. It could be collected as a fee during vehicle registration. This would be in addition to the VMT based user fee and the VMT based user fee rates could be adjusted considering this flat fee.

5.7. Sensitivity Analysis

The previous sections estimated revenues for various scenarios. These estimates were developed for specific conditions. In reality, these assumptions such as fuel prices and VMT for a future year are uncertain. The future estimates of revenues are based on these assumptions. Therefore, it is important to analyze the impacts of changes in these parameters on revenue. It would help in estimating future revenues for various scenarios of fuel prices and VMTs. Sensitivity analyses for some of the key selected options are illustrated here.

5.7.1. Charge Fuel Tax Based on Existing Rate

For this option, the two major variables are gasoline sales price and VMT. Six various gasoline prices and VMT are considered for the sensitivity analyses. Six gasoline prices; no change in gasoline price, gasoline price increase based on CPI annually, gasoline price increases 5 percent annually, gasoline price increases 10 percent annually, gasoline price decreases 5 percent annually, and gasoline price decreases 10 percent annually. Six types of VMTs are also considered; VMT increases by 1.04 percent, VMT do not change, VMT increases by 2 percent, VMT increases by 4 percent, VMT decreases by 2 percent,
and VMT decreases by 4 percent. Table 11 shows summary of various combinations of these conditions. In order to better understanding, the estimates less than the required level of funding to maintain the system for that corresponding years are shown in *Italic* font, the values over the required funding to improve the system are shown in **Bold** fonts, and the estimates in between the required funding to maintain the system and improve system are shown in regular fonts. These results show that for various combinations of gasoline prices and VMTs, the estimated revenues are less that the values required to maintain the system. This table also shows that the sensitivity of gasoline price is minimal and is almost hard to notice. On the other hand, the changes in VMT values have a bigger impact on the estimated revenues. This shows that even if the gasoline price changes significantly, the estimated revenues would not be affected significantly by the gasoline price, but the changes in VMTs have a bigger impact on the estimated revenues. This result is important, since it shows that based on the existing rate, the revenues could be estimated accurately as long as the VMT estimated are accurate.

5.7.2. Increase Existing Rate by 10 cents and Adjust for Inflation

Here, the same gasoline price and VMT combinations considered in the previous option is considered. Table 12 shows the estimated revenue for these options. These results show that for all cases on gasoline prices, the gasoline taxes would generate revenues at least to maintain the system, for all increases in VMTs. For cases of increasing VMTs by 4 percent, the estimated revenues are more that that required to improve the system. Similar to the previous option, here also the results show that the gasoline prices do not influence the estimated revenues and the VMTs influence the revenues.
5.7.3. Charge Tax as Percent Value based on 2004 Gasoline price

In this option also the same gasoline price and VMT combinations considered in the previous options is considered. Table 13 shows the estimated revenue for these options. These results show that for all the combinations of increases gasoline prices and increases in VMTs generate higher revenues, in some cases even more revenue than that is required to improve the system. This option shows that the estimated revenues are dependent on both the gasoline price and estimated VMTs. As the gasoline price decreases, the estimated revenue also decreases. These results show that when gasoline tax as a percent are considered, they are vulnerable to gasoline price, which would make the estimation uncertain, compared to the previous two options.

5.7.4. Converting Urban Interstates to Tollored Facility and Charge 10 cents/mile Adjusted based CPI

Tolling is directly proportional to the VMT on the facility. Here, it is assumed that once the interstate facilities are converted to toll facilities, more users would choose alternate routes in order to reduce costs. In order to study its impact on the estimated revenues, various changes in the existing estimates of VMTs on interstates are considered. Table 14 shows the summary of sensitivity analysis. As anticipated, this table shows that, as the proportion of VMT on interstates decreases, the estimated revenue also decreases. However, it is worth to note that even if 50 percent of the traffic chooses alternate options, the estimated revenues would be higher than those generated by the existing system.
5.7.5. VMT Based Charging for 1993 Rate Adjusted based on CPI

In this option, various proportions of changes in VMT based charges used vary from 75 percent to 120 percent. Here revenues are estimated for various proportional values. Table 15 shows the summary of the sensitivity analysis. Similar to the previous option, here also, the results show that as the VMT values increase, the revenue also increase. The results show that if the VMT value decreases to about 80 percent, the user fee would not be able to generate enough funds to even maintain the system based on the existing calculations. However, it is important to note that if the users drive less, corresponding costs to maintain and improve the systems would be lower, hence the revised values to maintain and improve systems would be able to sustain the system.

5.7.6. Tier System for Charging based on VMT

In this chapter, when this option is considered, it is assumed that 50 percent of the vehicles would be in the Tier 1, which runs less than 80 percent of the average VMT/vehicle for that particular year. However, there is a possibility that after calculating the savings, more people would tend to drive less. In order to estimate revenues, it is assumed that the changes in tier 1 are adjusted in the other tiers, from higher tiers to lower ones. For example, when the proportion of vehicles in tier 1 decreases from 50 to 45 percent, the change, 5 percent is added to the highest tier, Tier 5. In this section, various proportions of vehicles in tier 1 are considered for the sensitivity analysis. Table 16 shows the summary of the results. This table shows that as the proportion of vehicles in tier 1 increases, the corresponding revenues increases.
## Table 11. Sensitivity Analysis for Existing Gasoline Tax Rates (Revenue in Billions)

<table>
<thead>
<tr>
<th>Year</th>
<th>Gasoline Price Increases based on CPI</th>
<th>Gasoline Price do not Change</th>
<th>Gasoline Price Increases 5%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VMT increases by 1%</td>
<td>VMT do not change</td>
<td>VMT increases by 4%</td>
</tr>
<tr>
<td></td>
<td>VMT increases by 2%</td>
<td>VMT increase by 2%</td>
<td>VMT increases by 4%</td>
</tr>
<tr>
<td></td>
<td>VMT decreases by 2%</td>
<td>VMT decreases by 4%</td>
<td>VMT decreases by 4%</td>
</tr>
<tr>
<td></td>
<td>VMT increases by 1/04</td>
<td>VMT do not change</td>
<td>VMT increases by 5%</td>
</tr>
<tr>
<td></td>
<td>VMT increases by 2%</td>
<td>VMT increase by 2%</td>
<td>VMT increases by 5%</td>
</tr>
<tr>
<td></td>
<td>VMT decreases by 2%</td>
<td>VMT decreases by 4%</td>
<td>VMT decreases by 5%</td>
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**Note:** The table above shows the sensitivity analysis for existing gasoline tax rates, with revenues in billions. The analysis considers the impact of gasoline price increases based on CPI, as well as the impact of the gasoline price do not change, and the gasoline price increases by 5%. The analysis covers the years from 2006 to 2030, with each year showing the revenue impact of various scenarios.
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<th>VMT increases by 1.6%</th>
<th>VMT do not Change</th>
<th>Gasoline Price increases based on CPI</th>
<th>Gasoline Price do not Change</th>
<th>Gasoline Price Increases 5%</th>
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**Gasoline Price Increases 10%**

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<th>Gasoline Price increases based on CPI</th>
<th>Gasoline Price do not Change</th>
<th>Gasoline Price Increases 5%</th>
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Table 13. Sensitivity Analysis for Gasoline Tax as a Percent Value based on 2004 Price (Revenue in Billions)
Table 14. Sensitivity Analysis for Tolling Urban Interstates (Revenue in Billions)

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<th>Year</th>
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5.7.7. Charging based on Axle Load and VMT

Similar to the previous option, as the system tends towards charging user fee based on axle load and VMT, the users might tend to drive lighter vehicles. The revenues generated are proportional to the type of vehicles users drive. In order to estimate sensitivity of this option, various proportions of sedans, varying from 70 percent to 150 percent of the estimated numbers of small sedans estimated in this study. The results are
Table 15. Sensitivity Analysis for VMT based User Fees (Revenue in Billions)

<table>
<thead>
<tr>
<th>Year</th>
<th>75%</th>
<th>80%</th>
<th>90%</th>
<th>95%</th>
<th>100%</th>
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summarized in Table 17. The results, as expected show that as the proportion of small sedans increases, the estimated revenues would decrease. For increases of 140 percent or higher, the estimated revenues would not be able to even maintain the system at any of the years considered. As indicated in the previous section, this would not be really bad scenario. As there are more small sedans on the roads, the deterioration caused will be minimal, hence reducing the costs for maintenance and improvements.
Table 16. Sensitivity Analysis for Tier based VMT Charges (Revenue in Billions)

<table>
<thead>
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<th>Year</th>
<th>35%</th>
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<th>45%</th>
<th>50%</th>
<th>55%</th>
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Table 17. Sensitivity Analysis for Axle Load based VMT Charges (Revenue in Billions)

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CHAPTER 6

IMPLEMENTATION CONSIDERATIONS

The previous chapters identified several options to identify alternative funding sources to supplement and (or) replace the existing system of highway financing. Although they all look appealing, it is important to identify which of them are feasible to implement in the long run and, if selected, how these options can be implemented. This chapter discusses some of the implementation considerations for each of the options identified.

6.1. Gasoline Tax as a Fixed Amount

Collecting gasoline tax as a fixed amount has been working well over the years. Therefore, collecting tax as a fixed amount does not require any major changes. Oil companies and distributors typically pay a per-gallon tax on the motor fuels at the point where their fuel is loaded into tanker trucks or rail cars at a terminal (Hecker, 2002). This means that the gasoline taxes are collected even before it reaches the gasoline pump stations. Therefore, the existing system should be able to easily permit the implementation of this strategy from a technical perspective. Previous chapter showed that the ideal tax rate for implementation, assuming there are no political or public outcries over the policy, is to increase the gasoline tax rate by 10 cents in the
year 2009 and then adjust each year for inflation based on Producer Price Index (PPI). This means that the tax rate increases by 10 cents all of a sudden in one year as shown in Figure 41. This increase could be acceptable to most of the citizens if they were made aware that there has not been any increase of the gasoline taxes since 1993. Experience from Clark County, Nevada, where the local gasoline tax of 10 cents per Gallon was approved by a ballot initiative in the year 1990 and again in the year 2000. These voter approvals were earned by extensive public outreach and education campaigns. This shows that such measures are possible with buy in from the public.

On the other hand, in the absence of outreach and education efforts, this sudden change might not be a popular concept and would cause severe criticism from both public and elected officials. Therefore, a better option, under this scenario, would be to make the increments over a fixed number of years and make adjustments from then onwards. For illustration purposes, assume that the increment is spread evenly over three years. In this case, the average increment of tax could be calculated for the three years and then applying equally for three years. It is mathematically shown as:

\[
FT_{Ave} = \frac{(FT_{2011} - FT_{2008})}{3} \quad \text{.....(6.1)}
\]

\[
FT_i = FT_{i-1} + FT_{Ave} \quad \text{.....(6.2)}
\]

Where, \( FT_i \) is the Fuel Tax for the year \( i \)

for \( i = 2009 \) to \( 2011 \)

\[
FT_i = FT_{2011} \times (1 + r)^{(i-2011)} \quad \text{.....(6.3)}
\]

for \( i = 2012 \) and over
Using these equations, federal and state taxes are modified and it provided figure 42. Comparing Figures 41 and 42, shows that by distributing the changes over the years, the sudden impact to the users could be avoided. Table A109 in Appendix shows the tax rate estimates for the years 2006 to 2025.

After making these changes, the corresponding estimates of revenues generated from the gasoline tax would also change. Figure 43 shows the revised estimate of the revenues based on fuel tax. From this figure, it could be observed that for the revised fuel tax structure, the change in estimated revenue would be lower than those expected for years 2009 and 2010. However, from 2011 onwards, the revenue remains the same as the projected values.

Figure 41. Distribution of Gasoline Tax Rate over Time
Figure 42. Distribution of Gasoline Tax Rate over the Time after Applying Incremental Increase

Figure 43. Comparison of Revenue Generated for Gasoline Tax Rate Increased by 10 cents and Adjusted for Inflation based on PPI from 2009 Subjected to Incremental Increase, 2005-2025
6.2. Gasoline Tax as a Fixed Percent of Gasoline Price

Generating gasoline tax revenue as a fixed percent of gasoline price might look to be the same as that of the previous option. Theoretically, they are the same, generating revenue based on the gasoline price as compared to a fixed amount per gallon. However, from the collection point of view, these two options are different. Since the gasoline tax is collected as a percent of gasoline price, it has to be levied by the local gas station (i.e., retailer) based on the gasoline price at the time of sale. Therefore, collecting the tax would not be as simple as that in the previous option, where the taxes are collected directly from oil companies or distributors (at the wholesale level). This means that in order to make the tax collection efficient, revised collection processes need to be implemented. In reality these steps would consume some time to implement. Based on the information provided in the previous chapter, converting gasoline tax as a percent value based on gasoline price of the year 1993 would generate more revenue than what is required to even improve the system. On the other hand, a tax percent based on the gasoline price of the year 2004 would generate enough revenue to improve the system for a few years.

Assuming that the implementation of gasoline tax as a percent value is not an issue and if it were decided to implement the tax collection as a percent value equal to 10.4 percent for Federal Tax, similar to the previous option, a sudden change in tax and hence in the gasoline price would not be received well by public and elected officials. Therefore, similar to the implementation strategy developed for option 1, a revised implementation plan needs to be developed. The first step here is to convert the fixed gasoline tax rate of Federal Tax to an equivalent percent value for the year 2008.
Assuming an average gasoline sales price of $4.00, it is calculated as 5.08 percent. The difference between the new rate and 2008 rate is 5.32 percent. In order to make a smooth transition, this change could be distributed evenly over 5 years starting 2009, ending in the year 2013. This would mean an increase of 1.06 percent per year for five years to make up the difference of 5.32 percent by 2013. Each year starting 2009, the existing rate of 5.08 is increased by 1.06 percent and by the year 2013, the percent tax would be equal to 10.4. Based on our assumption throughout the study, the state and local taxes can also be adjusted similarly.

Figure 44 shows the revised estimate of revenue based on fuel tax for the revised scenario. From this figure, it is observed that for the revised fuel tax structure, the estimated revenue would be lower than those expected for years 2009 to 2012. However, from 2013 onwards, the revenue remains the same as those projected previously.

One of the drawbacks, other than the implementation issues, is that the estimates of revenue shown are based on assumption that average gasoline price would increase based on CPI value each year. However, the gasoline price does not vary based on CPI, but with various other factors, such as its demand, supply, season, natural or man made disasters. In case the price of gasoline decreases, the estimated gasoline tax and hence estimated revenue also would decrease at the rate directly proportional to gasoline price.
6.3. Converting Some Road Segments to Toll Roads

Traditionally in the US tolling has been used as a financing mechanism to support specific projects or as a means to enhance mobility by managing congestion (USGAO, 2006). In recent years, due to the decreasing buying power of state gasoline tax, several states have already started using tolling to finance new capacity. If adopted carefully, tolling has the potential to serve in the current scenario, where the long-term infrastructure financing challenges are predominant. However, there are several areas of concern before using tolling as a standard way of user fee. Transportation officials list several challenges in implementing toll facilities. They include securing public and political support. One of the main concerns among public and elected officials is that they consider tolling as a double taxation, since the users of the facility already pay the
traditional gasoline tax based fees. One other issue is the geographic inequity. There is a strong belief already that the funds collected from urban areas are used for rural facilities and this is considered to be inequitable. These are some of the serious issues to be addressed before considering tolling as a substitute or supplementary to the other forms of user fees. There are basically two thought processes for implementing tolling: and tolling as replacement for gasoline tax; and tolling as a supplemental source. They are described below.

Since tolling could be deployed only at interstates based on the current policies, other forms of user fee such as gasoline taxes still needs to be continued for all road users including users of interstates. As the literature showed, there are some serious concerns from public over the use of tolling revenue. The issue of geographic inequity could be addressed to an extent by using the toll based revenue collected from urban areas used completely in urban areas and user fees collected from other means used for infrastructure improvement in rural areas.

The other thought process is that tolling would be a supplemental source for the existing gasoline taxes. Traditionally, most of the toll roads were built by authorities through bond financing. The tolls were in place to pay off the construction bonds and to pay for the operations and maintenance costs as well as resurfacing and repairs. The authorities were supposed to dissolve the tolls once the bonds were paid off. However, in most cases, the authorities had to issue new bonds for reconstruction and maintenance because the maintenance price had increased significantly over the years. All the users of the existing toll roads pay the gasoline taxes as well. If they consider it as a double taxation, not so many users would choose these facilities. The toll is more than paid for
by the time savings and better service. A problem with using tolling to help finance a lot of other non-tolled facilities is that it would not be fair system for the toll facility users and could be considered as a triple taxation. In this concept, tolls could be used as an option for big projects, the others continue to use non-toll revenues from users. Because of the superior service and time savings, motorists would be willing to pay tolls for using these facilities. On some of concerns that the rural highways are maintained by using revenues from urban users, the reality is that every time they drive out of the cities, the motorists use rural facilities. Unless there are funds to maintain those facilities, they would not be able to provide their expected service levels. However, if alternate user fees are collected in addition to the tolls, the toll rates needs to be adjusted accordingly.

6.4. Charge based on VMT

Among various options discussed in the previous chapter, charging user fee based on VMT may be more equitable than fuel tax based user fee. On the other hand, implementing charging based on VMT is the most challenging among all other options discussed. With the advances in technology in data collection and data transfer, most of these issues have solutions. Kim, Porter and Wurl (2002) discuss several options for generating VMT based user fees for the state of Oregon. The three major components of a VMT based user fee are: collect VMT on a vehicle, transmit the VMT data from the vehicle, and calculate and collect proper VMT fee. In their report, six various scenarios for collecting VMT based user fee are explained in detail. Some of them are very similar. Therefore, only the major ones are discussed as follows:

6.4.1. Fee Collection Center Scenario
In this scenario, a Fee Collection Center (FCCTR) is utilized to collect user fee. Here the basic concept is to collect VMT based data using either GPS technology or sensors to gather odometer reading. The collected data are sent to FCCTR using either wireless communications or by using Radio Frequency Vehicle Identification (RF-AVI) in the vehicle and RF readers located at service stations, which are connected to the FCCTR using a communications link to transmit the data. Once the data are received at the FCCTR, the tax could be calculated after making adjustments for the estimated gasoline consumption by the user and invoice on a monthly or annual basis. The estimated gasoline consumption could be obtained by dividing the reported VMT with the EPA estimated fuel consumption estimates.

6.4.2. Actual VMT at Pump

In this scenario, VMT data collection is very similar to the previous scenario, based on either GPS technology, or based on odometer readings, along with RF-AVI technology. Instead of transmitting the data to the FCCTR, as in the previous scenario, gas stations are equipped with RF readers and the RF-AVI tags transmit VMT data to the tax collection units. Using the VMT data, the user fees are collected and the gasoline tax is deducted.

6.4.3. Estimated VMT at the Pump with Credit Estimate

This scenario is very similar to the previous one, with the exception that there are no actual VMT data are collected. Each of the vehicles is equipped with a RF-AVI tag, which provides information on the vehicle make, model, and EPA estimated fuel consumption. When the vehicle stops to fill up at gasoline stations which are equipped with RF readers, based on the gasoline consumed and EPA estimated fuel efficiency, the
VMT is estimated and the VMT based user fee is charged and the gasoline tax is deducted.

6.4.4. DMV/Other Public Collection Center Scenario

This scenario is very similar to scenario 6.4.1, except for the fact that there are no communications between the vehicles and collection centers on a frequent basis. The VMT based data are collected for an extended duration up to a year and stored in the RF-AVI tag. During the annual vehicle registration, the tag is read and the corresponding user fee is charged.

6.4.5. System-Wide Spot Tolling Scenario

Here, the user fee collection is very similar to tolling, with several RF readers placed at the key locations such as intersections and ramps. Readings of the RF-AVI tag on each vehicle are used to charge for their use either through monthly invoices or using pre-paid systems. Such systems are in use in Singapore and London.

Although all these scenarios are feasible, the Oregon DOT used option 6.4.2 for their demonstration study (Whitty, 2007) and it worked very well. If the US as a whole needs to move forward with the VMT based charging system, the best one would be to either option 6.4.1. or 6.4.2., using GPS technologies. Using GPS technologies to estimate VMT keeps the option open to track VMT travelled in different regions such as states, counties, and cities. It is important since each region's user fee might be different the same way as the current gasoline tax is. GPS enabled VMT estimation also could be used for other forms of enhanced user fee techniques such as congestion pricing, and varying charge based on roadway functional classes such as local roads, arterials, and freeways.
One of the major concerns for public would be invasion of privacy by using GPS. These issues should be addressed prior to implementation.

Even if the VMT based user fee collection process is adopted to replace the gasoline tax as the user fee, it has to be implemented in phases. It is relatively easy to implement the sensors and GPS technologies on the new vehicles before they are sold. However, installing the sensors on older vehicles would be time consuming and would require funding for each vehicle and gasoline stations. The Oregon study estimated that each equipment for each car cost around $300. Once the users realize that they pay more on a mileage based user fee, there will be reluctance in adopting the new system for older vehicle owners. Therefore, it is important to make sure that the user fee based on VMT is comparable to the existing gasoline tax based system at least for the first few years of implementation. Incentive programs and increasing gasoline tax are other options to attract more users to VMT based user fee. Another option would be to provide a time frame of 5 years for all the vehicles to convert to the new system. Also based on EPA survivability data, the maximum survivability of cars is about 25 years and for light trucks about 36 years. Therefore, if the users of older vehicles decided not to adopt the revised tax structure, it is important to estimate their impact on the user fee revenue.

6.5. Tier System for Charging based on VMT

Since the tier system based VMT user fee data requirements are relatively the same as that of the VMT based charge, the implementation plan for this option would be very similar to the previous one. One of the key factors for this option is the definition of tiers and corresponding fees. It is important to provide an option to change the tier definitions.
on a frequent basis, in order to account for change in driving behavior due to the tier definition.

6.6. Charge based on Axle Load and VMT

Since the axle load and VMT based user fee data requirements are relatively the same as that of the VMT based charge, the implementation plan for this option would be very similar to the VMT based user fee collection. The only difference is that information on vehicle class should be collected along with the VMT data. This could be easily done by using technologies such as in-vehicle instrumentation and a network of sensors.

6.7. Ease of Implementation

The previous sections in this chapter discussed the advantages and disadvantages of various options considered in this study. As illustrated here, each of them has its own pros and cons. The major issues related to implementation could be summarized as follows. For each of the six options, the ease of implementation is divided into seven items: social, political, environmental, revenue, equity, technological, and simplicity. Social stands for social acceptance of the options considered. Social acceptance would be high only for the existing gasoline tax structure, it would be medium for gasoline tax as a percent value of the gasoline sales price and for all others, tolling based and VMT based, the ease of implementation is low. Political is very similar to social criterion. This is the ease to make legislative changes to implement the options considered. This would be very similar to the social criterion. Environmental is related to the anticipated environmental impacts of each of the options considered. This shows whether these opti-

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Table 18. Ease of Implementation of Various Options to Generate User fee

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</tbody>
</table>

- ons would change the driving behavior of people. Options 1 and 4 are thought to rate high for this option. When the tolling option is considered, there would be traffic diversion away from interstates to other roadway classes. Similarly, as the axle load based charge for VMT is considered, people might tend to move away from heavier vehicles towards lighter vehicles. Revenue is the ease to generate enough revenue based on the requirements for a particular year. As discussed in the previous chapter, for options 1 and 2 it is rated low, for option 3 it is rated medium and for all other VMT based options it is rated high. Equity shows if these options are equitable for all users. This also, based on the results in previous chapters, it is rated low for options 1 and 2, medium for option 3, and high for options 4 to 6. Technological ease is rated high for options 1 and 2 because of the existing structure of collecting gasoline taxes and sales tax as a percent value systems. When tolling is considered, due to the existing advances in automated tolling technologies, it is assigned a rate of medium. All VMT based options are rated low value because of the challenges in collecting VMT data. Simplicity of implementation shows similar ranking as that of technological considerations.
6.8. Cost Associated per Average Vehicle for Various Scenarios

The previous sections illustrated the implementation strategies for various options and they all seem to be feasible, although some of them are easier to implement, some others are relatively more difficult. In this section, costs associated for various types of vehicles for each of the options are estimated. It would help compare the impacts of these options on typical users. The previous sections showed the impacts of the user fee options on the overall revenue generated for Highway Trust Fund. However, these steps did not show the impact these options will have on an average user. Such estimates of the costs make it easier for the general public and elected officials to compare the relative costs associated with each of these options. Here, for illustration purposes, four types of vehicles are considered: medium car, large light trucks, medium hybrid cars, and medium alternate fuel cars. In order to estimate costs associated for various scenarios, seven options are considered. They are:

1. Gasoline tax charge at the existing rate
2. Gasoline tax increase by 10 cents and adjust for inflation based on PPI
3. Gasoline tax as percent value based on 2004 price
4. Tolling based for urban interstates at 10 cents/VMT, adjusted for inflation based on CPI
5. VMT based charge based on the year 1993, adjusted for inflation based on CPI
6. Tier system for charging based on VMT to maintain the system adjusted for inflation based on CPI, and
7. Charge based on axle load and VMT to maintain the system adjusted for inflation based on CPI

Four years (2010, 2015, 2020, and 2025) are considered for this study. Average VMT per vehicle and average fuel efficiency of various vehicle classes are taken from previous estimates. Table 19 shows the summary of VMT and estimated fuel mileage of various vehicle classes considered.

Table 19. Average VMT/Vehicle and Vehicle Fuel Mileage of Various Vehicle Classes

<table>
<thead>
<tr>
<th>Year</th>
<th>Ave. VMT/Veh</th>
<th>Ave. Fuel Efficiency (Miles/Gallon)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ave. VMT/Veh</td>
<td>Med. Car</td>
</tr>
<tr>
<td>2010</td>
<td>12,484</td>
<td>24.6</td>
</tr>
<tr>
<td>2015</td>
<td>13,146</td>
<td>28.6</td>
</tr>
<tr>
<td>2020</td>
<td>13,842</td>
<td>33.1</td>
</tr>
<tr>
<td>2025</td>
<td>14,576</td>
<td>38.4</td>
</tr>
</tbody>
</table>

The user costs for each of the seven options considered for these four vehicle classes are estimated for each year. Figure 45 shows the user costs for these scenarios considered and Figure 46 shows the fuel based operating expenses for these scenarios. It is important to note that these estimated operating costs do not include regular maintenance costs, insurance, or registration related costs. It is assumed that alternate fuel vehicles use non-petroleum fuels such as electricity or Hydrogen fuel cells and that their fuel costs are half that of hybrid vehicle's fuel usage.

These results show that as expected for options other than those related to gasoline tax based systems, hybrid car and alternate fuel vehicles generate relatively equal
revenue. However, considering the overall fuel related expenses, the hybrid and alternate fuels cars provide cheaper modes of transportation. From a policy point of view, this is very important. Since there are savings associated with the use of these vehicles, the demand for these vehicles would continue to grow, which would in turn cause lesser fuel consumption. This in turn would help the US to reduce its reliance on non renewable fuel sources and imported petroleum. On the other hand, the reduced revenue generated for the Highway Trust Fund would badly compromise the quality and service of our transportation infrastructure. This is why a fair system of funding transportation systems is essential.
Figure 46. Estimated fuel based operating costs for options considered.
CHAPTER 7

CONCLUSIONS, DISCUSSIONS AND RECOMMENDATIONS

The objectives of this study were to estimate the impacts of improved fuel efficiencies and alternative fuel vehicles on gasoline tax revenues and to identify alternate strategies for financing the US road transportation infrastructure. This study developed models to estimate future automobile and light truck fleet mixes and their fuel consumption based on historical data. These models were used to develop several scenarios for user fees. As reported in the literature, this study also confirmed that the existing system of gasoline tax rates would not be adequate to generate the required revenues, or fair in paying for usage. It is important to revise the existing system over the short-term as a temporary fix before a permanent user fee structure is implemented. This study analyzed several options based on user fees and illustrated their benefits and drawbacks. A summary of each is discussed next.

7.1. Collecting Gasoline Tax as a Fixed Amount

Chapter 4 and 5 showed eight scenarios considered for this option. A summary of each of the findings, their advantages and drawbacks are discussed in this section.

7.1.1. Summary of Collecting Gasoline Tax as a Fixed Amount

This is the existing structure of generating revenue. This could be considered as one of the temporary options for generating road user fee based revenue before any major
transition occurs. Eight scenarios are analyzed for this option. Results from Chapter 5 show that the existing gasoline tax rate of $0.184 cents per gallon would not be able to generate enough revenues to even maintain the existing infrastructure. As the years go by, the gap between the required funds and the revenues generated increases. By the year 2025, the difference would be as large as $45 Billion to maintain the system and as large as $71 Billion to improve the system. Once the hybrid and alternative fuel vehicles (AFV) are considered, the gap increases even further.

Analyses show that by adjusting the existing tax rate for inflation based on either Consumer Price Index (CPI) or Producer Price Index (PPI) “for streets and highways construction” for the year 2009 and beyond, would increase the estimated revenue generated. However, these changes would not be able to fill the gap between the required and generated funds completely. On the other hand, adjusting the existing rate for inflation based on CPI from the year 1993, the year when the federal tax rate was set at $0.184 per Gallon, shows that for the first few years it would generate just enough funds to maintain the system. However, over the years and by considering hybrid and AFVs in the fleet mix, the revenue generated would be lower than the required funding. By adjusting the existing rate for inflation based on PPI from the year 1993, the estimated revenue generated would produce enough revenues to even improve the system. This shows that the fuel tax based revenue shortfall the nation faces currently could have been avoided had the gasoline tax been adjusted based on inflation, preferably PPI over the years. These are important findings that show the importance of considering inflation adjustments when user fee rates are determined.
Another scenario considered under this option was to increase the existing rate by 10 cents per gallon, as was debated recently by the US Congress. The analysis shows that such an increase would generate sufficient revenues to improve the system for a few years. However, after a few initial years and when hybrids and AFV are considered, the estimated revenue decreases and the gap widens each year. When the new tax rate is adjusted for inflation based on CPI, the estimated revenue would be slightly higher and this would provide sufficient funds to maintain the system until the year 2014. On the other hand when the new gasoline tax rate is adjusted for inflation based on PPI, the estimated revenue would be between the required funding to maintain and improve the systems for the entire study period. This further shows the importance of adjusting the taxes to inflation.

7.1.2. Advantages of Collecting Gasoline Tax as a Fixed Amount

The existing structure of generating revenues based on user fee as gasoline taxes has several advantages. It has been used over the years and has worked well because of its simplicity. A fixed amount per gallon enables the tax collection from the wholesale dealers or distributors rather than retail outlets, making it a very efficient system. Since the tax is not proportional to the gasoline price, the seasonal variations of gasoline prices do not have any impact on the revenue, as long as the fuel consumption remains relatively unaffected. Because of these plus points, estimating future revenues becomes simpler.

7.1.3. Drawbacks of Collecting Gasoline Tax as a Fixed Amount

In spite of the advantages specified in the previous section, there are several drawbacks for the current gasoline based tax as a user fee. With the existing system, the hybrids and
AFVs are not paying their fair share for using the infrastructure and a majority of the maintenance and improvement funds are generated from the revenue collected from users of gasoline based vehicles. Because of these characteristics, it is very vulnerable to technology and fuel efficiency improvements.

7.2. Collecting Gasoline Tax as a Fixed Percent of Gasoline Price

Chapter 4 and 5 showed three scenarios considered for this option. The summary of each of the findings, their advantages and drawbacks are discussed in this section.

7.2.1. Summary of Collecting Gasoline Tax as a Fixed Percent of Gasoline Price

Collecting gasoline tax as a fixed percent of gasoline price might look similar to the previous option. Here, instead of collecting as a fixed amount per gallon, the gasoline taxes are collected as a percent value of the gasoline. Using 2009 values as the base case, charging gasoline tax as a percent value starting in 2009 show that the revenues generated over the years would be slightly better than the estimated revenues generated using the existing rate as a fixed amount. Still this option would not generate enough revenues to either maintain or improve the existing transportation systems. This is based on the assumption that the average gasoline price would increase based on CPI. Similar to the previous case, when considering hybrids and AFVs the estimated revenue would decrease considerably.

The next scenario considered was to charge a percent value based on the gasoline sale price for 1993. By adapting this fee structure the estimated revenue generated would be much more than that required to either maintain or to improve the existing system, even after considering hybrids and AFVs. This shows that the revenues from gasoline taxes
would have been more than the required levels if the rate were set as a percent of the gasoline sale price. Although this would lead to higher revenues, it is unlikely to be a good choice because of the burden on the gasoline tax and because of anticipated opposition from the public and elected officials.

The final scenario analyzed under this option is to charge gasoline as a percent based system based on the year 2004. Here, the results indicate that the estimated revenue generated would be between the funding required to maintain and improve the system. It is important to note the gap between the two cases of considering hybrids and AFVs in the fleet mix and not considering their presence in the fleet mix on the estimated revenues. As the gasoline tax increases, the gap also increases, indicating the importance of considering hybrids and AFVs on the fleet mix to the estimated revenue generated.

7.2.2. Advantages of Collecting Gasoline Tax as a Fixed Percent of Gasoline Price

Converting the existing system of collecting gasoline tax as a percent value of gasoline sale price compared to a fixed amount per gallon has several advantages. Once the gasoline taxes are converted to percent based system, it is not necessary to adjust it for inflation since the gasoline price will get adjusted accordingly. Another advantage is that similar to the previous case, collecting the user fee as a tax is simpler than adapting any other user fee structure. It could be the same as collecting sales taxes from retailers.

7.2.3. Drawbacks of Collecting Gasoline Tax as a Fixed Percent of Gasoline Price

Generating gasoline tax based revenues as a percent of the gasoline sale price is somewhat similar to that based on a fixed amount per gallon. So, all the drawbacks mentioned for the previous option remain for this option as well. However, some other drawbacks also need attention. From a collection perspective, the two options are quite
different. If the gasoline tax is collected as a percent of the gasoline sale price, it has to be levied by the local gas station based on the gasoline price at the time of sale. Therefore, collecting the taxes would not be as simple as those in the previous option, where the taxes are collected directly from oil companies or distributors. This means that in order to make the tax collection efficient, revised collection processes must be implemented. In reality, these steps need some time to implement. Also, as shown in the sensitivity analysis, because the tax revenue is proportional to the gasoline price, variations in the gasoline sale prices will impact the revenues, making the estimation of revenues over time a challenging process. Another drawback is that the results showed in this study are based on the assumption that the gasoline price would increase over years based on CPI. Although it may be a safe assumption, any changes in the gasoline price would make the estimates incorrect and a decrease in gasoline price would cause disastrous results for highway financing.

7.3. Converting Some Road Segments to Toll Roads

Chapter 4 and 5 showed three scenarios considered for this option. The summary of each of the findings, their advantages and drawbacks are discussed in this section.

7.3.1. Summary of Converting Some Road Segments to Toll Roads

Converting more freeways to toll facilities is one of the ways to generate revenue. Various combinations of toll rates and the proportion of facilities tolled were analyzed in this option. Results indicate that when tolling is considered for urban interstates, a toll rate of at least 15 cents per mile, not adjusted for either CPI or PPI, needs to be charged on at least 75 percent of the all the urban interstate facilities to generate enough funds to
either maintain or improve the facilities. When all interstates are considered for tolling, a
toll rate of at least 10 cents per mile, not adjusted for either CPI or PPI, needs to be
charged on 75 percent or more of the interstates to generate enough revenues to at least
maintain the system. For higher toll rates per mile, there is a notable decrease in the
extent of facilities that need to be subjected to tolls. When these toll rates are adjusted for
inflation, there are notable increases in the revenues generated.

7.3.2. Advantages of Converting Some Road Segments to Toll Roads

Tolling has been used in several states over the years and it has gained acceptability
among the public when the funds are used for facility operations and improvement
projects. Technological improvements such as automated toll collection procedures have
shown tremendous potential over the years. With the automated tolling systems, it is
feasible to charge tolls based spatial and temporal use characteristics. It is important to
note that the results presented in this study for the tolling based user fee are without
considering gasoline tax based revenue. Tolling is not expected to replace the gasoline
tax because of the limited extent of the road network that will be subjected to tolls.
Therefore, once the gasoline based user fees are added, the required level of tolling would
decrease considerably, based on the gasoline tax rate selected.

7.3.3. Drawbacks of Converting Some Road Segments to Toll Roads

Despite some advantages, there are several disadvantages with this option. They
include securing public and political support. One of the main concerns among the public
and elected officials is that they consider tolling as a double taxation, since the users of
the facility already pay the traditional gasoline tax based fees. One other issue is the
geographic inequity. There is a strong belief already that the funds collected from urban
areas are used for rural facilities and citing it as a wrong practice. These are some of the serious issues to be addressed before considering tolling as a substitute or supplementary to the other forms of user fees. Another concern is that this would not be a fair system for the users of interstates that they are charged an additional usage rate per mile than those who do not use interstates and pay only gasoline tax based user fee.

7.4. VMT-based Charges

Chapter 4 and 5 showed five scenarios considered for this option. A summary of the findings for the scenarios, their advantages and drawbacks are discussed in this section.

7.4.1. Summary of VMT based Charges

Here, as the name suggests, the users are charged based on their system usage. Since the users are charged directly based on their usage of the system, it could be considered a fairer system than the ones discussed in the previous three options. Here five user fee rates were studied: using 2005 rate for rate per VMT; adjusting the 2005 rate for inflation based on CPI from 2009; adjusting the 2005 rate for inflation based on PPI from 2009; adjusting the 1993 rate per VMT for inflation based on CPI; and adjusting the 1993 rate per VMT for inflation based on PPI. Results indicate that by using the 2005 based rate (~$0.01 per VMT) without any adjustments, the estimated revenue generated will be more than the estimates based on the existing tax structure discussed in Option 1. However, it will not generate revenues that are adequate even to maintain the system. When the rates are adjusted for inflation based on CPI, the revenue estimates increase notably, but they not enough to either maintain or improve the system. However, when the 2005 VMT rate is adjusted for inflation based on PPI, the estimated revenue showed
that it would generate enough revenues to maintain the system starting in the year 2020. When the rate per VMT based on the year 1993 is used is adjusted for inflation based on CPI, the estimated revenues would be between that required to maintain the system and that to improve the system. On the other hand, adjusting the 1993 rate for inflation based on PPI would lead to estimated revenues that would be greater than the funding required to improve the system.

7.4.2. Advantages of VMT-based charges

Among various options discussed, user fees based on VMT is more equitable than a fuel tax based user fee especially for hybrid vehicles and AFVs. The VMT based charges are based on actual usage and equally for various types of users, locales, be it rural or urban or by facility type, such as, freeways, arterials, or local streets. Thus it is a fairer system. However, these facilities vary widely in the service they provide and in their construction, operations, and maintenance costs per mile.

7.4.3. Drawbacks of VMT-based charges

In spite of all the advantages discussed before, a user fee based on VMT is the most challenging among all other options discussed. The VMT based tax structure is prone to evasion, if not adopted properly. On the other hand, in order to collect user fee based on VMT, there needs to be several changes made to the vehicles and the revenue collection system. These changes would be expensive and could create public resistance. When compared to the existing system of collecting user fee as gasoline taxes, the revised system would require a lot more capital investment and these costs must be included in the estimates of required funding.
7.5. Tier system for VMT-based Charges

Chapter 4 and 5 showed six scenarios considered for this option. The summary of each of the findings, their advantages and drawbacks are discussed in this section.

7.5.1. Summary of Tier System for VMT-based Charges

This option is a modified version of the VMT-based charge option. The change is that instead of charging a flat fee for all users, the users who use the system less are charged at lower rates compared to those who use the system more. Six scenarios are considered for this option based on the estimated charge per VMT. They are: 1) establish the charge per VMT for various vehicle classes based on the funds required to maintain the system in the year 2009, and apply the same rates for all the years from 2009 to 2025, 2) the charges estimated in scenario 1 adjusted for inflation based on CPI, 3) the charges estimated in scenario 1 adjusted for inflation based on PPI, 4) same as scenario 1, except that instead of using the funds required to maintain the system, use estimates of the funds required to improve the system, 5) the charges estimated in scenario 4 adjusted for inflation based on CPI, and 6) the charges estimated in scenario 4 adjusted for inflation based on PPI.

The results show that when the rate is established based on the revenues required to maintain the system in 2009 without making adjustments for inflation, the revenues generated decrease over the years to levels below that required to maintain the system. When the same rate is adjusted for inflation based on CPI and PPI, the estimated revenues are greater than those required to maintain the system. A similar trend is seen for the charge to improve the system. These results, similar to previous results, show the importance of adjusting for inflation the user charges.
7.5.2. Advantages of the Tier System for VMT-based Charges

Since it is a modified version of the VMT-based charge system, it has all the advantages of option 4. Other than that, this structure exhibits some additional advantages as well. Using the tier based system rewards users who drive less. By doing so, there could be a reduction in the overall vehicular travel demand. This could reduce traffic congestion and also reduce fuel consumption. The public could relate to a tiered VMT-based system to pay for transportation infrastructure usage if it were compared to other utilities such as electricity or water which typically have similar rate structures.

7.5.3. Drawbacks of the Tier System for VMT-based Charges

Identifying tiers and their proportionate charges are keys to balancing the user concerns and also to accurately estimating revenue. Therefore, it has to be implemented carefully. Although this is a direct user fee, it is not based on the consumption of the useful life of the facilities, but just on the extent of travel on the roads. Deterioration caused to the pavement is dependent on the relative axle weights of the vehicles. Therefore, in that sense it is not a fair system.

7.6. Charges based on Axle Load and VMT

7.6.1. Summary of Charges based on Axle Load and VMT

This option is very similar to the tier system for VMT-based charges. The major change is that instead of changing the usage rate by tier, axle loads are used to estimate the user charges. In this option, heavier vehicles pay more for their usage compared to lighter vehicles for the same extent of usage. Once again, similar to the previous option, six scenarios are considered for this option based on the estimated charge per VMT. They
are: 1) establish charges per VMT for various vehicle classes (depending on axle loads) based on the funds required to maintain the system in the year 2009 and apply the same rates for all the years from 2009 to 2025, 2) the charges estimated in scenario 1 adjusted for inflation based on CPI, 3) the charges estimated in scenario 1 adjusted for inflation based on PPI, 4) same as scenario 1, except that instead of using the funds required to maintain the system, use estimates of the funds required to improve the system, 5) the charges estimated in scenario 4 adjusted for inflation based on CPI, and 6) the charges estimated in scenario 4 adjusted for inflation based on PPI.

The results show that the revenue generated has a very similar trend to that for option 5, indicating the importance of adjusting for inflation.

7.6.2. Advantages of Charges based on Axle Load and VMT

As indicated previously, this option enables user charge based on axle loads and is a more accurate reflection of charges based on a consumption of the useful life of the system. This option encourages the use of lighter vehicles, which in turn provides better fuel mileage and reduces fuel consumption.

7.6.3. Drawbacks of Charges based on Axle Load and VMT

Since it is a modified version of VMT based charge system, all the drawbacks of that system is applicable to this system as well.

7.7. Ease of Implementation

Chapter 6 summarized the ease of implementation of the options considered based on various factors such as social, political, environmental, revenue, equity, technological, and simplicity. Although VMT based charged systems are rated high for revenue
generation and equity, their ratings for social and political acceptance and on technological easiness were low.

7.8. Recommendations for Future Work

This study analyzed the impacts of changes in fuel efficiencies, including impacts of hybrid and alternate fuel vehicles, on the gasoline tax based user fee and studied various options to generate revenues for highways. There are several improvements that could be pursued. These are presented next.

1) This study addresses only the gasoline tax based revenues. It is important to estimate non-gasoline tax based revenues as well.

2) This study assumes that the states will follow the changes made in the federal portion of the gasoline taxes. It might not be a realistic assumption because of various political and demographic reasons. The states’ highway related revenue structure needs to be studied in greater detail.

3) As indicated in chapter 5, a combination of a fixed rate and a percent based tax for gasoline would be a good option to consider. The exact amount of fixed rate and percent portion needs to be identified if this option were to become viable.

4) In this study, regardless of whether they are tolled or not, it is assumed that users will keep driving on the interstate facilities. Therefore, it is important to identify the relationship between toll roads and driving behavior. On the other hand, if this option diverts traffic onto arterials, it would lead to increased traffic volumes and levels of congestion on the arterials in the short term, and faster deterioration of infrastructure in the long term. It is important to study these impacts.
5) A VMT based user fee could cause changes in driving behavior. It is important to study this aspect in detail since it would affect the revenues generated and also the funds required for infrastructure improvements.

6) Implementation of VMT based user fee may face significant criticism from the public and from elected officials. Therefore, the acceptance of such an approach by such constituents and decision makers needs to be studied in depth.

7) If a VMT based user fee, similar to the one used in Oregon, is adopted, the usage rates levied for passengers who use the facilities and do not fill gasoline at a particular region (city or county) needs to be studied.

8) Similar to other utility services, the concept of a fixed operating and regular operations and maintenance fee for highways needs to be explored in detail.

9) One of the major challenges of using a VMT based usage rate will be to identify interstate travelers, levy corresponding charges to them, and how these would be transferred among various state and local agencies.
REFERENCES


American Association of State Highway and Transportation Officials (AASHTO). Revenue resources to fund transportation needs, Washington D.C., Publication code: TIF4-12 September 2007c.


McNally, S. *Fuel tax increase may be required, business group's study suggests.* American Trucking Associations. 2005.


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