2012-01-01

Development of an Electronic Vehicle Miles Travelled Toll Model

Marketa Vavrova
University of Texas at El Paso, mvavrova@miners.utep.edu

DEVELOPMENT OF AN ELECTRONIC VEHICLE MILES TRAVELLED TOLL MODEL

MARKÉTA VAVROVÁ

Department of Civil Engineering

APPROVED:

Carlos Martin Chang-Albitres, Ph. D., Chair

Ruey Long Cheu, Ph.D.

doc. Ing. Ladislav Bína, CSc.

prof. Dr. Ing. Miroslav Svítek

Benjamin C. Flores, Ph.D.
Interim Dean of the Graduate School

DEDICATION

I dedicate this work to my family and friends who gave me support and motivation when I needed it most.

DEVELOPMENT OF AN ELECTRONIC VEHICLE MILES TRAVELLED TOLL MODEL

by

MARKÉTA VAVROVÁ, Bc.

THESIS

Presented to the Faculty of the Graduate School of

The University of Texas at El Paso

in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF SCIENCE

Department of Civil Engineering

THE UNIVERSITY OF TEXAS AT EL PASO

May 2012

ACKNOWLEDGEMENTS

I would like to thank my advisors Dr. Carlos M. Chang-Albitres and Dr. Ladislav Bína for their guidance, suggestions and feedbacks.

DECLARATION

This thesis is an output of the Transatlantic Dual Masters Degree Program in Transportation Science and Logistics Systems, a joint project between Czech Technical University, Czech Republic, The University of Texas at El Paso, USA and University of Zilina, Slovak Republic.

This thesis is jointly supervised by the following faculty members:

Carlos Martin Chang-Albitres, Ph.D., The University of Texas at El Paso

Ing. Ladislav Bína, Ph.D., Czech Technical University

The contents of this research were developed under an EU-U.S. Atlantis grant (P116J100057) from the International and Foreign Language Education Programs (IFLE), U.S. Department of Education. However, those contents do not necessarily represent the policy of the Department of Education, and you should not assume endorsement by the Federal Government.

This research is co-funded by the European Commission's Directorate General for Education and Culture (DG EAC) under Agreement 2010-2843/001–001–CPT EU-US TD.

ABSTRACT

This thesis presents the reasons why the fuel tax is no longer a viable source of revenues and suggests new sources of funding. One possibility is to replace the fuel tax with a distance-based toll applied nationwide. Vehicle miles travelled (VMT) fee is compared to the fuel tax, and the relationship between road infrastructure spending and fuel taxation in the United States (U.S.) and the European Union (EU) is explored. Also the European approach to taxation and tolling is described and compared to the situation in Texas.

The development of a statewide distance-based toll model to estimate the feasibility of a set base toll rate, regarding revenues is presented. The aim is to offer an alternative to the current road infrastructure financing system in the U.S. based mainly on the fuel-tax which has been having problems with balancing the outlays and receipts since 2001 and is no longer self-sufficient. The model differentiates the toll price to three categories of vehicles and three emission classes, following a trend from the EU that motivates fleet-renewal and lowers emissions. Also a decision situation is described by an influence diagram and a sequence flowchart, identifying factors that lead to a successful implementation of a distance-based program.

Findings of this thesis can be used to enlighten the decision situation foregoing a distance-based toll implementation and help decision makers with the dilemma of whether to implement a distance based toll or rather continue with the current system based on the fuel tax revenues.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

In the last decade, both the United States (U.S.) and the European Union (EU) have faced increasing congestion, air pollution from traffic and insufficient budget to cover costs of road infrastructure. All these problems have much in common. Transportation is facing a crisis as new issues are encountered, such as insufficient capacity, air pollution, infrastructure deterioration and many others. To solve or at least mitigate these problems, more funding is needed. In the case of Texas, Durden (2010) in his work “Funding Texas Highways for the Next 20 Years” estimated that “by 2012 existing revenues [budget], unless expanded and/or augmented, will be fully consumed by debt service and the cost of operating and maintaining the existing system.” The ideal goal is to have a self-supporting transportation system, which would generate sufficient revenues to cover costs of maintenance, modernization and also new projects.

According to the current transportation financing system in the U.S., the revenues derive mainly from the fuel tax, which was introduced more than 100 years ago to approximate the road usage, and also from toll, vehicle registrations and ownership tax. In the EU, funding comes from the fuel tax, toll, road tax, highway time coupons and other sources (such as State Budget and privatization). Unfortunately, as Whitty (2007) points out, the fuel tax has now become “rather a general tax unrelated to use, than a fee for service” as the correlation between fuel consumption and road usage is changing. The change can be seen in Figure 1.1, where the fuel consumption is not rising as quickly as the vehicle miles of travel are.

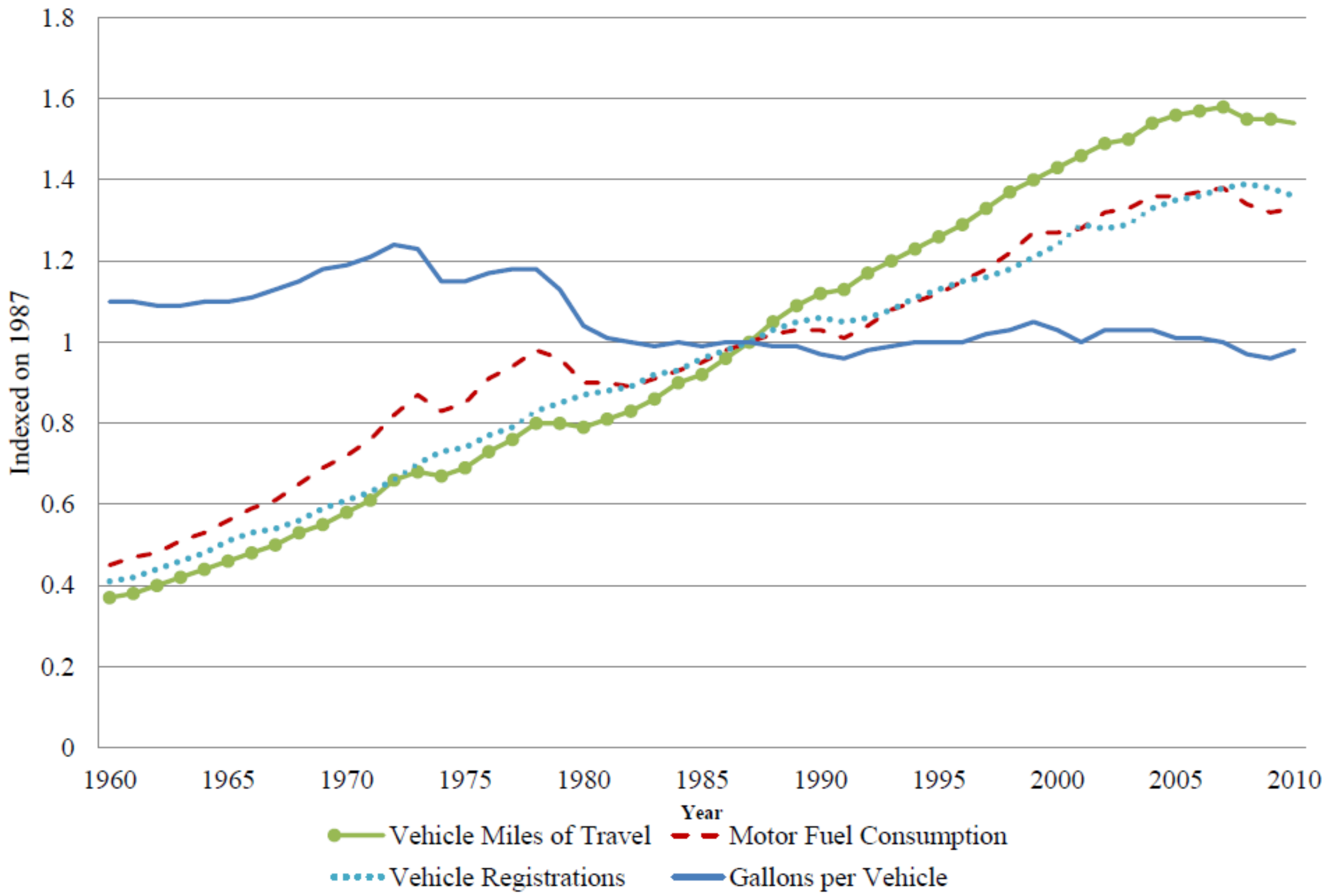


Figure 1.1 Vehicle Registrations, Fuel Consumption and Vehicle Miles of Travel as Indices
Source: FHWA Highway Statistics (2010)

Therefore, it is very important to think about a new, stable source of funding, particularly because it is a very serious decision to change the fundamentals of the transportation financing system. It is not a change that can be made day to day, as long time of planning must be carried out. The reason for action is not only the shortfall in receipts and outlays. With the world oil supplies estimated to run out in less than 50 years (Ward, 2011), increasing fuel efficiency and alternative-fuel-based vehicles entering the markets, the need to find a fuel tax replacement is becoming urgent.

A solution to this problem might be the replacement of the fuel tax with the vehicle miles travelled (VMT) fee, as the basis of a new transportation financing system, with rates set to provide a sufficient source of revenues to cover costs of building, operating and maintaining roads and highways

(plus collection costs, on board unit (OBU) distribution costs, enforcement costs and connected ITS applications costs). As for the VMT, a more accurate term would be distance travelled, but vehicle miles travelled has become the dominant term among policy makers and media in the United States. Even other terms are used, e.g. the mileage or kilometer charge in Europe. (Donath et. al., 2009)

1.1 VMT Fee vs. Fuel Tax

As mentioned earlier, the fuel tax is no longer a reliable indicator of road usage. Baker, et al. (2011a) indicates that "government regulation and continued increases in fuel prices could cut fuel consumption in the United States by 20 percent by 2025. While good news for the environment, this does not bode well for tax revenues generated by gasoline sales."

In 2011, Balducci, et al. conducted research for the Transportation Research Board about "Costs of Alternative Revenue-Generation Systems." The objective of the research "was to develop a methodology that can be used to analyze and compare the administrative, collection, and compliance costs of highway revenue-generation mechanisms" (Balducci et al., 2011). It focused on five usage-based charges: fuel tax, tolling, VMT fee and also congestion and cordon pricing. The discoveries concerning the fuel tax and the VMT fee are interesting for this thesis. For comparison, the tolling is also included in Table 1.1.

Table 1.1 Cost comparison between revenue systems – fuel tax, VMT fee and tolling

	Fuel Tax [1]	**VMT Fee** [2]	**Tolling** [1]
Cost per Line Mile	$50	$4,042	$150,595
Annual Operating Cost per Vehicle	$1.22	$75.16	N/A
Operating Costs	0.92% of revenues	6.6% of revenues	33.5% of revenues
Biggest Spending Item		administration costs 3.4% of revenues	collection costs 20% of revenues
[1] based on data collected in 2007 in U.S. [2] based on the revenue forecast to be collected in the Netherlands			

Source: (Balducci et al., 2011)

When compared, the VMT fee appears as the golden mean between the fuel tax and tolling. Although the VMT fee cost per line mile is 80 times higher than for fuel tax, it is still 37 times less than for tolling (tolling versus fuel tax is 3011 times higher). The low costs of the fuel tax are caused by its easiness. The tax is given and collected with every fuel purchase. The money collected go straight from the fuel company to the government's account. Invasions of this system are rare. Whilst for the VMT fee or the tolling, there always must be a strong enforcement to make the users pay. Also the costs building and operating of such tolling system increases the total costs.

Annual operating costs per vehicle for the VMT fee are 61 times higher than for fuel tax, which may seem like a quite high number, but considering that it includes all the infrastructure, applications, devices and enforcement costs, it is still a reasonable number.

The VMT fee operating costs are also reasonable, because with the 6.6% share on revenues are 7 times higher than operating costs for fuel tax (0.92% of revenues) but still 5 times less than for tolling (33.5% of revenues).

As for the biggest spending item, in a VMT system it is according Balducci, et al. (2011) the administrating costs with 3.4% of revenues, represented by wages and salaries, finance, accounting and audit activities, management and professional services, procurement and purchasing of toll equipment, planning activities related to toll-system development and expansion and buildings and utilities. This disaccords with the results of the congestion pricing trial-run in Seattle, Washington, where the majority of operating costs were costs of data communications (Pryne, 2008).

For tolling, the biggest spending item is the collection costs, taking away 20% of revenues. According to Balducci, et al. (2011), these costs include operation and maintenance of tollbooths, operation and maintenance of ETC and video tolling systems as well as related information technology hardware and software, customer account management, payment processing and inventory, distribution, and sale of OBU units.

As it appears from Table 1.1, the VMT toll is a golden mean between fuel tax and tolling – not as expensive as tolling and more usage corresponding and fair (from the point of view that alternative fuel based vehicles do not pay any tax).

Balducci, et al. (2011) also points out the other problem with the fuel tax: "another factor affecting the motor fuel tax revenue system is that fuel tax rates have not been indexed for inflation or increased at the federal level since 1993. From 1993 to 2008, the purchasing power of the federal gasoline tax, which has remained at the fixed rate of 18.4 cents per gallon, has declined by 33%." The easiness of simply increasing the fuel tax to get more revenues, it is only a speciosity. The resistance of tax payers increasing taxes is a strong hold-back here and it forces the government to keep the taxes at the existing level as long as it is feasible (and maybe even beyond that).

Table 1.2 shows Gasoline and Diesel Motor Fuel Taxes in the U.S. The state part includes the state excise tax and the other state tax. And there is also the federal part. It can be seen that the fuel tax on diesel is higher than on gasoline (in the EU is the opposite trend – see Table 2.1).

Table 1.2 Gasoline and diesel motor fuel taxes in the U.S. (¢/gal)

	State Excise	**Other State**	**Total State**	**Federal**	**Total State and Federal**
Gasoline	20.9	9.5	30.4	18.4	48.8
Diesel	19.0	10.6	29.6	24.4	54.0

Source: American Petroleum Institute (2012a)

As stated before, the current transportation system is not receiving sufficient revenues to cover its needs. Evidently, simple repeated increase in the fuel tax is not a solution. Aside from the possibility of basing the new transportation system on revenues from the VMT toll, there are other options. Balducci, et al. (2011) organized the known revenue systems into categories on the basis of taxation:

• **Vehicle ownership**

– Registration fees

– Licensing fees

– Personal property taxes

• **Highway user fees**

– Toll roads

– Congestion/cordon pricing

– High occupancy toll lanes

– VMT fees

• Energy consumption

– Motor fuel taxes

– Sales taxes on motor fuels

– Utility fees

• Beneficiary and local option fees

– Beneficiary charges/value capture

– Transportation impact fee

– Local option sales taxes

– Local option property taxes.

Note: In Texas there is no personal property tax, but in other states of the U.S. the personal property tax might be applicable. Part of the property tax may be used to finance transportation infrastructure.

From all these sources it is possible to get finances for the road network operation, maintenance and building. As for this thesis, it will mostly focus on the highway user fees and it will possibly show the VMT fee as a workable solution worth of a consideration when dealing with insufficient founding and congestions. This work will describe the current conditions in the U.S and in the EU. It will also summarize the VMT trial-runs. Then the factors leading to a successful VMT program will be explored and transformed into a model, to support a decision whether to do a VMT program or not.

1.2 Thesis Objective

This thesis is focused on a summary of electronic distance-based toll systems in the U.S. and the EU and on creating of a model to estimate the price of a VMT toll – with the objective to collect revenues needed to budget road maintenance, rehabilitation programs and connected operating costs.

Also the American and European approach is compared and recommendations are given for the application of the model.

1.3 Thesis Outline

Chapter 1 describes the motivation for a distance-based fee and compares the VMT fee with the fuel tax.

Chapter 2 describes the situation in the U.S. and the EU, and discusses topics such as relationship between road infrastructure spending and fuel taxation, tolling in Texas and Czech Republic, public acceptance, technical solution, and it also reviews methodologies.

Chapter 3 focuses on a development of an influence diagram, sequence flowchart and the final model.

Chapter 4 shows a case study for Texas with three different scenarios.

Chapter 5 summarizes all important findings of this thesis.

CHAPTER 2: LITERATURE REVIEW

2.1 U.S. Current State-of-the-Art

The fuel tax, which was introduced to approximate the road usage, is now nearly a century-old. It was first enacted in 1919 in Oregon and other states soon followed. The federal gasoline excise tax was introduced in 1932, with 1 cent per gallon (3.87 liters) (Tax Foundation, 2008). Now the gasoline federal tax is 18.4 cents (since October 1997). Together with state and local taxes, the fuel tax adds up to 48.8 cents per gallon of gasoline and 54.0 cents per gallon of diesel (US average, American Petroleum Institute, 2012a). Gasoline taxes combined at the local, state and federal level can be seen within Figure 2.1, which shows that the level of taxation differs among the states. The lowest level of taxation is in the southern states, whereas the coastal states have the highest level of fuel taxation (higher than the U.S. average). However these are still very low compared to fuel taxes in EU (see Table 2.1).

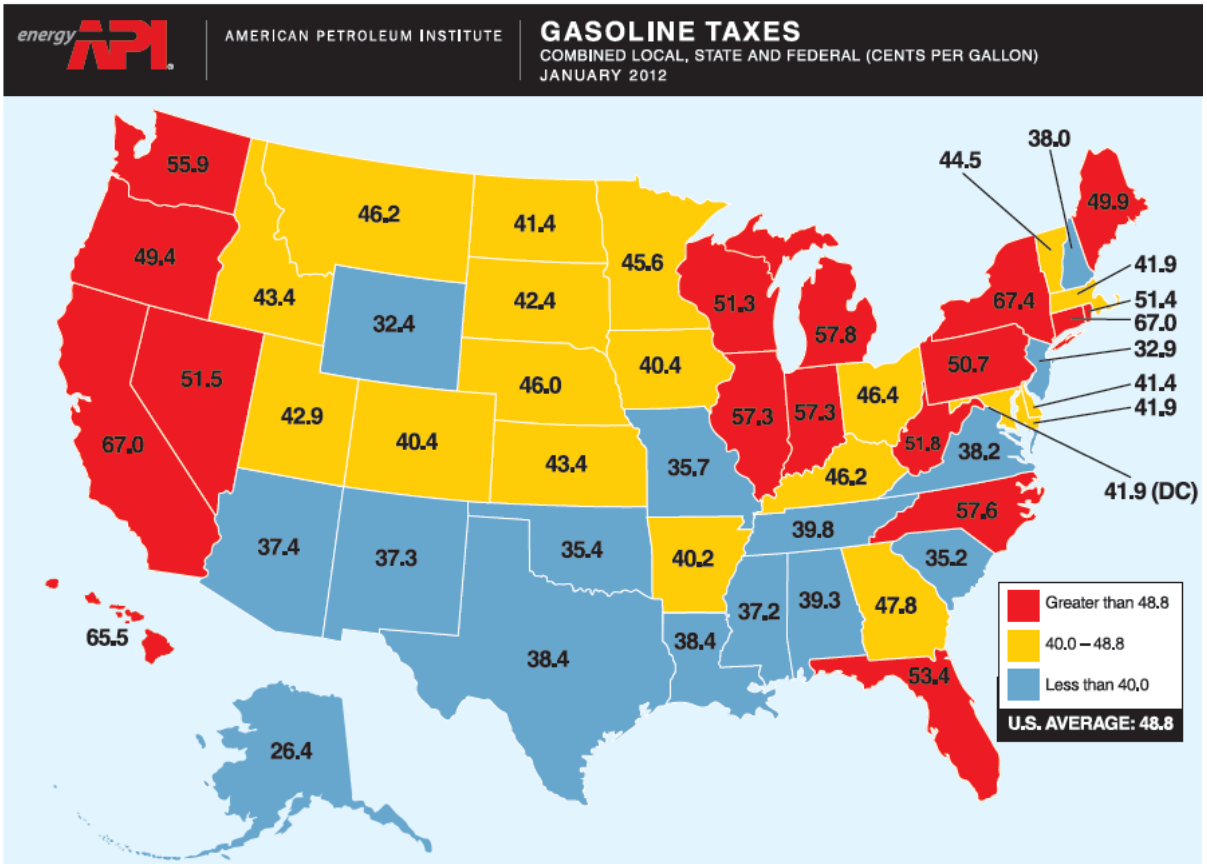


Figure 2.1 Gasoline taxes in the U.S., combined local, state and federal (¢/gal)
Source: American Petroleum Institute (2012b)

According to the FHWA (2010), the revenues collected from the federal part of the fuel tax in the U.S. flow into one of the several accounts forming the Highway Trust Fund. It was founded in 1956 and consists mostly of the Highway Account and the Mass Transit Account. Approximately 83 to 87% (depending on the fuel type) is deposited into the Highway Account (used for financing of road construction and maintenance), 11 to 15% goes to the Mass Transit Account. Other contributions to the Highway Trust Fund come from excise taxes on the sale of tires, trucks, buses, trailers and heavy vehicle use.

As Orszag (2008) states in "Overview of the Highway Trust Fund," most of the federal government's surface transportation programs are funded from the Highway Trust Fund and some transit programs receive appropriations from the Treasury's General Fund.

As Elmendorf, et al. (2008) claims in "Issues and Options in Infrastructure Investment," the balances in the Highway Account stayed steadily in the vicinity of $10 billion during the 1980s and in

the first half of the 1990s. But from 1996 to 2000 the receipts exceeded the outlays and the unexpected balance in the Highway Account grew from $10 billion in 1995 to a peak of about $23 billion in 2000 (see Figure 2.2). In general, spending has exceeded revenues since 2001 and Elmendorf, et al. (2008) predicted that in case the recent trend persists and spending from the Highway Trust Fund continues to exceed its revenues, the balances in the Highway Account will be depleted during fiscal year 2009.

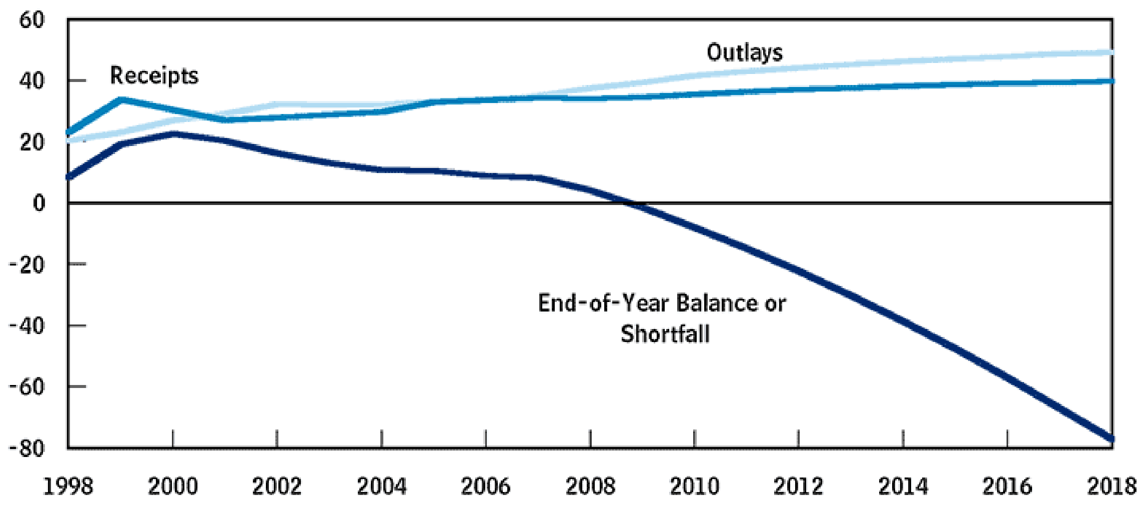


Figure 2.2 Actual and projected highway account annual receipts, annual outlays and cumulative balances or shortfalls, in bil. of $

Source: Elmendorf, D. W., et al. (2008)

As it showed, the Highway Account was depleted even earlier, in September 2008 (September is the end of the federal fiscal year), when Congress had to transfer $8 billion from the General Fund to cover a shortfall in the Highway Account. This happened again in 2009, the Highway Account was unable to meet obligations and required an infusion from the General Fund of $7 billion in 2009 (Elmendorf et al., 2010). In 2010 it required $14.7 billion (FWHA, 2012a). Results of years 2011 and 2012 do not suggest any improvement and probably the Highway Account will later require another infusion.

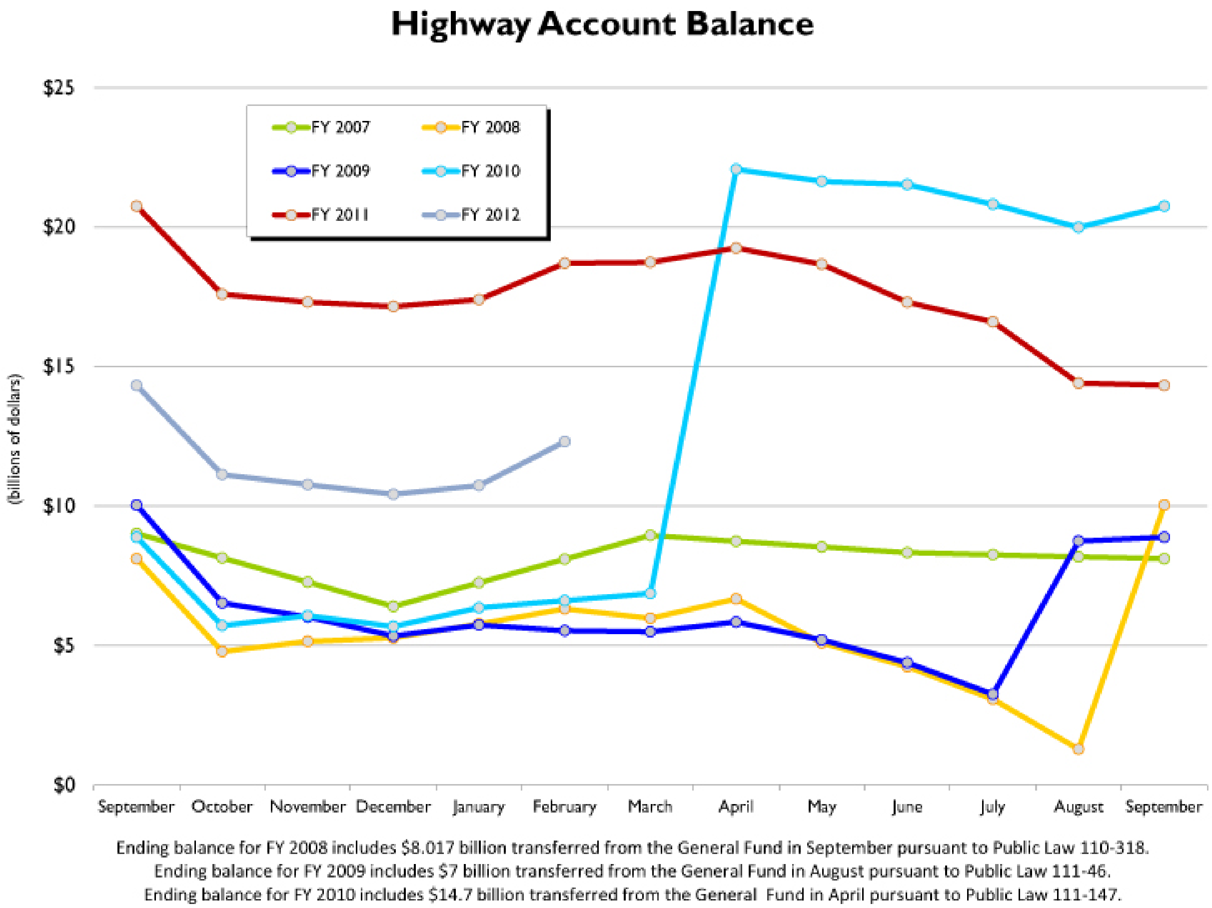


Figure 2.3 Highway Account balance

Source: FWHA (2012a)
Sequence from the top in September: 2011, 2012, 2009, 2007,2010, 2008.

Figure 2.3 indicates the U.S. has been having problems with the Highway Account balance in the last years. The source of finances for road infrastructure is experiencing severe problems, which will not get better with time. It is about time to come up with a new concept of obtaining funding. That is where the distance-based tolling can be considered as a possible replacement, as it offers an income depending on actual usage (which is linked to the wear-out) and is more fair for all road users, including alternative fuel based vehicles (who at the moment do not pay any equivalent to the fuel tax).

2.1.1 U.S Distance-based Studies

Problems with the Highway Account balance led to various distance-based trial runs. The following paragraph reflects the most important trial-runs in the U.S. Elmendorf, et al. (2011) reports that so far, there have been 4 studies in U.S. that focused on implementation of a distance-based fee.

2.1.1.1 Oregon Mileage Fee Project

The 12-month pilot run of the "Oregon Mileage Fee Project" took place in Portland, Oregon starting in April 2006. The technology it used was a combination of an odometer and a GPS unit (with a 2.45 GHz frequency). The scale of the project included the area of the city of Portland, 285 volunteer vehicles, 299 motorists and two service stations. The fee was paid at a standard fuel pump. For participants of this study the fuel tax was deducted and they paid only the calculated VMT fee. The fee was variable, according to if the miles were driven in rush hour. The GPS unit also distinguished between miles driven in Oregon or outside Oregon and in areas with no signal (which is important to know in case of invasion attempts). The participants were divided into 2 groups. The first group was charged $0.012 per mile. This amount was determined by dividing the then state gas tax of $0.240 per gallon by the 2004' average vehicle fuel efficiency of 20 miles per-gallon. This enabled the VMT fee to be fully comparable with the fuel tax. The second group was charged with $0.100 (about 8 times more than the average $0.012) in the rush hour (7-9 AM, 4-6 PM work days) and for non-rush hour miles $0.0043 (to pursue revenue neutrality) (Whitty 2007).

Whitty (2007) in "Oregon's Mileage Fee Concept and Road User Fee Pilot Program, Final Report" found that "91% of pilot program participants said that they would agree to continue paying the mileage fee in lieu of the gas tax if the program were extended statewide." That is very encouraging information, that such a high percentage of users who experienced the distance-based tolling would be willing to switch from the fuel tax. It shows that once drivers get to know the distance-based system, they realize that it is convenient and reasonable. Probably a considerable influence had the fact, that

drivers paid the VMT fee at the pump, with the same in process as they were used to pay the fuel tax. This approach could be easily used for phasing in the VMT fee gradually alongside the fuel tax. First, alternative fuel based vehicles could pay the VMT fee, while other vehicles would continue paying the fuel tax. Other alternative is that newly produced vehicles would be equipped with an OBU unit and paid the VMT fee, meanwhile the older cars would continue to pay the fuel tax and once the fleet is renewed, the system would be relying entirely on the VMT fee. Also as this study showed, congestion pricing for zones and time can be involved. In this particular case, a 22 % decline in driving during peak periods was archived.

2.1.1.2 Traffic Choices Study

The 18-month "Traffic Choices Study" took place around Seattle, Washington in 2005-2007 and was focused on tolling of interstate highways. The Puget Sound Region, where was the study carried out, has 6,290 square miles and contains 82 cities and towns. Two hundred seventy five households were involved in this project. The technology it used was a combination of OBU unit featuring GPS receivers, digital roadmaps and cellular communications (Elmendorf, 2011). Congestion tolling was applied on interstate highways, with the charge of $0.000 to $0.500 per mile that was deducted electronically from accounts. Participants were motivated to drive less, at cheaper times or take cheaper routes, by allowing them to keep whatever was left in their accounts when the experiment ended. The gained travel data from GPS receivers was entered into the regional council's computerized traffic model and estimated improvements in average peak-period afternoon commute times in 2010 could be dramatic, as reported by Pryne (2008). Travel time at about 37 miles on interstates between Bellevue and Tahoma, could decrease to 46 minutes with toll (average toll $13.41, $0.360 per mile) from the original 78 minutes without toll. Travel time at about 16 miles interstate section between Seattle and Lynnwood, could decrease to 22 minutes with toll (average toll $6.17, $0.390 per mile) from original 33 minutes without toll (Pryne, 2008). According the Puget Sound Regional Council (2008), estimated startup costs for this project were approximately $750 million, with annual operating costs about $288

million. Figure 2.4 captures the costs in detail. As can be seen, the majority of the startup costs were costs related to OBU units and for operating costs it were the costs of data communications. This distribution of costs seems naturally very typical of VMT projects, as the majority of system processes happens wirelessly.

System Elements	Capital (2008 Dollars)	Annual (2008 Dollars)
OBU and installation	$665,000,000	–
OBU / Installation – New Vehicles	–	$31,500,000
OBU – Repair / Replacement	–	$25,200,000
Training / Certification – Installers	$500,000	$50,000
Spare OBUs	$1,750,000	$20,000
OBU Subtotal	**$667,250,000**	**$56,770,000**
Stationary Stations	$20,000,000	$1,060,000
Transportable Stations	$1,875,000	$187,500
Mobile Stations / Vehicles	$1,200,000	$1,400,000
Enforcement Back Office	$5,000,000	$2,750,000
Enforcement Subtotal	**$28,075,000**	**$5,397,500**
Central System	$25,000,000	$20,000,000
Staff / Operations Training	$500,000	$100,000
Space for Central System / Back Office / Call Center	–	$200,000
Central System Subtotal	**$25,500,000**	**$20,300,000**
Data Communications Subtotal	**–**	**$201,758,800**
Other Subtotal	**$27,715,000**	**$3,500,000**
Grand Total	**$748,540,000**	**$287,726,300**

Figure 2.4 Network road tolling cost estimate for Puget Sound Region
Source: Puget Sound Regional Council (2008)

As Figure 2.5 from the “Traffic Choices Study – Summary Report” (Puget Sound Regional Council, 2008) indicates, the net present value (calculated by deducting costs from benefits) of the benefits to society from implementation of this network wide scenario of road tolling was estimated in the range of $28 billion. Over the 30-year implementation period for this scenario the present value of toll revenues was estimated at $87 billion (Puget Sound Regional Council, 2008).

Present Value Benefits/Costs	Millions of 2008 Dollars
Benefits	
Time Savings	$36,600
Reliability Benefits	$4,500
Operating Cost Savings	$2,500
Toll Effects on Consumer Surplus	-$97,100
System Operator Benefits (Tolls)	$87,000
Present Value of Benefits	$33,600
Costs	
OBU Costs	$1,500
Enforcement	$100
Central System	$500
Data Communication	$3,300
Other	$100
Present Value of Costs	$5,500
Present Value of Benefits less Costs	**$28,200**
Benefit-to-Cost Ratio	**6.1**

Figure 2.5 Benefits and costs of network road tolling of a 30-year implementation scenario
Source: Puget Sound Regional Council (2008)

2.1.1.3 Commute Atlanta Study

The 16-month "Commute Atlanta Study" by Georgia Institute of Technology and Clemson University was conducted in Atlanta, Georgia from September 2003 to December 2004. The technology was based on recording of vehicle speed, acceleration, position, and engine operating parameter collected by on-board GPS devices (Schönfelder et al., 2006). The aim of this study was according to FHWA (2011) to examine the effects of converting fuel taxes, registration fees, and insurance costs to variable costs for about 475 vehicles from 268 households. Participants were motivated to drive fewer miles than in previous year by earning 5 to 15 cents per mile not driven (FHWA, 2011). This resulted in a 3% reduction in overall miles traveled.

2.1.1.4 Road User Study

The 12-month "Road User Study" was conducted between August 2009 and July 2010 by the University of Iowa in cities in 12 states – New Mexico (Albuquerque), Texas (Austin), Maryland

(Baltimore), Montana(Billings), Idaho (Boise), Illinois (Chicago), eastern Iowa, Florida (Miami), Maine (Portland), the Research Triangle in North Carolina, California (San Diego) and Kansas (Wichita) with the total of 2650 participants (FHWA, 2011). Participants were surveyed on their reactions to receiving two types of monthly bill. One providing aggregate data only and the other showing detailed information that included routes of travel. Results of this study were not published by the closing date of this thesis.

Figure 2.6 shows VMT pilot projects in U.S.

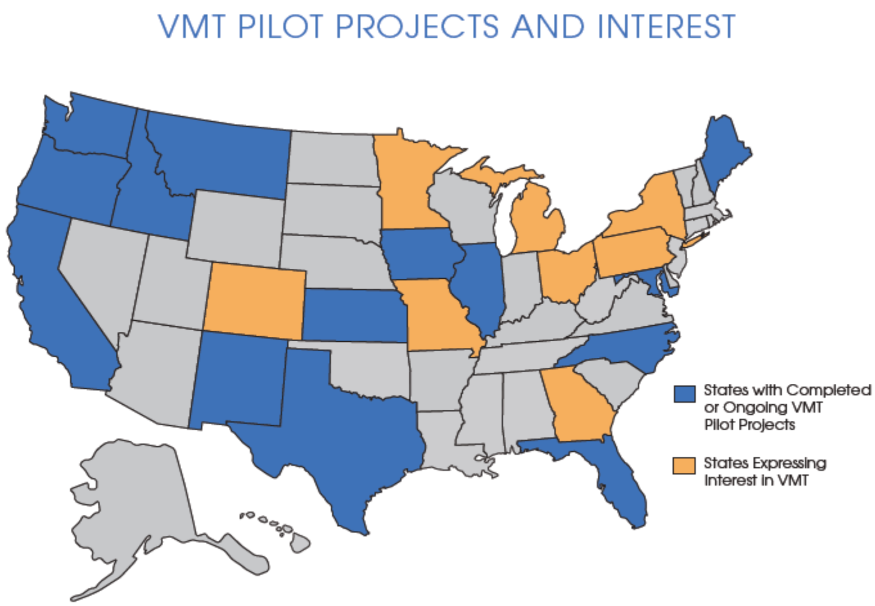


Figure 2.6 VMT pilot projects and interests in the U.S.
Source: Slone, S. (2009)

2.2. Road Infrastructure Spending and Fuel Taxation

To have a look at the larger picture, Table 2.2a and Table 2.2b show the road infrastructure gross investment spending in the U.S. and in 27 states of EU in years 1992-2009 and along with km of road of each state and the gasoline pump price. Since there is missing data for some states in every year, the only comparable years are 1995-2003. In these years the same states are missing and since these states are small, let us assume that their influence is insignificant.

In years 1995-1998 the EU spent on its 5.8 million km of roads more money than the U.S. did on its 6.5 million km of roads, the difference is on average 14%. In years 1999-2003 the U.S. spent on average 23% more on its kilometers of roads, although the U.S. has 11% more roads than the EU.

As the spending should be financed by the revenues in the fuel tax, it is important to look also at the taxation of gasoline and diesel in the U.S. and the EU (see Table 2.1). In the U.S. the tax is $0.488 per gallon of gasoline and $0.540 per gallon of diesel. Whereas the EU minimum level of fuel taxation is set according to the energy tax directive 2003/96 (Stampfer, 2011) to €0.359 per liter of gasoline ($1.890/gal), and €0.330 per liter of diesel ($1.737/gal), most of the countries have their levels set higher. For example Germany has much higher taxes: €0.6545 per liter of gasoline and €0.470 per liter of diesel. To sum up, in the EU taxes on fuels are more than 3 times higher. However, when comparing fuel consumption, the U.S. has about 3 times higher consumption (World Bank, 2011c). This means that revenues for both the U.S. and the EU are theoretically approximately the same. However, as mentioned in Table 2.1, in years 1999-2003 the U.S. invested on average 23% more into its road infrastructure. Despite this, according ASCE reports in years 1999-2009, the U.S. roads have been graded with a D+ or D- (ASCE, 2012). Here we can see once more the need of more funding so that we can maintain a better condition of roads and the implementation of the VMT fee could help significantly.

Table 2.1 Gasoline and fuel taxes in the U.S. and the EU

	$/gal[1]	**$/l**	**€/gal**	**€/l**
U.S. Gasoline[2]	$0.488	$0.129	$0.351	$0.093
EU Gasoline[3]	$1.890	$0.499	$1.361	$0.359
difference	**$1.402**	**$0.370**	**$1.009**	**$0.266**
U.S. Diesel	$0.540	$0.142	$0.389	$0.103
EU Diesel	$1.737	$0.458	$1.251	$0.330
difference	**$1.197**	**$0.316**	**$0.862**	**$0.227**

Source: American Petroleum Institute (2012a), Stampfer (2011)

[1] 1 gallon = 3.87 liters, $1=€0.72
[2] State and federal tax combined.
[3] Minimum tax recommended by the European Union.

Table 2.2a: Km of roads, Gasoline prices, Road infrastructure gross investment spending in 27 states of the EU and the U.S. in 1992-2000

		2008 km of roads		2010 gasoline pump price $US/liter	Road infrastructure gross investment spending [in millions of Euros]								
					1992	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Austria		110,778	Austria	1.63	557	467	483	457	426	366	432	392	477
Belgium		153,595	Belgium	1.87	920	957	1,244	1,069	987	954	1,134	1,253	1,300
Bulgaria	2005	40,231	Bulgaria	1.51	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Cyprus	2007	12,246	Cyprus	1.47	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Czech Republic		130,573	Czech Republic	1.75	n.a.	141	225	286	310	383	374	322	309
Denmark		73,257	Denmark	2.00	191	232	294	352	404	400	388	418	510
Estonia		58,034	Estonia	1.54	2	4	4	8	12	10	17	18	19
Finland		78,860	Finland	1.94	340	512	498	457	429	436	443	458	488
France		951,200	France	1.98	10,218	10,247	9,968	10,439	10,504	10,390	10,164	9,924	10,545
Germany		644,288	Germany	1.90	12,159	10,512	10,420	10,216	11,126	10,916	10,850	11,146	11,967
Greece		116,711	Greece	2.05	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1,402
Hungary		197,534	Hungary	1.67	167	229	265	131	123	299	281	208	177
Ireland	2004	96,602	Ireland	1.78	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Italy	2005	487,700	Italy	1.87	n.a.	n.a.	n.a.	4,980	5,052	5,144	6,258	6,365	6,930
Latvia	2007	69,687	Latvia	1.48	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Lithuania		81,030	Lithuania	1.59	n.a.	12	16	15	24	40	96	130	109
Luxembourg	2004	5,227	Luxembourg	1.55	150	155	136	114	107	101	113	146	166
Malta		3,096	Malta	1.63	2	6	4	3	7	10	8	7	11
Netherlands		136,135	Netherlands	2.13	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Poland		383,313	Poland	1.57	298	338	405	638	180	227	299	297	1,001
Portugal	2005	82,900	Portugal	1.85	398	405	649	737	748	970	905	554	964
Romania	2004	198,817	Romania	1.46	8	26	99	356	394	456	487	441	631
Slovakia		43,848	Slovakia	1.70	85	53	41	53	79	315	300	204	227
Slovenia		38,872	Slovenia	1.67	67	56	114	186	284	293	263	352	372
Spain		667,064	Spain	1.56	4,213	4,616	4,637	4,167	3,945	3,901	4,731	4,247	4,738
Sweden		574,741	Sweden	1.87	n.a.	n.a.	n.a.	999	1,014	891	1,046	927	912
United Kingdom		419,634	United Kingdom	1.92	6,445	6,169	6,136	5,225	4,864	5,082	4,233	4,758	5,564
EU total (27)		**5,855,973**	**EU average (27)**	**1.74**	**36,219**	**35,137**	**35,638**	**40,887**	**41,019**	**41,583**	**42,820**	**42,567**	**48,818**
United States	2005	**6,544,257**	**United States**	**0.76**	**26,142**	**30,486**	**32,812**	**30,335**	**32,523**	**40,437**	**39,608**	**49,231**	**61,267**

Table 2.2b: Km of roads, Gasoline prices, Road infrastructure gross investment spending in 27 states of the EU and the U.S. in 2001-2009

		2008 km of roads		**2010 gasoline pump price $US/liter**	**Road infrastructure gross investment spending** [in millions of Euros]								
					2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Austria		110,778	Austria	1.63	641	532	650	720	687	802	802	n.a.	n.a.
Belgium		153,595	Belgium	1.87	1,173	995	1,118	1,432	1,562	1,508	1,281	1,432	1,536
Bulgaria	2005	40,231	Bulgaria	1.51	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Cyprus	2007	12,246	Cyprus	1.47	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Czech Republic		130,573	Czech Republic	1.75	302	518	626	1,031	1,415	1,491	1,493	1,952	2,014
Denmark		73,257	Denmark	2.00	533	399	587	728	928	1,191	1,020	936	701
Estonia		58,034	Estonia	1.54	19	42	48	57	107	132	131	162	133
Finland		78,860	Finland	1.94	508	520	533	599	595	650	802	973	922
France		951,200	France	1.98	10,376	10,160	10,448	11,271	11,355	12,099	12,489	12,623	12,647
Germany		644,288	Germany	1.90	11,558	11,100	10,790	10,710	10,200	10,730	10,840	10,980	12,160
Greece		116,711	Greece	2.05	1,604	1,692	1,636	1,507	1,592	1,845	1,946	n.a.	n.a.
Hungary		197,534	Hungary	1.67	237	284	243	1,427	1,703	583	646	976	1,562
Ireland	2004	96,602	Ireland	1.78	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Italy	2005	487,700	Italy	1.87	4,582	5,071	6,874	7,572	9,169	14,280	13,664	13,051	n.a.
Latvia	2007	69,687	Latvia	1.48	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Lithuania		81,030	Lithuania	1.59	70	112	142	137	165	242	312	437	258
Luxembourg	2004	5,227	Luxembourg	1.55	186	213	188	135	128	176	157	138	n.a.
Malta		3,096	Malta	1.63	8	16	13	10	8	n.a.	n.a.	n.a.	n.a.
Netherlands		136,135	Netherlands	2.13	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Poland		383,313	Poland	1.57	1,094	1,035	1,010	1,237	1,877	2,605	3,442	4,511	5,337
Portugal	2005	82,900	Portugal	1.85	1,687	1,623	1,537	1,933	2,113	1,940	1,453	1,178	n.a.
Romania	2004	198,817	Romania	1.46	736	634	707	1,095	1,331	1,950	2,808	3,897	3,105
Slovakia		43,848	Slovakia	1.70	201	260	210	240	360	411	520	567	662
Slovenia		38,872	Slovenia	1.67	284	337	470	496	450	573	666	695	402
Spain		667,064	Spain	1.56	5,417	6,755	7,284	7,169	8,245	8,337	7,778	8,038	8,370
Sweden		574,741	Sweden	1.87	1,007	1,295	1,399	1,443	1,298	1,408	1,423	1,604	1,574
United Kingdom		419,634	United Kingdom	1.92	5,930	6,247	5,195	5,976	6,266	6,943	6,969	6,613	5,618
EU total (27)		**5,855,973**	**EU average (27)**	**1.74**	**48,154**	**49,839**	**51,710**	**56,927**	**61,553**	**69,898**	**70,644**	**70,762**	**57,001**
United States	2005	**6,544,257**	**United States**	**0.76**	**69,359**	**63,701**	**53,075**	**n.a.**	**n.a.**	**n.a.**	**n.a.**	**n.a.**	**n.a.**

Source: World Bank (2011a,b), International Transport Forum (2011), Nation Master (2011)

2.3 EU Current State-of-the-Art

In Europe the road tolling is more developed than in the U.S. Users have to pay a fee on most highways and speedways. For vehicles below 3.5 tons it is mostly on the time vignette basis. For vehicles over 3.5 tons many European countries introduced an electronic distance-based toll. Electronic fee collection for trucks in the whole EU is planned to be launched during 2012. Also one of the initiatives of the European Commission is to have a distance-based EU-wide electronic system for all classes of vehicles until 2014.

So far, reasons for implementing distance-based user charges in the EU were to (1) force international trucks to pay, (2) reduce truck volume (especially long distance haulage), (3) move long distance haulage on railways, (4) lower emission and noise reduction, (5) boost fleet renewal, and obviously (6) obtain money for financing roads, railways and inland waterways.

There are a few distance-based projects already in place for trucks in Austria, Czech Republic, Germany, Slovakia, Poland and Switzerland (not a member of the EU). Moreover, according to the Dutch Ministry of Transport (2007), Netherlands plans to introduce a statewide distance-based road user fee for trucks by 2012 and to expand the system to all vehicles by 2018. Unfortunately, this project was stopped after March 2010, when the government changed and due to the indignation of public. Presumably, the public was not given enough reasons for implementation of such a fee. Moreover, VMT fee was supposed to substitute the property tax, not the fuel tax, therefore the public saw it as a double taxation. Hopefully, Dutch government will reinvent the idea and they will implement it later on. More on this topic is covered in section 2.3.1.7.

The country-wide distance-based user fee would have been an innovative approach as in the other European countries with running distance-based projects, the fee is applied mostly on selected roads (mainly highways and selected speedways) and on vehicles over 3.5 tons (12 tons in Germany). In the future these countries would like to introduce a satellite based VMT system, which would include the whole road network, but so far no exact timeline has been set.

The tolling model in Europe apparently follows the “polluter pays principle”, as nowadays only vehicles over 3.5 tons pay the distance-based fee. The fee is imposed on trucks, because they are the greatest burden for the road and deteriorate its condition. Moreover, operators are motivated to use clean, optimally loaded vehicles on less congested routes therefore they are using the infrastructure more effectively, as concludes the “Proposal of Innovation of the Toll Directive” (2008). Other road users are charged on a time basis – mostly by year coupons for usage of highways and speedways. Apart from this, coupons also exist on the semi-electronic and the manual basis.

Figure 2.7 shows the tolling situation in 2010. Toll collection with a network of toll booths is widespread in the southern countries. Central European countries integrated electronic highway-network-wide distance-based tolling system for vehicles over 3.5 tons, mainly due to transit haulage. Northern countries joined for the Eurovignette system that tolls vehicles over 12 tons on a time-basis.

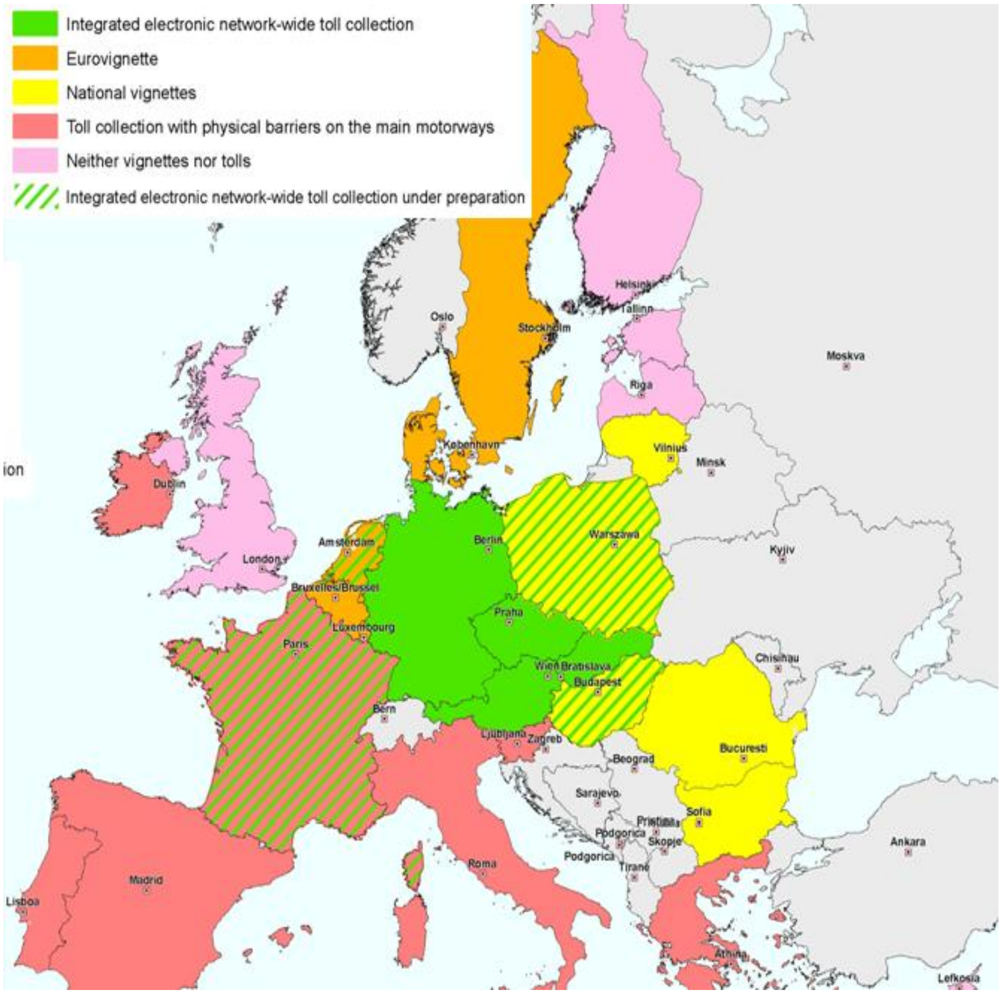


Figure 2.7 Road charging of trucks in the EU - situation in 2010

Source: Schmidt, S. (2010)

With the introduction of the Galileo satellite navigation system (launch estimated in 2017), it is expected that there will be an increase in electronic toll collection, especially in the field of zone-based and statewide distance-based applications.

In 2004 the European Electronic Toll Service (EETS) was established, to oversee that all implemented electronic fee collection systems in Europe will be interoperable. The "Communication from the Commission to the Council, the European Parliament" (2008) claims that "interoperability should therefore enable users to travel throughout the Union without charging procedures changing from one country to another and without having to install extra equipment to access other charging zones. This does not mean there would be one single supplier but that there should be sufficient technical compatibility between different systems so that paying charges on different stretches of road in the

Union would be a seamless operation." It means one subscription contract with one service provider and one single on-board unit for highways, tunnels, bridges, ferries and other parts of transportation infrastructure. The EETS is to be available starting in 2012 for vehicles over 3.5 tons and/or allowed to carry more than nine passengers and starting in 2014 for all types of vehicles.

Another step forward can be seen in the fact that in September 2011 Germany and Austria introduced a joint satellite-controlled electronic toll system TOLL2GO which allows vehicles above 12 tons fitted with a specific on-board unit to pay toll through the same device in both countries. Although only one on-board unit is used, customers still must have contracts with both toll operators.

2.3.1 EU Electronic Distance-based Tolling

Only countries with electronic distance-based toll systems (not toll plazas) are described in the following section.

2.3.1.1 Austria

The GO MAUT electronic distance-based tolling system has been in operation since January 2004 on highways and speedways in Austria. Vehicles over 3.5 tons has to be equipped with a GO-Box, which is an on board unit that registers every passage under the network of 800 portals (RDW, 2011). The communication uses the microwave technology Dedicated Short Range Communication (DSRC) at 5.8 GHz. Emergency vehicles, vehicles of armed forces and vehicles used for humanitarian relief operations are exempt from the toll (RDW, 2011).

The GO-Box can be purchased at any of the 250 sales points in Austria for €5 ($7) (RDW, 2011). At the sales point the following parameters are set (1) category of the vehicle, (2) emission class, (3) number of axles (RDW, 2011). Driver can later adjust the current number of axles by himself, but he is responsible for the correct set-up (RDW, 2011). Also both the driver and the owner of the registration number are liable for any infringement, as the GO-Box is attached to the windscreen with a velcro

(RDW, 2011). As the vehicle passes under a gateway, acoustic signal tells the driver if the transaction has been carried out correctly. The GO-Box contains a lithium battery with a lifetime of 5 years (RDW, 2011).

Table 2.3: Toll rates in Austria for 2012

$/mi	2 axles	3 axles	4+ axles
EURO 0-3	0.418	0.585	0.878
EURO 4-5	0.369	0.517	0.775
EURO EE5	0.335	0.470	0.704
EURO 6	0.324	0.454	0.681

Source: Go-Maut (2012), ($1=€0.72, 1 mi=1.61 km)

Rem.: EURO is an European emission standard.

Table 2.3 shows the toll rates for 2012. Enforcement is ensured by (1) enforcement units on toll portals, (2) portable units for temporary enforcement, (3) mobile enforcement officers, (4) inspections on existing traffic inspection sites (RDW, 2011). The penalty for driving without an OBU or blocking of the OBU is €220 ($305). Incorrect vehicle category or emission class setup penalty is €110 ($152).

Revenues from the GO MAUT system are subject to the 20% VAT and go to the network on which is the toll levied (RDW, 2011). There are no cash flows from the nation budget (RDW, 2011). Operating costs are 6% and percentage of dodgers is less than 1% (RDW, 2011). The toll can be paid either by a pre-paid credit or a post-paid bill received by mail or electronically, that can be paid by a fuel card or a debit/credit card (RDW, 2011).

For vehicles up to 3.5 tons a time-based vignette is required since 1997 (RDW, 2011).

2.3.1.2 Czech Republic

The MYTO CZ electronic distance-based tolling system has been in operation since January 2007 on highways and speedways in the Czech Republic for vehicles over 12 tons. Since 2010 vehicles

over 3.5 tons has to be equipped with a Premid unit, which is an on board unit that registers every passage under a portal. The communication uses Dedicated Short Range Communication (DSRC) at 5.8 GHz. Emergency vehicles (Czech police, fire brigade, emergency rescue) and vehicles of armed forces are exempt from the toll, but must carry a special OBU unit (RDW, 2011).

The Premid unit can be purchased at any of the 250 sales points in the Czech Republic for €60 ($83) (RDW, 2011). At the sales point the following parameters are set (1) category of the pulling vehicle, (2) emission class, (3) number of axles (RDW, 2011). Driver can later adjust the current number of axles by himself, but he is responsible for the correct set-up (RDW, 2011). As the vehicle passes under a gateway, acoustic signal tells the driver if the transaction has been carried out correctly. In case of a pre-paid method, the driver is informed by an acoustic signal if the credit drops below 600 CZK ($32) (RDW, 2011).

Table 2.4: Toll rates in Czech Republic for 2012

$/mi	**2 axles**	**3 axles**	**4+ axles**
EURO 0-2	0.285	0.483	0.702
EURO 3-4	0.222	0.379	0.549
EURO 5	0.142	0.243	0.351

Source: Premid (2012), ($1=18.9 CZK, 1 mi=1.61 km)

Table 2.4 shows the toll rates for highways in 2012. Rates for speedways are approximately half. The toll is differentiated in time – for Fridays 3 P.M. to 9 P.M., the toll is approximately 30% higher than the standard rate. Enforcement is ensured by (1) DSRC microwave technology, (2) Automatic Number Plate Recognition (ANPR), (3) vehicle dimensions classification, (4) portable enforcement devices, and (5) mobile enforcement devices of the Customs Administration (RDW, 2011). The toll can be either pre-paid credit or post-paid. For vehicles up to 3.5 tons a time-based vignette is required.

2.3.1.3 Germany

The LKW-Maut electronic distance-based tolling system has been in operation since January 2005 on highways and speedways in Germany. Germany was the first country worldwide to introduce a satellite-based system. Vehicles over 12 tons has to be equipped with an OBU, which contains a GPS receiver to determine the current section of the road and the vehicle is charged for the whole section, therefore the GPS signal is not used for the distance travelled (RDW, 2011). The accumulated amount of toll is sent from the OBU to the back-office using the Global System for Mobile Communications/General Packet Radio Service (GSM/GPRS) transmission (RDW, 2011). Emergency vehicles (police, fire brigade, emergency rescue) and vehicles of armed forces are exempt from the toll (RDW, 2011).

The OBU can be purchased at any of the 250 sales points in Austria for €5 ($7) (RDW, 2011). At the sales point the following vehicle parameters are set (1) category of the pulling vehicle, (2) emission class, (3) number of axles (RDW, 2011). The OBU can be either built-in or built-on by an authorized personnel, which ensures a correct connection to the odometer and the gyro (RDW, 2011).

Table 2.5: Toll rates in Germany for 2012

$/mi	**up to 3 axles**	**4+ axles**
EURO 0-2	0.274	0.288
EURO 3	0.190	0.204
EURO 4	0.169	0.183
EURO 5	0.141	0.155

Source: Toll Collect (2012), Bundesamt für Güterverkehr (2009), ($1=18.9 CZK, 1 mi=1.61 km)

Table 2.5 shows the toll rates for 2012. Enforcement is ensured by (1) 300 permanently installed gantries, (2) stationary inspections, (3) 300 mobile enforcement officers, and (4) random checks of trucking companies (RDW, 2011). The penalties are between €35 ($25) and €400 ($288) (RDW, 2011). For vehicles up to 3.5 tons a time-based vignette is required.

2.3.1.4 Slovakia

In 2010 there was on the network of highways and speedways launched a satellite-based toll system for vehicles over 3.5 tons. Its operation is based on the Global System for Mobile Communications/General Positioning System (GSM/GPS). Enforcement is ensured by many control toll gates. The OBU can be purchased for €50 ($36) (emyto.sk, 2012). Apart from this, on 4 transit corridors users can pay also via the ticketing system, where they can purchase a ticket valid for the next 18 hours for the amount equal to the toll calculated according to the length of the journey, vehicle category, number of axles and emission class (emyto.sk, 2012).

Table 2.6: Toll rates in Slovakia for 2012

$/mi	**3.5-12 tons**			
EURO 0-2	0.093			
EURO 3	0.086			
EURO 4+	0.083			
12+ tons	**2 axles**	**3 axles**	**4 axles**	**5 axles**
EURO 0-2	0.193	0.202	0.209	0.206
EURO 3	0.183	0.193	0.199	0.193
EURO 4+	0.179	0.189	0.196	0.189

Source: emyto.sk (2012)

Table 2.6 shows the toll rates for highways in 2012. Rates for speedways are approximately two thirds of the rate for highways.

2.3.1.5 Poland

In 2011 Poland launched a microwave toll system for vehicles over 3.5 tons on the network of selected highways and speedways. Table 2.7 shows the toll rates for highways in 2012.

Table 2.7: Toll rates in Poland for 2012

$/mi	3.5-12 tons	12+ tons
EURO 0-2	0.400	0.530
EURO 3	0.350	0.460
EURO 4	0.280	0.370
EURO 5	0.200	0.270

Source: Viatoll (2012)

2.3.1.6 France

Since 2007 vehicles over 3.5 tons are subject to toll on all national roads. To relieve the burden on users, road tax for these vehicles was cancelled. The tolling system is distance based on toll booths, where users can pay either cash or pass without stopping if using an OBU. A satellite-technology based trial run of distance-based eco-tax per kilometer is planned in 2012 in Alsace (RDW, 2011).

2.3.1.7 Netherlands

Between 2007 and 2010 Netherlands was preparing a launch of a satellite distance-based system "Anders Betalen voor Mobiliteit (ABvM) (RDW, 2011). This system was supposed to be launched in 2012 for vehicles over 3.5 tons and later to be expanded to all vehicles. The toll was supposed to be differentiated in time and place. All vehicles with a Dutch registration plate would be equipped with an OBU that would determine time and place and calculate the toll based on usage of the motor (RDW, 2011). However, this project was stopped after elections in March 2010, as there was no longer support for this kind of a project in the government (RDW, 2011).

2.3.1.8 Portugal

In addition to the toll booths tolling on selected speedwas, in 2010 Portugal introduced an electronic toll using a microwave technology on selected speedways that were not previously included in the toll network (RDW, 2011).

2.3.1.9 EU Electronic Distance-based Tolling Summary

In the EU the electronic distance-based toll is applied on the network of (selected) highways and speedways for vehicles over 3.5 tons (over 12 tons in Germany). It is differentiated by the number of axles and the emission class. Buses are subject to a lower toll. Both national and foreign vehicles are subject to tolls. The lowest toll rates are in Slovakia and Germany. The highest toll prices are in Germany.

In January 2011 Switzerland (not a member of the EU) launched an electronic distance-based toll based on a combination of odometer readings and OBU with a GPS and motion sensor - Leistungsabhängige Schwerverkehrsabgabe (LSVA). It applies to vehicles over 3.5 tons and it does not differentiate between classes of roads, so the toll applies to all public roads.

As an example of the European electronic tolling system in urban areas, can be mentioned the Stockholm Congestion Charging System and the London Congestion Charge. Both are based on the Automated License Plate Recognition (ANPR). This technology cannot be used as a main technology for a statewide tolling, therefore will not be discussed further.

2.4 Tolling in Texas and Czech Republic

In the next chapter, the VMT model will be developed based on the emission class differentiation and pricing levels inspired by the truck tolling system in the Czech Republic. As the developed model will be applied to the Texas environment, a short description of the tolling background in these two states is presented here.

2.4.1 Tolling in Czech Republic

The Czech Republic has been a member of the EU since 2004. Passenger vehicles (up to 3.5 tons) since 1995 are required to purchase a time toll vignette (a sticker) to access the tolled network of highways and speedways. Since 2010 vehicles over 3.5 tons are tolled on a distance basis for the usage of the tolled network. This electronic distance based toll is differentiated by number of axles and emission class.

This combination of time and distance tolling is very popular in the EU. Electronic distance-based toll is in place for vehicles over 3.5 tons (12 tons). Vehicles under 3.5 tons at selected sections of highways are either subject to a time toll vignette or pay the toll at a toll booth or pay the toll electronically. In a few states are vehicles under 3.5 tons are not a subject to toll at all.

According to EU policies, revenues from the electronic toll system cannot be higher than the sum of a state’s own funds into the annual budget for road infrastructure. Tolling rates are also differentiated according to various criteria. Calculation of the maximum possible amount of tolling rate is a complex analytical work, including models. Proposing toll rate levels is a significant political issue and it needs to be approved by the government and as part of the state budget by the parliament.

Revenues from the distance-based toll are an important share of the road infrastructure budget. As Figure 2.8 depicts, in 2011 the distance-based tolling had an 18% share of income in the road infrastructure budget, whereas income to this fund from the fuel tax had a 23% share. Since every year

the share of income from the distance-based tolling increases, it is expected that it will catch up with the fuel tax soon.

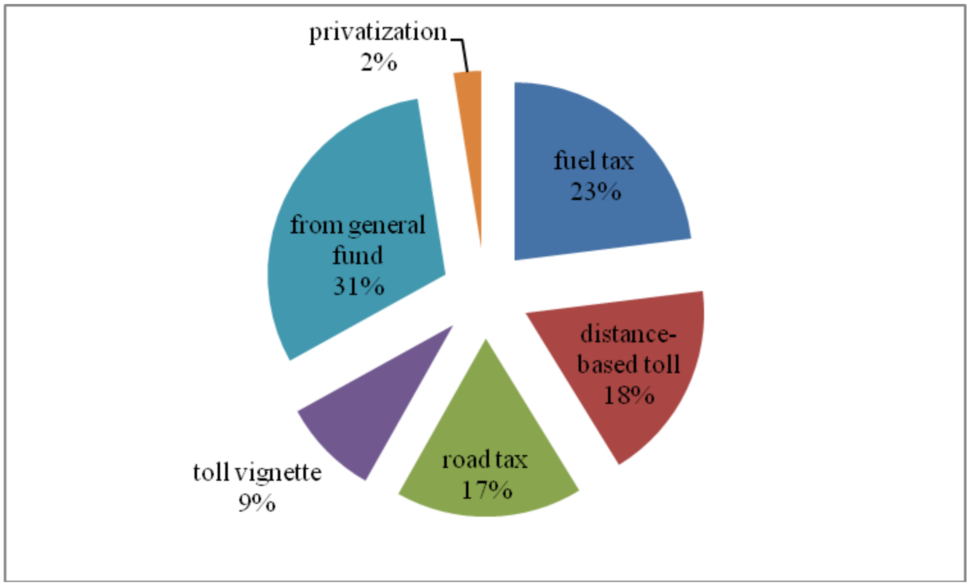


Figure 2.8 Income to the Czech road infrastructure fund in 2011
Source: SFDI (2010)

As for the Czech Republic, a majority of the revenues from the fuel tax go to the State Budget and only a minor part (20% until 2004, since then 9.1% - according to Silnice-Zeleznice.cz, 2004) goes to the road infrastructure fund, unlike in Texas, where approx. 73%[4] of state fuel tax revenues go to the State Highway Fund. The Texas approach shows more clearly how self-sufficient the transportation system is. In the case of the Czech Republic, the fact that fuel tax revenues go mainly to the State Budget and then are re-distributed back, makes it harder to see how sufficient the revenues are.

[4] Obtained by a comparison of the motor fuel tax collection to the motor fuels tax income to the State Highway Fund in years 2001-2010.

2.4.2 Tolling in Texas

In Texas the access to the road infrastructure is free of charge for all users, with only a few exemptions of tolled sections on newly built highways. A majority of income from the tolled sections is budgeted for financing of these sections (as seen on Figure 2.9, this source provides only 0.04% of the Highway State Fund income). Figure 2.9 shows major incomes to the Texas Highway State Fund in 2010.

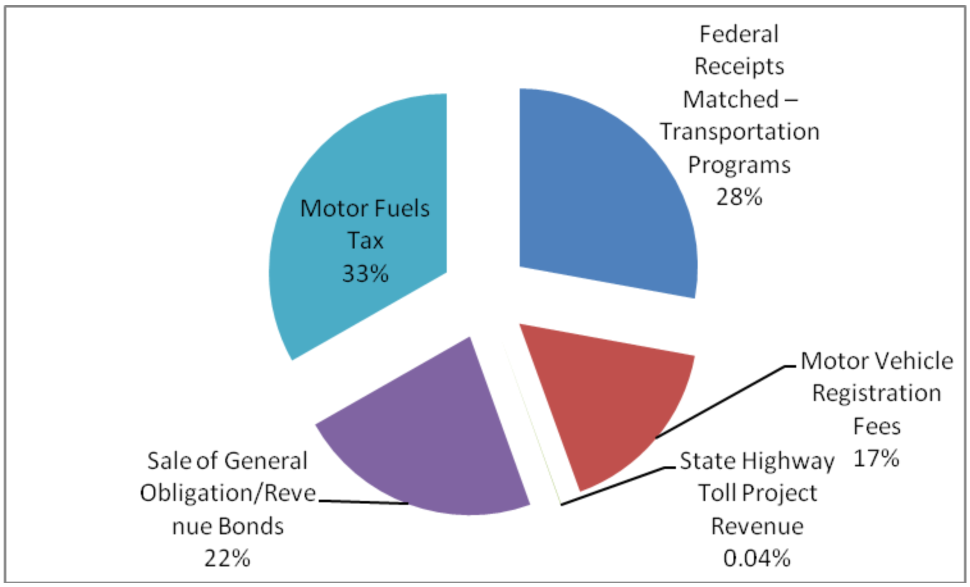


Figure 2.9 Major incomes and toll revenue income to the Texas Highway State Fund in 2010
Source: Combs, S. (2010)

In summary, Texas tolling policies are different to those in Czech Republic. There are no highway vignettes, nor distance-based tolling for trucks. Users contribute to the transportation financing system mainly via the tax on motor fuels and income from tolling on selected highways is insignificant.

In 2008, there were attempts to establish legislation for a distance-based fee program in Texas, but it was adjourned (Baker, Goodin, 2011b).

In 2010, the Texas Transportation Institute began to explore the distance-based toll for Texas and in early 2011 it published the "Exploratory study: Vehicle mileage fees in Texas". Baker and Goodin (2011b) recommend a trial deployment of a VMT fee in Texas for fully electric vehicles, where the

mileage would be read from odometers during vehicle inspections or drivers could go for an opt-in GPS system, which would guarantee a discount for out-of-state mileage. The group of fully electric vehicles was chosen for the near term application, because it is currently not subject to the fuel tax.

2.5 Public Acceptance

As the CURACAO (2008a) noted, "we live in a democratic society, so societal, political and technological innovations must be introduced via the democratic process". The public acceptance issue is therefore vital for a successful implementation of the distance-based fee. "A strong public resistance may inhibit implementation, as political parties fear consequences for their next election" (CURACAO, 2008a). The political commitment is very important. There should be a stable government, who will follow the decision, will have a stable attitude to the program and will provide intelligible information, so that the public can understand the reason why it is crucial to replace the fuel tax with a distance-based fee and supports this transition.

As the TxDOT's study "Is Texas Ready for Mileage Fees?" (Baker et al., 2011a), states that "the public favors fixing the current funding mechanism before trying to develop an alternative". During the implementation of a VMT program, a marketing campaign should be run to correct this attitude, explaining that the fuel taxation will no longer be sustainable, because it is no longer corresponding with the usage.

2.5.1 Electric Vehicles

One of the problems that the public recognizes, is the issue with high-efficient and electric vehicles paying lower or no taxes (Baker et al., 2011a). Therefore one option could be to utilize this issue and implement the VMT fee for these vehicles first (Baker et al., 2011a). This action could gain more support of the public, more belief in the profits of the distance-based fee before a large-scale implementation.

2.5.2 Increase in Costs

The possibility of a huge increase in driver's costs is also feared. It should be explained to the drivers, that the VMT fee is a replacement for the fuel fee, not another fee to pay together with the fuel tax.[5] Moreover, Whitty (2007) claims that, “a motorist driving a high-mileage Toyota Prius 12,000 miles per year and charged a per-mile fee of 1.2 cents per mile, for example, would see a monthly increase of approximately $7 in mileage-based road user fees, compared to the consumption-based gas tax,” which is still bearable.

2.5.3 Wasting of Revenues

Texans also disagree with spending the current fuel-tax revenues on non-transportation projects or wasting money on inefficient projects. In the case of a successful implementation of VMT fee, the revenues need to be transparently spent on improvement of transportation infrastructure to gain the acceptance of public more easily first (Baker et al., 2011a). As Arnold et al. (2010) report in “Reducing Congestion and Funding Transportation Using Road Pricing in Europe and Singapore”, “the use of revenue has been another means of addressing equity and perceptions of fairness. In Germany, a truck harmonization fund created from road pricing revenue pays for new truck equipment and training for cargo haulers. In Singapore, net revenues not invested in transportation projects are returned to motorists through rebates in vehicle taxes.”

[5] In Netherlands since January 2012 vehicles over 3.5 tons should have paid both fuel tax and distance-based fee. The Dutch Ministry of Transport substituted distance-based fee for ownership tax, probably due to primary administrative difficulties, as distance-based fee is responsibility of Ministry of Transport and fuel tax is responsibility of Ministry of Finance. Because of a change in government and general public indignation, this project was cancelled after election in March 2010 (RDW, 2011).

2.5.4 Fairness to Rural Drivers

As Baker, et al. (2011a) pointed out, “respondents reacted negatively to the notion of shifting fundamentally from a fuel-tax-based to a user-fee system,” mainly because Texans are concerned about the fairness of the distance-based fee. As Barker, et al. (2011) has indicated, “in Texas the most prominent concerns relate to rural drivers. As a class, rural drivers generally drive farther for every-day, basic services. Because mileage fees are based on how much of the transportation network a driver uses, they appear to unduly burden these drivers.” However, this presumption is not exactly true, in the case of replacement of the fuel-tax, the VMT fee price would correspond with the fuel tax. Therefore the presumption of drivers paying much more is inaccurate and should be disproved by informing the public. Although changes in driver's behavior are expected and believed in, as drivers will be led to be more conscious of the distance they travel. For example during the Oregon study, it showed that participants reduced their driving in total miles of more than 3 miles a day (12%), as Whitty (2007) concludes.

2.5.5 Privacy

Privacy is also a huge issue. The public is afraid to have a tracking device installed in their vehicle. The common idea, the public has, is that if they have the device installed, anyone can read who they are, where they are, where they were travelling and at what time. There are also fears of getting a penalty every time vehicle exceeds the speed limit, as people think this would be also tracked. There is no need to build the system to work like that. For example, in Oregon the data transmission ran only at fuel pumps and the transmitted data included only miles in/outside Oregon, rush hour miles, no signal miles and total miles to compare with previous data transmittals to eliminate evasions and avoiding the fee. In Singapore, the privacy issue of electronic payment system for parking and other facilities was solved with a smart cash card that contains only account balance and no user data (Arnold et al., 2010).

2.5.6 Cooperation

Another issue, which is very important to ensure, is to cooperate with the automotive industry to implement in-car OBU units. This approach might be less expensive and less evasion-threatened than having OBU units mounted into cars additionally. The question is; who would pay the costs of this extra device. As automotive companies are well known for cutting their prices to minimum, it is not probable that they would voluntarily add the cost of the OBU unit to the retail price.

2.5.7 Legislation

This could be solved with a change in legislation. Apart from solving this issue with legislation changes, also extensive changes in laws would have to be made, concerning both privacy protection and usage of revenues. Eventually, the whole fuel taxation system would have to be changed. This would also influence the alternative fuel based cars, which would no longer be omitted from paying taxes, which could destroy the biggest advantage for customers to prefer them to fuel cars.

2.5.8 Public Acceptance Summary

To summarize, the public should be provided with good information and made see that it is not only just another fee they have to pay, that will empty their pockets, but that it is a useful tool that will lead to a better road condition, a building of new roads and relieve from congestions. Therefore in the end it will be the driver who is benefiting. It should be made clear how the revenues will be used and the system should work well since the first day in operation, so that drivers can trust that they pay the right amount.

2.6 Technical Solution

When it comes to distance-based fees, the crucial question is how to determine the miles travelled. Basically, there are four possible approaches – the odometer reading, the microwave, the satellite and the cellular network system.

2.6.1 In-Vehicle Systems

2.6.1.1 Odometer Reading

The odometer reading system is probably the easiest and most vulnerable way how to determine the miles travelled. In the simplest way, odometer readings can be made in set periods by certified companies, usually during scheduled maintenance. The evasion risk here is significant, because cases of influencing odometers are not rare. Odometer reading can supplement the other systems. The electronic distance fee in Switzerland is based on this principle and combined together with GPS and motion sensor. The fee applies on all the roads, so there is no need to differentiate between them. In case a vehicle drives abroad, there are microwave beacons on the border, that turn off the counting of miles outside Switzerland. Figure 2.10 shows a possible odometer reading system for Texas.

Figure 2.10 Odometer Reading System

Source: Baker, Goodin (2011b), pg. 32

2.6.1.2 Speed Reading

As Donath, et al. (2009) mentioned, it is possible to access the starts, stops and speeds of a vehicle through the OBD-II port, which is available in all vehicles in the U.S. manufactured after 1996. Based on this information the mileage can be calculated. The main advantage in comparison to the manual odometer reading is that the mileage calculation occurs electronically (Baker, Goodin, 2011b).

2.6.1.3 Fuel Consumption Reading

As Whitty and Svadlenak (2009) showed, another possibility is to use radio frequency identification (RFID) tags with encoded vehicle's estimated fuel efficiency. This tag would communicate with a reader on a fuel station and mileage would be calculated based on the amount of fuel purchased and the efficiency. This approach would probably be the easiest to employ and

information about emission class could be easily added. However, there is a risk of drivers trying to manipulate the tag to obtain a lower fee.

All these approaches enable air pollution management by differentiation of the fee based on the emission class. However, they do not enable additional features such as congestion management, for which is needed information about time and place. Odometer reading and speed reading do not require additional in-vehicle devices.

2.6.2 Microwave System

The microwave system consists of a network of toll gates, which are built above traffic lanes. To allow electronic fee collection during movement of a vehicle, without slowing down or restriction of riding, there must be no barriers either on an entry or on an exit ramp. The toll gates are equipped with microwave technology which communicates with OBU units fastened on the windshield of the vehicle. Successful toll transaction is indicated by one beep right after passing a toll gateway. The microwave system operates at 5.9 GHz in the U.S. and at 5.8 GHz in Europe. As mentioned, this system requires a net of toll gates, which is a disadvantage if applied in a larger scale, due to the costs of many toll gates needed. This system is being used in many states in EU.

2.6.3 Satellite System

The satellite system is more convenient for larger scale applications, as it can cover all roads more easily with lower costs than would be needed for building toll gates. This system is based on on-board units that communicate with satellites to calculate its position. The Global Positioning System (GPS) which is currently being used, is mainly operated by the U.S. government. As the U.S. government can restrict the civil usage of the GPS anytime, for a system based on this technology such an outage could be fatal. This will be solved once the EU's project Galileo is in operation, because its services will be certified and of a guaranteed quality (more about the Galileo project in Chapter 2.2).

This system is not as easy to evade as odometer reading systems, but there are many challenges. On the technical issue, this system is quite complex to administer and enforce. There are also questions about usage in urban areas, as there the satellite signals reflect on large buildings and other elevations causing that the receiver gets first the direct signal and then with delay the reflected one, which is called the multi-path effect and is causing an error typically in the range of a few meters, making the data not reliable and accurate (Köhne, Wößner, 2009). Figure 2.11 shows a possible configuration of the satellite system.

Between advantages belongs the possibility to apply a time and location specific fee and enable congestion charging. As Balducci, et al. (2011) remark, congestion pricing is only feasible if the majority of vehicles are participating.

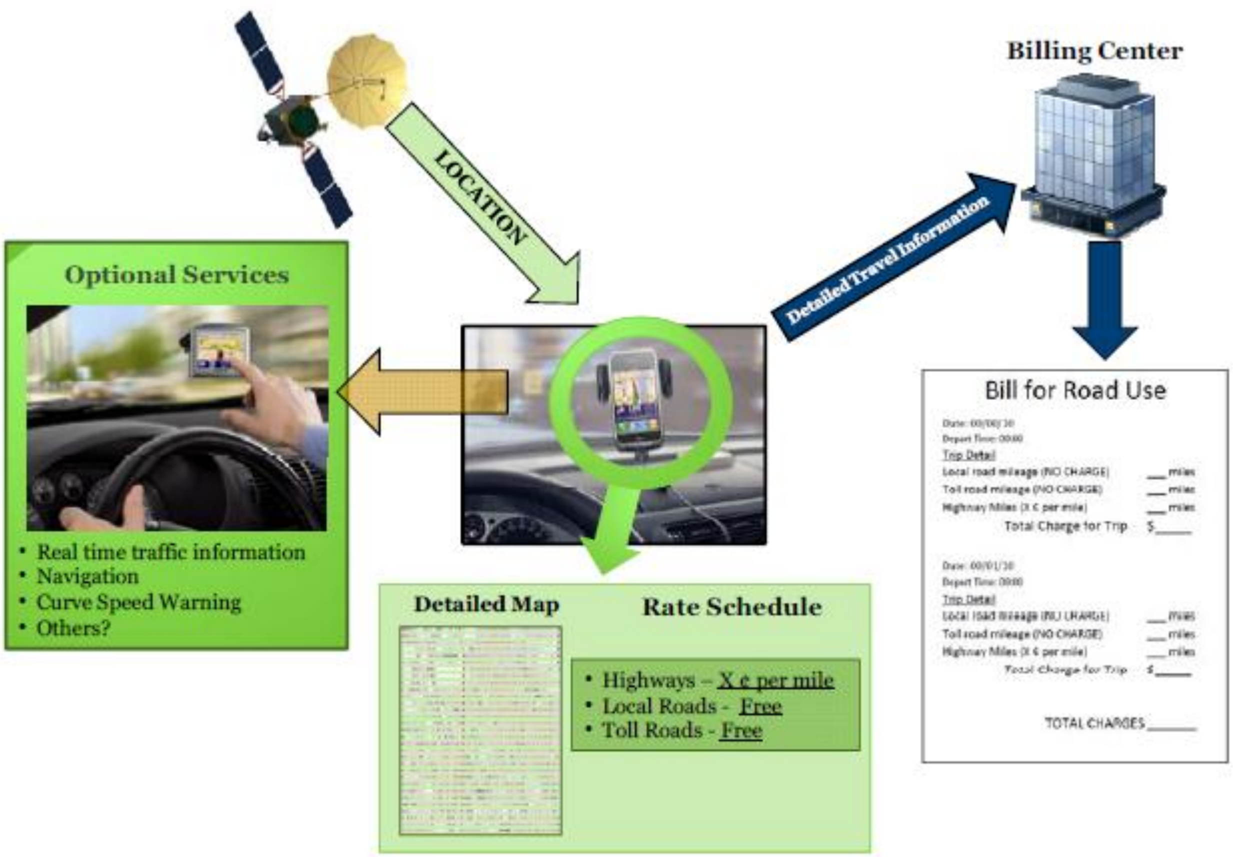


Figure 2.11 Satellite System

Source: Baker, Goodin (2011b), pg. 34

2.6.4 Cellular Network System

A huge advantage of the cellular network system (GSM) is that it uses the existing infrastructure of cell phone towers. Its resolution is not as precise as in the case of satellite systems. Therefore the fear of tracking and privacy issues could be less apparent, as it determines only current zone not specific location of the vehicle. On-board-devices could communicate via SMS. Figure 2.12 shows a possible configuration of the cellular network system.

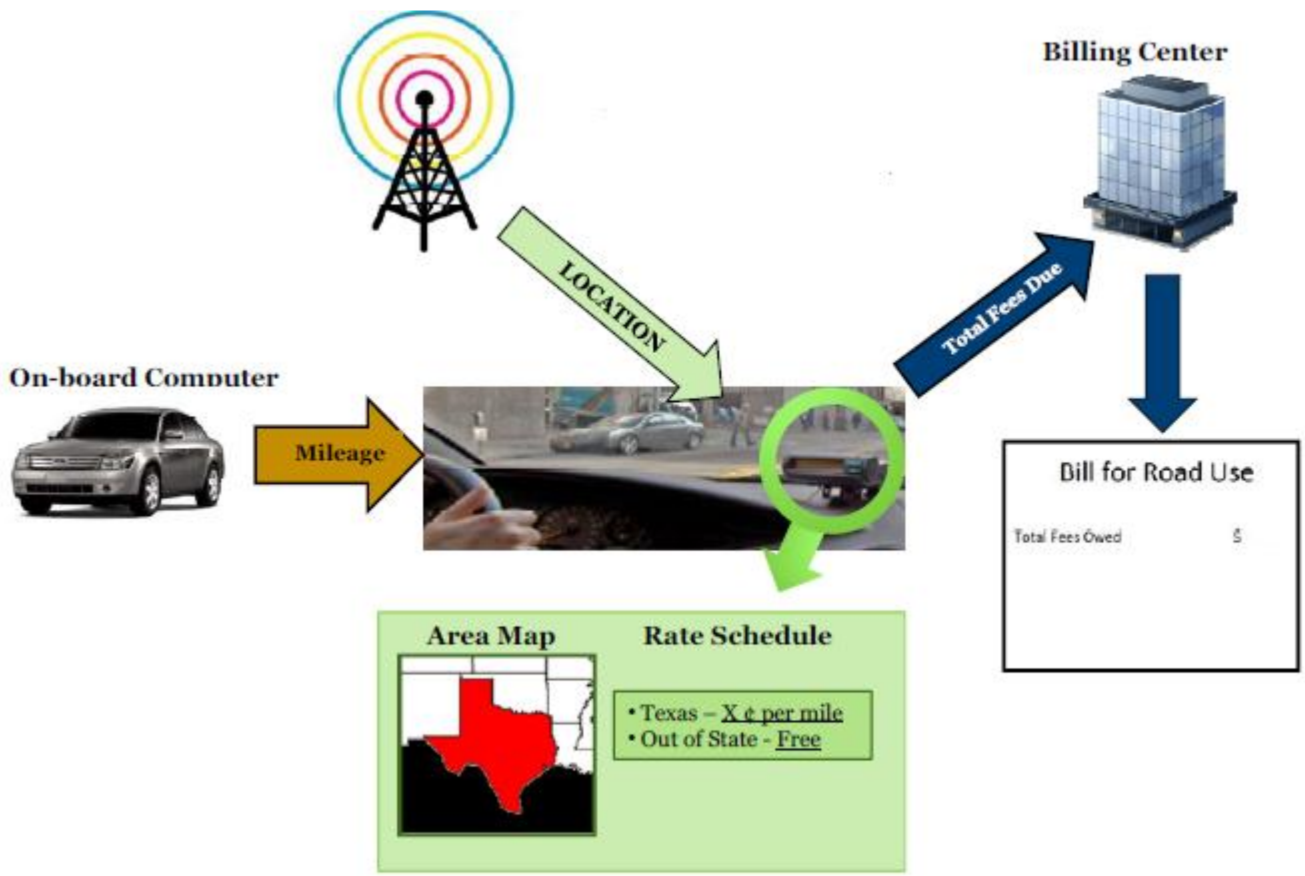


Figure 2.12 Cellular Network System

Source: Baker, Goodin (2011b), pg. 33

Figure 2.13 compares the odometer, satellite (GPS) and cellular network system in various factors.

	Odometer	Cellular	GPS
Detail of Travel Information	None	Low (In-state/Out-of-State only)	Detailed (route specific, time of day)
Technology Installation	None	Required by certified professional	Required, but can be self installed
Mileage Discount	None	Out-of-state mileage discounted	Mileage on non-state maintained roadways and out-of-state mileage discounted
Mileage Calculation	Manual	Calculated from start/stop and speed data	Calculated through GPS-based location data
Other Services	None	None	Various Added Value Services
Bill for Mileage	No detail. All mileage (in-state and out-of-state) paid	No detail. Only amount due is shown. All in-state mileage paid.	Detailed travel record on bill. Only mileage on state roadways is paid
Information System Configuration	None	Closed	Open

Figure 2.13 Comparison of the odometer, satellite (GPS) and cellular network system

Source: Baker, Goodin (2011b), pg. 35

For the first years of operation of a VMT program, the easiest way would be to base the system on odometer readings or RFID tags. These approaches would enable differentiation in vehicle class, and in emission class. For a trial run electric vehicles could be used, which are currently exempt from fuel taxation and volunteers with fuel-based vehicles, who would be given an attractive discount for participating in the study.

2.7 Review of Methodologies

According to Burger, et al. (2008) in “Public Private Partnerships: In Pursuit of Risk Sharing and Value for Money”, the risks for an infrastructure project can originate from legal and political risk (caused by government) and from commercial risk (here is demand and supply risk).

In Texas, there have been attempts to solve the problem of inaccurate estimations of toll revenues in the planning phase of a project. Stockton (2006) in his doctoral dissertation “Investigation of an Empirical Methodology for Linking Value of Time with Census Tract Median Income” states that “Texas Department of Transportation (TxDOT) had their “Preliminary Feasibility Tool” (TxDOT 2004) developed internally and a “Toll Viability Screening Tool” (Smith et al. 2004) developed through the TxDOT research program (Figure 2.14). Both of these tools address a wide range of factors influencing revenue, but neither tackles the challenging issue of willingness to pay. Instead, they use simplifying assumptions about toll rates without a specific analysis of how the toll rate relates to the value provided to the prospective users.”

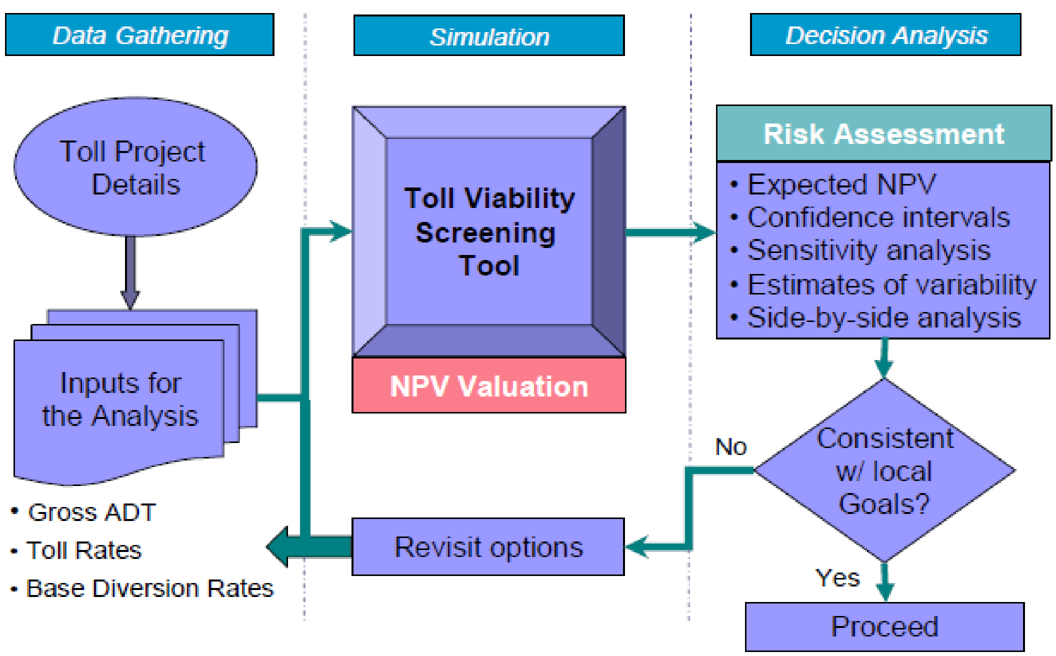


Figure 2.14 Conceptual model for estimating toll revenue
Source: Smith, et al. (2004)

This model operates with the question of how many drivers will use the toll road (according to savings in Travel Time, which are influenced by Value of Time). In the EU the toll system works on a different level – all highways and speedways are under toll, so the driver’s decision to use it is not primarily based on the every-day decision of savings in Travel Time.

2.8 Literature Review Summary

It is without a question, that a new way of funding for our transportation system needs to be found. We need to generate more money, but apparently there are only two ways how to generate money – produce savings or revenue. Even if we were able to do the first one, it definitely would not be sufficient to fund new projects. The second one means empty drivers‘ pockets, which is always a very unpopular step (see Chapter 2.3 Public Acceptance). For sure, fuel tax is no longer performing its duties. Hopefully, it is only a matter of time until we figure out the base of the new transportation financing system. No matter if it is a simple increase in fuel tax based on expected consumption and revenues needed for given year, or the combining of fuel tax with another fee (toll, vehicle registration fee, etc.), or the replacing of the fuel tax with a distance-based fee.

As for the VMT fee, its huge advantage is that it is tied to the usage of road, which influences the road’s deterioration and costs for maintenance. Factors in the decision of shifting to the vehicle miles travelled fee were recognized as:

Technology

The technology chosen for any VMT program should preferably be stable and as secured as possible to convince the public that money is collected in a correct and fair way. Also it should be as up-to-date as possible to work with a high efficiency in many following years.

Cost of implementation

The cost of implementation depends on the technology used and the area of coverage. It is one of the most important factors when deciding whether to implement a VMT fee or not.

Public acceptance

It is very important is to convince the public to support the change, to make public realize that even roads free of charge are not free.

Legislation

Many changes are expected to be done in laws concerning fuel tax (to avoid double taxation) and also new laws and regulations in the area of personal privacy need to be established.

Fee

The fee should be high enough to provide enough revenues to finance the transportation system, but still at the same time it should stay on a convenient level for user.

CHAPTER 3: ELECTRONIC VEHICLE MILES TRAVELLED MODEL

This chapter focuses on creating a model for an electronic VMT toll. This chapter first explored the conditions in which a VMT toll would successfully work. The aim of this study is to help decision makers with the dilemma of whether to implement a VMT toll or rather continue with the current system based on the fuel tax revenues. The fundamental goal, in this case, is to gain sufficient revenues to finance existing and new road infrastructure. The secondary benefits are public acceptance, congestion management, lower emissions, fleet renewal, and savings in Travel Time.

An influence diagram was first created, with all factors recognized to influence a successful VMT toll program. The real sequence of steps leading to the successful VMT toll program is shown in a flow chart. A model is created according to this sequence.

3.1 Influence Diagram Development

Deciding which factors contribute to the successful scenario is hard and complex. An influence diagram, as an analytical tool, provides structure and guidance for thinking systematically. It uses rectangular shapes for decisions, circles for uncertain events and a diamond for the final consequence.

As the influence diagram on Figure 3.1 indicates, the success of a VMT program is influenced by:

Technology

The choice of a technology influences building and operating costs. Technology also affects the reliability of the whole system, which influences revenues. As discussed in the Chapter 2, possible technologies are odometer reading, microwave, satellite or cellular networks. However the first two are easier to implement and do not have such high demands on new technologies as the latter ones. With respect to the requirement of a long-term employability, it is better to use newer technologies as they can

operate for many years in the future. Depending on the toll road length, various technologies can be preferred. For a large, nation-wide application a satellite or cellular network based technology is preferred.

Type of contract

The decision of how to finance the program is vital for future revenues and therefore, the whole success of the program. In the U.S. and EU, Public-Private Partnership (PPP) is a popular design-build-finance-operate concept. It allows the private sector to participate and build public service projects (Taothong, 2012). The work of Taothong (2012) indicates that “successful toll road PPP projects tend to be located in countries with lower corruption levels, lower levels of democracy, higher GDP growth rates, higher stability of the government, [and] lower income levels.” This kind of contract helps to manage risks by shifting some of them onto the provider and is also useful in case of lack of finances. According to the statement of the Texas Senate Transportation and Homeland Security Committee in February 2011, as of 2012 the state of Texas will have no new money to build new infrastructure (Austin Business Journal, 2011), which opens the door for the option of implementing the PPP concept, which so far has been used for projects such as the construction of the LBJ Expressway, DFW Connector, North Tarrant Express in the Dallas area and State Highway 130 in the area of Austin. The latest toll PPP project in the EU was in Poland (PPP contract over 8 years).

Public acceptance

Because the users of this system, are not only the VMT fee payers but also voters and payers of many other taxes, it is vital for the success of a program to have a public that is convinced that the VMT fee is for the good of their country (less congestion, better air quality) and that it will really help to have better infrastructure and ensure better quality of life. Public acceptance can be facilitated by an extensive marketing campaign, where the need and aims of this new fee can be explained and wide-spread fears and rumors can be corrected.

Preferably the VMT toll should differ by emission class, to support the fleet renewal and archive lower emissions and better air quality. This could be one of the popular reasons to gain public support for this new fee.

VMT toll can be varied with time and place to enable congestion management. Users can themselves feel the reduction of congestion and savings in travel time, therefore in gasoline bills.

Another vital step to public acceptance is to change current tax laws concerning fuel taxes. This was probably the major reason of the Dutch VMT fee implementation failure, when VMT fee was supposed to substitute the property tax rather than the fuel tax. Because of this the public saw it as a double taxation on travel. The implementation was cancelled a few months before it should have been launched.

To support all this, a stable government policy is needed, because a VMT fee is a long-term decision.

Revenues

The main reason for implementing a VMT fee, as mentioned in Chapter 1 is to have a self-supporting transportation system that would generate sufficient revenues to cover costs of maintenance, rehabilitation and also new projects. Therefore the revenues are vital for a successful VMT program. Moreover, it is the fundamental objective. The amount of revenues depends on:

- vehicle miles travelled estimate [km],
- vehicle class distribution [%],
- emission class distribution [%],
- target VMT revenue [$],
- and pricing levels for each combination of vehicle class and distribution class.

Apart from these, the revenues are influenced by annual costs and technology reliability.

VMT pricing levels

The level of VMT fee is influenced by building costs, operating costs, and projected revenues (as mentioned earlier, the fundamental objective is to generate sufficient funding). The VMT fee affects public acceptance and toll road length, therefore actual vehicle miles travelled and actual revenues.

Enforcement - Administration – Invoicing

Enforcement influences the technology reliability (due to toll collection success rate) and revenues. The way of administration and invoicing can raise operating costs dramatically. Electronic bills or paying at the fuel station together with the fuel are ways to cut these costs. In the case of paying at the fuel station, the burden on the driver would be smaller compared to a yearly bill.

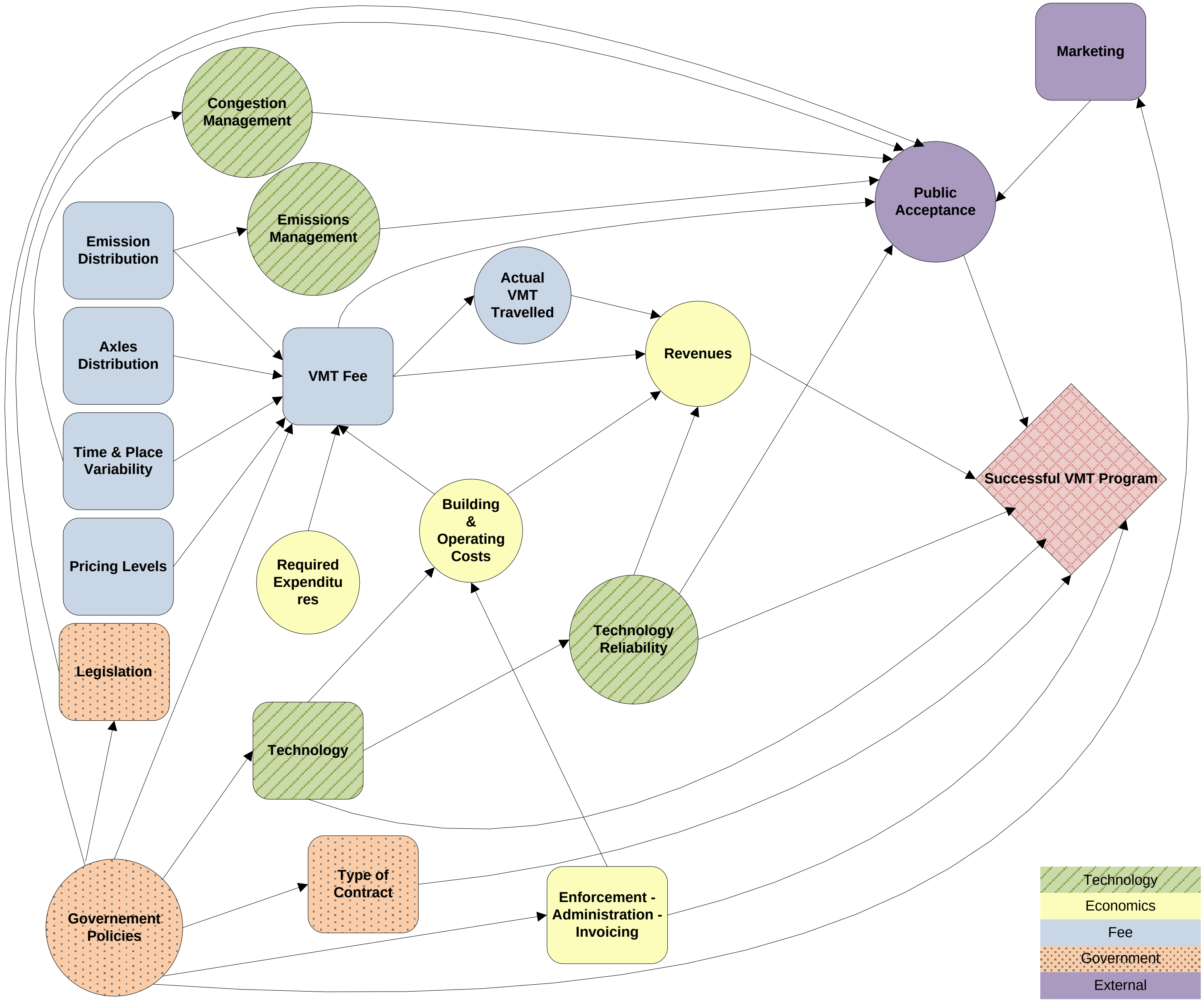


Figure 3.1 Influence diagram

3.2 Sequence Flowchart development

As a next step, the flowchart on Figure 3.2 was developed, which depicts the real sequence of steps leading to the successful VMT toll program.

3.2.1 Step 1 – Background study

The sequence of steps begins with a study that explores if there are stable government policies and the needed legislation support. This step should prevent the problem that occurred in Netherlands in 2010, when the distance-based mileage program that was supposed to be launched in 2011 was cancelled after selections, as the leading party changed. To increase the public acceptance, extensive legislation changes regarding taxes and privacy have to be carried out.

3.2.2 Step 2 – Feasibility study

At first a prediction of emission class, congestion, axles distribution and total vehicle miles travelled should be carried out. Also a conduction of a preliminary public opinion study is recommended, to explore the stance of public, how much would they be willing to pay, what would be more convenient and acceptable for them.

The next step is the technology study. It is fundamental to find an acceptable, and reliable technology, and address the issues of on-board-units and the data transfer between OBUs and the central database, which will affect the technology reliability and needed enforcement for a certain level of the toll prediction accuracy. In addition, penalty charges should be determined and administration issue resolved such as if driver will pay at the petrol station, online or will be mailed with a bill. The possible cooperation between adjoining systems (bordering states), for example, how to charge the miles travelled behind the border of the area..

Then follows the cost study. All the previous decisions influence the operating costs and building costs. These costs should be determined, as well as the discount rate. In case the expected costs regarding the financial sources available are not feasible, even with a PPP contract, a step back should be taken and more technologies should be explored.

3.2.3 Step 3 – VMT fee study

Having all previous issues covered, the VMT fee can be determined based on vehicle class and the emission class distribution. Variable fee in time and place can be also implemented for congestion management. Results of the preliminary public opinion can be considered and the VMT fee can be adjusted accordingly. For example, for the transition years the toll can be lower to make the process more viable. Also users voluntarily joining the VMT system trial run can be awarded with better prices than users staying on the fuel tax to the very last day. This approach can give more experience in the efficiency of the system and the possibility of eliminating bugs before the full operation starts. Also the deployment of a trial run for volunteer users can strongly support public acceptance.

Finally the expected revenues can be estimated. In case the expected revenues would not be feasible, it is recommended to go back to the cost study.

3.2.3 Step 4 – External relationships study

As mentioned earlier, public acceptance is a huge influence on the success of such a program. Once the VMT fee and penalty charges are known, a public opinion poll can be carried out to find out what drivers think and build a marketing campaign based on their prejudice and fears to explain the matter.

After a successful completion of these steps, a trial run can be carried out and then a full operation can be initiated.

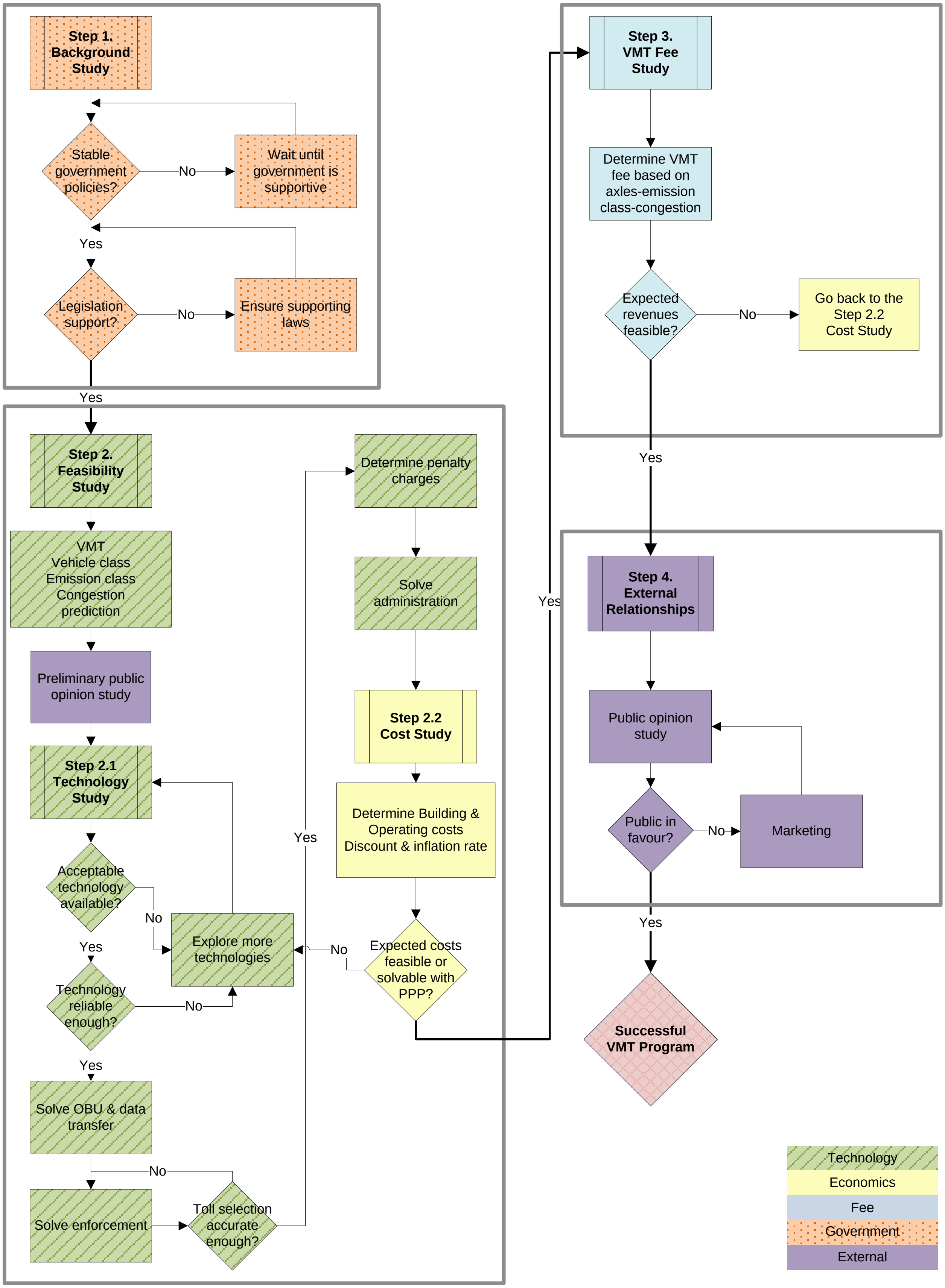


Figure 3.2 Sequence flowchart

3.3 Final Model Development

The final model is based on the influence diagram and the flowchart. It captures the decision situation that surrounds the decision whether to substitute the fuel tax with a distance-based fee. Users can enter a base VMT fee, that is later differentiated by the model according to emission classes and vehicle type. Users can estimate revenues, either gross or in case the building and operating costs are entered, the estimated net revenues and break-even year.

The model was created in Excel using extension @Risk for modeling uncertainties. @Risk is a risk analysis tool using Monte Carlo simulation. A brief description of the model follows. The screen shots of the model can be seen in Appendix A.

3.3.1 Data Input

The model requests following data:

- Gross VMT for considered years [mi]
- Share on VMT for each vehicle class [%]
- Share of BIN emission class in the fleet [%]
- Number of violations and penalty charges [$]
- Building costs [$], operating costs [$], discount rate [%]
- Average miles travelled per gallon for each fleet [mi/gal]
- Current fuel tax [$/gal]
- Pricing level for each fleet and emission class [$]
- Tested base VMT fee [$]
- Revenues from the fuel tax for tested years [$]
- Needed expenditures for tested years [$]

3.3.2 Background Study

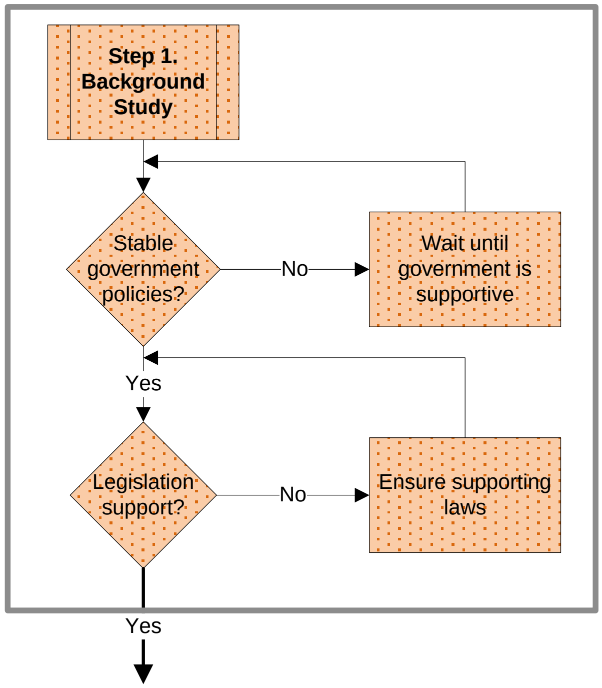


Figure 3.3 Background study steps

The background study explores the level of support in the government and legislation, as Figure 3.3 shows. The following questions are asked:

- How stable are the government policies in the state where the VMT fee is considered being implemented?

  Possible answers are:

  - stable political situation and government policies.
  - somewhat stable political situation, sudden change of government policies not expected.
  - unstable political situation, high risk of sudden change of government policies.

- Is the legislation supporting changing taxes, privacy and other VMT related issues? Possible answers are:
    - legislation is already in place.
    - legislation can be approved before the start of operation of the program.
    - legislation covering these topics will not be available before the start of operation of the program.

Based on answers to these questions recommendations are shown in the summary.

3.3.3 Feasibility Study

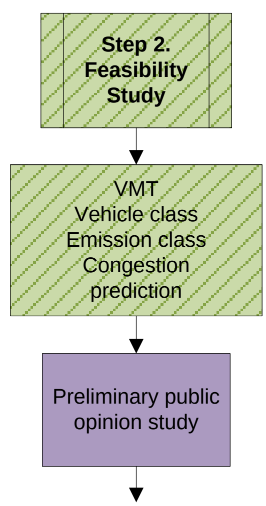


Figure 3.4 Feasibility study steps

As Figure 3.4 shows, the feasibility study consists of gathering the data needed for VMT fee calculation. It recapitulates the volume prediction (data entered previously by user in the data input), vehicle class distribution and based on that we estimated VMT miles for every vehicle category and year. Based on the data entered about the emission class distribution for each vehicle class VMT miles for each combination of BIN, vehicle class and year are estimated.

3.3.3.1 Technology Study

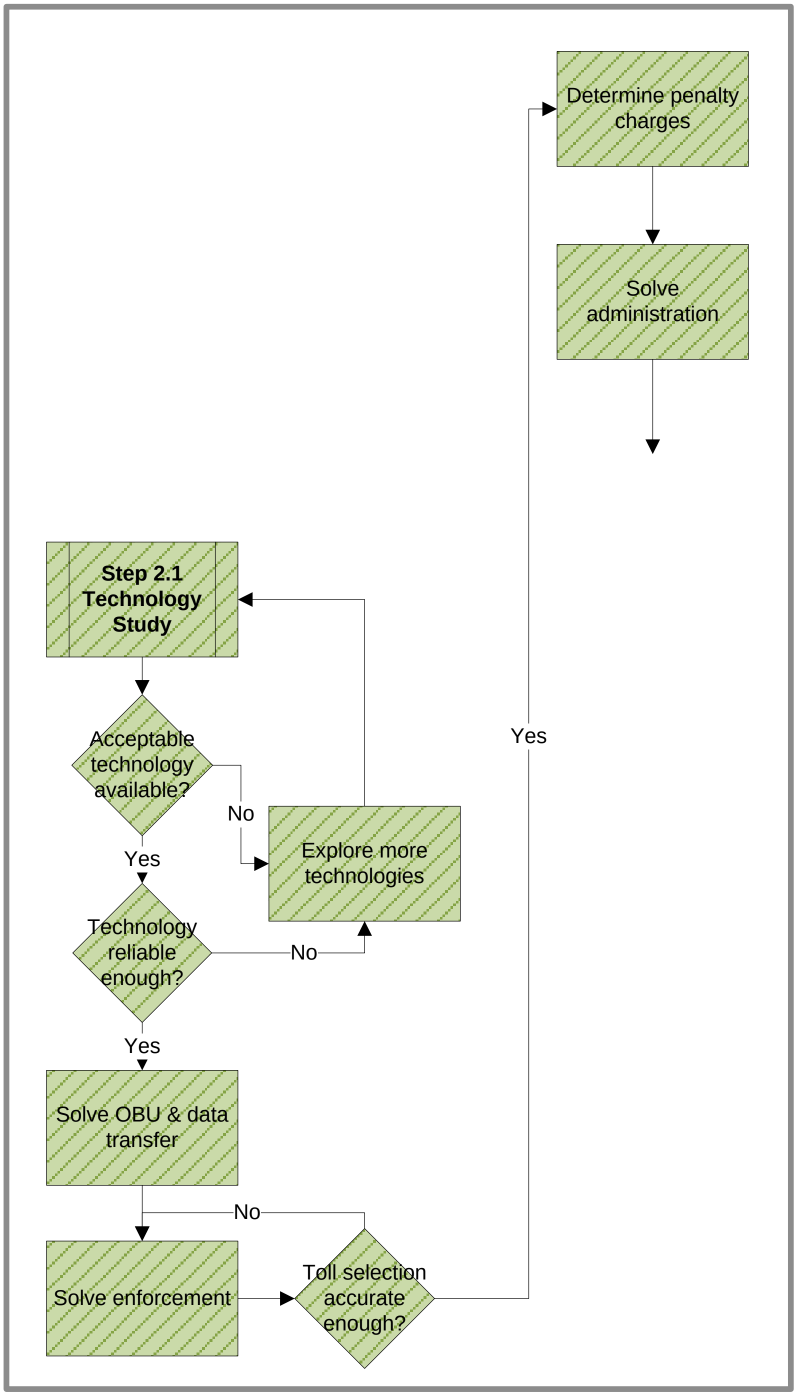


Figure 3.5 Technology study steps

The technology study, as Figure 3.5 shows, deals with the selection of a technology and solves on-board-units, data transfer, enforcement, penalty charges and administration.

Users are asked following questions and possible answers are:

- Is there an acceptable technology available? (in terms of resource constraints)
  - Yes, the selected technology covers all requirements.
  - Yes, but there are some deficiencies.
  - No, none of existing technology was found acceptable.
- Is the technology reliable enough?
  - Yes, the selected technology has acceptable reliability.
  - Yes, but the reliability should be improved.
  - No, the reliability is not sufficient.

Again, based on answers to these questions are set recommendation in the summary. According to the developed flowchart, on-board-units (OBUs), data transfer, enforcement and administration costs are examined. For simplification, all these costs are included in operation costs entered by the user. From the penalty charges and number of them entered by the user the model calculates income from every identified offence and total income from penalty charges.

3.3.3.2 Cost Study

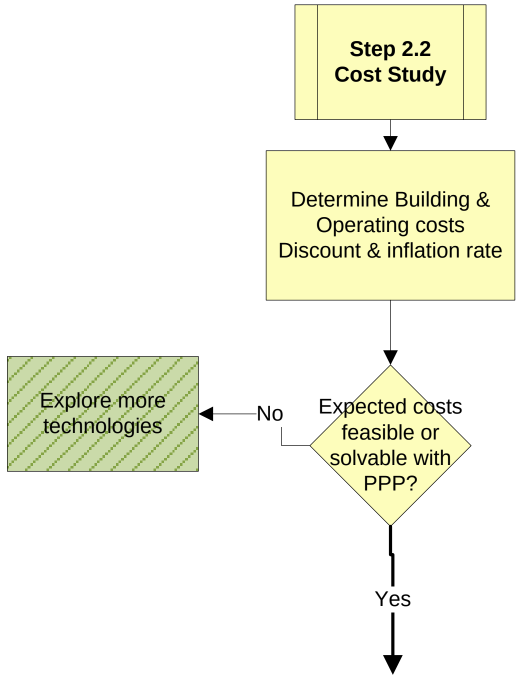


Figure 3.6 Cost study steps

As Figure 3.6 shows, the costs study sums up building and operating costs and discount rate, here stated by the user during the data input. Users are also asked if expected costs are feasible or solvable with Public-Private-Partnership (PPP).

3.3.4 VMT Fee Study

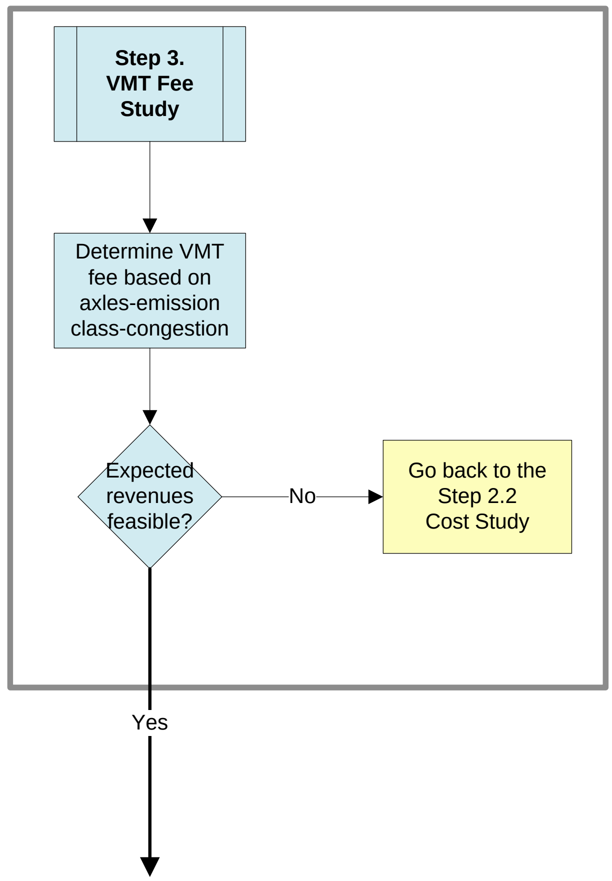


Figure 3.7 VMT fee study steps

The aim of the VMT fee study, as Figure 3.7 shows, is to determine the fee based on vehicle class and emission class. The fee can also vary in time, to help with the congestion management, but in this case it is not considered. The average number of miles per gallon for each vehicle class is determined according to data input previously. Together with the current fuel tax per gallon the fuel tax per mile for each fleet is estimated. The revenues are estimated for each category based on VMT fee for each year.

3.3.5 Summary

Based on entered data, users get a feedback described in the following subchapters:

3.3.5.1 Background Study Summary

- In (entered state) the government policies situation for VMT fee implementation was evaluated as:
    - stable and no sudden changes in political situation and government policies are anticipated. Therefore the VMT program has the best chances to be successfully finished.
    - somewhat stable, as the political situation is not entirely predictable, but still is believed to stay stable.
    - unstable, with a high risk of sudden change of government policies. In this case, there is a high risk of not finishing the VMT program in the case of a change in government policies. In this environment it is recommended to sign a deal by all governing parties, wherein they promise to continue with the VMT program even if the government changes.
- The legislation supporting changing taxes, privacy and other VMT related issues:
    - is already in place.
    - can be approved before the start of operation of the program.
    - will not be available before the start of operation of the program. It is not recommended to start operation without having proper legislative support. The whole program can lose its credibility and attractiveness for the public.

3.3.5.2 Technology Study Summary

- An acceptable technology:
  - was found and it covers all requirements for the VMT system.
  - was not found. In this case it is recommended to keep exploring the possible technologies and wait until an acceptable solution is available.
- The selected technology reliability was evaluated as:
  - acceptable.
  - improvable. Currently the reliability is about to reach the desired level, but more improvements need to be done.
  - insufficient. In this case it is recommended to keep exploring the possible technologies and wait until an acceptable solution is available.

3.3.5.3 Cost Study Summary

Building costs, operating costs, and discount rate are summarized and either:
"Expected costs are feasible or solvable with a PPP contract." or "Expected costs are NOT feasible or solvable with a PPP contract. Explore more technologies." comment is shown.

3.3.5.4 VMT Fee Study Summary

Considered fees are shown, as well as the estimated gross revenues, penalty income, building costs, operating costs and the needed expenditures for every year. Estimated VMT revenues are compared with the real fuel tax revenues and the difference is shown in percentage. Also the break-even year is estimated.

CHAPTER 4: CASE STUDY

The developed model was run with data from Texas. Texas, with area of 268,596 sq. mi (696,241 km^2) (TSHA, 2011) is second largest state in the U.S. Also its population of 25 million (U.S. Census Bureau, 2011) ranks it as the second most populous state in the U.S. Texas area and population makes it a good testing groundfor VMT tax in the U.S., especially regarding the two major issues – technology and public acceptance. If Texas succeeds in implementation of a statewide distance-based toll program, other states could easily follow.

4.1 Texas Case Study

The case study for Texas was carried out with known data from years 2001-2010. Data in years 2011-2040 were approximated – in VMT miles a 1.5% increase every year and for expenditures an increase of 0.5% every year.

4.1.1 Data Input

Gross VMT for considered years [mi]

VMT miles for Texas and years 2003-2010 were found in Traffic Volume Trends (FHWA, 2012b). For years 2001 and 2002 this source did not show data for urban arterial roads, but only for rural arterial roads. VMT miles for these 2 years were estimated considering the change in U.S. total VMT (RITA, 2012). For years 2011-2040, a 1.5% increase every year was assumed.

Share on VMT for each vehicle class [%]

According to the division of vehicle classes to 2, 3 and 4+ axles common in the EU, the tolled fleet was divided into 3 classes - light duty vehicle[6], single-unit truck and combination truck. Busses and motorcycles with a 1.19% share on VMT miles were not considered in this model (FHWA, 2009d). This proportions are for the whole U.S., but a similar percentages are expected to occur in Texas. U.S. data for year 2009 was available, therefore the model is based on a fixed share.

Share of BIN emission class in the fleet [%]

Vehicle emission class share data was requested from several agencies, including the Department of Transportation (DOT), Energy Information Administration (EIA) and Environmental Protection Agency (EPA). None of them had any available. Therefore a Canadian emission class distribution from year 2007 was used, assuming a similarity with the U.S. Present LDV/LLDT (light-duty trucks/light light-duty trucks) vehicles were assumed to correspond to light duty vehicles and single-unit trucks. HLDT/MDPV (heavy light-duty trucks/medium-duty passenger vehicles) vehicles were assumed to correspond to combination trucks. As a consequence of the emission class differentiated toll, a change is expected in the BIN distribution over the years, as drivers will be motivated to drive cleaner vehicles. This is not considered in this model, as it would require more research on the behavior of the market.

Number of violations and penalty charges [$]

Four violations were named: no OBU unit, evasion (such as unauthorized modification of OBU), not paid when billed and heavy violation (such as a false statement of vehicle category or emission class). Associated number of violations and penalty were entered based on an engineering judgment, because there has not been any studies published yet. For this case the violations were based on occurrence in the number of vehicles registered in Texas - 22,681,304 registered vehicles in 2010 according to the Texas Department of Motor Vehicles (2010). The following occurrences were set as shown in Table 4.1.

[6] Light duty vehicles - passenger cars, light trucks, vans and sport utility vehicles regardless of wheelbase (FHWA 2009d).

Table 4.1 Assumed violations

	occurrence	number of violations	penalty	income
no OBU unit	1.01%	230,000	$500	$115,000,000
evasion	0.05%	11,000	$10,000	$110,000,000
not paid when billed	4.41%	1,000,000	$300	$300,000,000
heavy violation	0.03%	7,000	$200	$1,400,000

Building costs [$], operating costs [$], discount rate [%]

Since no data about building costs are available, these costs were entered based on an engineering judgment, on 120% of average Highway Construction and Maintenance expenditures in years 2001-2010. Operating costs were considered to be 6.6% of revenues according to the VMT study in Netherlands (Balducci et al., 2011). Discount rate was set to 3% (engineering judgment).

Average miles travelled per gallon for each fleet [mi/gal]

Data for years 2001-2008 were found at RITA (2008a,b,c). Due to missing years 2009 and 2010 and small differences between years, further calculations were carried out with an average from years 2001-2008 for each of considered classes.

Current fuel tax [$/gal]

The current gasoline state fuel tax of $0.200 was used in this model. Diesel state fuel tax was in January 2012 at the same level ($0.200) (American Petroleum Institute, 2012a).

Pricing level for each fleet and emission class [$]

Three levels for emission classes were preset BIN 11-6, BIN 5-3 and BIN 2-1. Table 4.2 shows emission limits for light duty vehicles. Three levels were chosen to differentiate between dirtiest, medium polluting and cleanest vehicles, according to the European approach. The pricing levels were set based on the toll differentiation in Czech Republic in 2011. To estimate these pricing levels, extensive modeling needs to be done.

Table 4.2 Summary of current light-duty vehicle emission standards

US EPA Federal Light-Duty Vehicle Emission Standards for Air Pollutants								
Tier 2 Program								
Standard	Model Year	Vehicles	Emission Limits at Full Useful Life (100,000-120,000 miles)					Air Pollution Score
			Maximum Allowed Grams per Mile					
			NOx	NMOG	CO	PM	HCHO	
Bin 1	2004+	LDV, LLDT, HLDT, MDPV	0.00	0.000	0.0	0.0	0.0	10
Bin 2	2004+	LDV, LLDT, HLDT, MDPV	0.02	0.010	2.1	0.01	0.004	9
Bin 3	2004+	LDV, LLDT, HLDT, MDPV	0.03	0.055	2.1	0.01	0.011	8
Bin 4	2004+	LDV, LLDT, HLDT, MDPV	0.04	0.070	2.1	0.01	0.011	7
Bin 5	2004+	LDV, LLDT, HLDT, MDPV	0.07	0.090	4.2	0.01	0.018	6
Bin 6	2004+	LDV, LLDT, HLDT, MDPV	0.10	0.090	4.2	0.01	0.018	5
Bin 7	2004+	LDV, LLDT, HLDT, MDPV	0.15	0.090	4.2	0.02	0.018	4
Bin 8a	2004+	LDV, LLDT, HLDT, MDPV	0.20	0.125	4.2	0.02	0.018	3
Bin 8b	2004-2008	HLDT, MDPV	0.20	0.156	4.2	0.02	0.018	3
Bin 9a	2004-2006	LDV, LLDT	0.30	0.090	4.2	0.06	0.018	2
Bin 9b	2004-2006	LDT2	0.30	0.130	4.2	0.06	0.018	2
Bin 9c	2004-2008	HLDT, MDPV	0.30	0.180	4.2	0.06	0.018	2
Bin 10a	2004-2006	LDV, LLDT	0.60	0.156	4.2	0.08	0.018	1
Bin 10b	2004-2008	HLDT, MDPV	0.60	0.230	6.4	0.08	0.027	1
Bin 10c	2004-2008	LDT4, MDPV	0.60	0.280	6.4	0.08	0.027	1
Bin 11	2004-2008	MDPV	0.90	0.280	7.3	0.12	0.032	0

Source: EPA (2007)

Tested base VMT fee [$]

Table 4.3 shows the estimated current fuel taxation per mile for considered classes of vehicles. These values were obtained by dividing the current state fuel tax per gallon on gasoline ($0.200) by average miles per gallon every class travels per gallon (22.3 mi/gal, 8.2 mi/gal, 5.6 mi/gal).

Table 4.3 Current fuel taxation per mile

Estimated current state fuel tax per mile	
Light duty vehicle	$0.009
Single-unit truck	$0.024
Combination truck	$0.036

The base VMT fee was multiplied with the pricing levels in Table 4.4, to determine a fee for particular combination of vehicle class and emission class.

Table 4.4 Pricing levels

coefficient	2 axles	3 axles	4+ axles
BIN 11			
BIN 10			
BIN 9			
BIN 8			
BIN 7			
BIN 6	1.69	3.06	4.46
BIN 5			
BIN 4			
BIN 3	1.25	2.40	3.47
BIN 2			
BIN 1	1.00	1.92	2.77

Source: based on toll prices in Czech Republic for 2011 (Premid, 2011)

Three different values of base VMT fee were tested: \$0.009/mi (Scenario 1 - revenues similar to the fuel tax), \$0.013/mi (Scenario 2 - revenues approx. 150% of the current fuel fee revenues) and \$0.018/mi (Scenario 3 - revenues approx. 200% of the current fuel fee revenues).

Revenues from the fuel tax for tested years [$]

In this case revenues were used from years 2001 to 2010 (Window on State Government, 2010). These revenues should preferably contain only considered vehicle classes, however data used include also motorcycles and buses. This causes a certain inaccuracy, in fact the revenues should be lower, so the estimated VMT fee has in fact even higher percentage increase than stated here. Nevertheless, the user is highly encouraged to make this simulation with future years' predicted data.

Expenditures for tested years [$]

In Scenarios 2 and 3 these value were set to \$4,500,000,000 for year 2001 with a 2% increase for every following year. This assumption was based on "State of Texas Annual Cash Report - Highway Construction and Maintenance expenditures', which were on average 4,096,551,225 in years 2001-2009

(Combs, 2010). For Scenario 1 in years 2001-2010 actual expenditures were used according to the State of Texas Annual Cash Report and similarly years 2011-2040 also assumed a 2% increase.

4.1.2 Background Study

Considering Texas, the following answers were chosen:

- How stable are the government policies in the state where the VMT fee is considered being implemented?
    - stable political situation and government policies
- Is there the needed legislation support discussing taxes, privacy and other VMT related issues?
    - legislation can be approved before the start of operation of the program.

4.1.3 Feasibility Study

The feasibility study consists of gathering the data needed for VMT fee calculation. It recapitulates the volume prediction (data entered previously by user in the input data) (see Table 4.5), vehicle class distribution (see Table 4.6) and based on that calculates estimated VMT miles for every vehicle category and year. Based on the data entered, VMT miles are estimated for each combination of BIN, vehicle class and year.

Table 4.5 Volume prediction

Year	Gross VMT estimate [mi]
2001	219,266,000,000
2002	223,949,000,000
2003	222,744,000,000
2004	227,740,000,000
2005	234,470,000,000
2006	235,884,000,000
2007	240,194,000,000
2008	237,965,000,000
2009	237,421,000,000
2010	233,876,000,000

Table 4.6 Vehicle class distribution

Light duty vehicle	89.06%
Single-unit truck	4.07%
Combination truck	5.68%

4.1.3.1 Technology Study

Considering Texas, the following answers were chosen:

- Is there an acceptable technology available? (in terms of resource constraints)
    - yes, but there are some deficiencies
- Is the technology reliable enough?
    - yes, but the reliability should be improved

For simplification, OBUs, data transfer, enforcement and administration costs were included in operating costs.

4.1.3.2 Cost Study

Building costs were set at $5,000,000,000 (assumption was based on 120% of average Highway Construction and Maintenance expenditures in years 2001-2010). Operating costs were set to 6.6% of the average gross revenues according to Balducci, et al. (2011). Discount rate is assumed to be 3%.

Also based on the situation in Texas, the following answer was selected:

- Are expected costs feasible or solvable with Public-Private-Partnership (PPP)?
  - Yes

4.1.4 VMT Fee Study

According to previous input data, the average number of miles per gallon for each vehicle class is determined. The fuel tax per mile for each vehicle class is calculated together with the current fuel tax per gallon (see Table 4.3). Estimated revenues are based on entered data for each category based on VMT fee and total gross revenues for each year.

4.1.5 Summary

4.1.5.1 Background Study Summary

Following recommendations were given for Texas:

- In Texas the government policies situation for VMT fee implementation were evaluated as
  - somehow stable, as the political situation is not entirely predictable, but still is believed to stay stable. In this environment it is recommended to sign a deal by all governing parties, wherein they promise to continue with the VMT program even if the government changes.
- The legislation supporting changing taxes, privacy and other VMT related issues:
  - can be approved before the start of operation of the program.

4.1.5.2 Technology Study Summary

Following recommendations were given for Texas:

- An acceptable technology:
  - was found, but it has some deficiencies that will have to be solved.

According to Chapter 2.5, a satellite-based technology was chosen as an optimal solution. As mentioned, this technology is suitable for statewide applications and it enables congestion charging. However, it has still some flaws that needs to be solved, such as administration, enforcement and usage related issues for urban areas.

- The selected technology reliability was evaluated as:
  - improvable. Currently the reliability is about the reach the desired level, but more improvements need to be done.

4.1.5.3 Cost Study Summary

Building costs, operating costs, and discount rate are summarized, as Table 4.7 shows.

Table 4.7 Cost study summary

Building costs were estimated at:	$5,000,000,000
Operating costs were estimated at:	$261,065,110
Discount rate was estimated at:	3.00%

The following answer was chosen: Expected costs are feasible or solvable with a PPP contract.

4.1.5.4 VMT Fee Study Summary

This part of the summary shows a table of taxation levels, gross estimated revenues, a graph of relationship between the estimated gross VMT revenues and real fuel tax revenues, and a table of estimated net revenues considering operation costs, penalty income and discount rate. The break-even year is also estimated, based on net VMT revenues deducted by expenditures (both including discount rate).

4.2 Scenarios for Texas

4.2.1 Scenario 1

Scenario 1 approximates the situation, where the gross revenues from VMT fee are similar to the current revenues from the fuel tax. This can be achieved with the VMT base fee set to $0.009/mi (see Table 4.8 for all taxation levels).

Table 4.8 Taxation levels for Scenario 1 ($0.009/mi)

BIN	Light-Duty Vehicle	Single-Unit Truck	Combination Truck
6-11	$0.015	$0.028	$0.040
3-5	$0.011	$0.022	$0.031
1-2	$0.009	$0.017	$0.025

For these taxation levels the following gross revenues were estimated (see Table 4.9).

Table 4.9 Gross revenues for Scenario 1 ($0.009/mi)

year	estim. VMT revenues	real fuel tax revenues	difference
2001	$2,854,939,061	$2,765,510,548	103%
2002	$2,915,913,766	$2,833,607,460	103%
2003	$2,900,224,139	$2,838,776,695	102%
2004	$2,965,274,241	$2,917,706,870	102%
2005	$3,052,901,780	$2,934,580,537	104%
2006	$3,071,312,677	$2,993,569,575	103%
2007	$3,127,430,759	$3,053,812,019	102%
2008	$3,098,408,206	$3,101,526,779	100%
2009	$3,091,325,088	$3,032,770,482	102%
2010	$3,045,167,640	$3,041,973,016	100%

Figure 4.1 shows the relationship of estimated gross VMT revenues and real fuel tax revenues.

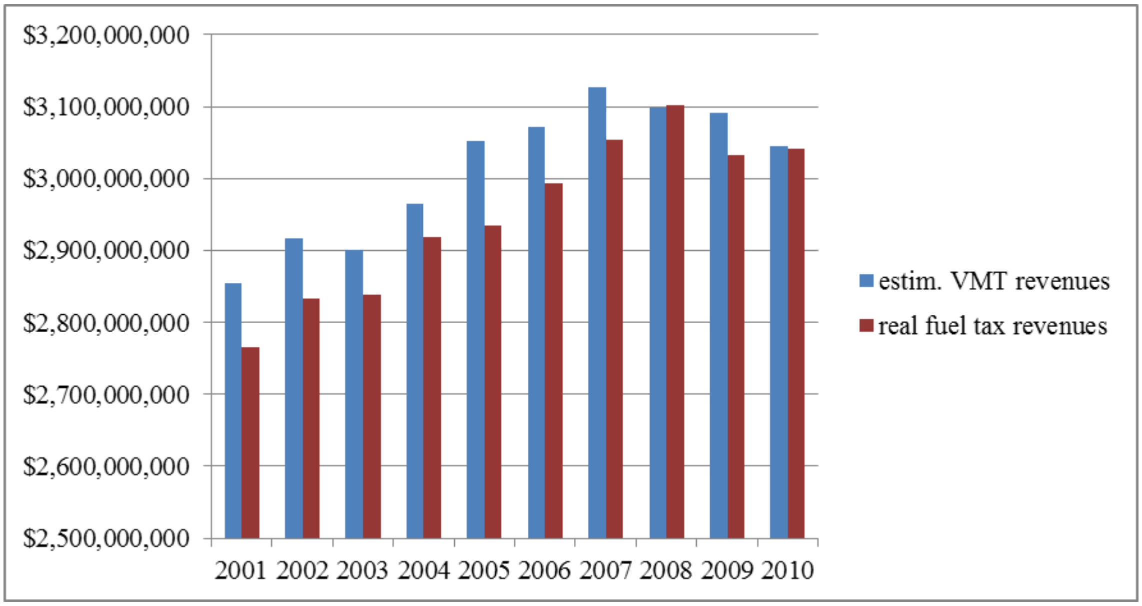


Figure 4.1 Estimated gross VMT revenues and real fuel tax revenues for Scenario 1 ($0.009/mi)

Considering also operating costs of $180,737,384 (6.6% of revenues), a discount rate of 3%, and the penalty income of $526,400,000, the net revenues were estimated as Table 4.10 shows.

Table 4.10 Estimated net revenues for Scenario 1 ($0.009/mi)

	est. VMT revenues	**real fuel tax revenues**	**difference**
2001	$3,107,380,269	$2,765,510,548	112%
2002	$3,074,348,555	$2,833,607,460	108%
2003	$2,970,446,191	$2,838,776,695	105%
2004	$2,941,724,514	$2,917,706,870	101%
2005	$2,931,631,502	$2,934,580,537	100%
2006	$2,861,663,013	$2,993,569,575	96%
2007	$2,823,942,741	$3,053,812,019	92%
2008	$2,718,781,310	$3,101,526,779	88%
2009	$2,634,164,885	$3,032,770,482	87%
2010	$2,523,096,160	$3,041,973,016	83%

If the expected expenditures are equal to real “Highway Construction and Maintenance expenditures” in years 2001-2009 (Combs, 2010) as Table 4.11 shows, with an yearly increase of 0.5% for years 2011-2040 and the building costs of $5,000,000,000, the estimated break-even year is year 37.

Table 4.11 Considered expenditures incl. discount rate for Scenario 1 ($0.009/mi)

year	expenditures
2001	$2,892,073,603
2002	$3,080,885,780
2003	$3,008,680,811
2004	$3,103,433,087
2005	$3,994,225,648
2006	$4,298,655,030
2007	$4,357,680,499
2008	$4,111,710,279
2009	$3,259,478,035
2010	$2,495,294,436

This scenario is similar to funding based on the fuel tax revenues. Its aim is to show, if considering the same revenues as from the fuel tax, that the VMT taxation levels would be very similar to what the driver pays in the current system. For a clean light duty vehicle (BIN 2-1) the price would be the same. For a light duty vehicle (BIN 5-3) the price would increase from $0.009 to $0.011/mi and for BIN 11-6 the increase would be up to $0.015/mi. For other classes of vehicles the increase in price is less dramatic. A single-unit truck in the current system pays approximately $0.024/mi. In the VMT system, it would pay even less, if falling into the BIN 2-1 group $0.017/mi or the BIN 5-3 group $0.022/mi. Only for the dirtiest BIN 11-6 would there be an increase in the price to $0.028/mi. The same tendency can be seen in the rates for combination trucks. This could motivate the usage of cleaner vehicles, nevertheless not pushing the prices of transportation up and therefore negatively affecting the final retail prices. In sum, a VMT based financing system seems like an interesting option.

4.2.2 Scenario 2

Scenario 2 approximates the situation, where the gross revenues from VMT fee are around 150% of the current revenues from the fuel tax, enabling higher expenditures than in Scenario 1. This can be achieved with the VMT base fee set to $0.013/mi (see Table 4.12 for all taxation levels).

Table 4.12 Taxation levels for Scenario 2 ($0.013/mi)

BIN	**Light-Duty Vehicle**	**Single-Unit Truck**	**Combination Truck**
6-11	$0.022	$0.040	$0.058
3-5	$0.016	$0.031	$0.045
1-2	$0.013	$0.025	$0.036

For these taxation levels the following gross revenues were estimated (see Table 4.13).

Table 4.13 Gross revenues for Scenario 2 ($0.013/mi)

	estim. VMT revenues	**real fuel tax revenues**	**difference**
2001	$4,123,800,866	$2,765,510,548	149%
2002	$4,211,875,439	$2,833,607,460	149%
2003	$4,189,212,646	$2,838,776,695	148%
2004	$4,283,173,904	$2,917,706,870	147%
2005	$4,409,747,015	$2,934,580,537	150%
2006	$4,436,340,533	$2,993,569,575	148%
2007	$4,517,399,985	$3,053,812,019	148%
2008	$4,475,478,519	$3,101,526,779	144%
2009	$4,465,247,349	$3,032,770,482	147%
2010	$4,398,575,480	$3,041,973,016	145%

Figure 4.2 shows the relationship of estimated gross VMT revenues and real fuel tax revenues.

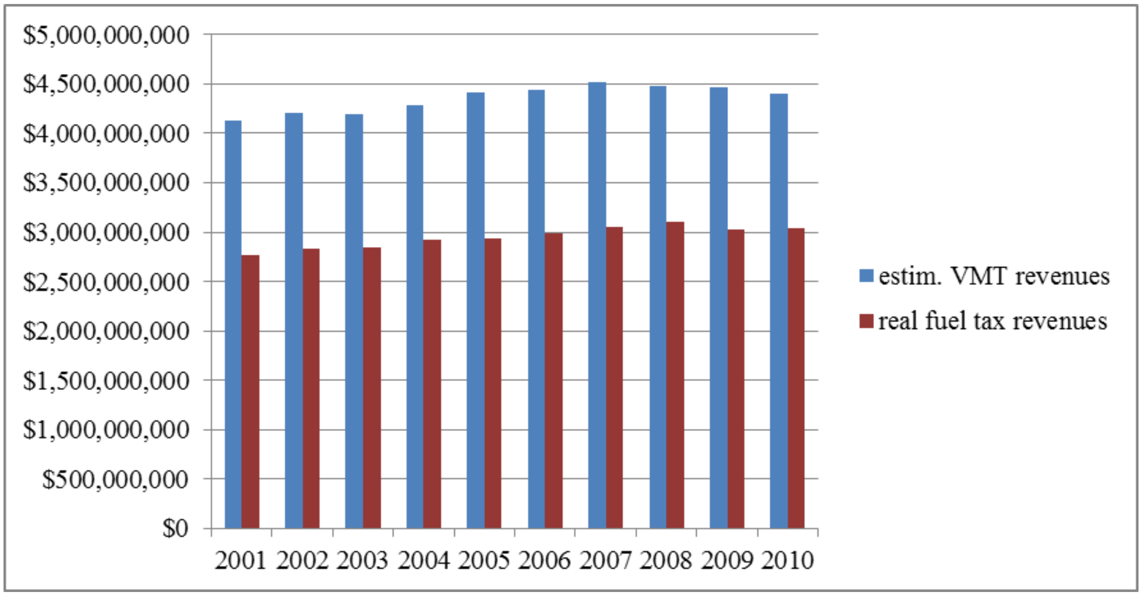


Figure 4.2 Estimated gross VMT revenues and real fuel tax revenues for Scenario 2 ($0.013/mi)

Considering operating costs of $ $261,065,110 (6.6% of revenues), a discount rate of 3% and the penalty income of $526,400,000, the net revenues were estimated as Table 4.14 shows.

Table 4.14 Estimated net revenues for Scenario 2 ($0.013/mi)

year	est. VMT revenues	real fuel tax revenues	difference
2001	$4,261,296,850	$2,765,510,548	154%
2002	$4,220,200,140	$2,833,607,460	149%
2003	$4,076,542,023	$2,838,776,695	144%
2004	$4,041,291,150	$2,917,706,870	139%
2005	$4,032,766,718	$2,934,580,537	137%
2006	$3,937,579,147	$2,993,569,575	132%
2007	$3,888,801,128	$3,053,812,019	127%
2008	$3,742,441,883	$3,101,526,779	121%
2009	$3,625,597,382	$3,032,770,482	120%
2010	$3,470,387,326	$3,041,973,016	114%

If expecting yearly expenditures in year 2001 equal to $4,500,000,000 (110% of average real "Highway Construction and Maintenance expenditures" in years 2001-2010, that is $4,096,551,225

(Combs, 2010)) with an increase of 0.5% every year and building costs of $5,000,000,000, the estimated break-even year is year 41.

This scenario combines larger expenditures with a still acceptable VMT rate. For a clean light duty vehicle (BIN 2-1) the price would increase from $0.009/mi to $0.013/mi. For BIN 5-3 the price would increase to $0.016/mi, and for BIN 11-6 the increase would be up to $0.022/mi. Again, for other classes of vehicles the increase in price is less dramatic. A single-unit truck in the current system pays approx. $0.024/mi. In Scenario 2, it would pay even less, if falling into the BIN 2-1 group $0.025/mi. In case of the BIN 5-3 group, the price would increase to $0.031/mi. For the dirtiest BIN 11-6 an increase would be in the price to $0.040/mi. This could again motivate the usage of better efficient vehicles, nevertheless not pushing the prices of transportation up and therefore negatively affecting the final retail prices. The fee charged per vehicle mile in the Oregon Mileage Fee Project was determined by dividing the current state gas tax of 24 cents per gallon by the 2004 average vehicle fuel efficiency of 20 miles per-gallon, resulting in the fee of $.012/mi (Whitty, 2007). As Durden (2010) reported, to generate total revenues equal to $258 billion needed between 2012 and 2030, the distance-based toll would need to be $0.0143/mi (under the normal adoption scenario) or $0.0164/mi (under the aggressive adoption scenario). According to the model developed here, prices for Scenario 2 are similar to those Durden (2010) reported. However the revenues between 2012 and 2030 according to this model are $136 billion (gross) and $82 billion (net). This difference can be caused by inaccurate interpolation of the expected VMT volume. All in all, a VMT based financing system seems like an interesting option.

4.2.3 Scenario 3

Scenario 3 approximates the situation where the gross revenues from VMT fee are around 200% of the current revenues from the fuel tax. This can be achieved with the VMT base fee set to $0.018/mi (see Table 4.15 for all taxation levels).

Table 4.15 Taxation levels for Scenario 3 ($0.018/mi)

BIN	Light-Duty Vehicle	Single-Unit Truck	Combination Truck
6-11	$0.031	$0.055	$0.080
3-5	$0.023	$0.043	$0.062
1-2	$0.018	$0.035	$0.050

For these taxation levels the following gross revenues were estimated (see Table 4.16).

Table 4.16 Gross revenues for Scenario 3 ($0.018/mi)

	estim. VMT revenues	real fuel tax revenues	difference
2001	$5,709,878,122	$2,765,510,548	206%
2002	$5,831,827,531	$2,833,607,460	206%
2003	$5,800,448,279	$2,838,776,695	204%
2004	$5,930,548,482	$2,917,706,870	203%
2005	$6,105,803,559	$2,934,580,537	208%
2006	$6,142,625,354	$2,993,569,575	205%
2007	$6,254,861,518	$3,053,812,019	205%
2008	$6,196,816,411	$3,101,526,779	200%
2009	$6,182,650,176	$3,032,770,482	204%
2010	$6,090,335,280	$3,041,973,016	200%

Figure 4.3 shows the relationship of estimated gross VMT revenues and real fuel tax revenues.

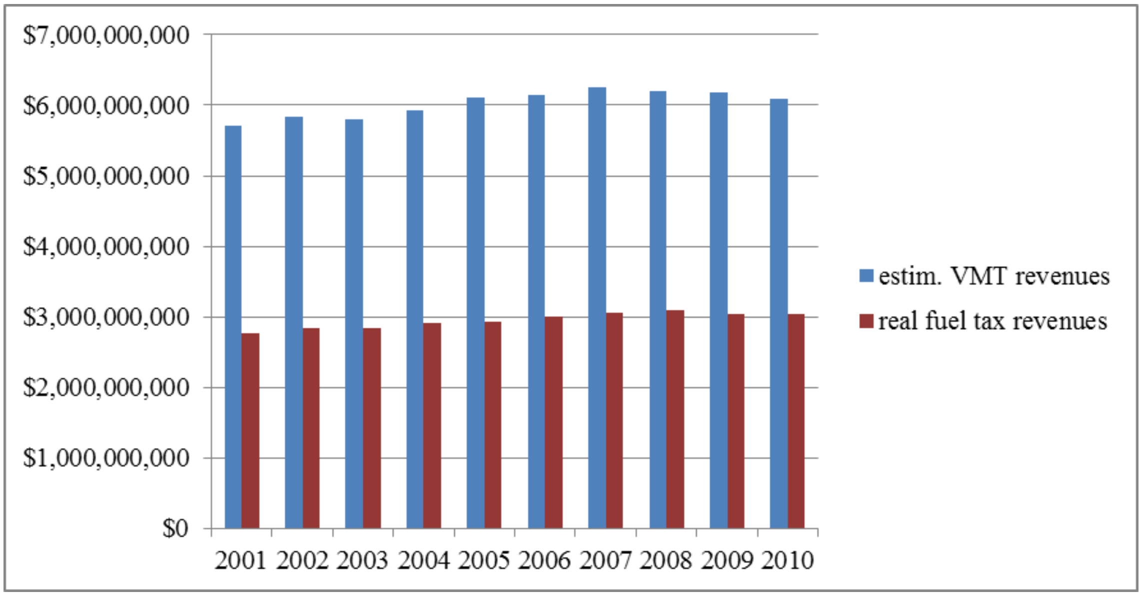


Figure 4.3 Estimated gross VMT revenues and real fuel tax revenues for Scenario 3 ($0.018/mi)

Considering also the operating costs of $ $361,474,768 (6.6% of revenues), a discount rate of 3% and the penalty income of $526,400,000, the net revenues were estimated as Table 4.17 shows.

Table 4.17 Estimated net revenues for Scenario 3 ($0.018/mi)

year	est. VMT revenues	real fuel tax revenues	difference
2001	$5,703,692,576	$2,765,510,548	206%
2002	$5,652,514,622	$2,833,607,460	199%
2003	$5,459,161,813	$2,838,776,695	192%
2004	$5,415,749,445	$2,917,706,870	186%
2005	$5,409,185,739	$2,934,580,537	184%
2006	$5,282,474,314	$2,993,569,575	176%
2007	$5,219,874,111	$3,053,812,019	171%
2008	$5,022,017,599	$3,101,526,779	162%
2009	$4,864,888,002	$3,032,770,482	160%
2010	$4,654,501,283	$3,041,973,016	153%

If expecting yearly expenditures equal to $4,500,000,000 (110% of average real "Highway Construction and Maintenance expenditures" in years 2001-2010, that was $4,096,551,225 (Combs, 2010) with an increase of 0.5% every year and building costs of $5,000,000,000, the estimated break-even year is 4.

This scenario combines larger expenditures with a quick break-even gain, but also with an apparent increase in the price for drivers. For a clean light duty vehicle (BIN 2-1) the price would increase from $0.009/mi to $0.018/mi. For BIN 5-3 the price would increase to $0.023/mi and for BIN 11-6 the increase would be up to $0.031/mi. Again, for other classes of vehicles the increase in price is less dramatic. A single-unit truck in the current system pays approximately $0.024/mi. In Scenario 2, it would pay $0.035/mi if falling into the BIN 2-1 group. In case of the BIN 5-3 group, the price would increase to $0.043/mi. For the dirtiest BIN 11-6 an increase in the price would be to $0.055/mi. These pricing levels might not be accepted by the public. However, when compared to the toll in the Czech Republic, where fuel tax exists side by side with a distance-based toll on highways for vehicles over 3.5 tons, the Czech toll is still 10 times higher than in Scenario 3.

4.3 @Risk analysis

According to the correlation coefficients (Spearman rank), factors that influence the gross revenues are (in descending order): VMT volume, vehicle class share, toll pricing level, and emission class share, as Figure 4.4 shows.

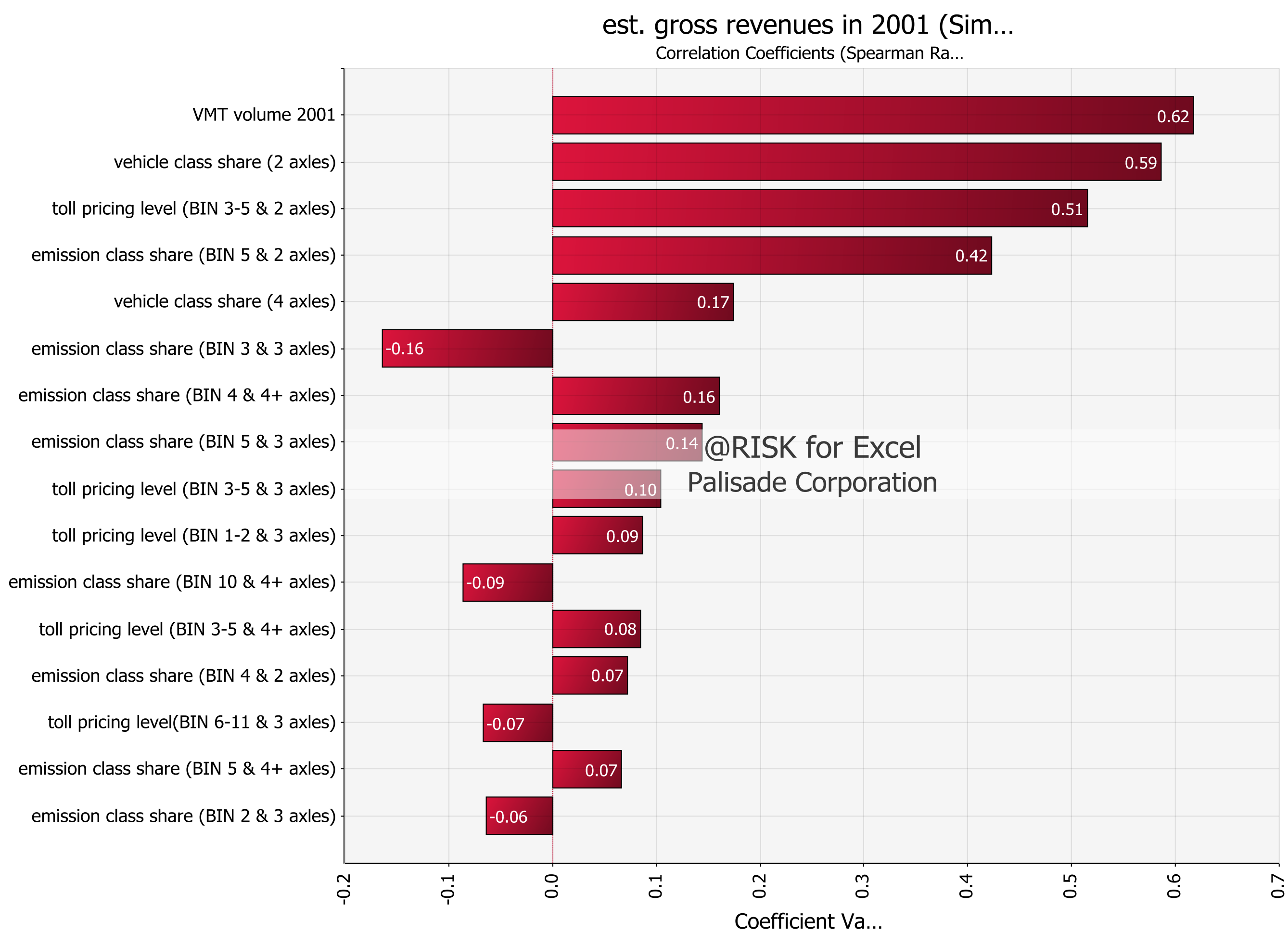


Figure 4.4 Scenario 1: Correlation coefficients for estimated gross revenues in 2001

As for net revenues the factors are following: VMT volume, toll pricing levels, vehicle class share, emission class share, and violations, as Figure 4.5 shows.

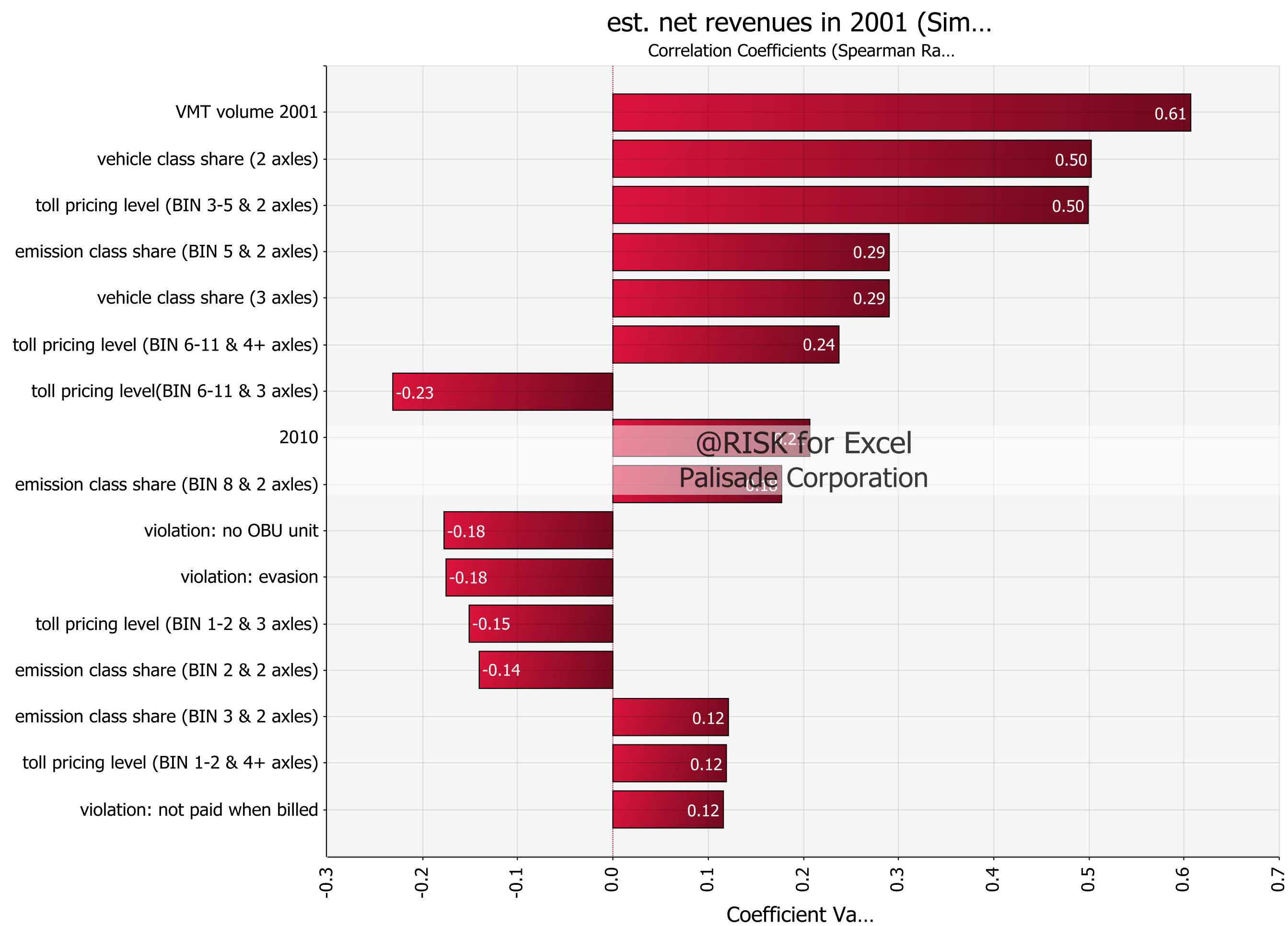


Figure 4.5 Scenario 1: Correlation coefficients for estimated net revenues in 2001

Figure 4.6 shows that there is an increasing risk in estimated gross revenues after year 2010.

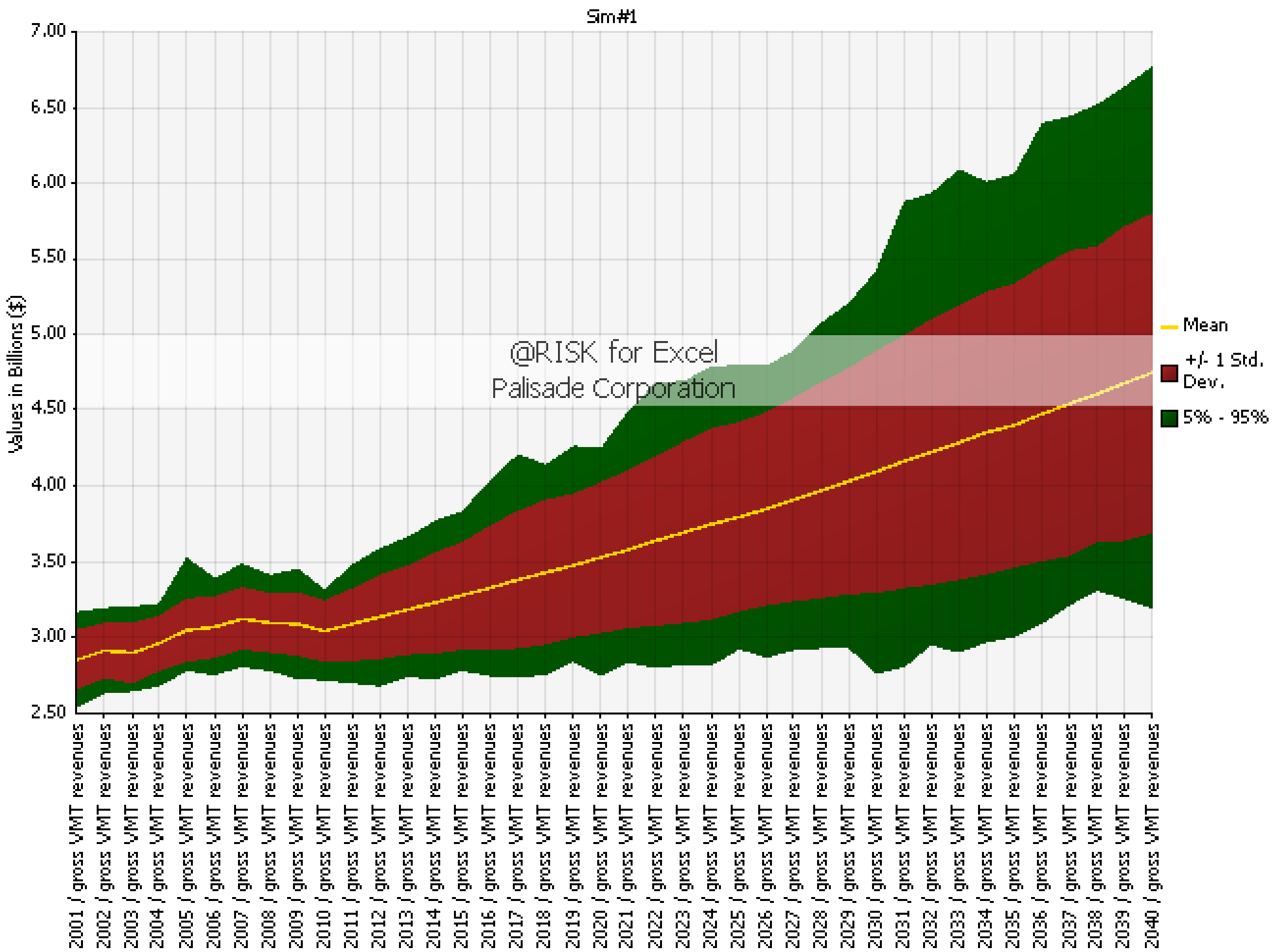


Figure 4.6 Scenario 1: Summary trend for estimated gross VMT revenues 2001-2040

Figure 4.7 indicates that for estimated net revenues in years 2001-2040 the risk increases after year 2010.

Both increases in risk after 2010 are probably caused by the fact that data for years 2001-2010 were real VMT volume data and for following years was expected a yearly increase of 1.5%.

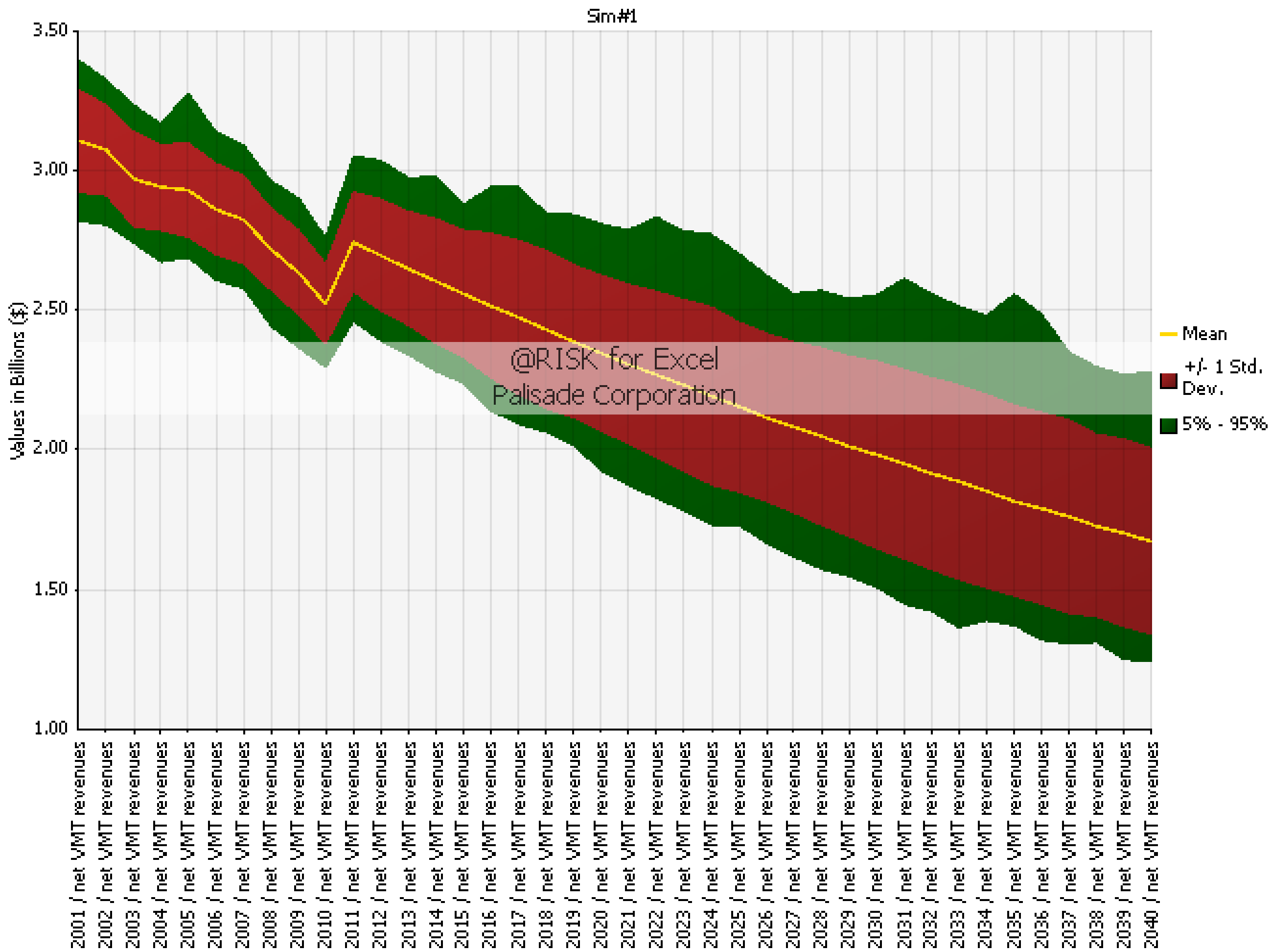


Figure 4.7 Scenario 1: Summary trend for estimated net VMT revenues 2001-2040

4.4 Discussion of Results

Statewide distance-based tolling is an interesting possibility for funding the U.S. roads. Although building costs for such a system can be high, in the long-term it is a reliable source of revenues, differentiated by axles (indicator of stress on road) and by emission class (indicator of air pollution); it is therefore fair on drivers to pay for their usage.

As for the toll, rates in Scenario 2 correspond with the estimation by Durden (2010). He estimated that the distance-based toll would need to be \$0.014/mi or \$0.016/mi (under the normal or aggressive adoption scenario) to generate total revenues equal to \$258 billion needed between 2012 and 2030. Scenario 2 also counts with expenditures on average \$1 billion higher than the present ones.

Further study is needed on how much the distance-based fee could be without having a negative impact on the economy and on the willingness of drivers to pay. A pricing level model for the U.S. needs to be developed, considering these factors and the actual U.S. vehicle fleet. For comparison, the actual toll rate according to the North Texas Tollway Authority is $0.153/mi (NTTA, 2011) and by 2017 is expected to increase to $0.180/mi. However, drivers are charged by section, not distance, and the toll is differentiated only by number of axles into 5 classes. These rates are similar to the lowest toll rate in the Czech Republic (EU), where the distance-based tolling is applied on the network of all highways and pricing levels are dependent on number of axles (2, 3, 4+) and 3 emission classes. The base toll level in 2011 (2 axles, cleanest vehicle) was $0.069/mi (2.12 CZK/km) and for the 4+ axles dirtiest vehicle $0.310/mi (9.46 CZK/km), these rates are 4 times higher than those in Scenario 3. If considered alongside the EU's more than 3 times higher fuel taxation, this shows that drivers can pay more if they are convinced and the government decides for it.

Table 4.18 shows a comparison of fuel tax and the 3 scenarios.

Table 4.18 Comparison of fuel tax and the 3 scenarios

		fuel tax	Scenario 1	Scenario 2	Scenario 3
	base fee $/mi	-	$0.009	$0.013	$0.018
Light Duty Vehicle	**BIN 11-6**	$0.009	$0.015 (69%)	$0.022 (144%)	$0.031 (239%)
	BIN 5-3	$0.009	$0.011 (26%)	$0.016 (81%)	$0.023 (150%)
	BIN 2-1	$0.009	$0.009 (0%)	$0.013 (44%)	$0.018 (100%)
Single-Unit Truck	**BIN 11-6**	$0.025	$0.028 (10%)	$0.040 (59%)	$0.055 (120%)
	BIN 5-3	$0.025	$0.022(-14%)	$0.031 (25%)	$0.043 (72%)
	BIN 2-1	$0.025	$0.017 (-31%)	$0.025 (0%)	0.035 (38%)
Combination Truck	**BIN 11-6**	$0.037	$0.040 (9%)	$0.058 (57%)	$0.080 (117%)
	BIN 5-3	$0.037	$0.031 (-16%)	$0.045 (22%)	$0.062 (69%)
	BIN 2-1	$0.037	$0.025 (-32%)	$0.036 (-2%)	$0.050 (35%)
	building costs	-	$5,000,000,000	$5,000,000,000	$5,000,000,000
	operating costs (6.6%)	-	$180,737,384	$261,065,110	$361,474,768
	average expenditures in year 1-40	$2,172,901,961	$2,172,901,961	$3,143,111,233	$3,143,111,233
	penalty income	-	$526,400,000	$526,400,000	$526,400,000
	discount rate	-	3%	3%	3%
	average net revenues	$2,951,383,398	$2,337,139,072	$3,240,671,816	$4,370,087,745
	break-even year	-	37	41	4

It is important to note that some inaccuracy is to be expected in presented results. For example, building costs were based on engineering judgment. As the building costs contribute to the calculation of the break-even year, the year stated here might be inaccurate. Further, the net revenues, which are influenced by the penalty income (which is not based on real data) and operation costs that were estimated in accordance with the Dutch program. The vehicle class distribution was taken from a Canadian database and similarity is assumed for the U.S. fleet. The vehicle fleet in this model was divided into three classes. However, in real implementation the fleet should be divided into more classes, including buses.

Based on previous assumptions, a base fee of at least $0.013/mi appears to be a feasible solution to the problems that the current system is going through, gaining revenues as Table 4.19 shows. Net revenues take into account penalty income, operation costs and discount rate. Fuel tax revenues in Table 6 should preferably contain only considered vehicle classes. However, this data also includes

motorcycles and buses. This causes a certain inaccuracy, in fact the real fuel tax revenues should be lower, so the estimated VMT fee has an even higher percentage increase than stated here.

Table 4.19 Estimated net revenues for Scenario 1, 2 and 3

	real fuel tax revenues	Scenario 1	difference	Scenario 2	difference	Scenario 3	difference
2001	$2,765,510,548	$3,107,380,269	112%	$4,261,296,850	154%	$5,703,692,576	206%
2002	$2,833,607,460	$3,074,348,555	108%	$4,220,200,140	149%	$5,652,514,622	199%
2003	$2,838,776,695	$2,970,446,191	105%	$4,076,542,023	144%	$5,459,161,813	192%
2004	$2,917,706,870	$2,941,724,514	101%	$4,041,291,150	139%	$5,415,749,445	186%
2005	$2,934,580,537	$2,931,631,502	100%	$4,032,766,718	137%	$5,409,185,739	184%
2006	$2,993,569,575	$2,861,663,013	96%	$3,937,579,147	132%	$5,282,474,314	176%
2007	$3,053,812,019	$2,823,942,741	92%	$3,888,801,128	127%	$5,219,874,111	171%
2008	$3,101,526,779	$2,718,781,310	88%	$3,742,441,883	121%	$5,022,017,599	162%
2009	$3,032,770,482	$2,634,164,885	87%	$3,625,597,382	120%	$4,864,888,002	160%
2010	$3,041,973,016	$2,523,096,160	83%	$3,470,387,326	114%	$4,654,501,283	153%

4.5 Implementation in the EU

A run of the model with data from the Czech Republic was explored, to see what results the model would offer and to see what the fee would be like. Since the model was developed based on data available for Texas, these required Czech data were not possible to find on the internet..

As mentioned earlier, excise taxation in the EU is more than 3 times higher than in the U.S. The fuel in the Czech Republic is subject to two taxes – VAT (Value Added Tax, 20%) and excise tax (12.84 CZK/l for gasoline and 10.95 CZK/l for diesel), resulting in total taxation of 51% ($3.91/gal) for gasoline and 48% ($3.50/gal) for diesel. Table 4.20 indicates that the Czech excise tax on gasoline is 7 times higher and in case of diesel, the Czech excise tax is 5 times higher than in Texas. These revenues go mainly to the State Budget and only 9.1% of the excise fuel tax revenues go to the Road Infrastructure Fund (SFDI), unlike in Texas, where approximately 73%[7] of state fuel tax revenues go to

[7] Obtained by a comparison of the motor fuel tax collection to the motor fuel tax income to the State Highway Fund in years 2001-2010.

the State Highway Fund. This approach in the Czech Republic should be changed in order to better see if the road infrastructure is self-sufficient or not.

Table 4.20 Comparison of fuel taxation in Texas and Czech Republic

	Texas		Czech Republic	
retail price	gasoline	diesel	gasoline	diesel
retail price [CZK/l]	-	-	37.60	36.82
retail price [$/gal]	$3.70	$3.99	$7.70	$7.54
excise tax [$/gal]	$0.38	$0.44	$2.63	$2.24
VAT tax 20% [$/gal]	-	-	$1.28	$1.26
total taxes [$/gal]	$0.38	$0.44	$3.91	$3.50

Considering this high current taxation, in order to get VMT revenues higher than from the fuel tax, the VMT toll would have to be much higher than those estimated for Texas. In the Czech Republic there already exists an electronic distance based toll collection for trucks differentiated by vehicle class, emission class and time (higher toll for Friday 3 P.M.-9 P.M.). Table 4.21 summarizes the differences between the current Czech and Texan system.

Table 4.21 Comparison of the current tolling situation in Texas and Czech Republic

	Texas	Czech Republic	VMT model
current excise tax on gasoline	$0.38	$2.63	
current excise tax on diesel	$0.44	$2.24	
share of revenues going to a special fund	73%	9.1%	
toll applied on	selected highways only	all highways[8]	statewide
income to the special fund from all tolls	0.04%	27%	100%
e-toll vehicle class differentiation	6 classes[9]	4 classes[10]	3 classes
e-toll emission class differentiation	no	3 classes	3 classes
e-toll time differentiation	no	Friday 3 P.M. - 9 P.M.	no

[8] time vignette or electronic distance based toll for trucks and buses
[9] 2, 3, 4, 5, 6 axle vehicle and unibody truck
[10] buses and 2, 3, 4+ axles trucks

The model developed in this thesis could be applied to the situation in the Czech Republic, if the Ministry of Transport provides the necessary data that are currently not accessible on the internet. As the current tolling for trucks differentiates emission classes, this model would be innovative in also including passenger vehicles.

CHAPTER 5: CONCLUSION

It is without a question that it is necessary to find a new way of funding for our transportation system. We need to generate more money, but apparently there are only two ways to get money – produce savings or revenue. Even if we were able to do the first one, it definitely would not be sufficient to fund new projects. The second one means reaching into tax payer's pockets, which is always a very unpopular step. For sure, fuel tax is no longer performing its duties.

5.1 Findings

The findings of this thesis are presented in the sequence of steps developed in Chapter 3:

5.1.1 Background Study

Distance-based tolling situation in the U.S.

There have been many smaller scale trial runs of distance-based tolling throughout the U.S. and the topic of a statewide implementation of such a program is still being explored. This work therefore explored the possibility of replacing the fuel tax by a statewide tolling system with prices differing not only in number of axles but also in emission class to offer an air quality enhancing tool.

5.1.2 Feasibility Study

Feasibility of distance-based tolling

The broad decision situation is analyzed and a model estimating the revenues is created to help decide whether this replacement would be feasible, together with pricing levels that need to be discussed with the public to ensure that they are acceptable. According to the presented results, a

statewide distance-based tolling is a feasible alternative. It ensures a more stable source of revenues, insensitive to changes in fuel efficiency and the increasing number of alternative-fuel vehicles. Emission class differentiation motivates drivers to own cleaner vehicles and such fleet renewal causes less emissions. Also an overall consciousness of a usage-based fee implies lower energy consumption. The possibility to differ the toll in time and place can ensure congestion management and imply saving in travel time, indirectly lowering the energy consumption.

5.1.2.1 Technology Study

When considering a statewide distance based toll program, it is fundamental to find an acceptable and reliable technology. As discussed in section 2.6 Technical Solution, all current technologies have advantages and disadvantages, therefore the technology should be selected carefully. In order to make the transition from the fuel tax easier, the VMT fee can first apply on alternative fuel based vehicles, to show that the system is working and to earn trust of the public. In the first years VMT fee can be optional (with some advantages to encourage drivers to voluntarily switch to this program), existing alongside the fuel tax.

5.2.1.2 Cost Study

Building and operating costs and the ability to recover them over years represent one of the crucial issues. The VMT model developed in this thesis predicts a break-even year when provided with the costs of building and operating.

5.1.3 VMT Fee Study

VMT model vs. TVST model

This VMT model, in comparison with the Toll Viability Screening Tool (TVST) developed by TTI in 2004, employs a differentiation in emission classes and 3 classes of vehicles (TVST has 2 classes of vehicles) and considers all rural and urban arterial roads (TVST considers a specific toll length). On the other hand, this VMT model is more static, as vehicle class distributions, and toll rates do not change over years. The TVST model had 4 scenarios with a toll rate level set to $0.100/mile, $0.120/mile, $0.140/mile, $0.160/mile and $0.180/mile, which are about 10 times higher than those used in the VMT model here - $0.009/mile, $0.013/mile, $0.018/mile. In sum, the TVST model is more appropriate for tolling applied to sections of highways, whereas the VMT model is meant for a statewide application.

Results of the VMT model

3 Scenarios were considered – (1) a base fee of $0.009/mile to achieve gross revenues from VMT fee similar to the current revenues from the fuel tax, (2) a base fee of $0.013/mile to achieve gross revenues from VMT fee around 150% of the current revenues from the fuel tax, and (3) a base fee of $0.018/mile to achieve gross revenues from VMT fee around 200% of the current revenues from the fuel tax. Based on the VMT model results, a base fee of at least $0.013/mi appears to be a feasible solution to the problems that the current system is going through, gaining revenues as Table 5.1 shows.

Table 5.1 Comparison of the fuel tax and Scenarios 1-3

	BIN	$/mi Light-Duty Vehicle	$/mi Single-Unit Truck	$/mi Combination Truck	Average Net Revenues	Average Expenditures[11]	Breakeven Year
fuel tax	**1-11**	$0.009	$0.024	$0.036	$2,951,383,398	$2,172,901,961	-
Scenario 1	**6-11**	$0.015	$0.028	$0.040	$2,337,139,072	$2,172,901,961	37
	3-5	$0.011	$0.022	$0.031			
	1-2	$0.009	$0.017	$0.025			
Scenario 2	**6-11**	$0.022	$0.040	$0.058	$3,240,671,816	$3,143,111,233	41
	3-5	$0.016	$0.031	$0.045			
	1-2	$0.013	$0.025	$0.036			
Scenario 3	**6-11**	$0.031	$0.055	$0.080	$4,370,087,745	$3,143,111,233	4
	3-5	$0.023	$0.043	$0.062			
	1-2	$0.018	$0.035	$0.050			

Feasibility of the VMT model

The developed VMT model is feasible, but some inaccuracy is to be expected in presented results. The following limitations should be taken into an account:

- building costs were based on engineering judgment, as so far there is no such project to take this data from. As the building costs contribute to the calculation of the break-even year, the year stated here might be inaccurate.
- net revenues that are influenced by the penalty income (which is not based on real data) and operation costs that were estimated in accordance with the Dutch program may not reliably apply to the situation in the U.S.
- vehicle class distribution was taken from a Canadian database and similarity is assumed for the U.S. fleet.
- vehicle fleet in this model was divided into 3 classes, due to data available for this division. However, in real implementation the fleet should be divided in accordance to the 13 FHWA classifications.

[11] Difference between Average Net Revenues and Average Expenditures is caused by including the discount rate in Average Expenditures.

- vehicle and emission class distributions are static, not dynamic in time, which would correspond better with the reality, as drivers are motivated to drive cleaner vehicles.

All these simplifications were made due to the lack of accurate data and could be explored in future research.

Applicability of the VMT model

The decision situation and sequential steps as described in Chapter 3 can be used for any state. A difference may stem from the level of public involvement in some countries.

As for the VMT model, it can be also used for another country. In that case, pricing levels should be determined for each country separately to ensure results correspond to the reality. Also @Risk distribution parameters should be adjusted, based on data available. If the technology reliability differs from 100%, this can be solved by entering only the detected miles to the expected VMT volume.

In sum, the sequence flowchart explores the conditions of a successful VMT program and guides step by step through the implementation. The VMT model developed in Excel spreadsheet estimates revenues, the break-even year and also gives recommendations based on user's answers to 4 questions investigating the background (see Chapter 3.3 or Appendix A). As the estimated VMT revenues are compared with the fuel tax revenues, it can be easily seen whether it is favorable to replace the fuel tax with a VMT fee or not.

5.1.4 External Relationships

Feasibility of a higher tax burden on drivers

In comparison with the EU, European drivers are burdened with more than 3 times higher fuel taxes and toll on all highways. This indicates that even an apparently unpopular and unacceptable decision is feasible and acceptable in the long-term. Moreover, if the revenues also went to improvements in the public transport and the public had the possibility to choose between modes - public transport or a car - the change to a distance-based toll could be more acceptable. At present people are forced to own a vehicle in order to get around. Some of them do not even have a sidewalk in the street where they live. This situation should change in the future and people should be given the opportunity to choose which means of transport they will use, if it is walking, cycling, riding public transport or driving a car. The revenues from the distance-based financing system could help to renovate the current system, by building new infrastructure with more possibilities for the public.

5.2 Future Research

The topics that require future research are technology selection, billing frequency, toll pricing levels, public acceptance, interoperability of devices between states, involvement of congestion pricing and those issues named in the *Feasibility of the VMT model* section.

LIST OF REFERENCES

American Petroleum Institute (2012a). "State Gasoline Tax Reports." < http://www.api.org/Oil-and-Natural-Gas-Overview/Industry-Economics/~/media/Files/Statistics/gasoline-diesel-summary.ashx> (Mar. 24, 2012).

American Petroleum Institute (2012b). "Gasoline Taxes Map." < http://www.api.org/Oil-and-Natural-Gas-Overview/Industry-Economics/~/media/21EBD0B62EBA42B1965EE82EFFB6585D.ashx> (Mar. 24, 2012).

Arnold, R., et al. (2010). "Reducing Congestion and Funding Transportation Using Road Pricing in Europe and Sinagapore." FHWA, Research Report FHWA-PL-10-030

ASCE (2012). "Report Card for America's Infrastructure." <https://apps.asce.org/reportcard/2005/index.cfm> (Feb. 7, 2012).

Austin Business Journal (2011). "Let companies build Texas roads." <http://www.bizjournals.com/austin/print-edition/2011/03/25/let-companies-build-texas-roads.html> (Feb. 2, 2012)

Baker, T., Goodin, G., Pourteau, C. (2011a). "Is Texas Ready for Mileage Fees? A Briefing Paper", Texas Transportation Institute, Texas Department of Transportation

Baker, R., Goodin, G. (2011b). "EXPLORATORY STUDY: VEHICLE MILEAGE FEES IN TEXAS." Texas Transportation Institute, FHWA/TX-11/0-6660-1, January 2011

Bína, L. et al. (2010). "Návrh mýtných tarifů pro rok 2011. Finální zpráva." Fakulta dopravní, ČVUT, Praha, Czech Republic

Bína, L. et al. (2008). "Ekonomika mýtných systémů." Sborník přednášek 2. semináře o hybridních mýtných systémech. Fakulta dopravní, ČVUT, Praha, Czech Republic

Balducci, P., et al. (2011). "Costs of Alternative Revenue-Generation Systems." Transportation Research Board, NCHRP Report 689

Bundesamt für Güterverkehr (2009). "Guide for determining the emissions classes of heavy commercial vehicles."<http://www.toll-collect.de/fileadmin/content/Dokumente/PDFs/Informationen/Leitfaden_Schadstoffklassen/leitfaden_schadstoffkl_gb.pdf> (Apr. 18, 2012)

Burger, P., Bergvall, D., and Jacobzone, S. (2008). "Public Private Partnerships: In Pursuit of Risk Sharing and Value for Money" OECD, Paris, France

Combs, S. (2010). "State of Texas Annual Cash Report 2010".

"Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions of 21 December 1998 on interoperable electronic fee collection systems in Europe." Commission of the European Communities, Brussels, Belgium, Report COM/98/0795 final

CURACAO (2008a). "Acceptability." < http://www.curacaoproject.eu/workfiles/files/work-packages/WP4/Fact%20Sheets/Final%20Version%20Themes/Acceptability.pdf> (Feb. 8, 2011).

Directorate General for Mobility and Transport (2011). “The European Electronic Toll Service - Guide for the Application of the Directive on the Interoperability of Electronic Road Toll Systems.” <http://ec.europa.eu/transport/publications/doc/2011-eets-european-electronic-toll-service_en.pdf> Luxembourg, Publications Office of the European Union, 2011

Donath, M., et al. (2009). “Technology Enabling Near-Term Nationwide Implementation of Distance Based Road User Fees, Final Report.” Intelligent Transportation Systems Institute, University of Minnesota, Minneapolis, MN

Durden, D. J. (2010). “Funding Texas Highways for the Next 20 Years”, *Texas Civil Engineer*, Winter 2010, Volume 81

Dutch Ministry of Transport (2007). “Making a Start on a Price per Kilometre”

Elmendorf, D. W., et al. (2008). “Issues and Options in Infrastructure Investment.” *The Budget and Economic Outlook: Fiscal Years 2010 to 2020*, <http://www.cbo.gov/ftpdocs/91xx/doc9135/AppendixB.5.1.shtml> (Oct. 30, 2011).

Elmendorf, D. W., et al. (2010). “Trust Funds and Measures of Federal Debt.” *The Budget and Economic Outlook: Fiscal Years 2010 to 2020*, The Congress of the United States - Congressional Budget Office, <http://www.cbo.gov/ftpdocs/108xx/doc10871/AppendixD.shtml> (Oct. 30, 2011).

Elmendorf, D. W., et al. (2011). “Alternative Approaches to Funding Highways.” The Congress of the United States - Congressional Budget Office, <http://www.cbo.gov/ftpdocs/121xx/doc12101/03-23-HighwayFunding.pdf> (Oct. 30, 2011).

emyto.sk (2012). “Sadzby myta.” < https://www.emyto.sk/web/guest/toll/rates> (Apr. 18, 2012)

EPA (2007). “Summary of Current and Historical Light-Duty Vehicle Emission Standards.” Office of Transportation and Air Quality, <http://www.epa.gov/greenvehicles/detailedchart.pdf>

FHWA (2009a). “Status of The Federal Highway Trust Fund, Fiscal Years 1957-2009.” *Highway Statistics 2009,* <http://www.fhwa.dot.gov/policyinformation/statistics/2009/fe210.cfm> (Sep. 10, 2011)

FHWA (2009b). “Status of The Federal Highway Trust Fund, October 1, 2009 - September 30, 2010.” *Highway Statistics 2009*, <http://www.fhwa.dot.gov/policyinformation/statistics/2009/fe10_2009.cfm > (Sep. 10, 2011)

FHWA (2009c). “Status of The Federal Highway Trust Fund, October 1, 2008 - September 30, 2009.” *Highway Statistics 2009*, <http://www.fhwa.dot.gov/policyinformation/statistics/2009/fe10.cfm> (Sep. 10, 2011)

FHWA (2009d). “Annual Vehicle Distance Traveled in Miles and Related Data - 2009 1/ By Highway Category and Vehicle Type.” Highway Statistics 2009, Federal Highway Administration, < http://www.fhwa.dot.gov/policyinformation/statistics/2009/vm1.cfm> (Mar. 2, 2012)

FHWA (2009e). “State Motor Vehicle Registrations.” *Highway Statistics 2009*, < http://www.census.gov/compendia/statab/2012/tables/12s1096.xls> (Apr. 18, 2012)

FHWA Highway Statistics (2010). “Vehicle Registrations, Fuel Consumption, and Vehicle Miles of Travel as Indices.” < http://www.fhwa.dot.gov/policyinformation/statistics/2010/rc1c.cfm > (Apr. 18, 2012).

FHWA (2010). “Motor Fuel Tax Compliance Outreach, Frequently Asked Questions.” <http://www.fhwa.dot.gov/motorfuel/faqs.htm> (Oct. 30, 2011).

FHWA (2011). “Road Pricing: Study Reports.” *Innovative Program Delivery*, <http://www.fhwa.dot.gov/ipd/revenue/road_pricing/study_reports/auto_use_costs.htm> (Dec. 2, 2011).

FHWA (2012a). “Status of the Highway Trust Fund.” <http://www.fhwa.dot.gov/highwaytrustfund/index.htm> (Mar . 24, 2012).

FHWA (2012b). “Traffic Volume Trends.” <http://www.fhwa.dot.gov/policyinformation/travel_monitoring/tvt.cfm> (Mar. 2, 2012)

Go-Maut (2012). “Tarife.” < http://www.go-maut.at/bezahlung/tarife> (Apr. 18, 2012).

Inflationdata.com (2012). “Annual Inflation Rate.” Capital Professional Services, <http://inflationdata.com/inflation/inflation_rate/currentinflation.asp> (Mar. 15, 2012)

International Transport Forum (2011). “Road Infrastructure Gross Investment Spending.” *Infrastructure Investments*, <http://www.internationaltransportforum.org/statistics/investment/Data/InvRoad.xls> (Sep. 10, 2011)

Köhne, A., Wößner, M. (2009). “Sources of Errors in GPS.” *The GPS System*, <http://www.kowoma.de/en/gps/errors.htm> (Jan. 30, 2012).

Moos, P. (2008). “Mýtný systém z hlediska dopravní politiky ČR.” Sborník přednášek 2. semináře o hybridních mýtných systémech. díl 1, Fakulta dopravní, ČVUT, Praha, Czech Republic

Nation Master (2011). “Roads, total network, km (most recent) by country.” *Transportation Statistics*, 2011, <http://www.nationmaster.com/graph/tra_roa_tot_net_km-transportation-roads-total-network-km> (Sep. 10, 2011)

Nilsson, M. (2011). “Briefing: Transport Fuels & the Energy Tax Directive.” Transport & Environment – European Commission

NKÚ (2009). “Výroční zpráva 2009.” < http://www.nku.cz/vyr-zpravy/vyrocni-zprava-nku-2009.pdf> Nejvyšší kontrolní úřad, Czech Republic (Apr. 20, 2012)

NKÚ (2010). “Výroční zpráva 2010.” < http://www.nku.cz/assets/publikace/vyrocni-zprava-nku-2010.pdf> Nejvyšší kontrolní úřad, Czech Republic (Apr. 20, 2012)

NKÚ (2011). “Výroční zpráva 2011.” < http://www.nku.cz/assets/publikace/vyrocni-zprava-nku-2011.pdf> Nejvyšší kontrolní úřad, Czech Republic (Apr. 20, 2012)

Orszag, P. R. (2008). “Overview of the Highway Trust Fund.” *Issues and Options in Infrastructure Investment*, <http://www.cbo.gov/ftpdocs/91xx/doc9135/AppendixB.5.1.shtml> (Sep. 10, 2011)

Premid (2011). “Tabulka sazeb mýtného 2011.” < http://www.premid.cz/index.php?id=2551&L=3> (Oct. 19, 2011)

Premid (2012). “Toll Rates Table.” <http://www.premid.cz/index.php?id=2551> (Apr. 18, 2012)

“Proposal of Innovation of the Toll Directive.” ST11857 CS08, 2008

Pryne, E. (2008). “Wide use of tolls could unclog roads, Seattle study says” *The Seattle Times* <http://seattletimes.nwsource.com/html/localnews/2004369904_tolls24m.html> (Dec. 2, 2011).

Přibyl, P. (2007a). “Česko-slovenský mýtný systém v evropském kontextu.” Technologies & Prosperity, roč. XII, Czech Republic

Přibyl, P. (2007b). "Mýtný systém v České republice v evropském kontextu." VIII. dopravně - inženýrské dny, Brno, Czech Republic

Puget Sound Regional Council (2008) "Traffic Choices Study – Summary Report." Seattle, WA

RDW (2011). "Road Pricing in Europe – First Version." RDW in cooperation with EReg, Netherlands, March 2011

RITA (2008a). "Passenger Car and Motorcycle Fuel Consumption and Travel." Research and Innovative Technology Administration, Bureau of Transportation Statistics. <http://www.bts.gov/publications/national_transportation_statistics/html/table_04_11.html> (Mar. 2, 2012)

RITA (2008b). "Single-Unit 2-Axle 6-Tire or More Truck Fuel Consumption and Travel." Research and Innovative Technology Administration, Bureau of Transportation Statistics. <http://www.bts.gov/publications/national_transportation_statistics/html/table_04_13.html> (Mar. 2, 2012)

RITA (2008c). "Combination Truck Fuel Consumption and Travel." Research and Innovative Technology Administration, Bureau of Transportation Statistics. <http://www.bts.gov/publications/national_transportation_statistics/html/table_04_14.html> (Mar. 2, 2012)

RITA (2012). "U.S. Highway Vehicle-Miles Traveled." Multimodal Transportation Indicators, Research and Innovative Technology Administration, Bureau of Transportation Statistics. <http://www.bts.gov/publications/multimodal_transportation_indicators/february_2012/excel/highway_vehicle_miles_traveled.xls> (Mar. 2, 2012)

Schönfelder, S., et al. (2006). "Analysis of Commute Atlanta Instrumented Vehicle GPS Data: Destination Choice Behavior and Activity Spaces" Manuscript submitted to TRB annual meeting 2006

Schmidt, S. (2010) "The proposed revision of the 'Eurovignette' Directive." Manuscript submitted to *The Pricing of Progress Conference 2010*, Brussels, Belgium

Schweizerische Eidgenossenschaft (2011). "Performance-Related Heavy Vehicle Fee, Overview." Bern, Switzerland

SFDI (2010). "Rozpočet Státního fondu dopravní infrastruktury na rok 2011 a střednědobý výhled na roky 2012 a 2013. Státní fond dopravní infrastruktury"

Silnice-Zeleznice.cz (2004). "Financování rozvoje dopravní infrastruktury." < http://www.silnice-zeleznice.cz/clanek/financovani-rozvoje-dopravni-infrastruktury/> (Apr 11, 2012)

Slone, S. (2009). "Vehicle Miles Travelled Fees, A Trends in America Special Report", The Council of State Governments

Smith, D. R., Chang-Albitres, C., Stockton, W. R., and Smith, C. R. (2004). "Estimating Revenues Using a Toll Viability Screening Tool." FHWA Report TX-05/0-4726-1, Texas Transportation Institute, College Station, Texas, 2004

Stampfer, C. (2011). "EU Plans to Increase Diesel Tax." *The Diesel Driver*, <http://www.thedieseldriver.com/2011/04/eu-plans-to-increase-diesel-tax/> (Dec. 2, 2011).

Stockton, W. R. (2006). "Investigation of an Empirical Methodology for Linking Value of Time with Census Tract Median Income", doctoral dissertation, Texas A&M University, College Station, TX

Taothong, S., Jiwattanakulpaisarn P., Kanitpong K. (2012). "An Empirical Analysis of Success and Failure Factors for Public-Private Partnerships in Toll Road Investments." Transportation Research Board, 11-3586

Tax Foundation (2008). "Federal Gasoline Excise Tax Rate, 1932-2008." <http://www.taxfoundation.org/taxdata/show/1067.html> (Oct. 30, 2011).

Texas Department of Motor Vehicles (2010). "Actual Performance for Output/Efficiency Measures." Report

TSHA (2011). "Facts." < http://www.texasalmanac.com/topics/facts-profile > Texas State Historical Association (Apr. 19, 2012)

U.S. Census Bureau (2011). "Annual Estimates of the Population for the United States." <http://www.census.gov/popest/data/state/totals/2011/tables/NST-EST2011-01.csv> (Apr. 19, 2012)

U.S. Census Bureau (2012). "Motor Vehicle Distance Traveled by Type of Vehicle." *The 2012 Statistical Abstract*, <http://www.census.gov/compendia/statab/2012/tables/12s1101.xls> (Jan. 31, 2012)

Viatoll (2012). "Toll Rates." <http://www.viatoll.pl/en/light-vehicles/toll-rates> (Apr. 18, 2012)

Ward, K. (2011). "HSBC says world will be out of oil by 2060." <http://gm-volt.com/2011/03/30/hsbc-says-world-will-be-out-of-oil-by-2060/> (Oct. 30, 2011).

Window on State Government (2010). "Tax Collections By Major Tax." Texas Net Revenue by Source – Fiscal, < http://www.window.state.tx.us/taxbud/revenue_hist.html> (Mar. 5, 2012)

Whitty, J. M. (2007). "Oregon's Mileage Fee Concept and Road User Fee Pilot Program, Final Report." Oregon Department of Transportation (ODOT)

Whitty, J. M., Svadlenak, J. R. (2009). "Discerning the Pathway to Implementation of a National Mileage-Based Charging System." Oregon Department of Transportation, Paper prepared for the Transportation Research Board, October 2009

World Bank (2011a). "Roads, total network." *Data*, <http://data.worldbank.org/indicator/IS.ROD.TOTL.KM > ((Sep. 10, 2011).

World Bank (2011b). "Pump price for gasoline." *Data*, <http://data.worldbank.org/indicator/EP.PMP.SGAS.CD - 2010> (Sep. 10, 2011).

World Bank (2011c). "Road sector gasoline fuel consumption." *Data*, <http://data.worldbank.org/indicator/IS.ROD.SGAS.KT/countries?page=1&display=default> (Oct. 30, 2011).

APPENDIX A

THE UNIVERSITY OF TEXAS AT EL PASO

CZECH TECHNICAL UNIVERSITY IN PRAGUE

ELECTRONIC VEHICLE MILES TRAVELLED TOLL MODEL

An Introduction to the ELECTRONIC VEHICLE MILES TRAVELLED TOLL MODEL

The ELECTRONIC VEHICLE MILES TRAVELLED TOLL MODEL was developed to model the decision situation that surrounds the decision whether to substitute the fuel tax with a distance-based fee. User can enter a base VMT fee and differentiate the fee according to emission classes and vehicle type and see what happens with revenues, given building and operating costs.

First, fill out data in Data Input. Then go through Steps 1 to 3 to see how the data entered were analyzed and then see Summary for the final report.

Step 2-a **Enter gross VMT estimate for considered years [mi]**

2001	219,266,000,000	2%	triangular
2002	223,949,000,000	-1%	triangular
2003	222,744,000,000	2%	triangular
2004	227,740,000,000	3%	triangular
2005	234,470,000,000	1%	triangular
2006	235,884,000,000	2%	triangular
2007	240,194,000,000	-1%	triangular
2008	237,965,000,000	0%	triangular
2009	237,421,000,000	-1%	triangular
2010	233,876,000,000	1%	triangular
2011	237,384,140,000	1.5%	triangular
2012	240,944,902,100	1.5%	triangular
2013	244,559,075,632	1.5%	triangular
2014	248,227,461,766	1.5%	triangular
2015	251,950,873,692	1.5%	triangular
2016	255,730,136,798	1.5%	triangular
2017	259,566,088,850	1.5%	triangular
2018	263,459,580,183	1.5%	triangular
2019	267,411,473,885	1.5%	triangular
2020	271,422,645,994	1.5%	triangular
2021	275,493,985,683	1.5%	triangular
2022	279,626,395,469	1.5%	triangular
2023	283,820,791,401	1.5%	triangular
2024	288,078,103,272	1.5%	triangular
2025	292,399,274,821	1.5%	triangular
2026	296,785,263,943	1.5%	triangular
2027	301,237,042,902	1.5%	triangular
2028	305,755,598,546	1.5%	triangular
2029	310,341,932,524	1.5%	triangular
2030	314,997,061,512	1.5%	triangular
2031	319,722,017,435	1.5%	triangular
2032	324,517,847,696	1.5%	triangular
2033	329,385,615,412	1.5%	triangular
2034	334,326,399,643	1.5%	triangular
2035	339,341,295,637	1.5%	triangular
2036	344,431,415,072	1.5%	triangular
2037	349,597,886,298	1.5%	triangular
2038	354,841,854,592	1.5%	triangular
2039	360,164,482,411	1.5%	triangular
2040	365,566,949,648		triangular

* data source: http://www.fhwa.dot.gov/policyinformation/travel_monitoring/tvt.cfm
http://www.bts.gov/publications/multimodal_transportation_indicators/february_2012/excel/highway_vehicle_miles_traveled.xls
since for years 2001-2002 FHWA has data only for rural arterial roads, not for urban arterial, these years were estimated considering the change in U.S. total VMT

Step 2-a **Enter estimated share on VMT for each vehicle class**

* the bus and motorcycle fleet (share on VMT 1.19%) is not considered in this model
* estimate is the same for all years in the analysis, no dramatic changes are expected

Light duty vehicle - 2 axles		89.06%	triangular
Single-unit truck- 3 axles		4.07%	triangular
Combination truck - 4 axles		5.68%	triangular

* data source: http://www.fhwa.dot.gov/policyinformation/statistics/2009/vm1.cfm

Step 2-b **Enter estimated share of BIN classes in the fleet**

* U.S. data not available (DOT, EIA, EPA requested)
* Canadian data used, similarity assumed
* LDV/LLDT assumed to correspond to light duty vehicles and single-unit trucks (2 and 3 axles)
* HLDT/MDPV assumed to correspond to combination trucks (4+ axles)

BIN number	BIN 2 axles	BIN 3 axles	BIN 4+ axles	
11	0.00%	0.00%	0.00%	
10	0.00%	0.00%	1.91%	triangular
9	0.00%	0.00%	0.00%	
8	0.69%	0.69%	62.58%	triangular
7	0.00%	0.00%	0.00%	
6	0.00%	0.00%	0.00%	
5	93.69%	93.69%	32.89%	triangular
4	4.79%	4.79%	2.62%	triangular
3	0.66%	0.66%	0.00%	triangular
2	0.17%	0.17%	0.00%	triangular
1	0.00%	0.00%	0.00%	

* data source: http://www.ec.gc.ca/lcpe-cepa/default.asp?lang=En&n=440ABCFF-1#Q

Step 2.1 **Enter estimated number of violations and penalty charges**

	occurrence	number of violations	penalty	income
no OBU unit	1.01%	230,000	$500	$115,000,000
evasion	0.05%	11,000	$10,000	$110,000,000
not paid when billed	4.41%	1,000,000	$300	$300,000,000
heavy violation	0.03%	7,000	$200	$1,400,000

Total number of vehicles registered in Texas	22,681,304
	1.01%
	0.05%
	4.41%
	0.03%

Step 2.2 **Enter estimated costs**

Building costs	$5,000,000,000	triangular
Operating costs	$180,737,384	triangular
Discount rate	3.00%	triangular

Operating costs should include costs for operation of the whole system (administration, enforcement, data transfer)

Step 3 **Enter average miles travelled per gallon for each fleet**

2 axles	[mi/gal]
2001	22.1
2002	22.0
2003	22.2
2004	22.5
2005	22.1
2006	22.5
2007	22.5
2008	22.6
2009	
2010	

3 axles	[mi/gal]
2001	7.5
2002	7.4
2003	8.8
2004	8.8
2005	8.3
2006	8.2
2007	8.2
2008	8.5
2009	
2010	

4+ axles	[mi/gal]
2001	5.4
2002	5.2
2003	5.9
2004	5.9
2005	5.2
2006	5.1
2007	6.0
2008	6.0
2009	
2010	

* data source: http://www.bts.gov/publications/national_transportation_statistics/html/table_04_11.html
http://www.bts.gov/publications/national_transportation_statistics/html/table_04_13.html
http://www.bts.gov/publications/national_transportation_statistics/html/table_04_14.html
*since for years 2009 and 2010 are no data available, ???

Step 3 **Enter the state and state fuel tax**

State	Texas
State fuel tax	$0.200

Step 3 **Enter the pricing levels for each fleet and emission class**

* pricing levels were based on the levels used in the Czech Republic

coefficient	2 axles	3 axles	4+ axles
BIN 11			
BIN 10			
BIN 9			
BIN 8			
BIN 7			
BIN 6	1.69	3.06	4.46
BIN 5			
BIN 4			
BIN 3	1.25	2.40	3.47
BIN 2			
BIN 1	1.00	1.92	2.77

Step 3 **Enter the tested base VMT fee**

*must be larger than the current state fuel tax per mile:

			Scenario 1	Scenario 2	Scenario 3
base VMT fee	$0.009		$0.009	$0.013	$0.018

Estimated current state fuel tax per mile	
Light duty vehic	$0.009
Single-unit truck	$0.024
Combination truc	$0.036

Step 3 **Enter revenues from the fuel tax (used for comparison)**

2001	$2,765,510,548
2002	$2,833,607,460
2003	$2,838,776,695
2004	$2,917,706,870
2005	$2,934,580,537
2006	$2,993,569,575
2007	$3,053,812,019
2008	$3,101,526,779
2009	$3,032,770,482
2010	$3,041,973,016

* data source: http://www.window.state.tx.us/taxbud/revenue_hist.html

* includes also revenues from motorcycles and buses, preferably should contain only considered vehicle classes

Enter expenditures for every year

		yearly increase	inc. discount rate	Scenario 1	Scenario 2	Scenario 3
2001	$2,978,835,811		$2,892,073,603	$2,978,835,811	$4,500,000,000	$4,500,000,000
2002	$3,268,511,724	9.72%	$3,080,885,780	$3,268,511,724	$4,590,000,000	$4,590,000,000
2003	$3,287,666,757	0.59%	$3,008,680,811	$3,287,666,757	$4,681,800,000	$4,681,800,000
2004	$3,492,941,281	6.24%	$3,103,433,087	$3,492,941,281	$4,775,436,000	$4,775,436,000
2005	$4,630,402,241	32.56%	$3,994,225,648	$4,630,402,241	$4,870,944,720	$4,870,944,720
2006	$5,132,818,911	10.85%	$4,298,655,030	$5,132,818,911	$4,968,363,614	$4,968,363,614
2007	$5,359,397,359	4.41%	$4,357,680,499	$5,359,397,359	$5,067,730,887	$5,067,730,887
2008	$5,208,591,565	-2.81%	$4,111,710,279	$5,208,591,565	$5,169,085,504	$5,169,085,504
2009	$4,252,879,534	-18.35%	$3,259,478,035	$4,252,879,534	$5,272,467,215	$5,272,467,215
2010	$3,353,467,064	-21.15%	$2,495,294,436	$3,353,467,064	$5,377,916,559	$5,377,916,559
2011	$3,370,234,399	assumed an increase of 0.5	$2,434,729,037			
2012	$3,387,085,571	Scenario 1 Y1-Y10 based on	$2,375,633,672			
2013	$3,404,020,999		$2,317,972,661			
2014	$3,421,041,104		$2,261,711,188			
2015	$3,438,146,310		$2,206,815,286			
2016	$3,455,337,041		$2,153,251,808			
2017	$3,472,613,726		$2,100,988,415			
2018	$3,489,976,795		$2,049,993,550			
2019	$3,507,426,679		$2,000,236,425			
2020	$3,524,963,812		$1,951,686,997			
2021	$3,542,588,632		$1,904,315,954			
2022	$3,560,301,575		$1,858,094,693			
2023	$3,578,103,083		$1,812,995,307			
2024	$3,595,993,598		$1,768,990,566			
2025	$3,613,973,566		$1,726,053,902			
2026	$3,632,043,434		$1,684,159,390			
2027	$3,650,203,651		$1,643,281,735			
2028	$3,668,454,669		$1,603,396,256			
2029	$3,686,796,943		$1,564,478,871			
2030	$3,705,230,927		$1,526,506,083			
2031	$3,723,757,082		$1,489,454,964			
2032	$3,742,375,867		$1,453,303,145			
2033	$3,761,087,747		$1,418,028,797			
2034	$3,779,893,185		$1,383,610,622			
2035	$3,798,792,651		$1,350,027,840			
2036	$3,817,786,615		$1,317,260,174			
2037	$3,836,875,548		$1,285,287,840			
2038	$3,856,059,925		$1,254,091,533			
2039	$3,875,340,225		$1,223,652,418			
2040	$3,894,716,926		$1,193,952,117			

Step 1. - Background Study

The background study explores the level of support in the government and legislation.

1.I How stable are the government policies in the state where the VMT fee is considered being implemented?

2

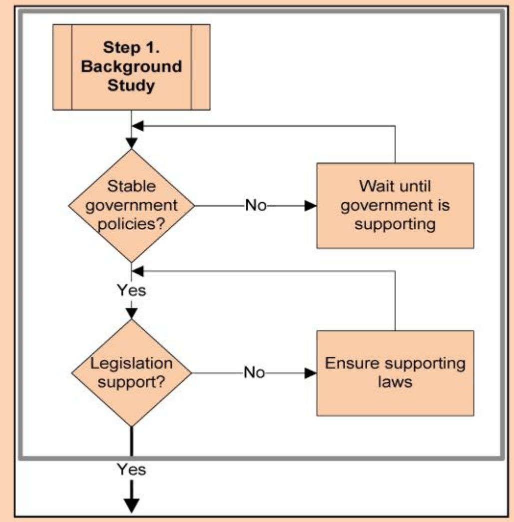
- ○ stable political situation and government policies
- ● somewhat stable political situation, sudden change of government policies not expected
- ○ unstable political situation, high risk of sudden change of government policies

1.II Is the legislation supporting changing taxes, privacy and other VMT related issues?

2

- ○ legislation is already in place
- ● legislation can be approved before the start of operation of the program
- ○ legislation covering these topics will not be available before the start of operation of the program

NEXT: continue to Step 2 - Feasibility Study (Step 2-a)



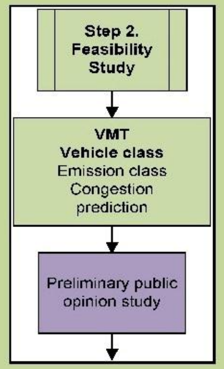
Step 2. - Feasibility Study

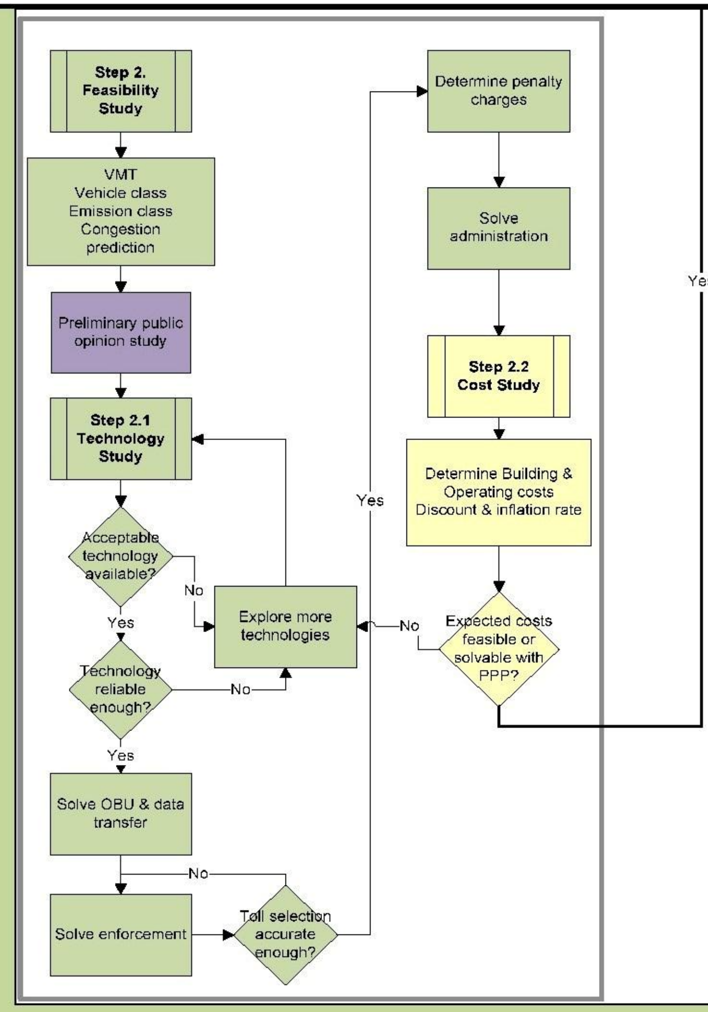
The feasibility study consists of gathering the data needed for VMT fee calculation.

2.I **Volume prediction**

Year	Gross VMT estimate [mi]
2001	219,266,000,000
2002	223,949,000,000
2003	222,744,000,000
2004	227,740,000,000
2005	234,470,000,000
2006	235,884,000,000
2007	240,194,000,000
2008	237,965,000,000
2009	237,421,000,000
2010	233,876,000,000
2011	237,384,140,000
2012	240,944,902,100
2013	244,559,075,632
2014	248,227,461,766
2015	251,950,873,692
2016	255,730,136,798
2017	259,566,088,850
2018	263,459,580,183
2019	267,411,473,885
2020	271,422,645,994
2021	275,493,985,683
2022	279,626,395,469
2023	283,820,791,401
2024	288,078,103,272
2025	292,399,274,821
2026	296,785,263,943
2027	301,237,042,902
2028	305,755,598,546
2029	310,341,932,524
2030	314,997,061,512
2031	319,722,017,435
2032	324,517,847,696
2033	329,385,615,412
2034	334,326,399,643
2035	339,341,295,637
2036	344,431,415,072
2037	349,597,886,298
2038	354,841,854,592
2039	360,164,482,411
2040	365,566,949,648

Types of values
from data-sheet
functions





2.II Vehicle class distribution

Light duty vehicle	89.06%
Single-unit truck	4.07%
Combination truck	5.68%

VMT [mi]	Light duty vehicle	Single-unit truck	Combination truck
2001	195,274,588,330	8,920,823,239	12,460,481,297
2002	199,445,188,866	9,111,350,796	12,726,607,527
2003	198,372,036,262	9,062,325,448	12,658,129,606
2004	202,821,389,300	9,265,587,389	12,942,043,047
2005	208,815,013,389	9,539,397,011	13,324,496,501
2006	210,074,297,856	9,596,925,510	13,404,851,506
2007	213,912,710,905	9,772,277,586	13,649,780,836
2008	211,927,601,233	9,681,590,863	13,523,110,888
2009	211,443,124,041	9,659,458,258	13,492,196,374
2010	208,286,007,043	9,515,230,158	13,290,740,579
2011	211,410,297,149	9,657,958,611	13,490,101,688
2012	214,581,451,606	9,802,827,990	13,692,453,213
2013	217,800,173,380	9,949,870,410	13,897,840,012
2014	221,067,175,981	10,099,118,466	14,106,307,612
2015	224,383,183,621	10,250,605,243	14,317,902,226
2016	227,748,931,375	10,404,364,322	14,532,670,759
2017	231,165,165,345	10,560,429,786	14,750,660,821
2018	234,632,642,826	10,718,836,233	14,971,920,733
2019	238,152,132,468	10,879,618,777	15,196,499,544
2020	241,724,414,455	11,042,813,058	15,424,447,037
2021	245,350,280,672	11,208,455,254	15,655,813,743
2022	249,030,534,882	11,376,582,083	15,890,650,949
2023	252,765,992,905	11,547,230,814	16,129,010,713
2024	256,557,482,799	11,720,439,276	16,370,945,874
2025	260,405,845,041	11,896,245,866	16,616,510,062
2026	264,311,932,716	12,074,689,554	16,865,757,713
2027	268,276,611,707	12,255,809,897	17,118,744,079
2028	272,300,760,883	12,439,647,045	17,375,525,240
2029	276,385,272,296	12,626,241,751	17,636,158,118
2030	280,531,051,380	12,815,635,377	17,900,700,490
2031	284,739,017,151	13,007,869,908	18,169,210,997
2032	289,010,102,408	13,202,987,957	18,441,749,162
2033	293,345,253,945	13,401,032,776	18,718,375,400
2034	297,745,432,754	13,602,048,268	18,999,151,031
2035	302,211,614,245	13,806,078,992	19,284,138,296
2036	306,744,788,459	14,013,170,176	19,573,400,371
2037	311,345,960,286	14,223,367,729	19,867,001,376
2038	316,016,149,690	14,436,718,245	20,165,006,397
2039	320,756,391,935	14,653,269,019	20,467,481,493
2040	325,567,737,814	14,873,068,054	20,774,493,715

NEXT: continue to Step 2. - Feasibility Study (continued) (Step 2-b)

Step 2. - Feasibility Study (continued)

The feasibility study consists of gathering the data needed for VMT fee calculation.

2.III **Emission class distribution**

BIN number	2 axles	3 axles	4+ axles
11	0.00%	0.00%	0.00%
10	0.00%	0.00%	1.91%
9	0.00%	0.00%	0.00%
8	0.69%	0.69%	62.58%
7	0.00%	0.00%	0.00%
6	0.00%	0.00%	0.00%
5	93.69%	93.69%	32.89%
4	4.79%	4.79%	2.62%
3	0.66%	0.66%	0.00%
2	0.17%	0.17%	0.00%
1	0.00%	0.00%	0.00%

Types of values
from data-sheet
functions

		VMT [mi]	
2001	**2 axles**	**3 axles**	**4+ axles**
BIN 11	0	0	0
BIN 10	0	0	237,995,193
BIN 9	0	0	0
BIN 8	1,347,394,659	61,553,680	7,797,769,196
BIN 7	0	0	0
BIN 6	0	0	0
BIN 5	182,952,761,807	8,357,919,293	4,098,252,299
BIN 4	9,353,652,781	427,307,433	326,464,610
BIN 3	1,288,812,283	58,877,433	0
BIN 2	331,966,800	15,165,400	0
BIN 1	0	0	0

		VMT [mi]	
2002	**2 axles**	**3 axles**	**4+ axles**
BIN 11	0	0	0
BIN 10	0	0	243,078,204
BIN 9	0	0	0
BIN 8	1,376,171,803	62,868,320	7,964,310,990
BIN 7	0	0	0
BIN 6	0	0	0
BIN 5	186,860,197,449	8,536,424,561	4,185,781,216
BIN 4	9,553,424,547	436,433,703	333,437,117
BIN 3	1,316,338,247	60,134,915	0
BIN 2	339,056,821	15,489,296	0
BIN 1	0	0	0

		VMT [mi]	
2003	**2 axles**	**3 axles**	**4+ axles**
BIN 11	0	0	0
BIN 10	0	0	241,770,275
BIN 9	0	0	0
BIN 8	1,368,767,050	62,530,046	7,921,457,507
BIN 7	0	0	0
BIN 6	0	0	0
BIN 5	185,854,760,774	8,490,492,712	4,163,258,827
BIN 4	9,502,020,537	434,085,389	331,642,996
BIN 3	1,309,255,439	59,811,348	0
BIN 2	337,232,462	15,405,953	0
BIN 1	0	0	0

		VMT [mi]	
2004	**2 axles**	**3 axles**	**4+ axles**
BIN 11	0	0	0
BIN 10	0	0	247,193,022
BIN 9	0	0	0
BIN 8	1,399,467,586	63,932,553	8,099,130,539
BIN 7	0	0	0
BIN 6	0	0	0
BIN 5	190,023,359,636	8,680,928,825	4,256,637,958
BIN 4	9,715,144,547	443,821,636	339,081,528
BIN 3	1,338,621,169	61,152,877	0
BIN 2	344,796,362	15,751,499	0
BIN 1	0	0	0

		VMT [mi]	
2005	**2 axles**	**3 axles**	**4+ axles**
BIN 11	0	0	0
BIN 10	0	0	254,497,883
BIN 9	0	0	0
BIN 8	1,440,823,592	65,821,839	8,338,469,910
BIN 7	0	0	0
BIN 6	0	0	0
BIN 5	195,638,786,044	8,937,461,059	4,382,426,899
BIN 4	10,002,239,141	456,937,117	349,101,808
BIN 3	1,378,179,088	62,960,020	0
BIN 2	354,985,523	16,216,975	0
BIN 1	0	0	0

		VMT [mi]	
2006	**2 axles**	**3 axles**	**4+ axles**
BIN 11	0	0	0
BIN 10	0	0	256,032,664
BIN 9	0	0	0
BIN 8	1,449,512,655	66,218,786	8,388,756,072
BIN 7	0	0	0
BIN 6	0	0	0
BIN 5	196,818,609,661	8,991,359,511	4,408,855,660
BIN 4	10,062,558,867	459,692,732	351,207,109
BIN 3	1,386,490,366	63,339,708	0
BIN 2	357,126,306	16,314,773	0
BIN 1	0	0	0

		VMT [mi]	
2007	**2 axles**	**3 axles**	**4+ axles**
BIN 11	0	0	0
BIN 10	0	0	260,710,814
BIN 9	0	0	0
BIN 8	1,475,997,705	67,428,715	8,542,032,847
BIN 7	0	0	0
BIN 6	0	0	0
BIN 5	200,414,818,847	9,155,646,870	4,489,412,917
BIN 4	10,246,418,852	468,092,096	357,624,258
BIN 3	1,411,823,892	64,497,032	0
BIN 2	363,651,609	16,612,872	0
BIN 1	0	0	0

		VMT [mi]	
2008	**2 axles**	**3 axles**	**4+ axles**
BIN 11	0	0	0
BIN 10	0	0	258,291,418
BIN 9	0	0	0
BIN 8	1,462,300,449	66,802,977	8,462,762,794
BIN 7	0	0	0
BIN 6	0	0	0
BIN 5	198,554,969,595	9,070,682,479	4,447,751,171
BIN 4	10,151,332,099	463,748,202	354,305,505
BIN 3	1,398,722,168	63,898,500	0
BIN 2	360,276,922	16,458,704	0
BIN 1	0	0	0

		VMT [mi]	
2009	**2 axles**	**3 axles**	**4+ axles**
BIN 11	0	0	0
BIN 10	0	0	257,700,951
BIN 9	0	0	0
BIN 8	1,458,957,556	66,650,262	8,443,416,491
BIN 7	0	0	0
BIN 6	0	0	0
BIN 5	198,101,062,914	9,049,946,441	4,437,583,387
BIN 4	10,128,125,642	462,688,051	353,495,545
BIN 3	1,395,524,619	63,752,424	0
BIN 2	359,453,311	16,421,079	0
BIN 1	0	0	0

		VMT [mi]	
2010	**2 axles**	**3 axles**	**4+ axles**
BIN 11	0	0	0
BIN 10	0	0	253,853,145
BIN 9	0	0	0
BIN 8	1,437,173,449	65,655,088	8,317,345,455
BIN 7	0	0	0
BIN 6	0	0	0
BIN 5	195,143,159,999	8,914,819,135	4,371,324,577
BIN 4	9,976,899,737	455,779,525	348,217,403
BIN 3	1,374,687,646	62,800,519	0
BIN 2	354,086,212	16,175,891	0
BIN 1	0	0	0

Congestion prediction and preliminary public opinion study (according to the flowchart) is not considered here.

NEXT: continue to Step 2.1 - Feasibility Study

Step 2.1 - Technology Study

The technology study deals with the selection of a technology, solves on-board-units, data transfer, enforcement, penalty charges and administration.

Types of values
from data-sheet
functions

2.1.I **Is there an acceptable technology available? (in terms of resource constraints)**

2

- ○ yes, the selected technology covers all requirements.
- ● yes, but there are some deficiencies.
- ○ no, none of existing technology was found acceptable.

2.1.II **Is the technology reliable enough?**

2

- ○ yes, the selected technology has acceptable reliability.
- ● yes, but the reliability should be improved.
- ○ no, the reliability is not sufficient.

2.1.III **OBU & data transfer** These costs are included in operating costs.

2.1.IV **Enforcement** These costs are included in operating costs.

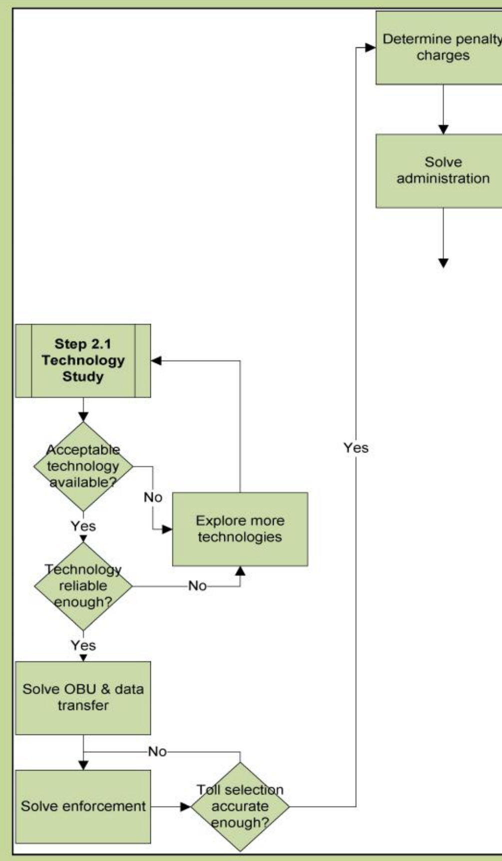
2.1.V **Penalty charges**

per year	number of	penalty	income
no OBU unit	230000	$500	$115,000,000
evasion	11000	$10,000	$110,000,000
violation 3	1000000	$300	$300,000,000
violation 4	7000	$200	$1,400,000

Total income from penalty charges	$526,400,000

2.1.VI **Administration** These costs are included in operating costs.

NEXT: continue to Step 2.2 - Cost Study



Step 2.2 -Cost Study

The costs study determines building and operating costs, discount rate and inflation rate.

2.2.I	**Building costs**	$5,000,000,000
2.2.II	**Operating costs**	$180,737,384
2.2.IV	**Inflation rate**	3.00%

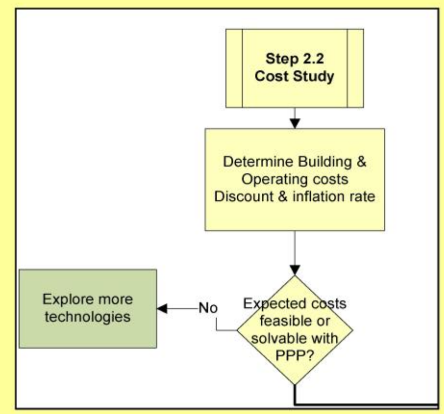
Types of values
from data-sheet
functions

2.2.IV **Are expected costs feasible or solvable with Public-Private-Partnership (PPP)?**

1

- (•) yes
- ( ) no

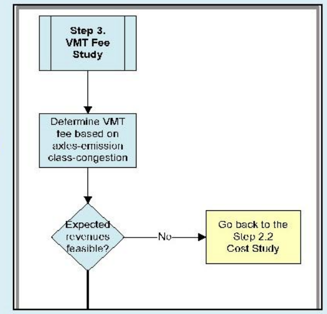
NEXT: continue to Step 3 - VMT Fee Study



Step 3. -VMT Fee Study

The aim of the VMT fee study is to determine the fee based on vehicle class and emission class.
The fee can also vary in time, to help with the congestion management, but in this case it is not considered.

Types of values
from data-sheet
functions



3.I How many miles per gallon travels each fleet?

Light duty vehicle - 2 axles	[mi/gal]
2001	22.1
2002	22.0
2003	22.2
2004	22.5
2005	22.1
2006	22.5
2007	22.5
2008	22.6
2009	0.0
2010	0.0

Average	22.3

Single-unit truck - 3 axles	[mi/gal]
2001	7.5
2002	7.4
2003	8.8
2004	8.8
2005	8.3
2006	8.2
2007	8.2
2008	8.5
2009	0.0
2010	0.0

Average	8.2

Combination truck - 4 axles	[mi/gal]
2001	5.4
2002	5.2
2003	5.9
2004	5.9
2005	5.2
2006	5.1
2007	6.0
2008	6.0
2009	0.0
2010	0.0

travels 4x less

Average	5.6

3.II What is the state fuel tax per gallon?

Texas	$0.200

3.III What is the current state fuel tax per mile for each fleet?

Light duty vehicle	$ 0.009
Single-unit truck	$ 0.024
Combination truck	$ 0.036

3.IV Determination of pricing levels

coefficient	2 axles	3 axles	4+ axles	
BIN 11-6	1.69	3.06	4.46	pays 4x more
BIN 5-3	1.25	2.40	3.47	
BIN 1-2	1.00	1.92	2.77	

3.V Determination of the VMT fee [$/mi]

	2 axles	3 axles	4+ axles
BIN 11-6	$0.0152	$0.0275	$0.0402
BIN 5-3	$0.0113	$0.0216	$0.0312
BIN 1-2	$0.0090	$0.0172	$0.0250

3.VI Estimated gross revenues for each category based on VMT fee

2001	2 axles	3 axles	4+ axles	2006	2 axles	3 axles	4+ axles
BIN 11-6	20,535,057	1,693,307	322,719,330	BIN 11-6	22,091,393	1,821,641	347,177,978
BIN 5-3	2,177,946,302	190,732,284	138,063,690	BIN 5-3	2,343,011,163	205,187,736	148,527,430
BIN 1-2	2,987,701	261,389	0	BIN 1-2	3,214,137	281,199	0
2002	**2 axles**	**3 axles**	**4+ axles**	**2007**	**2 axles**	**3 axles**	**4+ axles**
BIN 11-6	20,973,637	1,729,472	329,611,847	BIN 11-6	22,495,040	1,854,926	353,521,507
BIN 5-3	2,224,462,053	194,805,872	141,012,402	BIN 5-3	2,385,821,943	208,936,863	151,241,278
BIN 1-2	3,051,511	266,971	0	BIN 1-2	3,272,864	286,337	0
2003	**2 axles**	**3 axles**	**4+ axles**	**2008**	**2 axles**	**3 axles**	**4+ axles**
BIN 11-6	20,860,785	1,720,166	327,838,308	BIN 11-6	22,286,287	1,837,712	350,240,828
BIN 5-3	2,212,492,913	193,757,682	140,253,658	BIN 5-3	2,363,681,518	206,997,929	149,837,759
BIN 1-2	3,035,092	265,535	0	BIN 1-2	3,242,492	283,680	0
2004	**2 axles**	**3 axles**	**4+ axles**	**2009**	**2 axles**	**3 axles**	**4+ axles**
BIN 11-6	21,328,678	1,758,748	335,191,504	BIN 11-6	22,235,339	1,833,511	349,440,160
BIN 5-3	2,262,117,660	198,103,538	143,399,455	BIN 5-3	2,358,278,023	206,524,722	149,495,222
BIN 1-2	3,103,167	271,490	0	BIN 1-2	3,235,080	283,031	0
2005	**2 axles**	**3 axles**	**4+ axles**	**2010**	**2 axles**	**3 axles**	**4+ axles**
BIN 11-6	21,958,967	1,810,722	345,096,829	BIN 11-6	21,903,337	1,806,134	344,222,570
BIN 5-3	2,328,966,048	203,957,744	147,637,087	BIN 5-3	2,323,065,908	203,441,043	147,263,067
BIN 1-2	3,194,870	279,513	0	BIN 1-2	3,186,776	278,805	0

3.VII Estimated gross revenues in each year

	est. VMT revenues	real fuel tax revenues	difference	
2001	$2,854,939,061	$2,765,510,548	3%	
2002	$2,915,913,766	$2,833,607,460	3%	
2003	$2,900,224,139	$2,838,776,695	2%	
2004	$2,965,274,241	$2,917,706,870	2%	
2005	$3,052,901,780	$2,934,580,537	4%	
2006	$3,071,312,677	$2,993,569,575	3%	
2007	$3,127,430,759	$3,053,812,019	2%	
2008	$3,098,408,206	$3,101,526,779	0%	VMT revenues are not higher than from fuel tax! - set higher VMT fee
2009	$3,091,325,088	$3,032,770,482	2%	
2010	$3,045,167,640	$3,041,973,016	0%	
2011	$3,090,845,155			
2012	$3,137,207,832			
2013	$3,184,320,308			
2014	$3,232,029,939			
2015	$3,280,510,388			
2016	$3,329,718,044			
2017	$3,379,663,814			
2018	$3,430,417,331			
2019	$3,481,814,153			
2020	$3,534,041,365			
2021	$3,587,051,986			
2022	$3,640,857,766			
2023	$3,695,533,717			
2024	$3,750,902,692			
2025	$3,807,166,232			
2026	$3,864,273,726			
2027	$3,922,237,831			
2028	$3,981,139,359			
2029	$4,040,787,470			
2030	$4,101,399,282			
2031	$4,162,920,271			
2032	$4,225,364,075			
2033	$4,288,817,749			
2034	$4,353,075,704			
2035	$4,407,833,138			
2036	$4,484,647,418			
2037	$4,551,917,129			
2038	$4,620,274,757			
2039	$4,689,498,824			
2040	$4,759,841,306			

NEXT: continue to Summary

Summary

1. **Background Study**

1.I **In Texas the government policies situation for VMT fee implementation were evaluated as:**

somewhat stable, as the political situation is not entirely predictable, but still is believed to stay stable.
In this environment it is recommended to sign a deal by all governing parties, where they promise to continue with the VMT program even if the government changes.

1.II **The legislation supporting changing taxes, privacy and other VMT related issues:**

can be approved before the start of operation of the program.

2.1 **Technology Study**

2.1.I **An acceptable technology:**

was found, but it has some deficiencies that will have to be solved.

2.1.II **The selected technology reliability was evaluated as:**

improvable. Currently the reliability is about to reach the desired level, but more improvements need to be done.

2.2 **Cost Study**

2.2.I	**Building costs were estimated at:**	$5,000,000,000
2.2.II	**Operating costs were estimated at:**	$180,737,384
2.2.III	**Inflation rate was estimated at:**	3.00%
2.2.IV	**Expected costs are feasible or solvable with a PPP contract.**	

3 VMT Fee Study

If considering following fees:

BIN	Light-Duty Vehicle	Single-Unit Truck	Combination Truck
6-11	$0.015	$0.028	$0.040
3-5	$0.011	$0.022	$0.031
1-2	$0.009	$0.017	$0.025

Then the estimated gross revenues are:

	gross VMT revenues	real fuel tax revenues	difference
2001	$2,854,939,061	$2,765,510,548	103%
2002	$2,915,913,766	$2,833,607,460	103%
2003	$2,900,224,139	$2,838,776,695	102%
2004	$2,965,274,241	$2,917,706,870	102%
2005	$3,052,901,780	$2,934,580,537	104%
2006	$3,071,312,677	$2,993,569,575	103%
2007	$3,127,430,759	$3,053,812,019	102%
2008	$3,098,408,206	$3,101,526,779	100%
2009	$3,091,325,088	$3,032,770,482	102%
2010	$3,045,167,640	$3,041,973,016	100%
2011	$3,090,845,155		
2012	$3,137,207,832		
2013	$3,184,320,308		
2014	$3,232,029,939		
2015	$3,280,510,388		
2016	$3,329,718,044		
2017	$3,379,663,814		
2018	$3,430,417,331		
2019	$3,481,814,153		
2020	$3,534,041,365		
2021	$3,587,051,986		
2022	$3,640,857,766		
2023	$3,695,533,717		
2024	$3,750,902,692		
2025	$3,807,166,232		
2026	$3,864,273,726		
2027	$3,922,237,831		
2028	$3,981,139,359		
2029	$4,040,787,470		
2030	$4,101,399,282		
2031	$4,162,920,271		
2032	$4,225,364,075		
2033	$4,288,817,749		
2034	$4,353,075,704		
2035	$4,407,833,138		
2036	$4,484,647,418		
2037	$4,551,917,129		
2038	$4,620,274,757		
2039	$4,689,498,824		
2040	$4,759,841,306		

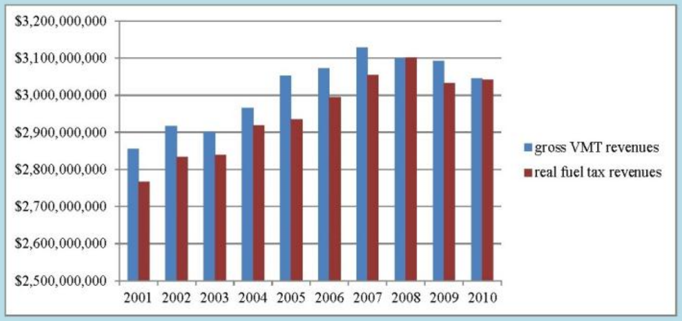
penalty income +	$526,400,000
operating costs -	$180,737,384

Estimated net revenues (incl. penalty income, operation costs and discount rate)

	net VMT revenues	real fuel tax revenues	difference
2001	$3,107,380,269	$2,765,510,548	112%
2002	$3,074,348,555	$2,833,607,460	108%
2003	$2,970,446,191	$2,838,776,695	105%
2004	$2,941,724,514	$2,917,706,870	101%
2005	$2,931,631,502	$2,934,580,537	100%
2006	$2,861,663,013	$2,993,569,575	96%
2007	$2,823,942,741	$3,053,812,019	92%
2008	$2,718,781,310	$3,101,526,779	88%
2009	$2,634,164,885	$3,032,770,482	87%
2010	$2,523,096,160	$3,041,973,016	83%
2011	$2,743,743,394		
2012	$2,696,346,387		
2013	$2,649,893,330		
2014	$2,604,253,657		
2015	$2,559,519,364		
2016	$2,515,634,841		
2017	$2,472,581,936		
2018	$2,430,377,328		
2019	$2,388,900,529		
2020	$2,348,237,843		
2021	$2,308,338,386		
2022	$2,269,186,063		
2023	$2,230,797,118		
2024	$2,193,060,311		
2025	$2,156,056,548		
2026	$2,119,739,229		
2027	$2,084,094,057		
2028	$2,049,136,777		
2029	$2,014,764,640		
2030	$1,981,053,439		
2031	$1,947,960,458		
2032	$1,915,472,988		
2033	$1,883,606,213		
2034	$1,852,265,193		
2035	$1,817,775,604		
2036	$1,791,334,101		
2037	$1,761,693,526		
2038	$1,732,613,753		
2039	$1,704,007,019		
2040	$1,675,939,716		

Expenditures excl. discount rate

2001	$2,978,835,811
2002	$3,268,511,724
2003	$3,287,666,757
2004	$3,492,941,281
2005	$4,630,402,241
2006	$5,132,818,911
2007	$5,359,397,359
2008	$5,208,591,565
2009	$4,252,879,534
2010	$3,353,467,064



Estimated building costs

$5,000,000,000

Estimated net revenues minus expenditures (both incl. discount rate)

	est. VMT revenues	total balance incl. building costs
2001	$215,306,666	-$4,784,693,334
2002	-$6,537,225	-$4,791,230,560
2003	-$38,234,620	-$4,829,465,180
2004	-$161,708,574	-$4,991,173,753
2005	-$1,062,594,147	-$6,053,767,900
2006	-$1,436,992,017	-$7,490,759,917
2007	-$1,533,737,757	-$9,024,497,675
2008	-$1,392,928,969	-$10,417,426,644
2009	-$625,313,150	-$11,042,739,794
2010	$27,801,724	-$11,014,938,070
2011	$309,014,357	-$10,705,923,713
2012	$320,712,715	-$10,385,210,998
2013	$331,920,669	-$10,053,290,329
2014	$342,542,469	-$9,710,747,860
2015	$352,704,079	-$9,358,043,782
2016	$362,383,033	-$8,995,660,748
2017	$371,593,521	-$8,624,067,227
2018	$380,383,778	-$8,243,683,449
2019	$388,664,104	-$7,855,019,345
2020	$396,550,845	-$7,458,468,500
2021	$404,022,433	-$7,054,446,067
2022	$411,091,370	-$6,643,354,697
2023	$417,801,811	-$6,225,552,886
2024	$424,069,745	-$5,801,483,141
2025	$430,002,646	-$5,371,480,495
2026	$435,579,838	-$4,935,900,657
2027	$440,812,322	-$4,495,088,335
2028	$445,740,521	-$4,049,347,814
2029	$450,285,769	-$3,599,062,044
2030	$454,547,356	-$3,144,514,688
2031	$458,505,494	-$2,686,009,194
2032	$179,477,666	-$2,506,531,528
2033	$465,577,416	-$2,040,954,112
2034	$468,654,571	-$1,572,299,542
2035	$467,747,764	-$1,104,551,778
2036	$474,073,927	-$630,477,851
2037	$476,405,687	-$154,072,165
2038	$478,522,220	$324,450,055
2039	$480,354,601	$804,804,656
2040	$481,987,599	$1,286,792,256

Estimated break-even year

2038
2039
2040

CURRICULUM VITA

Markéta Vavrová was born in Kadan, Czech Republic. In 2010 she received her Bachelor's Degree of Transportation Engineering in Automation and Informatics from the Czech Technical University in Prague. In the fall of 2011 she entered the Graduate School at the University of Texas at El Paso as a dual master student in the ATLANTIS program in cooperation with the Czech Technical University in Prague.

Permanent address: Dobiasova 857/8

Liberec, Czech Republic, 46006

This thesis/dissertation was typed by Markéta Vavrová.