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Final Report

**FORECASTING OF HIGHWAY REVENUES UNDER
VARIOUS OPTIONS**

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Forecasting of Highway Revenues under Various Options

Introduction

The imminent shortfall in highway revenue motivates efforts to improve the current funding mechanism and/or to search for alternative options. In the U.S., as well as internationally, financing tools other than the traditional tax system (i.e., motor fuel taxes and vehicle registration fees) are attracting a great deal of attention for their potential as highway revenue sources.

To establish and implement an effective and efficient financing strategy, it is required to envisage the possible outcomes of financing schemes in terms of their impacts on revenue stream and highway users and to study the sensitivity of those outcomes with respect to changes in external factors. This present study provides forecasts of future revenue streams under various highway financing scenarios. Both long-term and short-term forecasting approaches were considered.

Findings

Models to estimate expected highway revenues from the existing sources, indicate that, if no change is made to the tax rate, fuel revenue will continue to decline due to enhancement in vehicle fuel efficiency.

Proposed modifications to the existing revenue sources included an increase in the fuel tax rates, inflation-indexing of the tax rates and an introduction of ad valorem tax. These changes were found to increase revenue only in the short-term but in the medium to long-term, expected revenues will continue to dwindle due to continued increased in fuel efficient vehicles.

In the medium to long-term, new financing options need to be considered, especially to replace the fuel tax structure. These new sources must be efficient, effective and equitable to road users. In this present study, two new revenue

sources were identified (VMT fees and weight-distance truck fees). The fees from these new sources were determined by dividing the existing fuel tax rate for each vehicle category by the vehicle's fuel efficiency. This approach was considered reasonable because the resulting rates would make the fees revenue neutral in the implementation year. In order to evaluate the impact of these new revenue sources on the users, a series of sensitivity analysis was conducted.

Apart from these new sources that could be classified as substitutes for the existing fuel tax structure, other supplementary revenue sources were also considered and analyzed. These supplementary sources included tolling, congesting pricing and cordon pricing. Tolling and congestion pricing were considered for urban interstates while

cordon pricing was considered for downtown Indianapolis.

In order to incorporate the forecasting models and procedures discussed in this report, the existing INDOTREV-1 software package was

revised to provide INDOTREV-2. In addition to forecasting highway revenues from existing sources, INDOTREV-2, can be able to predict possible revenues and conduct preliminary impact analysis from alternative highway revenue sources.

Implementation

The software will be used by the Economic and Contract Audit Division of INDOT.

The INDOTREV-2 software package has been tested and used by the INDOT staff. As a part of the implementation plan it should be further enhanced with augmented data when available.

The research results can be used for further studies which will be necessary to design properly any of the options considered. For example, the VMT fee implementation will require legislative approval and procedures for collecting the fee and associated technologies should be identified. The weight-distance truck fee implementation will require a highway cost allocation study to ascertain an equitable fee structure among vehicle weight classes, along with the identification of necessary legal and technological requirements.

Tolling implementation requires legislative approval as well as identification of candidate interstates and the determination of appropriate toll fees. In addition, congestion pricing implementation will require detailed study of the physical and traffic characteristics of each of the identified roadways. The feasibility study should identify the traffic and traffic mix distribution for the selected interstates. Furthermore, a willingness-to-pay study of road users should also be carried out to determine the fee structure. Similarly, cordon pricing for downtown Indianapolis will require a study of the actual traffic distribution and traffic mix during peak hours. A willingness-to-pay survey should also be undertaken and procedures for administration of the pricing scheme should be determined.

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The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Indiana Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification or regulation

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16. Abstract <p>Throughout the United States, state highway revenue, which is dominated by receipts from fuel taxes, has failed to keep up with expected investments required for infrastructure preservation and improvement. The reasons for this trend include the increasing fuel efficiency of vehicles, slowing of the growth in vehicle-miles of travel, and the erosion of the purchasing power of the dollar due to inflation. This development motivates highway agencies not only to seek revisions of existing funding structures but also to consider potential alternative sources.</p> <p>To establish and implement an effective and efficient financing strategy that incorporates potential new funding sources, it is necessary to model the possible outcomes of these sources in terms of their impacts on revenue stream and to study the sensitivity of these outcomes with respect to changes in key revenue factors such as vehicle-miles of travel and fuel price. In addressing this issue, this study utilizes data on amounts of travel, fuel price, and other primary information to enhance the existing models for state highway revenue forecasting in Indiana.</p> <p>To facilitate implementation of the study results, the existing revenue forecasting software package has been enhanced to include traditional and new revenue sources, to estimate revenue under several different scenarios, and also to analyze sensitivity of revenue to changes in input factors such as fuel price, per capita income, gross domestic product, driving age population, and traffic growth rate. The package provides annual forecasts for both existing and alternative highway revenue sources in Indiana. Short range forecasts for fuel tax revenues are also estimated.</p>					
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CHAPTER 1 INTRODUCTION

1.1 Background

The current and imminent shortfall in highway revenue motivates efforts to improve the current funding mechanism and/or to search for alternative options. To establish and implement an effective and efficient financing strategy, it is required to envisage the possible outcomes of financing schemes in terms of their impacts on revenue stream and highway users and to study the sensitivity of those outcomes with respect to changes in external factors.

This present study provides forecasts of future revenue streams under various highway financing scenarios. In the early 1991, INDOTREV, the highway revenue forecasting model for Indiana, was developed to mimic the highway financing system in Indiana and to predict future revenues from gasoline tax, special fuel, motor carrier surcharge tax, motor carrier fuel use tax and vehicle registration fees under steady state economic conditions (Varma et al., 1991). This model is almost two decades old and needs to be modified in order to improve the reliability of prediction and to accommodate new features, such as scenario-based analysis, increased user flexibility, and sensitivity analysis. The present study updated the existing model and incorporated possible new funding sources. Both long-term and short-term forecasting approaches were considered. Long-term forecasting models are needed for planning purposes while short-term forecasts, ranging from about 1 to 3 years, are useful for budgeting and cash flow management purposes.

In this report, the forecasting model developed in 1991 will be called INDOTREV-1 and the revised forecasting model developed based on the current study will be called INDOTREV-2. In addition to the improvement of the existing revenue forecasting model, INDOTREV-2 will be able to predict revenue and conduct preliminary impact analysis from alternative highway revenue sources. In the U.S., as well as internationally, financing tools other than the traditional tax system (i.e., motor fuel taxes and vehicle registration fees) are attracting a great deal of attention for their potential as highway revenue sources. Such candidates include value pricing schemes, such as distance-based pricing schemes, weight-

distance truck fees, tolling and congestion pricing. These various financing tools are characterized differently in terms of regions and user groups, implementation costs, and external factors that affect the revenue.

Taking into account these characteristics, the present study evaluates options for possible consideration in Indiana. For the identified pricing strategies, revenue estimation procedures were developed and the sufficiency and stability of future revenue streams were analyzed. In many cases, new pricing schemes would require planning procedures before their implementation, including legislation, installment of equipment, pilot studies and public input, which would take a significant amount of lead time.

1.2 Study Objectives

The aims of this study are:

- a. revise and enhance the existing highway revenue forecasting models;
- b. identify alternative financing strategies;
- c. develop tools to forecast revenues from alternative financing strategies;
- d. compare outcomes of various revenue options;
- e. formulate adequate and sustainable long-term financing options by evaluating and comparing alternatives that would include new revenue sources either as a complement or replacement of the current system; and
- f. perform revenue sensitivity analysis with respect to changes in the external factors under both near- and long-term scenarios.

1.3 Organization of the Report

This report has six chapters. Review of existing literature and the study framework related to the concepts of highway financing, alternative sources for highway revenue generation and highway revenue forecasting studies are discussed in Chapter 2.

Chapter 3 describes data requirements including data types used to develop the updated VMT, registrations and other models. Chapter 3 also includes a description of the requisite data collected and identifies the existing highway revenue sources. In addition,

the disbursement structures for highway revenue and the methodology for forecasting highway revenue within Indiana are discussed.

Chapter 4 presents an overview of the modeling approaches used for predicting revenue based on vehicle-miles of travel and registration. The statistical approaches used for preparing the models, assumptions and the statistical significance of the model variables are also expatiated with model results given and discussed. Validation for each model is presented in this chapter. The estimated highway revenues and disbursements into the various highway accounts, within the forecasting period, are discussed.

Chapter 5 considers possible modifications to the existing fuel tax rate structure. Alternative financing options for generating revenue over the analysis period for short to long terms are also presented in this chapter. Comparison and discussion are presented between the expected revenue from the alternative and existing revenue sources. This chapter also discusses the performance of highway revenue sensitivity analysis with respect to changes in the external factors. Summary of the report, conclusions and future research recommendations are presented in Chapter 6.

CHAPTER 2 BACKGROUND INFORMATION

2.1 Introduction

This chapter reviews past studies on revenue forecasting study framework related to the concepts of highway financing, as well as the justification for updating the existing models within the highway revenue forecasting package of INDOTREV-1. Finally, a general description of the existing highway revenue sources in the state of Indiana and the forecasting methodology is presented.

2.2 Highway Revenue Forecasting in the USA

The State of Oregon was the first to implement a fuel tax as a “user tax” and source of revenue for roadway projects in 1919. By 1929, all of the states with the exception of Hawaii and Alaska (not yet states) had some form of tax on fuel purchases. In 1932, the federal gasoline tax was implemented on a temporary basis and then made permanent with the Revenue Act of 1941 (Williams, 2002). The departments of transportation (DOTs) in several states, within the late 1980s and the early 1990s, encountered challenges coming from the reduction in revenues due to the instability of highway revenue sources such as motor fuel taxes, uncertainties in project costs due to economic instability and increasing construction, maintenance, and operation costs. Many states developed and periodically updated forecasts of various revenue sources for planning and budgeting purposes. Ever since, the process of revenue forecasting has become an important function and transportation agencies have used the process to undertake initiatives to enhance revenues as well as to improve the equity and efficiency of various taxes and promote private investment for various planned projects (DCID, 2005).

Most states use linear regression time-series models to directly project revenue, while a few states have developed highway revenue forecasting models based on a series of regression relationships that describe the influence of socio-economic conditions (Varma et

al., 1991). A broad method for forecasting state transportation revenues for six states was discussed by Reno et al. (1981). In that study, the emphasis was placed on estimating the primary revenue determinants, which were motor fuel consumption, motor vehicle registration, and licensed drivers. It was found that the registration of vehicles was sensitive to the income level and state economy. Motor fuel consumption was found to be sensitive to fuel price, federal automobile and light truck fuel economy standards, the number of registered vehicles, and the percentage of light trucks and automobiles. Population and economic factors were found to be the driving forces that affect vehicle ownership, travel behavior and vehicle use (Reno et al., 1981; Varma et al., 1991).

Real per capita income, driver age population, average vehicle fuel efficiency, real price of motor fuel, real personal income, U.S. industrial production, auto sales, highway vehicle registrations, U.S. consumer price index, and appropriate price indices were the indicators used by various states for developing motor fuel and registration related revenues (Hobeika et al., 1981; Warner, 1990; Varma et al., 1991).

2.3 Highway Revenue Studies in Indiana

In the mid 1970s, a state highway finance and user taxation study was conducted for Indiana (McCarthy, 1976) whereby population was used as the input variable in the calibration of vehicle miles of travel and vehicle registration models. Mannering and Sinha (1979) developed a methodology to evaluate the impact of energy prices, the national economy and public policies on state highway financing and performance in Indiana. The study developed a fleet fuel efficiency modeling procedure where the auto fleet was categorized by the model year, and a cohort survival technique was applied to project annually the auto population by age. The procedure considered survival rate changes, the relative miles of travel by automobile by model year, and model year fuel efficiencies. A detailed Indiana highway cost allocation study was conducted in mid-1980s to develop cost responsibilities and revenue attribution for various different vehicle classes (Sinha et al., 1985), and the findings of that study were used to revise the highway financing/funding policies in Indiana (Sinha et al., 1986).

Based on the modeling concept developed earlier for the various states, Varma et al. (1991) developed models for predicting vehicle miles of travel and vehicle registration which were used to predict highway revenue. The expected motor fuel tax revenue was estimated

from vehicle miles of travel and fleet fuel efficiencies. Vehicle fleet fuel efficiencies were determined using the approach derived earlier (Mannering and Sinha, 1979). An interactive software package “INDOTREV”, labeled as INDOTREV-1 in the present report, was developed. INDOTREV-1 provided short-term and long-term forecasts of highway revenues from motor fuel tax rate and vehicle registration fees. The disbursement ratios and formulas in effect in the late 1980s were employed to estimate highway revenues for the various highway accounts within Indiana.

Other revenue related studies (Sinha et al., 2005) were conducted to assess fiscal needs where models by Varma et al. (1991) were updated and used. Forecasted highway revenues from the updated models pointed to the fact that there was a need to identify alternative highway revenue sources which would be sustainable, adequate and equitable to road users. A recent study (Oh and Sinha, 2008) identified the need for Indiana to gradually move from the traditional unstable highway revenue sources (such as motor fuel tax) to alternative highway revenue sources (such as VMT fees).

The existing highway revenue sources for Indiana currently include gasoline tax, special fuel tax, motor carrier surcharge tax, motor carrier fuel use tax, vehicle registration and others (permits, international registration plan, state court fees, etc). The study (Oh and Sinha, 2008) proposed increasing or indexing of the existing motor fuel tax rates in the short-term, while introducing alternative revenue sources, such as VMT fees, in the long-term.

2.4 Past Studies of Alternative Highway Revenue Sources

Amid growing concerns over the long-term sustainability of the fuel tax as the primary mechanism for funding roadway programs at the state and federal level, exploration of various alternative taxing mechanisms is gaining interest (Baker et al., 2008). The past decade has been particularly challenging as transportation agencies coped first with rapid traffic growth during the economic boom of the 1990s and then with stagnant revenues and state government fiscal crises (TRB, 2006). The 2006 TRB study reiterated the need for reviewing the traditional or existing highway revenue sources to include alternative sources and recommended that, although in the next decade, the nation would continue to rely on the present framework of transportation funding, there was an urgency to start planning and implementing alternative highway financing schemes which

are sustainable and adequate in the long-term. Furthermore, the study (TRB, 2006) concluded that cost allocation studies should be used to estimate the user fee for each vehicle class based on the damage done on the highways and finally, charging road users for vehicle miles of travel would allow for equity. Possible alternative revenue sources identified from studies (Oh and Sinha, 2008; Sisiopiku et al., 2006; Sorensen and Taylor, 2005; Whitty, 2003; Verhoef, 1997; Giuliano, 1994) include: vehicle miles of travel fees, weight-distance truck fees, tolling and congestion pricing (cordon pricing, high occupancy toll (HOT) lanes, etc).

While some of the alternative sources may generate sufficient revenues, concerns have been raised on a number of pertinent problems including invasion of privacy of road users, institutional governance issues, political and public acceptance, pricing policy and implementation issues (Sorensen and Taylor, 2005). These concerns are legitimate and recent studies (Oh and Sinha, 2008; Sorensen and Taylor, 2005; Whitty, 2003) have shown that the concerns can be addressed. For instance, privacy protection could be implemented through both technological and legal means.

The institutional governance issues pertain to administration, technological provision and the supervision of the program (Sorensen and Taylor, 2005). Several approaches used were successful based on the jurisdiction and implementation of the institutional governance can be done via public-private partnership or solely private or public.

Alternative pricing approaches such as VMT fee can be implemented either by instant rollout (as in the case used in the Swiss and Austrian truck toll programs where all domestic users were required to install the on-board equipment at the onset of the program) or the rollout can be phased in over a period of time as followed in the case of Oregon distance tolls project (Sorensen and Taylor, 2005).

2.5 Concept and Case Studies of Alternative Revenue Sources.

2.5.1 Vehicle-Miles-Traveled (VMT) Fees

This concept states that “you pay for the mileage you travel” and it is a direct way of asking road users to pay for using the road network. This form of charging is

usually a fixed rate per vehicle type per mile regardless of the level of congestion. However, the level of congestion can be included into the charging scheme to manage the demand along congested routes. Integrating the level of congestion pricing scheme will require pre-defined areas designated as congested and the requisite technological infrastructure.

A feasibility and demonstration study of a mileage based fee program was recently conducted in the State of Oregon (Whitty, 2007). In 2001, the Road User Fee Task Force was formed by a mandate from the Oregon State Legislature. The objectives of the task force included the feasibility of replacing the fuel tax with a mileage based fee.

In April 2006, a 12-month pilot program was designed to test the feasibility of the system using in-vehicle units featuring GPS receivers and short wave radio communications. A total of 285 trial vehicles and two service stations in Portland were included in the pilot program. The trial concluded that if the program were extended statewide, 91 percent of the users would be willing to pay the mileage-based fee instead of the current fuel tax, the program would result in a 22 percent reduction in peak hour travel, privacy of participants could be protected, evasion potential would be minimal and paying at the pump would be viable as it worked well during the trial. The mileage fee received can be collected from equipped vehicles whilst non-equipped vehicles can continue paying the current fuel tax. This indicates that the mileage fee can be phased in gradually alongside the current fuel tax. However, one big challenge is that retrofitting of vehicles can be found to be expensive and difficult (Whitty, 2007).

2.5.2 Weight-Distance Truck Fees

This type, part of the broader concept called pay-as-you-drive, seeks to recover the cost associated with the operation of heavy vehicles on the road network. Fees are imposed on heavy vehicles based on their respective weight and the distance traveled on the road network. The unit cost per mile traveled by a heavy vehicle is directly linked to the vehicle class and weight (i.e. actual weight, maximum weight or axle configuration). Based on equity pricing, this option is more desirable than fuel taxes for heavy vehicles because the roadway costs imposed by trucks are more accurately reflected under this scheme.

A very few states collect some form of weight truck tax. However, Oregon is the only state that charges heavy trucks exclusively on the basis of weight-distance tax while the other states use such a tax in addition to diesel fuel tax (Adkins, 2000).

Truck-only lane is another possible near-term application of specialized toll facility only on Interstate routes with heavy truck traffic. An analysis conducted in 2002 of such facilities estimated the potential productivity gains of truck-only toll lanes on long distance Interstate routes and concluded that in many cases truckers would willingly pay tolls in the range of 40 to 80 cents per mile to obtain the increased payload benefits (Samuel et al., 2002). The study proposed that longer combination vehicles (for example, a tractor pulling two full-sized semitrailers) be required to use the truckways but conventional heavy trucks, which are legal on all Interstates, have the option of using either the truck-only lanes or the regular lanes. The rationale for such facilities is partly fiscal and partly operational. The operational rationale is a combination of safety and productivity. Separation of cars from heavy trucks is expected to produce significant safety gains. Also, if heavy trucks operate in barrier separated lanes, there should be fewer safety objections to longer and heavier combination vehicles, which can significantly increase the productivity of trucking by permitting a single rig and driver to haul increased payloads.

In urban areas, relief from freeway congestion should further enhance productivity gains to truckers. The voluntary approach, with free lanes and toll lanes accessible to conventional trucks, might have more success in gaining trucking industry support than mandatory tolls, which the industry has opposed (McNally, 2005).

Truck-only toll lanes feature in the plans of several public agencies. In 2005 the Virginia Department of Transportation was considering proposals of a private sector bidder for an \$11 billion project to add two truck-only toll lanes in each direction to all 325 miles of I-81 in Virginia. The possible tolling of all lanes on I-81 was considered as part of this project (Bowman, 2004). Although the I-81 tier final environmental impact statement prepared by the Virginia Department of Transportation (VDOT) was approved in early June 2007 by the FHWA, the proposal to build separate truck lanes is no longer under consideration. However, the Commonwealth Transportation Board, the policy board for VDOT, has directed the Virginia Department of Rail and Public Transportation to conduct freight rail study on I-81 in order to identify short-term rail improvements and to study possible long-term diversion of truck traffic to rail (VDOT, 2007). In Texas, the first of a number of long-distance trans-Texas corridors entered the negotiation stage with the Texas

Department of Transportation's selection of a winning bidder for the first major segment of the corridor that will parallel I-35. This \$6 billion project will initially build a four-lane divided toll highway open to all traffic. When it is subsequently expanded to as many as 10 lanes, the original four lanes will become truck-only lanes (Powers, 2004). The final environmental impact statement (FEIS) for the trans-Texas corridor-35 project was released in April, 2010 and it is out for public hearings (TxDOT, 2010).

2.5.3 Road Tolls

A road toll is a classic way of funding highway and bridge maintenance or improvement. This method generally involves road or bridge facilities constructed and maintained by private companies or quasi public authorities, with the tolls going into recouping the construction and maintenance cost. Tolls collected from the facility users are committed to the costs associated with the facility; hence, it is considered to be more equitable and economically efficient than some other funding options.

The first privatization agreement of an existing toll road in the U.S was the Chicago Skyway in Illinois. The Chicago Skyway connects Indiana Toll Road on the east end and Interstate 90 at the Dan Ryan Expressway on the west end. The 7.8-mile toll road, which was previously publicly-owned toll road, served 17.4 million motorists to yield \$39.7 million dollars in 2003. In 2005, the city of Chicago leased the road for 99-years at a price of \$1.83 billion to the Skyway Concession Company (SCC), a joint-venture between Australian Macquarie Infrastructure Group and Spanish Cintra Concesiones de Infraestructuras de Transporte S.A. (Oh and Sinha, 2008). From 8 am to 4 pm, tolls range from \$3.0 (for two axle vehicle) to \$17.7 (for vehicles with 7 or more axles). Although tolls are not different for two axle vehicles, from 4 pm to 7:59 am vehicles with multiple axles pay up to \$12.6 in March, 2010 (Chicago Skyway, 2010).

The 157-mile Indiana Toll Road stretching from the northern part of Indiana and connecting part of the New York-Chicago toll road system, was leased at a price of \$3.85 billion to a consortium, Indiana Toll Road Concession Company, made up of Macquire Infrastructure Group, from Australia and Cintra, a Spanish construction firm, for 75 years. From 1981 to 2006, Indiana Department of Transportation operated the highway which carries a significant volume of heavy trucks with an average daily traffic of 145,000. The concessionaire agreement includes implementation of over \$770 million in planned

upgrades to the expressway. The mode of payment on the toll road is either by I-Zoom (an electronic toll collection system) or by cash. A toll for an automobile is either \$4.15 (using an I-Zoom) or \$6.15 (by cash) along the section from Portage to East point, with an extra \$0.50 (for I-Zoom users) and \$1.25 (for users who pay by cash) at the WestPoint barrier (Oh and Sinha, 2008). Vehicles with 7 or more axles traversing the total 157 miles will be expected to pay a toll of \$69.75 in March, 2010 (ITR, 2010).

2.5.4 Congestion Pricing

It is a form of value pricing and it seeks to charge road users higher prices under congested conditions and relatively lower fees or no fees under uncongested conditions. This concept aims at reducing peak-period traffic volumes to the most favorable levels. Tolls are structured either as a fixed amount or a variable amount as per the level of congestion that exists during a particular period. The motive behind congestion pricing is to primarily manage demand so as to avoid the need to add capacity. In some highway corridors, a blend of value priced lanes and unpriced lanes has been implemented. This allows road users to select whether to drive through a congested lane without paying a toll or drive in a less uncongested lane and paying a value fee. Congestion pricing schemes are currently structured in four ways: area-wide charges, cordon pricing, variably priced lanes and variable tolls on entire roadways.

Area-wide pricing involves variable charges imposed on vehicles for using the highway system. The charges, paid per mile traveled, vary according to the level of congestion experienced by the vehicle when it is driven within an area or roadway network. This form of charging is similar to the VMT fee discussed in Section 2.5.1 but the difference is that the pricing per mile is not fixed but varies based on the level of congestion experienced by the vehicle.

Cordon toll is a variation of area-wide pricing where fees are paid by motorists to drive in a particular area, usually a central business district. It is not uncommon to have cordon tolls apply during peak periods and some periods within off-peak periods. This could be implemented by requiring vehicles driven within the cordon to display a pass, or by tolling at each entrance to the area. Cordon pricing practiced in Singapore, Stockholm, Central London, Rome and Norway were found to be effective in travel time delay

reduction, exhaust emission reduction. Additional impacts of such a pricing scheme can be increased use of public transportation and generation of revenue (FHWA, 2009).

In 1975, Singapore became the first country to introduce cordon pricing. A \$1 peak period fee was imposed on single occupancy private vehicles entering into the central business district during the morning rush hour. Freight vehicles, motorcycles, buses and carpools were exempted from the charges. The impact was a 73-percent reduction in single occupancy private car usage, doubling of trips by transit and a 30% increase in carpool. In 1998, an automated electronic charging system was introduced in the city, in which vehicles can be tracked from the use of cameras and license plate reading equipments via in-vehicle electronic devices. Payment is made through smart card. The resultant effect included 13-percent traffic reduction and increased vehicle speed by 22-percent (USGAO, 2003; FHWA, 2009).

The Stockholm city pricing scheme was designed to charge motorists not only during peak periods but also during some portions of off-peak periods. The pricing scheme is enforced from 6:30 am to 6:29 pm where a motorist, who enters or uses the city center, is expected to pay an amount ranging from \$1.38 to \$2.76 (highest amount during peak hours) and after that it is free (from 6:30 pm to 6:29 am). In order to implement the full scale pricing scheme, a pilot study was conducted in 2006. Although public acceptance was about 30% before the pilot study, the acceptance rate increased to 52% after the pilot study. The cordon pricing became permanent in August, 2007 after residents voted for its implementation in a referendum in September, 2006. During the pilot implementation (from January to July, 2006), the following results were reached: 14% reduction in exhaust emissions in the inner city, 22-percent decrease in vehicle trips, decrease in travel time coupled with a 9-percent rise in public transit ridership and injury-related traffic accidents fell by 5 to 10 percent (Hugosson et al., 2006; FHWA, 2009)

Central London in February 17, 2003 implemented a cordon pricing scheme where motorists, who drive within the 15-square mile area of West and Central London cordon from 7:00 a.m. to 6:30 p.m of weekdays, are expected to pay £8 (\$16) per day. A number of exemptions are made within the payment plan. For example, residents within the cordon have a 90-percent exemption on payment. Payments from motorists can either be made on a daily, weekly, monthly or annual terms via the internet, telephone, regular mail, or at retail outlets. This pricing scheme coupled with improvements in public transit system within central London resulted in a 15-percent reduction in traffic (with no displacement to

local roads within the area) and a 30-percent reduction in travel time delays (Transport for London, 2007; FHWA, 2009)

The third form of congestion pricing involves variable tolls on separated lanes on a highway such as High Occupancy Toll (HOT) lanes. HOT lanes allow vehicles not meeting the occupancy requirements on High Occupancy Vehicle (HOV) lanes to pay tolls, while other vehicles, such as emergency vehicles and transit buses pay reduced or no toll. As one approach to a managed lane, HOT lanes give motivation for modal shift, enable more efficient use of HOV lanes, and can reduce general purpose lane occupancy. HOT lanes are not uncommon in the USA, and currently operational HOT lanes include those on SR 167 in the Puget Sound Region-Washington, I-394 in Minneapolis, Minnesota, I-15 in San Diego-California and I-25/US 36 in Denver-Colorado.

The HOT lane project on SR 167 in the Puget Sound Region, Washington was implemented after it was estimated that by 2030, 45% of the main freeway system in the Seattle metropolitan area would be congested. In May 2008, the 4-year HOT lane pilot project started by converting the existing 12-mile HOV SR-167 to HOT lanes with the aim of managing congestion and generating revenue. One year after the pilot project, the following were realized during the peak periods; speeds on the general purpose lane increased by 21- percent (40 to 49mph) coupled with an 11% increased in traffic, and speeds on the HOT lane increased by 6 percent (from 57 to 61 mph) with an increased 4-percent in traffic volume northbound. Average number of toll trips per weekday continues to grow with an average toll rate of \$1.00. Gross revenue of \$316,600 was generated from May 3, 2008 through April 30, 2009 (Stone, 2009; FHWA, 2009).

In May, 2005, the first phase of the express lane project in Minnesota was implemented on the 11-mile stretch, from downtown Minneapolis to the western suburbs, on I-394 by converting an existing HOV lane into the new HOT lane. During peak periods, the HOT lanes, which are dynamically priced, remain free to HOVs and motorcycles and they become free to all road users during the off-peak periods. To maintain the average flow speed on the express lanes (50 to 55mph), the toll rates are often adjusted every three minutes during peak periods. The tolls range from 25 cents to \$8 and an average \$1 to \$4 during peak periods. For the first two years of operation, average daily revenue of \$29,641 has been generated and an average toll trips (in December 2009) of 22,506 (FHWA, 2009; Zmud, 2006).

The fourth form of congestion pricing, variable tolls on entire road networks, by time of day and area of travel, is the most desirable approach to accomplish efficient road pricing. This approach discourages road users from using certain parts of the network during peak periods but rather encourages off-peak period usage. The pricing approach can be introduced on existing toll-free roads to manage traffic flow especially during peak periods, if the level of congestion is observed to be high.

2.5.5 Public-Private Partnerships

Highway public-private partnerships in building and operating toll roads can have potential benefits, such as sharing risks with the private sector, efficient operations and management of facilities, increased mobility and cost-effective investment decisions. There are also potential costs and trade-offs. Toll rates are likely to rise faster on a privately operated highway than they would on a publicly operated toll road. There are also financial trade-offs. Unlike public toll authorities, the private sector pays federal income taxes and can deduct depreciation on assets for which they have effective ownership. The extent of these deductions and the amount of foregone revenue, if any, to the federal government is difficult to determine (USGAO, 2008).

2.6 Review of Statistical Approach Used in Estimating Highway Revenue

2.6.1 Long-Term Forecasting Methodology

Past highway revenue studies for Oregon, California, Kentucky, Arizona, Washington, Virginia and Wisconsin used regression analysis approaches in estimating the expected revenue for the long-term. The long-term fuel revenue forecasting methodology was anchored primarily on estimating vehicle miles of travel and fleet fuel efficiency for vehicle categories such as automobiles, combination trucks, light duty trucks, single unit trucks, buses and motorcycles. Both fuel and vehicle registration long-term revenues were based on socio-economic and demographic factors, such as: driving age population, Gross State Product, Per Capita Income, and other statistically significant variable. The methodology used in estimating fuel revenue from vehicle miles of travel can be adopted in

forecasting long term revenue from alternative sources such VMT fees and weight distance truck fees.

Linear regression is a statistical technique which seeks to establish a relationship between two or more variables such that, a dependent (response) variable is predicted from one or many independent (explanatory) variables. The functional form of linear regression model is: $Y_i = \beta_0 + \beta_1 X_{1i} + \varepsilon_i$, where Y_i is the response variable value in the i^{th} trial, X_{1i} is the independent variable value in the i^{th} trial, with β_0 and β_1 been the estimated parameters and ε_i , been the error term. The subscript, i , corresponds to the individual trial or observation, where $i = 1, 2, 3 \dots n$. Linear regression assumes the existence of a continuous dependent variable and more so, the existence of linearity between dependent and independent variables. The error term is assumed as not correlated, has zero mean / expected value $E(\varepsilon) = 0$, normally distributed; constant variance for all observations $E(\varepsilon^2) = \sigma^2$ and the random variables ε_i are statistically independent, thus $E(\varepsilon_i \varepsilon_j) = 0$ for all $i \neq j$ (Pindyck et al., 1998; Washington et al., 2003). The linearity requirement is not the restrictive term it appears to be, because the scale of both the dependent and independent variables can be transformed and a suitable linear relationship can often be found (Washington et al., 2003).

Regression analysis has some challenges which need to be addressed for acceptable modeling output. One of the challenges is multicollinearity; this is the case in which two or more explanatory variables in the regression model are highly correlated, making it difficult or impossible to isolate their individual effects on the dependent variable (Salvatore and Reagle, 2001). The coefficients can be statistically insignificant due to multicollinearity in spite of having a higher value of R^2 . The effect of multicollinearity can be minimized by transforming the functional relations or one of the highly collinear independent variables in the model will have to be eliminated.

Another challenge when using regression is heteroscedasticity; which is observed when the ordinary least square assumption, which states that, the variance of the error term is constant for all observations does not hold true. This can lead to unbiased but inefficient estimates of the coefficients, as well as biased estimates of the standard error, and thus incorrect statistical tests and confidence intervals. The test for detecting and correcting for is shown in the literature (Washington et al., 2003).

Autocorrelation is another challenge which occurs when using linear regression time-series models; this challenge is due to the positive correlation between the error term in one time period and the error term in the previous time period. This is very common in time-series analysis and leads to downward-biased standard errors, which then, leads to incorrect statistical tests and confidence interval.

2.6.2 Short-Term Forecasting Methodology

For long-term forecast, a steady state economic condition is assumed. These figures cannot be used for short term budgeting and / or cash flow analysis. Budgeting estimation requires revenue estimation for one to two years, while for cash flow analysis, month by month revenue estimation may be required. In the short-term, economic conditions fluctuate significantly and revenue estimation procedures must consider the volatility of the prevailing market reflected particularly in fuel prices and associated changes in vehicle miles of travel.

Various techniques have been used in short-term revenue forecasting including regression and decomposition methods (Hartmann et al., 1981; Cervero, 1985; Varma et al., 1991). For instance, Hartmann et al. (1981) estimated demand for gasoline in the short-term by regressing on 11 monthly dummy variables and the real price of gasoline. Within the same study, another case was found where log-linear model was used to estimate gasoline demand as a function of gasoline retail price index, personal income and a 12-month lag demand. A three step methodology was developed in the study (Hartmann et al., 1981) to predict monthly gasoline demand, which includes: (a) indicate the annual relationship between endogenous variable (demand for gasoline) and exogenous variables such as motor gasoline price, automobile fuel efficiency, stock of motor vehicles and national income; (b) from the relationships developed in (a) coupled with the assumptions on fuel efficiency, stock and price, compute the annual gasoline demand level and; (c) predict the monthly distribution of gasoline demand; monthly distribution is estimated by development of seasonal factors using the decomposition of a monthly time series data into seasons, trends and irregular components.

Wilhemi (1984) developed a 3-equation model for monthly estimation of fuel demand. Gasoline gallonage was predicted in the first equation with diesel gallonage predicted in the second equation and the third equation was an identity that defined total

fuel gallonage. Each prediction was done on a three-month (quarter) seasonally adjusted annual basis. Annual forecasts were based on the averaged quarterly predictions. Seasonal adjustment factors were applied to the annual forecast to spread the annual forecast to months.

Cervero (1985) developed short-term highway revenue forecasting models based on the autoregressive integrated moving average (ARIMA) technique; a technique developed by Box and Jenkins (1970). ARIMA models attempt to replicate the past behavior of a time series by decomposing data into interpretable secular, seasonal and stochastic components rather than investigating any direct causal relationships. ARIMA models were observed to be excellent short-term forecasting models for a wide variety of time series, and have often outperformed more complex econometric systems for a number of economic series (Cleary and Levenbach, 1982). However, the limitation of ARIMA stems from its univariate structure; as a result, causal explanations (such as the influence of gasoline demand explanatory variables including income, price, et cetera) are not explicitly stated in the models.

In the present study, linear regression models were used to estimate expected gasoline and special fuel revenues for a short-term period of 1 to 2 years, based on VMT models. For month by month revenue estimation, seasonal decomposition method was used.

CHAPTER 3 DATA REQUIREMENTS FOR UPDATING EXISTING HIGHWAY REVENUE FORECASTING SOFTWARE

3.1 Introduction

This chapter describes the data requirements; sources and how the data was used to develop the updated VMT, registration-related and other forecasting models. Furthermore, the general description of the existing highway revenue forecasting methodology for the state of Indiana is discussed and the Indiana highway revenue and disbursement structure for the different highway accounts and funds is also reviewed.

3.2 Data Sources, Requirements and Uses

Requisite data used in revising the existing highway revenue models came mainly from the same sources as in previous studies (Varma et al., 1991; Shah, 2005).

Primary data collected from state agencies included vehicle miles of travel by vehicle category (automobiles, light duty trucks, motorcycles, single unit trucks and combination trucks), gasoline tax rate and revenue, special fuel tax rate and revenue, motor carrier surcharge and motor carrier fuel use tax rates and revenues, and number of vehicles registered. These state agencies were Indiana Department of Transportation (INDOT), the Indiana Department of Revenue and the Indiana Bureau of Motor Vehicles. Other required information included relative travel by different vehicles by model year, state and national socio-economic data, demographic data and vehicle fuel efficiency factors. Table 3.1 identifies specifics of the data used.

Table 3.1 Data Sources

Data Type	Source
<i>VMT, Fuel Tax Rates and Consumption & Vehicle Registration</i> Vehicle Miles of Travel for Automobiles, Light Duty Trucks, Motorcycles, Single Unit Trucks, Buses and Combination Trucks	INDOT
Number and Type of Registered Vehicles and Fees including Licensed Drivers and Titles	Shah(2005); ILSA(2009)
Motor Fuel Tax Rates (gasoline, special fuel, motor carrier fuel tax, motor carrier surcharge tax), Gasoline Consumption and Special Fuel Consumption	INDOT; Highway Statistics
Highway Revenue Vehicle Registration (annual); International Registration Plan (annual); Gasoline (monthly and annual); Special Fuel (monthly and annual); Motor Carrier Fuel Use Tax (monthly and annual); Motor Carrier Surcharge Tax (monthly and annual); Indiana Transportation Funding and Disbursement Chart	INDOT; ILSA (2009)
Demographic Population Projections; Total Population; Driving Age Population	Highway Statistics; Indiana Business Research Center; U.S Census Bureau; FHWA
Economic Indicators Indiana Per Capita Income (PCI); Gross Domestic Product (GDP) of USA; Consumer Price Index; Producer Price Index (PPI); Gasoline Price (Midwest)	BEA ; BLS; USDL (2009); USEIA (2009)
Vehicle Technology National Vehicle Fuel Efficiency for Automobiles, Light Duty Trucks, Motorcycles, Single Unit Trucks, Buses and Combination Trucks; Relative Vehicle Miles Traveled by Aged Vehicles for Automobiles and Trucks	Highway Statistics; Davis et al. (2009)

3.2.1 Economic and Demographic Data

The economic factors used in developing registration-related models include: Indiana Per Capita Income (PCI) and the USA Gross Domestic Product (GDP), chained to 2008 dollars using consumer and producer price indices respectively (as shown in Table A.1). GDP and PCI historical data was obtained from USBEA (2009). GDP and PCI (indexed to 2008\$) values for the forecast years (2010 - 2035) were estimated by regressing historical GDP and PCI values with Year to obtain a time series equation. Time series equations are discussed in Chapter 4. Historical annual and monthly fuel prices within the Midwest region were obtained from USEIA (2009), as shown in Table A.2.

Demographic data included total population, driving age population (above 16 years old) was considered in this study. The sources for the population data were: (i) Indiana Business Research Center, Indiana University and (ii) Census of Population by the U.S. Bureau of Census. The actual and projected driving age populations from 2010 to 2035 are shown in Tables A.3 and A.8 respectively.

3.2.2 Data on Licensed Drivers and Vehicle Registration

Data on licensed drivers and vehicle registration from 1996 to 2005 was collected by Shah (2005) from Bureau of Motor Vehicles (BMV) and augmented with data from the highway statistics reports. Vehicle registration fee structures for different vehicle categories came from the BMV. Historical data on the number of vehicles registered per vehicle class and other registration-related items such as the number of licensed drivers was used in developing vehicle registration estimation models.

3.2.3 Data on Vehicle Sales and Vehicle Operation

The development of INDOTREV-1 was based on annual vehicle sales by vehicle type data and the annual miles of travel per vehicle category; this data came from R.L.Polk and company. After 2001, the publication of this data was discontinued (Davis et al., 2009); hence the methodology for estimating fleet fuel efficiency in INDOTREV-2 was modified using national data as discussed in Section 4.4.

3.2.4 Data on Vehicle Miles of Travel and Vehicle Fuel Efficiency

Vehicle miles of travel data (Table A.4), classified into six vehicle categories: automobiles, motorcycles, light duty trucks (which includes sport utility vehicles, minivans and pick-up trucks), single unit trucks, buses and combination trucks, came from the Indiana Department of Transportation. The data on national relative vehicle-miles of travel by age cohort within each vehicle category during 1987 - 2001 was obtained from the publications of the Oak Ridge National laboratory (Davis et al., 2009). The information was used to estimate the expected relative miles of travel by each age cohort within a vehicle category, as discussed in Chapter 4.

Data on fleet fuel efficiency per vehicle category during 1996 - 2006 was obtained from highway statistics reports (FHWA, 2007) as shown in Table A.5. Data on vehicle model year fuel efficiency and Corporate Average Fuel Economy (CAFE) was available only for automobiles and light duty trucks (Davis et al., 2009). This data was required to enable estimation of the expected fleet fuel efficiency per vehicle category within the analysis period (2010 to 2035).

3.2.5 Data on Fuel Tax Rates and Revenues

Data on the annual and monthly gasoline, special fuel, motor carrier surcharge and fuel use revenues was obtained from various sources including highway statistics, ILSA (2009) and INDOT and the resulting information is shown in Table A.6.

3.2.6 Data on Other Revenues

Apart from the main revenue sources (fuel and vehicle registration), which constituted about 75% of the total revenue in 2008, data on other revenue sources such as International Registration Plan (IRP), permits, state court fees and miscellaneous was obtained from INDOT. The data on other revenues was available only for the period, 2003-2007, as presented in Table A.7.

3.3 Indiana Highway Revenue from Existing Sources and Disbursement

Highway revenue sources currently available to Indiana are gasoline tax, special fuel tax, motor carrier surcharge tax, motor carrier fuel use tax, vehicle fees (i.e. registration, title and license fees), International Registration Plan, permits, transfers, state court fees and miscellaneous. Brief descriptions of selected revenue sources in Indiana are given below:

1. *Gasoline Tax* is paid at the time of purchase of gasoline in Indiana. It is paid by the wholesaler and the cost is passed on to the retailer and then the final consumer. The current tax rate of 18 cents per gallon was effective January 1, 2003 (ILSA, 2009).
2. *Special Fuel Tax* is a tax on special fuel (diesel) purchased and consumed in Indiana. Tax is paid by consumer at the pump. Trucking companies file quarterly claims for reimbursement of taxes paid on diesel fuel consumed out-of-state. The current tax rate of 16 cents per gallon was effective in 1988 (ILSA, 2009).
3. *Motor Carrier Surcharge Tax* is an add-on tax charged on all diesel fuel consumed by motor carriers within Indiana. It is paid quarterly by the carrier to the Department of Revenue on or before the last day of the month immediately following the quarter. The amount of motor fuel consumed by a carrier is the total amount of motor fuel consumed in its entire operations within and without Indiana multiplied by a fraction, the numerator of which is the total number of miles traveled in Indiana, and the denominator of which is the total number of miles traveled within and without Indiana. If no records show the total number of miles traveled, it is presumed that one gallon is consumed for every 4 miles traveled. In 1988, the tax rate was changed from 8 cents per gallon to 11 cents per gallon and it has remained same. (ILSA, 2009).
4. *Motor Carrier Fuel Use Tax* is the tax on fuel consumed by trucks in Indiana but purchased in another state. It is reconciled quarterly by the carrier to the Department on or before the last day of the month immediately following the quarter. The tax is based on the amount of fuel consumed in Indiana, following the procedure used for Motor Carrier Surcharge Tax. This tax rate has remained the same since 1985 (ILSA, 2009).

5. Passenger vehicle registration is a flat fee paid on an annual basis to register autos and light trucks (under 7000 lbs). Assessed annually on vehicle owners and collected on a 10-month cycle (Varma et al., 1991).
6. A motor vehicle driver's license is required to operate a motor vehicle on highways and roads of Indiana. Licenses are renewed in the applicant's birth month (Varma et al., 1991).
7. Indiana joined the International Registration Plan (IRP) in the late 1980s where registration fee revenues collected from long haul commercial heavy vehicles are distributed among the states whose highway facilities are used according to the miles driven in each state. The IRP is a reciprocal agreement on motor carrier registration fees and it is applicable to:
 - i. Power units having 3 or more axles regardless of weight,
 - ii. Vehicles having a gross weight in excess of 26,000 lbs, and
 - iii. Vehicles used in combination when the gross weight of the combination exceeds 26,000 lbs.

Motor fuel taxes, vehicle registration fees, and driver license fees are the dominant sources of highway revenue. In 1923, the gasoline tax, the earliest adopted tax in Indiana, was originally charged on a per gallon basis (Varma et al., 1991) but changed to an ad valorem tax to keep up with adverse economic changes in the early 1980s. However in 1985 gasoline tax reverted to a per gallon basis. In 1985, a surcharge tax was levied on fuel consumption by heavy vehicles. The Motor Carrier Fuel Use Tax (MCFUT) is used to address the issue of in-state and out-of-state diesel fuel purchases. Registration fees for heavy vehicles such as trucks, tractors, and buses are based on gross registered vehicle weight. A detailed description of the entire fee structure is found in ILSA (2009).

The Indiana system of funding transportation infrastructure includes two major accounts: the Motor Vehicle Highway Account (MVHA) and the Highway Road and Street Fund (HRSF). Some of the other accounts include the Special Distribution Account (SDA), the State Highway Road Construction and Improvement Fund (SHRCIF), and the Motor Carrier Regulation Fund (MCRF). Highway revenues are distributed to different accounts

and funds according to the legislatively mandated ratios. A funding flow chart showing the different revenue sources is presented in Figure 3.1.

Vehicle registration revenues are distributed to the MVHA and HRSF accounts, whereas driver license revenues are gathered only in the MVHA account. The gasoline tax and special fuel tax revenues are distributed into the various stipulated accounts and funds as shown in Figure 3.1. Similarly, the flow of funds showing disbursements of the revenues generated to and from the MVHA and HRSF accounts is also indicated in Figure 3.1. Detailed information about the funds and accounts can be obtained in the literature (ILSA, 2009; Sinha et al., 2005; Varma et al., 1991).

Figure 3.1 Indiana Transportation Funding Chart (INDOT, 2003)

3.4 Methodology for Revenue Forecasting

Socio-economic indicators, demography, technological advancement in vehicle fuel efficiency, travel demand and legislative instruments are factors that affect highway revenues over the years. The need for personal mobility and commodity transportation drives travel demand which can be predicted based on economic factors such as state per capita income (PCI) and gross domestic product (GDP).

Population within a geographical area determines vehicle registration. Increasing vehicle fuel efficiency through technological advancement adversely affects highway revenue. Corporate average fuel economy (CAFE) standards are expected to keep increasing with profound impacts on highway revenue.

Fuel tax rates and disbursement ratios are the prerogative of the legislature; these ratios are shown in Figure 3.1. Long-term existing highway revenue sources forecasting are broadly disaggregated in the present study, as shown in Figure 3.2. Fuel revenue (gasoline tax, special fuel tax, motor carrier surcharge tax, motor carrier fuel use tax) is estimated with prediction models for VMT and fleet fuel efficiency factors. Vehicle registration revenue includes registration, driving license and transfer fees and it is estimated from population and income models. Other revenues include international registration plan, state court fees and miscellaneous items and the amounts are estimated on the basis of predicted trends. Short-term revenue forecasting methods used in this study are linear regression and seasonal decomposition to obtain both annual and monthly revenues respectively.

Figure 3.2 Components of Existing Highway Revenue

CHAPTER 4 HIGHWAY REVENUE PREDICTION EQUATIONS

4.1 Introduction

This chapter presents the modeling approach used for predicting existing highway revenue sources based on vehicle miles of travel, vehicle registration, registration-related items and others (state court fees, permits, international registration plan and miscellaneous). The statistical approaches used for preparing the models, assumptions and the statistical significance of the model variables are also discussed. Estimated highway revenues from existing sources and disbursements into the various highway accounts, within the forecasting period, are presented.

4.2 Vehicle Miles of Travel (VMT) Prediction Models

Vehicle miles of travel models were based on three independent variables; Indiana per capita income, gross domestic product of the United States, indexed to 2008 dollar and driving age population in Indiana. Models developed were specific to six vehicle categories namely: automobiles, motorcycles, light duty trucks, single unit trucks, buses and combination trucks.

Automobiles and light duty trucks (i.e. minivans, pickup trucks and sport utility vehicles) are predominantly used for personal travel and Indiana's per capita income (PCI) was identified as a significant explanatory variable. The data used in the automobile and light duty truck VMT calibration was from 1997 to 2003. From the historical data, automobile VMT had an increasing trend from 1997 to 2003 and started decreasing from 2004 to 2006. In order to determine outliers in the data, the influence of automobile VMT observations in year 2004 and 2006 was assessed using Cook's distance method and other outlier detection techniques to determine the influence of the response and explanatory variables (Kutner et al., 1996). The assessment indicated that these observations were not influential cases. Automobile VMT trend from 1997 to 2003 was found to reflect the long

term trend in automobile usage. Therefore for long-term analysis, this trend was considered to reflect the future pattern when the economy starts to recover in the next year or two. The computed t-statistics were statistically different from zero at 95% confidence level as shown in Table 4.1.

The travel demand on motorcycles was found to be significantly dependent on the driving age population. Observations from 1997 to 2005 were used to calibrate the model. The t-statistic observed was statistically different from zero (at 95% confidence level) coupled with a good R^2 value, as presented in Table 4.1. Single unit trucks (SUTs) had PCI of Indiana as a significant explanatory variable. This is expected because PCI reflects economic conditions in the state. The t-statistic value estimated was statistically different from zero (at 95% confidence level) as shown in Table 4.1.

PCI was also found to be a significant explanatory variable in estimating VMT for buses. Historical observations show that an increase in Per Capita Income results in reduction for bus VMT. This is intuitive and indicative of the data which also shows that bus VMT increased slightly during periods of very high fuel prices. However fuel (gasoline or special fuel) prices were found to be statistically insignificant in predicting bus VMT in the long term. Observations from 1997 to 2005 were used in the development of the bus VMT model and the estimated t-statistic for PCI was found to be statistically different from zero, at 95% confidence level.

Combination truck VMT is directly dependent on the national economy and thus, GDP was found to be the most significant explanatory variable. The dataset from 1997 to 2005 was used in the model calibration with the t-statistics for GDP, different from zero at the 95% confidence level. All the above models were validated with 2006 to 2008 data.

Table 4.1 Models for Predicting Long Term Vehicle Miles Travel

Vehicle Category	VMT Model	Variable	t-statistic	R ²
Automobile	AutoVMT = 35505 + 0.446 (PCI ₂₀₀₈)	Intercept	7.92	0.68
		PCI ₂₀₀₈	3.22	
Combination Truck	CTVMT = 4628 + 0.166 (GDP/10 ⁹) ₂₀₀₈	Intercept	4.60	0.44
		(GDP/10 ⁹) ₂₀₀₈	2.35	
Light Duty Truck	LDTVMT = - 652654 + 64036 (LnPCI ₂₀₀₈)	Intercept	-3.05	0.62
		LnPCI ₂₀₀₈	3.12	
Single Unit Truck	SUTVMT = 1866.02+0.0164 (PCI ₂₀₀₈)	Intercept	8.34	0.65
		PCI ₂₀₀₈	2.38	
Bus	LnBusVMT = 9.27 - 0.000106 (PCI ₂₀₀₈)	Intercept	5.48	0.38
		PCI ₂₀₀₈	-2.07	
Motorcycle	MCVMT = -1331.51+0.000368 (DPOP)	Intercept	-2.79	0.61
		DPOP	3.53	

NB: The predicted VMTs are in millions

Where,

AutoVMT: vehicle miles of travel by automobiles,

LDTVMT: vehicle miles of travel by light duty trucks (minivans, sport utility vehicles and pick-up trucks),

MCVMT: vehicle miles of travel by motorcycles,

BusVMT: vehicle miles of travel by buses,

SUTVMT: vehicle miles of travel by single unit trucks,

CTVMT: vehicle miles of travel by combination trucks,

PCI₂₀₀₈: per capita income in Indiana in 2008 dollars,

GDP₂₀₀₈ : gross domestic product of the USA in 2008 dollars, and

DPOP: driving age population in Indiana.

To facilitate the prediction of VMT outcomes, input parameter models were developed for per capita income, gross domestic product and driving age population as shown in Table 4.2.

Table 4.2 Models to Predict Input Parameters for VMT Equations

Description	Model	Variable	t-statistics	R ²
Per Capita Income	$PCI_{2008} = - 563735 + 298 (w)$	Intercept w	-4.21 4.45	0.74
Gross Domestic Product	$GDP_{2008} = - 461285.75 + 237.501(w)$	Intercept w	-4.34 4.47	0.80
Driving Age Population	$DPOP = - 74356793 + 39423 (w)$	Intercept w	-9.12 9.67	0.92

Where,

PCI_{2008} : per capita income of Indiana in 2008 dollars,
 GDP_{2008} : gross domestic product of the USA in billions of 2008 dollars,
 $DPOP$: driving age population of Indiana, and
 w : prediction year.

4.3 Estimation of Vehicle Fleet Fuel Efficiency

Estimation of on-the-road fleet fuel efficiency for vehicles could be based on the age cohort survival approach as discussed in Varma et al. (1991). However due to the lack of new vehicles sales as well as old vehicles scrappage data in the state, a modified age cohort survival approach was used by employing the national percentages of relative vehicle miles traveled for each age cohort to approximate the expected fleet fuel efficiencies. The national dataset came from the publicly available data on fuel efficiency (Davis et al., 2009).

The age cohort survival approach (used in INDOTREV-1) involves three steps. The first step is the determination of the proportion of vehicle category by age cohort. The second step estimates the relative miles traveled by each age cohort within a vehicle category. The third step involves estimating fleet fuel efficiency for each vehicle category based on model year fuel efficiencies. For cars and light duty trucks the corporate average fuel economy (CAFE) was used by Varma et al. (1991) as the model year fuel efficiency. However, for combination trucks, single unit trucks and buses, published values in the earlier publications of the Transportation Energy Data Book from Oak Ridge National Laboratory were used. Detailed discussion of the cohort survival approach is given in both Mannering et al. (1979) and Varma et al. (1991). The approach requires information on historic annual vehicle sales (new and used) in Indiana. Such information, obtained from R.L. Polk in past studies, is no more readily available. Consequently, in the present study,

this approach could not be followed. Hence, a modified approach based on national dataset for relative miles travel by age cohort was used (Davis et al., 2009).

The modified approach consisted of four steps. The first step was the estimation of the total VMT for each vehicle category. The second step involved the estimation of age cohort VMT within a specific vehicle category. Eleven cohorts were used as available in the various editions of the Oak Ridge National Laboratory publications (Davis et al., 2009).

Age cohort VMT proportions were obtained by multiplying the total VMT for a specific vehicle category with the estimated age cohort distribution factors. These distribution factors could be derived only for two broad vehicle categories (automobiles and trucks). The national dataset (Davis et al., 2009) available was for 1987, 1989 and 1994 through 2001.

In order to incorporate the variation in VMT by age cohort from year to year, a regression model was developed for each age cohort. However only the “under 1 year” age automobile cohort, which represents vehicles less than 1 year old, as compared to the remaining ten age cohorts dependent variables, was found to have time as a statistically significant variable coupled with a significant R^2 . Hence a time series equation for “under 1 year” age cohort VMT model was used. The remaining VMT fraction was distributed using the derived arithmetic average (Table A.16) proportions. Since the expected total VMT distribution factors may not sum up to 1.0, each estimated VMT age cohort factor was recalibrated using the relative weights (based on the historical arithmetic averages from 1987, 1989, 1994 to 2001) to enable the sum total be 1.0. This procedure was also applied to the distribution of trucks. The derived arithmetic averages for tractors are shown in Table A.17.

The estimated annual distribution factors for various vehicle categories are shown in Tables A.18 and A.19. For automobiles, light duty trucks and motorcycles the age cohort VMT distribution factors as shown in Table A.18 were used, while for single unit trucks, buses and combination trucks, the truck age cohort VMT distribution factors as shown in Table A.19 were used.

The third step was the estimation of the model year fuel economy for new automobiles and light duty trucks. Currently only automobiles and light duty trucks are covered under the CAFE standards; hence it is possible to obtain national corporate average values for new model year automobiles and light duty trucks. The Energy

Independence and Security Act (2007), which amended the Energy Policy and Conservation Act, mandated that the model year (MY) 2011-2020 CAFE standards be set sufficiently high to ensure that the industry-wide average of all new passenger cars and light trucks, combined, is not less than 35 miles per gallon by MY 2020 (EISA 2007). The Secretary of Transportation prescribed an annual increase of four-and-a-half percent in the fleet-wide fuel economy, from MY 2011 through MY 2015. For automobiles, this means that CAFE will increase from the current 27.5 miles per gallon standard to an average of 35.7 miles per gallon by 2015. For light trucks, the proposal calls for an increase from 23.5 miles per gallon in 2010 to 28.6 miles per gallon in 2015. Based on the above legislation, the estimated MY fuel economy for automobiles and light duty trucks can be expected to increase by an annual rate of 4.5% up to 2015 and 2% from 2016 to 2035, respectively.

In the absence of a fuel efficiency standard for the other vehicle categories (motorcycles, single unit trucks and combination trucks), the national average fleet vehicle efficiencies for each vehicle category as reported in the literature (FHWA, 2007 ; Davis et al., 2009) were used as basis for projecting the expected fleet fuel efficiencies for these vehicle categories. The fleet fuel efficiency values for motorcycles, single unit trucks, buses and combination trucks were increased by an annual rate of 2% up to 2020 and 1% from 2021 to 2035. These rates were pivoted on past reported average fuel efficiencies (FHWA, 2007).

The fourth step was the calculation of the fleet fuel efficiency for the i^{th} age cohort within vehicle category k , based on the formulas shown in Figure 4.1. Past fuel efficiency estimation (Varma et al., 1991) was based on the assumption that model year fuel efficiency of a vehicle would continue to remain unchanged regardless of the year of the vehicle. Even though no empirical studies have established the rate of deterioration in model year fuel efficiency, studies conducted by Ross et al. (1995) and Kortum et al. (1997) indicate that fuel efficiencies continue to reduce with vehicle age because carbon monoxide, hydrocarbons and other emissions from older vehicles continue to be higher than newer vehicles. Based on the inference, an α -factor, which modifies the model year fuel efficiency to reflect the expected declining rate of fuel efficiency, was used. The modification factor (α -factor) ranges from 0.66 to 1.0 (1.0 for vehicles less or equal to 1 year old and 0.66 for vehicles ten years old and above). Figure 4.1 illustrates the methodology for estimating fleet fuel efficiency for vehicle category k .

Figure 4.1 Methodology for Estimating Fleet Fuel Efficiency for Vehicle Category k

Where,

FE_{bK} :	fuel efficiency for automobiles and light duty trucks in the manufactured year (model year), b,
α_{iK} :	deterioration factor of fuel efficiency for the i^{th} age cohort for vehicle category k (automobiles and light duty trucks only) as they age.
EFE_{iK} :	fuel efficiency in a given year of the i^{th} age cohort for vehicle category k,
FFE_{iK} :	fleet fuel efficiency of the i^{th} age cohort for vehicle category k in a given year,
VMT_{iK} :	vehicle miles traveled by the i^{th} age cohort for vehicle category k in a given year, and
VMT_k :	total vehicle miles traveled by vehicle category k in a given year $\left(VMT_K = \sum_I VMT_{iK} \right).$

The estimation of automobile fleet fuel efficiency for a given year is illustrated in Table 4.3. The i^{th} age cohort is shown in Column (a) and the percentage VMT for each age cohort is in column (b). Total VMT estimated for automobile in 2010 based on equation in Table 4.1 is in column (c). Calculation of automobile VMT for 2010 is as follows: $PCI_{2008} = -563735 + 298 (2010) = 35245$ (equation from Table 4.2). Automobile VMT (Table 4.1) is calculated as $AutoVMT = 35505 + 0.446 (35245) = 51224.3$ (in millions). The proportion of VMT for each automobile age cohort is computed by the product of column (b) and (c). The model year automobile fuel efficiency for the i^{th} age cohort is estimated using the equation shown in Figure 4.1. For example, in 2010, “under 1 year” age cohort will be automobiles manufactured in 2010 and the average fuel efficiency of automobiles will be estimated by the equation, $FE_{bK} = -424.69 + 0.2271 (2010) = 31.78$ mpg. For automobiles 1 year old in 2010, the manufactured (model) year fuel efficiency (in 2009) was $-424.69 + 0.2271(2009) = 31.55$ mpg. However, since this age cohort is one year old, the estimated fuel efficiency will be adjusted for deterioration in fuel efficiency using the α -factor, shown in column (f), for automobiles of 1 year old cohort. The effective fuel efficiency for 1 year old automobiles is as $EFE = 31.55 \times 0.98 = 30.92$ mpg. This estimation approach is repeated for the other age cohorts.

Estimation of fuel efficiency is based on the harmonic mean approach; hence in column (h), the estimated VMT for the i^{th} age cohort is divided by the effective fuel efficiency for the i^{th} age cohort. For example, for the 1 year old age cohort, the value in column (h) is calculated as $4906.64 / 30.92 = 158.67$.

Finally, the fuel efficiency for vehicle category k (in this case automobile) is found by dividing the total VMT for automobile in 2010 (VMT_k), in column (c), by the summation of

column (h). The calculation for automobile fleet fuel efficiency for 2010 is computed as $(51224.27 / 2075.62) = 24.68$ mpg. This approach could be used only for automobiles and light duty trucks because the data for these vehicles was available in the literature (Davis et al., 2009). Typical examples for the other vehicle categories are shown in Tables A.20 to A.24.

The estimated fleet fuel efficiencies for various vehicle categories k from 2010 to 2035 are shown in Table 4.4. Estimated model year fuel efficiencies for vehicle categories are presented in Table A.25

Table 4.3 Estimation of Automobile Fleet Fuel Efficiency for Year 2010

Age Cohort (i th)	Age Cohort VMT (%)	VMT _k (in millions)	VMT _{IK} (in millions)	MYF E (mpg)	α- factor	EFE _{IK}	VMT _{IK} / EFE _{IK}	FFE _k (mpg)
(a)	(b)	(c)	(d) = (b) x (c)	(e)	(f)	(g) = (e) x (f)	(h)= (d)/ (g)	(i) = (c) / Σ(h)
under 1	8.35	51224.27	4278.02	31.8	1.00	31.78	134.61	24.68
1	9.58		4906.64	31.6	0.98	30.92	158.67	
2	9.10		4659.29	31.3	0.96	30.07	154.93	
3	8.38		4290.79	31.1	0.94	29.23	146.78	
4	7.54		3861.71	30.9	0.92	28.40	135.96	
5	7.09		3629.50	30.6	0.90	27.58	131.59	
6	6.49		3326.62	30.4	0.88	26.77	124.28	
7	6.08		3114.61	30.2	0.86	25.96	119.96	
8	5.85		2998.50	30.0	0.82	24.57	122.04	
9	5.26		2695.62	29.7	0.78	23.19	116.22	
10 and older	26.28		13462.97	27.9	0.66	18.43	730.60	
Total	100.0		51224.27				2075.62	

Table 4.4 Estimated Fleet Fuel Efficiency

Year	Fleet Fuel Efficiency (FFE) in mpg					
	Auto	LDT	MC	Bus	SUT	CombT
2010	24.68	19.50	55.62	7.43	8.71	5.99
2011	24.87	19.81	56.26	7.46	8.76	6.02
2012	25.02	20.08	56.93	7.51	8.82	6.04
2013	25.16	20.35	57.67	7.58	8.90	6.06
2014	25.33	20.64	58.51	7.65	8.99	6.08
2015	25.56	20.98	58.72	7.74	9.10	6.11
2016	25.80	21.32	61.88	7.84	9.22	6.14
2017	26.01	21.65	62.69	7.97	9.40	6.19
2018	26.17	21.93	63.16	8.04	9.48	6.22
2019	26.30	22.19	64.40	8.21	9.68	6.25
2020	26.46	22.47	65.65	8.38	9.88	6.31
2021	26.67	22.79	66.99	8.55	10.08	6.34
2022	26.92	23.14	68.40	8.73	10.29	6.37
2023	27.14	23.47	69.82	8.91	10.50	6.41
2024	27.31	23.76	71.19	9.09	10.71	6.45
2025	27.44	24.02	72.54	9.27	10.93	6.48
2026	27.59	24.29	73.94	9.45	11.15	6.52
2027	27.79	24.60	75.43	9.64	11.37	6.56
2028	28.03	24.95	77.01	9.83	11.59	6.59
2029	28.27	25.29	78.62	10.02	11.82	6.63
2030	28.45	25.60	80.19	10.21	12.04	6.67
2031	28.59	25.86	81.72	10.41	12.28	6.70
2032	28.72	26.12	83.28	10.61	12.52	6.74
2033	28.90	26.42	84.93	10.82	12.76	6.78
2034	29.14	26.76	86.70	11.04	13.01	6.82
2035	29.39	27.11	88.52	11.26	13.27	6.85

Where,

Auto: automobile,

MC: motorcycle,

LDT: light duty truck,

SUT: single unit truck, and

CombT: combination truck.

4.4 Models for Predicting Vehicle Registration Revenue

Vehicle registration models developed in INDOTREV-1 were based on datasets from 1976 to 1989 (Varma et al., 1991). In the present study, datasets from 1996 to 2005, used earlier by Shah (2005), were employed. The regression analysis considered three independent variables (driving age population in Indiana, per capita income in Indiana and gross domestic product). Vehicle forecasting models were grouped into automobiles, motorcycles, trucks, tractors, buses, trailers (including semi-trailers) and miscellaneous (special machinery, watercraft, miscellaneous items, recovery and recreational vehicles). Models for driving licenses and title registrations were similarly developed.

The final equations are presented in Table 4.5. Automobiles are vehicles predominantly used for personal travel. Per capita income was found to be the sole significant explanatory variable for the number of registered automobiles. Driving age population was found to explain most of the variation in the demand for motorcycle registration as compared to economic indicators. The number of buses registered is usually based on bus travel demand. An indicator of bus ridership is the driving population within a state and this variable was found to be statistically significant.

The number of tractors or trucks registered depends on the volume of trucking activity. A good indicator of trucking activity is the gross domestic product, and this variable was found to be statistically significant in estimating the number of truck and tractor registrations. Trucks were classified into 29 weight classes (from 7000 lbs to 66,000 lbs and more); in order to predict the expected truck registration frequency for each weight classification, the total for all the 29 weight classes was estimated and thereafter distributed using the distribution factors shown in Table A.9. This procedure was also applied for estimating the number of tractors, trailers and buses (Table A.9).

Registrations of recreational and recovery vehicles, special machinery, watercraft and miscellaneous items are generally dependent on economic conditions and GDP was the sole significant independent variable. Vehicles registered as mobile plant and having an operating mass of greater than 4.5 tons are considered special vehicles and GDP was found to be significant for estimating the number of special vehicles registered. In the modeling equation, recreational, special vehicles, recovery vehicles, watercraft and miscellaneous items were summed up and the total served as the response variable, with GDP as the independent variable as shown in Table 4.5.

The number of vehicle title registrations is expected to be influenced by the working age population. The driving age population is a reflection of the working age population. The variable representing driving age population variable was found to be significant in estimating the number of titles registered as shown in Table 4.5.

The outcome of all the models developed showed good agreement with the actual data. Statistical significance of all the explanatory variables was tested, using the t-statistics. Detailed information about statistical tests can be obtained in the literature (Kutner et al., 2005; Washington et al., 2003; Anderson et al., 2002).

The significance of the variables used in the models was tested at the 95% confidence level. At 95% confidence level, the absolute threshold value of t-statistic for the variable to be significant, should be greater than or equal to 1.645. The developed models, t-statistics and R^2 values for registration-related items are illustrated in Table 4.5.

Table 4.5 Models for Predicting Number of Vehicle and Other Registration-Related Items

Registration Model	Variable	t-statistic	R ²
PassengerReg. = 2017642 + 49.9 (PCI ₂₀₀₈)	Intercept	3.97	0.56
	PCI ₂₀₀₈	3.18	
TruckReg. = 395551.80 + 68.16(GDP ₂₀₀₈)	Intercept	1.86	0.72
	GDP ₂₀₀₈	4.50	
TractorReg. = 3203.918 + 0.523(GDP ₂₀₀₈)	Intercept	2.55	0.81
	GDP ₂₀₀₈	5.84	
TrailerReg. = -3347308.87 + 406801.14 Ln(GDP ₂₀₀₈)	Intercept	-3.43	0.63
	LnGDP ₂₀₀₈	3.97	
MReg. = - 526924.36 + 0.143 DPOP	Intercept	-1.09	0.35
	DPOP	1.62	
MiscReg= -55844640.5 + 4526.15 (GDP) ₂₀₀₈	Intercept	-2.39	0.62
	GDP ₂₀₀₈	2.84	
BusReg = - 15910 + 0.00548 DPOP	Intercept	-1.49	0.40
	DPOP	2.31	
TitReg = - 5460852.347 + 1.952DPOP	Intercept	-2.92	0.73
	DPOP	4.70	
DrLReg = - 2054406.245 + 0.907 DPOP	Intercept	-2.83	0.80
	DPOP	5.64	

Where,

PassengerReg: number of passenger vehicles registered,

TruckReg: number of trucks by weight registered in Indiana. The weight ranges from 7,000 lbs to 66,000 lbs and over,

TractorReg: number of tractors by weight (both farm and non-farm) registered in Indiana. The weight ranges from 20,000 lbs to 78,000 lbs and over,

TrailerReg: number of semi-trailers and trailers registered in Indiana,

MReg: number of motorcycles registered in Indiana,

MiscReg: number of recovery and recreational vehicles, special machinery, watercrafts and other miscellaneous items registered in Indiana,

BusReg: the number of buses registered in Indiana,

TitReg: number of titles registered in Indiana,

DrLReg: number of driving licenses issued in Indiana,

PCI₂₀₀₈: per capita income in Indiana in 2008 dollars,

GDP₂₀₀₈ : gross domestic product of the USA in billions of 2008 dollars, and

DPOP: driving age population in Indiana.

4.5 Prediction Models for Other Revenues

Apart from fuel tax and registration-related revenues, which account for most of the total highway revenue, there are a few other sources of highway revenue including international registration plan (IRP), state court fees, federal reimbursement, permits and miscellaneous.

Other revenues were estimated, using a time series model, on the basis of data available from 2003 through 2007, as shown in Table 4.6. IRP revenue estimation could be expressed as a function of truck registration but the dataset available for truck registration was from 1996 to 2005 while the dataset available for IRP was from 2003 to 2007, hence a suitable model could not be developed relating IRP and truck registration. The available data for state court fees did not show any change during 2003 to 2007 (Table A.5), therefore a constant amount of \$3.6 million was assumed for state court fees from 2010 to 2035. From the available data, miscellaneous revenue appears to be decreasing at an annual rate of 13.6%. Using a time series, the estimated revenue from the model (Table 4.6) would be negative after 2012. Therefore, a constant amount of \$0.5 million was assumed for miscellaneous revenue from 2013 to 2035, as shown in Table 4.13.

Table 4.6 Other Revenues Prediction Model

Model	Variable	t-statistics	R ²
IRP = 96.742 - 1.95 (q)	Intercept	28.723	0.796
	q	-1.977	
PR=-1034643.62 + 522.28 (p)	Intercept	-8.372	0.960
	p	8.473	
MiscR=26.39-2.49 (q)	Intercept	8.78	0.717
	q	-2.75	

Where,

p: prediction year,

q: p – 2002,

IRP: IRP revenue (in millions of dollars),

PR: permits revenue (in thousands of dollars), and

MiscR: miscellaneous revenue (in millions of dollars).

4.6 Fuel Consumption Estimation

Annual fuel consumption is estimated by dividing VMT for each vehicle category by the respective estimated fleet fuel efficiency in that year. The amount of fuel consumed by automobiles and motorcycles were considered 100% from gasoline, while 95% of light duty and single unit trucks were considered to use gasoline; and 5% were considered to use special fuel (diesel). This assumption was based on the relative consumptions of these two fuels in United States, (as given in Table 2.5 of the 28th edition of the Transportation Energy Data Book (Davis et al., 2009). Fuel consumed by commercial tractors and buses was considered to be 100% special fuel (diesel). The volumes of consumption (in gallons) for different vehicle categories within the prediction period are shown graphically in Figure 4.2 while detailed values are given in Table 4.7.

Figure 4.2 Predicted Fuel Type Consumption (2010 – 2035)

Table 4.7 Predicted Fuel Consumption, 2010 - 2035

Year	Gasoline Consumption (in millions)				Special Fuel Consumption (in millions)			
	Auto	LDT	MC	SUT	LDT	SUT	Bus	CombT.
2010	2076	868	8	267	46	14	34	1218
2011	2065	880	9	266	46	14	33	1220
2012	2058	893	9	264	47	14	32	1222
2013	2052	906	9	262	48	14	30	1224
2014	2043	918	9	260	48	14	29	1225
2015	2030	927	9	258	49	14	28	1228
2016	2016	935	9	255	49	13	27	1227
2017	2005	943	9	251	50	13	25	1223
2018	1998	953	9	249	50	13	24	1224
2019	1993	964	9	244	51	13	23	1224
2020	1986	973	9	240	51	13	22	1220
2021	1975	980	9	235	52	12	21	1220
2022	1962	985	9	231	52	12	20	1221
2023	1951	991	9	227	52	12	19	1219
2024	1944	998	9	223	53	12	18	1217
2025	1939	1007	9	219	53	12	17	1218
2026	1934	1014	9	215	53	11	16	1217
2027	1925	1020	9	211	54	11	15	1215
2028	1913	1023	9	208	54	11	15	1215
2029	1902	1027	9	204	54	11	14	1215
2030	1894	1032	9	200	54	11	13	1213
2031	1889	1039	9	197	55	10	13	1212
2032	1885	1045	9	194	55	10	12	1212
2033	1878	1050	9	190	55	10	11	1211
2034	1867	1052	9	187	55	10	11	1210
2035	1856	1054	9	184	55	10	10	1209

Where,

Auto: automobile,

LDT: light duty truck,

MC: motorcycle,

SUT: single unit truck, and

CombT: combination truck.

4.7 Existing Fuel Tax Rate

Estimation of expected fuel revenue will be based on tax rates. The existing tax rates are shown in Table 4.8. As discussed in Section 3.3, gasoline tax rates in Indiana have not changed since 2003 while special fuel and motor carrier surcharge tax rates have remained the same since 1988. Motor carrier fuel use tax rate has remained the same since 1985 (ILSA, 2009).

Table 4.8 Existing Fuel Tax Rates

Description	Tax Rate (¢/gallon)
Gasoline	18
Special Fuel	16
Motor Carrier Surcharge Tax	11
Motor Carrier Fuel Use Tax	16

4.8 Estimating Highway Revenues from Existing Sources

4.8.1 Fuel Revenue

Fuel revenue is estimated by multiplying the volume of fuel consumed by the specific fuel type tax rate shown in Table 4.8. Motor carrier fuel use tax and surcharge tax apply only to combination trucks while gasoline is consumed by automobiles, motorcycles, light duty trucks and single unit trucks as discussed in Section 4.6. Motor carrier surcharge tax revenue and motor carrier fuel use tax revenues were computed by using the equations shown in Table 4.9. The estimated gasoline revenue for any year will be the product of the gasoline tax rate and the estimated consumption by each of these vehicle categories. The estimated long-term revenues from gasoline tax, special fuel tax, motor carrier fuel use tax and motor carrier surcharge tax are shown in Table 4.10.

Table 4.9 Motor Carrier Surcharge Tax and Motor Carrier Fuel Use Tax Revenue Equations

Description	Equation
Motor Carrier Fuel Tax Revenue	$MCFUT = \beta \times \left(\frac{CTVMT}{CTFFE} \right) \times MCFUT_R$
Motor Carrier Surcharge Tax Revenue	$MCST = \lambda \times \left(\frac{CTVMT}{CTFFE} \right) \times MCST_R$

Where,

MCST: motor carrier surcharge tax revenue (\$M),

MCFUT: motor carrier fuel use tax revenue (\$M),

CTVMT: vehicle miles of travel by combination trucks,

CTFFE: combination truck fleet fuel efficiency (mpg)

β : proportion of MCFT diesel gallons to total diesel gallons in the year z and given by the equation $\beta = -0.016 \times LN(z - 1996) + 0.059$, and

λ : proportion of MCST diesel gallons to total diesel gallons and has a constant value of 0.71482.

Table 4.10 Predicted Long-Term Fuel Revenue

Year	Revenue (\$M)				Total
	Gasoline Tax	Special Fuel Tax	Motor Carrier Fuel Use Tax	Motor Carrier Surcharge Tax	
2010	579.27	209.85	2.71	95.76	887.59
2011	579.36	210.06	2.53	95.91	887.85
2012	580.29	210.36	2.35	96.10	889.11
2013	581.29	210.59	2.19	96.27	890.34
2014	581.36	210.66	2.04	96.36	890.42
2015	580.28	210.85	1.90	96.52	889.56
2016	578.66	210.65	1.77	96.50	887.57
2017	577.45	209.82	1.64	96.17	885.09
2018	577.69	209.82	1.53	96.22	885.25
2019	577.86	209.75	1.42	96.26	885.29
2020	577.46	208.91	1.32	95.92	883.60
2021	575.96	208.85	1.22	95.97	882.01
2022	573.84	208.74	1.14	95.99	879.71
2023	572.09	208.29	1.06	95.84	877.28
2024	571.36	207.88	0.98	95.70	875.92
2025	571.32	207.85	0.91	95.73	875.82
2026	571.02	207.63	0.85	95.68	875.17
2027	569.71	207.24	0.79	95.55	873.29
2028	567.60	207.04	0.73	95.50	870.87
2029	565.58	206.92	0.68	95.50	868.69
2030	564.47	206.64	0.63	95.41	867.16
2031	564.22	206.38	0.59	95.32	866.51
2032	563.98	206.26	0.55	95.30	866.09
2033	562.90	206.04	0.51	95.24	864.69
2034	560.87	205.71	0.47	95.12	862.17
2035	558.65	205.45	0.44	95.04	859.58

4.8.2 Registration Revenue

Revenue expected from vehicle registration is calculated as the product of the number of vehicles registered and the respective average registration fees. Registration revenues from driving licenses and other registration-related items are also estimated as the product of the number for each registration-related item and the corresponding registration fee.

The most current vehicle registration and registration-related fee structure, presented by ILSA (2009), was used for estimating vehicle registration and registration-related revenues for the analysis period. Table 4.11 shows the estimated number of registered vehicles and registration-related items while Table 4.12 shows the revenues from vehicle registration and registration-related items.

Table 4.11 Number of Registration-Related Items Estimation

Year	Number of Registration (in millions)								
	Autos	Trucks	Tractors	Trailers	Buses	Motorcycles	Driving License	Titles	*Misc
2010	3.78	1.49	0.01	0.59	0.01	0.17	2.37	4.07	16.99
2011	3.79	1.51	0.01	0.60	0.01	0.18	2.41	4.15	18.06
2012	3.81	1.52	0.01	0.60	0.01	0.18	2.45	4.23	19.14
2013	3.82	1.54	0.01	0.61	0.01	0.19	2.48	4.30	20.21
2014	3.84	1.56	0.01	0.62	0.01	0.19	2.52	4.38	21.29
2015	3.85	1.57	0.01	0.62	0.01	0.20	2.55	4.46	22.36
2016	3.87	1.59	0.01	0.63	0.01	0.21	2.59	4.53	23.44
2017	3.88	1.61	0.01	0.63	0.01	0.21	2.63	4.61	24.51
2018	3.90	1.62	0.01	0.64	0.01	0.22	2.66	4.69	25.59
2019	3.91	1.64	0.01	0.64	0.01	0.22	2.70	4.76	26.66
2020	3.93	1.65	0.01	0.65	0.01	0.23	2.73	4.84	27.74
2021	3.94	1.67	0.01	0.65	0.01	0.23	2.77	4.92	28.81
2022	3.95	1.69	0.01	0.66	0.01	0.24	2.80	5.00	29.89
2023	3.97	1.70	0.01	0.66	0.01	0.24	2.84	5.07	30.96
2024	3.98	1.72	0.01	0.67	0.01	0.25	2.88	5.15	32.04
2025	4.00	1.74	0.01	0.67	0.01	0.26	2.91	5.23	33.11
2026	4.01	1.75	0.01	0.68	0.01	0.26	2.95	5.30	34.19
2027	4.03	1.77	0.01	0.68	0.01	0.27	2.98	5.38	35.26
2028	4.04	1.78	0.01	0.69	0.01	0.27	3.02	5.46	36.34
2029	4.06	1.80	0.01	0.69	0.01	0.28	3.05	5.53	37.41
2030	4.07	1.82	0.01	0.70	0.02	0.28	3.09	5.61	38.49
2031	4.09	1.83	0.01	0.70	0.02	0.29	3.13	5.69	39.56
2032	4.10	1.85	0.01	0.71	0.02	0.30	3.16	5.76	40.64
2033	4.12	1.86	0.01	0.71	0.02	0.30	3.20	5.84	41.71
2034	4.13	1.88	0.01	0.72	0.02	0.31	3.23	5.92	42.79
2035	4.15	1.90	0.01	0.72	0.02	0.31	3.27	6.00	43.86

*Miscellaneous registration includes recreational and recovery vehicles; watercraft; special machinery and miscellaneous items

The estimated total registration revenue was calculated using the equation:

$$\text{RegRev} = (\text{PVR} \times \text{PRF}) + (\text{MCR} \times \text{MCRF}) + (\text{TKR}_i \times \text{TKF}_i) + (\text{TR}_k + \text{TF}_k) + (\text{STR}_i \times \text{STF}_i) + (\text{BusR}_m \times \text{BusF}_m) + (\text{RVR} \times \text{RVF}) + (\text{SpMR} \times \text{SpMF}) + (\text{RcVR}_n \times \text{RcVF}_n) + (\text{DLN} \times \text{DLF}) + (\text{MisN} \times \text{MisF}) + (\text{WcN} \times \text{WcF}) + (\text{TiN} \times \text{TiF}) + \text{IRPR}$$

Where,

RegRev:	total registration revenue,
PVR:	number of passenger vehicles registered,
PRF :	average yearly passenger vehicle registration fee,
MCR:	number of motor cycles registered,
MCRF:	average yearly motor cycle registration fee,
TKR _i :	number of trucks registered by weight type i,
TKF _i :	average yearly truck registration fee by weight type i,
TR _k :	number of trailers registered by weight type k,
TF _k :	average yearly trailer registration fee by weight type k,
STR _i :	number of semi trailers registered by weight type i,
STF _i :	average yearly semi-trailer registration fee by weight type i,
BusR _m :	number of bus registration by usage class m,
BusF _m ;	average yearly bus registration fee by class m,
RVR	number of recreational vehicles registered,
RVF :	average yearly recreational vehicle registration fee,
SpMR:	number of special machinery registered,
SpMF :	average yearly special machinery registration fee,
RcVR _n :	number of recovery vehicles by weight type n,
RcVF _n :	average yearly recovery vehicle registration fee by weight type n,
DLR :	number of driving licenses registered,
DLF:	average yearly driving license fee,
MisN :	number of miscellaneous items registered,
MisF:	average yearly miscellaneous items registration fee,
WcN :	number of watercrafts registered,
WcF:	average yearly water craft registration fee,
TiN :	number of titles,
TiF:	average yearly title registration fee, and
IRPR:	revenue from IRP.

Table 4.12 Registration-Related Revenues

Year	Registration Revenue (in millions of \$)									Total
	Autos	Trucks	Tractors	Trailers	Buses	Motor cycles	Driving License	Titles	*Misc.	
2010	78.36	76.81	9.29	18.34	0.36	4.41	19.97	36.89	51.44	295.87
2011	78.67	77.65	9.39	18.52	0.36	4.56	20.27	37.59	54.70	301.70
2012	78.98	78.48	9.49	18.70	0.37	4.70	20.57	38.28	57.96	307.53
2013	79.29	79.31	9.59	18.88	0.38	4.85	20.87	38.98	61.21	313.36
2014	79.59	80.15	9.69	19.06	0.38	4.99	21.17	39.68	64.47	319.18
2015	79.90	80.98	9.79	19.23	0.39	5.14	21.47	40.37	67.72	325.00
2016	80.21	81.81	9.89	19.40	0.40	5.28	21.77	41.07	70.98	330.82
2017	80.52	82.65	9.99	19.57	0.40	5.43	22.08	41.77	74.23	336.64
2018	80.83	83.48	10.09	19.74	0.41	5.58	22.38	42.47	77.49	342.45
2019	81.14	84.31	10.18	19.91	0.42	5.72	22.68	43.16	80.74	348.26
2020	81.45	85.14	10.28	20.07	0.43	5.87	22.98	43.86	84.00	354.07
2021	81.75	85.98	10.38	20.23	0.43	6.01	23.28	44.56	87.26	359.88
2022	82.06	86.81	10.48	20.39	0.44	6.16	23.58	45.26	90.51	365.68
2023	82.37	87.64	10.58	20.54	0.45	6.30	23.88	45.95	93.77	371.49
2024	82.68	88.48	10.68	20.70	0.45	6.45	24.18	46.65	97.02	377.29
2025	82.99	89.31	10.78	20.85	0.46	6.59	24.48	47.35	100.28	383.09
2026	83.30	90.14	10.88	21.00	0.47	6.74	24.78	48.04	103.53	388.89
2027	83.61	90.98	10.98	21.15	0.48	6.88	25.08	48.74	106.79	394.68
2028	83.91	91.81	11.08	21.30	0.48	7.03	25.38	49.44	110.04	400.48
2029	84.22	92.64	11.18	21.45	0.49	7.17	25.68	50.14	113.30	406.27
2030	84.53	93.48	11.28	21.59	0.50	7.32	25.98	50.83	116.56	412.06
2031	84.84	94.31	11.38	21.73	0.50	7.46	26.28	51.53	119.81	417.85
2032	85.15	95.14	11.48	21.87	0.51	7.61	26.59	52.23	123.07	423.64
2033	85.46	95.98	11.57	22.01	0.52	7.75	26.89	52.92	126.32	429.42
2034	85.76	96.81	11.67	22.15	0.52	7.90	27.19	53.62	129.58	435.21
2035	86.07	97.64	11.77	22.29	0.53	8.04	27.49	54.32	132.83	440.99

*includes recreational and recovery vehicles; watercraft; special machinery and miscellaneous items

4.8.3 Other Revenues

Other revenues included revenues from international registration plan, permits, state court fees, and miscellaneous. The estimated amounts are shown in Table 4.13. The basis for the predicted revenue for each individual source was discussed in Section 4.5.

Table 4.13 Other Revenues Predictions

Year	International Registration Plan (\$M)	Permits (\$M)	State Court Fees (\$M)	Miscellaneous (\$M)	Total (\$M)
2010	81.1	15.1	3.6	6.5	106.4
2011	79.2	15.7	3.6	4.0	102.4
2012	77.2	16.2	3.6	1.5	98.5
2013	75.3	16.7	3.6	0.5	96.1
2014	73.3	17.2	3.6	0.5	94.7
2015	71.4	17.8	3.6	0.5	93.3
2016	69.4	18.3	3.6	0.5	91.8
2017	67.5	18.8	3.6	0.5	90.4
2018	65.5	19.3	3.6	0.5	89.0
2019	63.6	19.8	3.6	0.5	87.5
2020	61.6	20.4	3.6	0.5	86.1
2021	59.7	20.9	3.6	0.5	84.7
2022	57.7	21.4	3.6	0.5	83.3
2023	55.8	21.9	3.6	0.5	81.8
2024	53.8	22.5	3.6	0.5	80.4
2025	51.9	23.0	3.6	0.5	79.0
2026	49.9	23.5	3.6	0.5	77.6
2027	48.0	24.0	3.6	0.5	76.1
2028	46.0	24.5	3.6	0.5	74.7
2029	44.1	25.1	3.6	0.5	73.3
2030	42.1	25.6	3.6	0.5	71.8
2031	40.2	26.1	3.6	0.5	70.4
2032	38.2	26.6	3.6	0.5	69.0
2033	36.3	27.2	3.6	0.5	67.6
2034	34.3	27.7	3.6	0.5	66.1
2035	32.4	28.2	3.6	0.5	64.7

4.9 Disbursement of Highway Revenue

The total estimated highway revenue is allocated to the state and local agencies via a set of accounts and funds, according to the ratios and structures outlined in Chapter 3 and summarized in Table 4.14. Expected disbursements of revenues into the two major highway funds, Motor Vehicle Highway Account and Highway Road and Street Fund, for 2010 – 2035, are presented in Table 4.15. The estimated revenues in both funds appear to remain almost flat over the next two decades under the existing highway structure.

Table 4.14 State Highway Revenue Disbursement Formulas

Description		Disbursement Formula
Motor Vehicle Highway Account (MVHA)	a.	75% of the gasoline revenue after subtracting 22.25% (i.e., 4/18 cents) of the total revenue generated by the gasoline tax and a flat amount of \$25 million which goes to the Special Distribution Account (SDA)
	b.	75% of the special fuel revenue after subtracting a flat amount of \$25 million, which goes to the SDA
	c.	70% of registration revenue
	d.	100% of International Registration Plan
	e.	45.5% of motor carrier surcharge tax
	f.	100% of State Court Fees
Highway Road and Street Fund (HRSF)	a.	25% of the gasoline revenue after subtracting 22.25% (i.e., 4/18 cents) of total revenue generated by gasoline tax and a flat amount of \$25 million, which goes to the SDA.
	b.	25% of the special fuel revenue after subtracting a flat amount of \$25 million, which goes to the SDA
	c.	10% of registration revenue
Special Distribution Account (SDA)		Flat amount of \$25 million each from gasoline and special fuel revenue
State Highway Fund (SHF)	a.	5.55% (1/18 cent) of gasoline tax (effective since January 1, 2003)
	b.	40% of the revenue from the SDA
	c.	55% of the HRSF
	d.	100% of the MCFUT
	e.	45.5% of the Motor Carrier Surcharge Tax (MCST)
	f.	Transfer from previous years if any
	g.	Federal reimbursement and permits
	h.	Miscellaneous
	i.	53% of the net MVHA (after subtracting the expenses related to state police, BMV, miscellaneous, and Traffic Safety from the Gross MVHA account)
State Highway Road Construction and Improvement Fund (SHRCIF)	a.	11.11% (2/18 cent) of the gasoline tax
	b.	Transfer from previous years if any
Motor Carrier Regulation Fund (MCRF)		9% of the MCST

Table 4.15 Disbursements of Revenues in Major Accounts

Year	MVHA	HRSF
2010	794.0	182.3
2011	796.4	182.9
2012	799.4	183.8
2013	802.4	184.6
2014	804.6	185.2
2015	806.4	185.6
2016	807.4	185.9
2017	808.1	186.0
2018	810.3	186.6
2019	812.5	187.2
2020	813.6	187.5
2021	814.9	187.8
2022	815.7	187.9
2023	816.4	188.1
2024	817.7	188.4
2025	819.8	189.0
2026	821.5	189.4
2027	822.6	189.7
2028	823.3	189.8
2029	824.1	189.9
2030	825.3	190.2
2031	827.1	190.7
2032	828.9	191.2
2033	830.2	191.5
2034	830.8	191.6
2035	831.4	191.7

NB: Amounts are in millions of dollars

Where,

MVHA: Motor Vehicle Highway Account,

HRSF: Highway Road and Street Fund,

4.10 Short-Term Forecasting of Highway Revenue

In order to accommodate short-term fluctuations in highway revenues, two approaches were used; (i) linear regression approach and (ii) seasonal decomposition.

4.10.1 Short-Term Gasoline Tax Revenue Estimation

A linear regression model was developed to predict short-term automobile VMT used in estimating gasoline tax revenue. The purpose for this effort was to capture the volatility of the prevailing market reflected particularly in fuel prices and associated changes in vehicle miles of travel.

While gasoline price was not found to be statistically significant in predicting long-term automobile VMT, it was significant in estimating short-term VMT. Diesel fuel price, on the other hand, was not significant either for long-term or short-term truck VMT. Neither gasoline price nor diesel price was found to be significant in estimating short-term VMT for light duty trucks, single unit trucks and buses, however, per capita income was found to be significant for both short-term and long-term. The estimated short-term automobile VMT model is presented in Table 4.16. Gasoline price was estimated using a time series model shown in Table 4.17. The developed short-term VMT model is suitable for short-term (2 to 3 years) estimation purposes only. Recalibration of this model is required, after two to three years, to enhance the estimation reliability. The estimated short-term gasoline tax revenues are shown in Table 4.18.

From the available data, short-term VMT estimation for motorcycles, light duty trucks, single unit trucks, buses and combination trucks was considered to be the same as long-term VMT. From the available data also, per capita income, gross domestic product and driving age population were found not to vary significantly in the short-term. Consequently, time series models presented in Table 4.2 were used to estimate the short-term per capita income, gross domestic product and driving age population. Therefore, the developed models presented in Table 4.1 were used to estimate short-term VMTs for these vehicle categories.

Table 4.16 Model for Estimating Short-Term Automobile Vehicle Miles of Travel

VMT Model	Variable	t-statistic	R ²
$\text{AutoVMT} = 38506 - 14.9 \text{ GP}_{2008} + 0.423 (\text{PCI}_{2008})$	Intercept	5.46	0.53
	GP_{2008}	-2.8	
	PCI_{2008}	1.8	

NB: The estimated VMT is in millions

Where,

AutoVMT: vehicle miles of travel by automobiles,

PCI₂₀₀₈: per capita income in Indiana in 2008 dollars, and

GP₂₀₀₈: gasoline price in Indiana in 2008 dollars

Table 4.17 Short-Term Gasoline Price Prediction Model

Model	Variable	t-statistic	R ²
$\text{GP}_{2008} = -204 + 0.103 (w)$	Intercept	-3.92	0.69
	w	3.95	

Where,

GP₂₀₀₈: gasoline price in Indiana in 2008 dollars, and

w: prediction year

Table 4.18 Estimated Short-Term Gasoline Revenue

Year	2010	2011	2012
Gasoline Tax Revenue	550.58	548.42	547.12

4.10.2 Seasonal Factor Approach

For month by month revenue estimation, the seasonal decomposition method can be used to distribute the estimated annual revenues into monthly revenues. The annual revenues can be based on short or long term yearly forecasts. Seasonal factors for fuel tax revenues were developed using the data available from INDOT for monthly gasoline tax and special fuel tax revenues in Indiana from January, 2006 to September, 2008.

The resulting factors are shown in Table 4.19. Seasonal factors for motor carrier fuel use tax and motor carrier surcharge tax revenues were assumed to be the same as those for diesel fuel as presented in Table 4.19, due to the absence of monthly historical data. In the absence of recent monthly vehicle registration and driver license revenues, seasonal factors developed by Varma et al. (1991) were used as shown in Table 4.20.

Table 4.19 Seasonal Factors for Gasoline and Special Fuel Revenues

Month	Gasoline Tax Revenue	Special Fuel Tax Revenue
Jan.	0.98	1.00
Feb	0.95	0.93
Mar	0.87	1.01
Apr	0.99	1.10
May	0.96	0.76
Jun	1.03	0.91
Jul	1.00	1.06
Aug	1.07	0.87
Sep	1.12	1.19
Oct	1.02	1.18
Nov	1.04	0.95
Dec	0.98	1.04

Table 4.20 Seasonal Factors for Registration Revenue

Month	Registration Revenue	Driving License Revenue
Jan.	0.36	0.88
Feb	2.14	0.76
Mar	3.41	0.95
Apr	1.60	1.02
May	0.98	1.00
Jun	0.97	1.02
Jul	0.89	1.15
Aug	0.53	1.07
Sep	0.40	1.13
Oct	0.37	1.15
Nov	0.25	0.92
Dec	0.10	0.95

Source: Varma et al. (1991)

4.11 Validation of Models

In order to validate the models, revenues collected from gasoline tax, special fuel tax, motor carrier surcharge tax and motor carrier fuel use tax for 2006 – 2008 were compared with the predicted values from the long-term forecasting models, as shown in Table 4.21. The difference between the actual and predicted fuel revenues was found to be within 5%. In 2008, the difference between actual revenue for gasoline (\$555.3M) and

predicted revenue (\$559.72M) was 1.34% and the difference between actual total special fuel tax revenue (\$302.1M) and the predicted total revenue (\$307.21M) was 1.69%.

Short-term annual forecasting models for fuel tax revenues were also validated as shown in Table 4.22. For example, in 2007, the difference between actual revenue for gasoline (\$570.63M) and predicted revenue (\$558.342M) was 2.2%. The month by month revenues could not be validated due to the unavailability of monthly revenues from 2006 to 2008.

Registration-related revenues were validated using 2005 data as shown in Table 4.23. This is the only recently available data set. The difference between predicted and actual passenger vehicle registration in 2005 was 1.0%. Month to month validation could not be done due to the unavailability of monthly registration-related revenues.

Validation of other revenues (international registration plan, permits, state court fees and miscellaneous) was done using available data set for 2007. The difference between the predicted and actual other revenues in 2007 was 1.95%. Revenues coming from some of these sources are ad hoc as observed from the 5-year dataset (2003 to 2007) shown in Table A.7 in the Appendix.

The updated models appear to be reliable in predicting the expected highway revenue from the existing sources. The higher percentage difference observed for some of the model output could be due to the limited data size (1996 to 2006); nonetheless, the updated models can be able to predict, on the average, within 5% difference.

Table 4.21 Validation of Long-Term Prediction Models for Motor Fuel Revenue

Year	Gasoline Tax Revenue (in millions of \$)		% Diff.	Special Fuel Tax + MCST + MCFUT (in millions of \$)		% Diff.
	Actual	Predicted		Actual	Predicted	
2006	570.49	578.03	1.32	300.34	305.81	1.82
2007	570.63	579.72	1.59	310.10	306.70	-1.10
2008	553.46	580.30	4.85	302.10	307.20	1.69

Where,

MCST: motor carrier surcharge tax,

MCFUT: motor carrier fuel use tax,

Pred.: predicted revenue, and

Diff.: $\left(\frac{\text{Predicted Revenue} - \text{Actual Revenue}}{\text{Actual Revenue}} \right) \times 100$

Table 4.22 Validation of Short-Term Estimation Model for Gasoline Tax Revenue

Year	Revenue (in millions of \$)		% Diff.
	Actual	Predicted	
2006	570.49	559.37	-1.95
2007	570.63	558.34	-2.15
2008	553.46	556.34	0.52

Where,

Pred.: predicted revenue, and

Diff.: $\left(\frac{\text{Predicted Revenue} - \text{Actual Revenue}}{\text{Actual Revenue}} \right) \times 100$

Table 4.23 Validation of Vehicle Registration and Other Revenues Models

Revenue Source	Actual (in millions of \$)	Predicted (in millions of \$)	% Difference
Registration Fees (for 2005)			
Passenger Cars	76.06	76.82	1.00
Trucks (both farm & non-farm)	80.81	72.64	-10.11
Tractors (both farm & non-farm)	8.81	8.79	-0.23
Trailers/Semi-Trailers (both farm & non-farm)	16.55	17.37	4.95
Bus	0.31	0.32	3.23
Misc (i.e. Recreational & Recovery vehicles; special machinery, watercrafts and miscellaneous items)	38.54	35.17	-8.74
Motorcycles	3.64	3.69	1.37
Titles	34.57	33.4	-3.38
Driver License fees	17.77	18.47	3.94
*Others (for 2007)	117.02	119.3	1.95

*includes international registration plan, permits, state court fees and miscellaneous registration items.

CHAPTER 5 ALTERNATIVE HIGHWAY REVENUE SOURCES

5.1 Introduction

This chapter discusses revenue generation options under (a) modifications of the current tax system and (b) introduction of new revenue sources as supplements or substitutes for the current tax system. Modifications of the current tax system can be considered for near term options. In the medium to long term, alternative revenue sources can be phased in. This chapter presents pricing scenarios for generating revenue from each alternative revenue source.

5.2 Impact of Travel Cost on VMT

Changes in the current fuel tax structure or the introduction of new highway revenue sources can be expected to impact on vehicle miles of travel. Understanding of these impacts on VMT enables appropriate estimation of revenue. Impact estimation can be measured using elasticity. Elasticity is the percentage change in demand due to 1% change in a decision attribute. In the present study, these attributes include gasoline price, per capita income, gross domestic product and driving age population.

When the value of elasticity is greater than 1 or lower than -1, demand is defined as elastic with respect to the decision attribute, however if the estimated elasticity is greater than -1 or lower than 1, then demand is defined as inelastic or relatively insensitive to the decision attribute.

Elasticity computations were done using the arc elasticity approach. For example, arc elasticity values of VMT with respect to fuel prices were computed for each vehicle category using Equation 5.1.

$$e_{FP}(VMT) = \left(\frac{VMT_1 - VMT_0}{VMT_1 + VMT_0} \right) \times \left(\frac{FP_1 + FP_0}{FP_1 - FP_0} \right) \dots\dots\dots \text{Equation 5.1}$$

Where,

$e_{FP}(VMT)$: elasticity of VMT with respect to fuel price, FP,

VMT₁: vehicle miles traveled when fuel price is FP₁, and

VMT₀: vehicle miles traveled when fuel price is FP₀.

The annual Indiana VMT by vehicle category and the annual Midwestern gasoline and diesel prices from 1996 to 2006 were used to estimate elasticity values. Arc elasticities were computed for each 2-year group. The resulting 10 values were averaged to produce the elasticities over the entire period as shown in Table 5.1. From Table 5.1, the VMT elasticity values for automobiles, light duty trucks, single-unit trucks and motorcycles are direct elasticities with respect to gasoline price, while the elasticity value for bus is a cross elasticity with respect to gasoline price. Combination truck VMT is a direct elasticity with respect to diesel price. These values were used in estimating impacts of modifying the current fuel tax structure as well as implementing VMT fees and weight-distance truck fees. The justification for using these values for VMT fees and weight-distance truck fees was that these fees were assumed to replace appropriate fuel tax fees.

Table 5.1 Estimated VMT Elasticities with respect to Fuel Price

Vehicle Category	Elasticity
Automobile	-0.073
Motorcycle	-0.200
Light Duty Truck	-0.001
Single Unit Truck	-0.069
Bus	0.904
*Combination Truck	-0.066

*Value represents arc elasticities with respect to diesel price

Tolling and congestion pricing approaches were considered not to replace the existing fuel tax structure. They were assumed to be additional revenue sources. Consequently, the elasticity values for these two pricing schemes were estimated separately.

For tolling, unlike for other revenue sources, the VMT elasticity values developed by Oh and Sinha (2008) for interstates were adopted. In the present study, the VMT elasticity values (Table 5.2) used were the average of the minimum and maximum elasticity values developed by Oh and Sinha (2008). As can be expected, these values are much higher than the values associated with fuel prices.

Table 5.2 Estimated VMT Elasticity with respect to Hypothetical Toll Rates

Vehicle Category	Elasticity
Automobile	-0.37
Light Duty Truck	-0.37
Single Unit Truck	-0.15
Bus	-0.15
Combination Truck	-0.76

In order to estimate congestion pricing elasticity, previous studies (Harvey and Deakin, 1998; Davis, 2008; Litman, 2009) were reviewed. A congestion fee of 18 cents per mile at peak hour was considered for all vehicle categories except for transit buses. This fee rate was set using the results of a willingness-to-pay survey conducted by Davis (2008) along the 12-mile I-69 corridor in Indianapolis area. Harvey and Deakin (1998) simulated the expected effect of congestion pricing on transportation impacts within California for year 2010 and found that an average congestion fee of 19 cents per mile could reduce VMT and congestion delay by 3.3% and 32% respectively in South Coast. In 2005, a congestion price change in Central London from £5 to £8 resulted in a 38% reduction in traffic volumes (Litman, 2009). In the present study, reduction in traffic volume was considered based on the elasticity values presented in Table 5.2.

In cities around the world where cordon pricing has been practiced, overall traffic reduction varied from 15% to 22%, as discussed in Chapter 2. In the present study, reduction in traffic volume was considered based on the elasticity values presented in Table 5.2.

5.3 Modification of the Current Tax System

In Indiana, the current gasoline tax rate is \$0.18 per gallon and special fuel tax rate and motor carrier fuel surcharge tax rate are \$0.16 and \$0.11 per gallon, respectively. The motor carrier fuel use tax is \$0.16 per gallon. Although the average annual inflation rate for Midwestern states in recent years (1996 – 2009) has been about 3% (USDL, 2009), the existing motor fuel tax rates have not seen any amendment to reflect the erosion of purchasing power of the dollar. Consequently, the legislature may consider increasing the gallonage fuel tax rates or implementing an ad valorem tax on the retail motor fuel price paid at the pump.

5.3.1 Expected Revenue from Increased Motor Fuel Tax Rates

Figure 5.1 shows the impact of an increase in both gasoline and diesel tax rates by 1 or 3 cents per gallon in 2010. Expected annual revenues under these three scenarios (no increase in fuel tax rate, 1 cent increase and 3 cents increase) are presented in Table A.26. It is clear that while such an option can generate additional revenue in the short run, in the medium to long term, the revenue gain will not continue. This is primarily because of the expected continued enhancement of vehicle fuel efficiency.

Figure 5.1 Revenues from Increase in Fuel Tax Rates and Existing Fuel Tax

5.3.2 Expected Revenue from Ad Valorem Tax on Motor Fuel

An ad valorem tax is charged based on the value of a commodity. An ad valorem fuel tax can be levied on motor fuel price at the time of purchase from the pump, less federal, state and sales taxes. As discussed in Section 3.3, Indiana adopted an ad valorem tax in the early 1980s but switched back to the flat per gallon tax in 1985.

An ad valorem tax of 6.5% was considered in the present study. This rate falls within the lower limit of 6.4% and upper limit of 7%. The lower limit of 6.4% represents the fraction of the current gasoline tax amount within the total retail gasoline price (after removing the state, federal and sales taxes) in the first quarter of 2010, and the upper limit of 7% is based on the current sales tax rate in Indiana.

An ad valorem tax rate of 6.5% will make it equivalent to the current gallonage tax rate and therefore the revenue collected will not change in 2010. Figure 5.2 presents the expected revenue stream from ad valorem tax. In 2011, an ad valorem fuel tax of 6.5% with estimated retail gasoline price of \$2.5 and diesel price of \$2.56 (gasoline and diesel prices are without federal, state and sales tax) could generate a total fuel tax revenue of 918.43 million dollars as compared to the expected revenue of 887.85 million dollars from the

existing gallonage tax structure. An ad valorem fuel tax can generate significantly more revenue as compared to the option of increasing gallonage fuel tax rates, assuming continued trend of fuel price increase. Appropriate floor and ceiling to the tax rates can minimize the impact of wide fluctuations in fuel price in the future.

Figure 5.2 Comparison of Ad Valorem Fuel Tax Scenarios with Existing Fuel Tax Scheme

5.3.3 Indexing Motor Fuel Tax Rate to Inflation

Inflation-indexing is a way to keep the real value of the expected revenue from eroding due to inflation. The consumer price index was used for adjusting gasoline tax rate and producer price index was used for diesel tax rate. The projected indices used for indexing the fuel tax rates were based on data from 1996 to 2008 obtained from USDL (2009).

Analysis indicated that inflation-indexing of fuel tax rates could generate in 2020, on the average, 34.2% more revenue than the expected revenue from fuel tax rate of the existing system. The expected inflation-indexing revenue and revenue from the current fuel tax structure are presented in Figure 5.3 and Table A.27.

Figure 5.3 Comparison of Inflation Indexing of Fuel Tax Rates with Existing Fuel Tax Scheme

5.4 Revenue Estimation from New Sources

Methodologies used for estimating revenues from alternative sources (VMT fees, weight-distance fees, tolling and congestion pricing) are presented in this section. The concepts of these revenue sources were discussed in Sections 2.4 and 2.5.

5.4.1 VMT Fee Methodology and Estimated Revenue

In the present study, revenue from VMT fee is categorized into four pricing scenarios: (i) flat VMT fee to replace the current fuel tax (gasoline tax, special fuel tax, motor carrier surcharge tax and motor carrier fuel use tax); (ii) 1% annual increase of the VMT fee in (i); (iii) 2% annual increase of the VMT fee in (i); and (iv) 3% annual increase of the VMT fee in (i). Vehicle registration fees and the other existing highway revenue sources are considered to remain unchanged.

The fee structure for the first VMT pricing scenario was estimated by dividing motor fuel tax rate by the estimated fleet fuel efficiency for a specific vehicle category. For example, the VMT fee to be paid by an automobile in 2010, the year of implementation, would be \$0.00692 per mile (\$0.18 / 26 mpg). The remaining VMT fee scenarios are based on increasing the initial VMT fee annually by 1%, 2% and 3% respectively, starting in 2011. Table 5.3 shows the VMT fee rate for each vehicle category for 2011 under the corresponding VMT fee scenarios.

The introduction of VMT fee will not affect VMT values in 2010 but will change from 2011 as the travel cost starts to increase. In order to estimate the expected impact on VMT in the years after the implementation year, travel demand elasticity values given in Table 5.1 were used. Estimated VMT fee revenues for the four pricing scenarios are shown in Figure 5.4 and Table A.28.

Table 5.3 VMT Fee Scenarios

Vehicle Category	VMT Fee Scenario 1: Replaces Fuel Taxes (cents/mile)	VMT Fee Scenario 2: 1% Annual Increase in VMT Fee Scenario 1 (cents/mile)	VMT Fee Scenario 3: 2% Annual Increase in VMT Fee Scenario 1 (cents/mile)	VMT Fee Scenario 4: 3% Annual Increase in VMT Fee Scenario 1 (cents/mile)
Automobile	0.692	0.699	0.706	0.713
Motorcycle	0.321	0.325	0.38	0.331
Light Duty Truck	0.857	0.866	0.874	0.883
Single Unit Truck	2.057	2.078	2.098	2.119
Bus	2.162	2.184	2.205	2.227
Combination Truck	4.426	4.470	4.515	4.559

Figure 5.4 Comparison of VMT Fee with Existing Fuel Tax Scheme

5.4.2 Weight-Distance Truck Fee Methodology and Estimated Revenue

Weight-distance truck fee is a fee imposed upon a vehicle on the basis of the weight and the distance it travels within a given region over a given period of time (Fwa and Sinha, 1987). Weight measurement varies depending upon the actual operating weight, maximum registered laden weight, or axle configuration of heavy trucks.

The purpose of this fee is to recover infrastructure costs associated with heavy vehicle operations on the road network and the unit infrastructure cost per mile of travel varies according to vehicle class and weight. The weight-distance truck fee has been assumed to apply to only single unit trucks and combination trucks with registered gross weight of 26,000 lbs and above. Estimation of an appropriate fee per vehicle weight class would require a highway cost allocation study (HCAS) (TRB, 2006).

In the absence of a recent highway cost allocation study, weight-distance truck fees were estimated using the current special fuel tax rates paid by appropriate trucks. This approach was considered reasonable because the resulting rates would make the fees revenue neutral in the implementation year. As noted in Section 5.1, weight-distance truck fee was assumed to replace special fuel tax for trucks. Single unit trucks

weighing above 26,000 lbs and all combination trucks, of all weight classes were considered to consume special fuel. Currently, single unit trucks pay 16 ¢/gallon while combination trucks pay a total fuel tax of 27 ¢/gallon. In order to estimate the floor and ceiling weight-distance truck fees, the amount currently paid by single unit trucks in the weight category 26,000 to 30,000 lbs in cents per mile was considered, while for ceiling the amount paid by combination trucks weighing over 78,000 lbs was used.

The fleet fuel efficiency for single unit trucks (26,000 lbs – 30,000 lbs) in 2010 is 8.71 mpg. The floor for weight distance-truck fees was thus computed as 16 ¢/gallon divided by 8.71 mpg which is equal to 1.81 ¢/mile. Similarly, the ceiling was thus computed as 27 ¢/gallon divided by 5 mpg which equals 5.4 ¢/mile.

In order to estimate fee rates between the floor and the ceiling, an average value of 13% fee rate increase from one vehicle weight class to the next weight class was assumed. The 13% value was observed to be the average percentage difference in the fee structure for vehicle weight classes in the recent Oregon highway cost allocation study (EcoNorthWest, 2009). The estimated weight-distance truck fees are presented in Table 5.4.

Table 5.4 Weight-Distance Truck Fee

Vehicle Gross Registered Weight Class (lbs)		Weight Distance Truck Fee Rate (\$/mile)
From	To	
26,000	30,000	0.0181
30,001	36,000	0.0210
36,001	42,000	0.0270
42,001	48,000	0.0290
48,001	54,000	0.0320
54,001	60,000	0.0340
60,001	66,000	0.0380
66,001	72,000	0.0440
72,001	78,000	0.0490
78,001	Above	0.0540

In order to estimate miles of travel for these trucks, the VMT models developed for combination trucks and single units trucks presented in Table 4.1 were used. The total VMT for the estimation of weight-distance revenue included 5% of single unit truck VMT and 100% of combination truck VMT, reflecting the percentages using special fuel.

In order to distribute the total miles travel into the various registered weight classes, the approximate fraction of miles of travel for each registered truck weight obtained from INDOT were used as shown in Table 5.5.

Table 5.5 Single Unit and Combination Trucks VMT Distribution

Vehicle Gross Registered Weight Class (lbs)		Fraction of VMT
From	To	
26,000	30,000	0.02
30,001	36,000	0.02
36,001	42,000	0.04
42,001	48,000	0.05
48,001	54,000	0.09
54,001	60,000	0.12
60,001	66,000	0.20
66,001	72,000	0.20
72,001	78,000	0.19
78,001	Above	0.07

Revenue from weight-distance truck fee was categorized into four pricing scenarios: (i) flat weight-distance truck fee to replace the current fuel tax (special fuel tax and / or motor carrier surcharge tax); (ii) 1% annual increase of the weight-distance truck fee in (i); (iii) 2% annual increase of the weight-distance truck fee in (i); and (iv) 3% annual increase of the weight-distance truck fee in (i).

Estimated weight-distance truck fee revenues for the four pricing scenarios are shown in Figure 5.5 and Table A.29. The introduction of weight-distance truck fee will not affect weight-distance travel in 2010 but will change from 2011 as the travel cost starts to increase. In order to estimate the expected impact on single unit truck and combinations truck miles of travel in the years after the implementation year, VMT elasticity values given in Table 5.1 were used.

Figure 5.5 Comparison of Weight-Distance Truck Fee (WDTF) with Existing Fuel Tax Scheme

5.4.3 Road Tolls Methodology and Estimated Revenue

The steps followed to estimate possible revenue from tolling are presented in Figure 5.3. Tolling, in this present study, was considered for urban interstate sections only. The urban interstate sections identified in the present study included parts of I-465, I-64, I-65, I-69, I-70, I-74, I-80, I-80/I-90, I-90 and I-94. In order to estimate the expected VMT within each vehicle category using an interstate, linear time series models were developed on the basis of a dataset (FHWA, 2007) of annual miles of travel on all interstates in the United States (Table A.30). The models for automobiles, light duty trucks and combination trucks were statistically significant as shown in Table 5.6. For motorcycles, single unit trucks and buses, interstate VMT was estimated by redistributing the remaining proportion with each vehicle's 13-year average vehicle miles traveled (Table A.31).

In order to estimate the possible minimum tolling revenue, the minimum of rates charged on the Indiana toll road (I-90/I-80) for those using I-Zoom were adopted as shown in Table 5.7. In order to estimate the impact of toll rates on demand, elasticity values presented in Table 5.2 were used.

Possible tolling revenues for year 2010 after adjusting for elasticity, for interstates along urban sections are presented in Figure 5.7 with the estimated tolling revenues for selected years (2010, 2020, 2030 and 2035) presented in Table A.33. The lengths of urban sections along these identified interstates are presented in Table A.33.

Figure 5.6 Methodology for Estimating Tolling Revenue from a Specific Toll Route

Table 5.6 Models for Estimating VMT Proportion by Vehicle Category at a Typical Interstate Section

Vehicle Type	Model	Variable	t-statistics	R ²
Automobile VMT Proportion (AP)	$AP = 1321.379 - 0.631(z)$	Intercept	5.86	0.72
		z	-5.60	
Light Duty Truck VMT Proportion (LP)	$LP = -1053.02 + 0.542(z)$	Intercept	-4.83	0.67
		z	4.98	
Combination Truck VMT Proportion (CP)	$CP = -141.727 + 0.0738(z)$	Intercept	-6.33	0.78
		z	6.60	

Where, z: year of prediction

Table 5.7 Toll Rates

Vehicle Category	Toll Rate (\$/mile)
Automobile	0.03
Motorcycle	-
Light Duty Truck	0.04
Single Unit Truck	0.12
Bus	0.1
Combination Truck	0.26

NB: Toll rates are based on those charged on the Indiana Toll Road (ITR, 2010)

Figure 5.7 Estimated Urban Interstate Tolling Revenue in 2010

5.4.4 Congestion Pricing Methodology and Estimated Revenue

The steps followed to estimate possible congestion pricing revenue are presented in Figure 5.8. Five urban interstate sections (I-465, I-65, I-69, I-70 and I-80) in Indiana were included in the analysis because of their high v/c ratio values. Available traffic data for year 2002 was projected in future years using appropriate growth factors from INDOT (2007).

The traffic volume, v , and capacity, c , for each interstate link were used to compute threshold “volume-to-capacity” ratio (v/c) at each year using the methodology given in Gunawardena et al. (1994) and Opsuth et al. (1996). As suggested by Gunawardena et al. (1994), a volume-to-capacity ratio of 0.8 was set as the threshold for congestion for urban interstates; sections identified as congested were selected as candidate roads for congestion pricing to be implemented in a given year during the analysis period (2010 – 2035).

A congestion fee of 18 cents per mile at peak hour was considered for all vehicle categories except for transit buses. This fee rate was set using the results of a willingness-to-pay survey conducted by Davis (2008) along the 12-mile I-69 corridor in Indianapolis area. This rate translates to \$2.16 for a 12-mile section representing low end of the range of fees travelers were willing to pay for all trips, work and non-work. Congestion pricing fees can be made to vary by time of day, as practiced at I-15 HOT in San Diego and at other places in and outside the United States. In the present study, congestion pricing was considered for morning peak periods (7am – 10am) for week days only.

The proportion of traffic volume occurring in a peak hour was estimated by adjusting the average daily traffic using a k-factor of 0.093, the recommended HCM value for urbanized areas (TRB, 2000). With the exception of transit buses, all vehicle categories are expected to pay a congestion fee and at the same rate.

From the elasticity discussion in Section 5.2, the expected impact on traffic was based on the elasticity values presented in Table 5.2. The estimated congestion pricing revenues, after adjusting for elasticity, are summarized in Table A.34 for the years 2010, 2020, 2030 and 2035. Figure 5.9 shows the estimated congestion pricing revenues for urban interstates for 2030.

Figure 5.8 Methodology for Estimating Congestion Pricing Revenue from a Specific Route

Figure 5.9 Estimated Congestion Pricing Revenues from Urban Interstates in 2030

5.4.5 Cordon Pricing Methodology and Estimated Revenue

Cordon tolls are fees paid by motorists to drive in a particular area, usually a central business district. It is not uncommon to have cordon tolls apply during peak periods and some periods within off-peak periods. This could be implemented by requiring vehicles driven within the cordon to display a pass, or by tolling at each entrance to the area. Cordon pricing practiced in most countries has one objective; to manage congestion by reducing the number of vehicles coming into urban centers at peak periods.

The downtown of Indianapolis was selected, in the present study, as the designated area for estimating possible revenue from cordon pricing. For possible revenue estimation, only morning peak periods (7am – 10am) were considered. Downtown traffic data came from a recent study (Sinha et al., 2004). Appropriate traffic growth factors (INDOT, 2007) were used to project traffic to future years (2010 – 2035).

To obtain the proportion of traffic during the average peak period, a k-factor of 0.093 was used, the recommended Highway Capacity Manual value for urbanized areas (TRB, 2000). Revenue estimation from cordon pricing excluded internal traffic generated from residents in downtown Indianapolis. Internal traffic was estimated by multiplying the average vehicle-trips per day for a household by the total number of households. With the number of households of 2959 within the downtown (Onboard, 2007) and assuming an

average household vehicle-trips per day as 3.4 (Davis et al., 2009), the estimated number of vehicle-trips per household was 10,061 (2959×3.4) and this constituted 2.5% ($10061 / 401,323$) of the average daily traffic. The identified roads used for the cordon pricing with their corresponding estimated morning peak period traffic volumes are presented in Table A.35.

Automobiles and light duty trucks were considered to pay a cordon fee under a possible cordon pricing scheme. During morning peak periods, 95% of all traffic entering the downtown area was assumed to include automobiles and light duty trucks. This number is reasonable considering that most heavy vehicles, except transit buses, would be bypassing around the downtown during peak periods.

To estimate possible revenue, a flat fee of \$2 was considered. This fee rate was set using the results of a willingness-to-pay survey conducted by Davis (2008) along the 12-mile I-69 corridor in Indianapolis area. The expected reduction in traffic was based on the elasticity values presented in Table 5.2. The estimated cordon pricing revenue, after adjusting for elasticity, during the analysis period (2010 – 2035) is presented in Figure 5.10 and Table A.36.

Figure 5.10 Estimated Cordon Pricing Revenue

5.5 Comparative Analysis

A comparative analysis of revenues from the modifications in the existing fuel tax structure and alternative revenue sources replacing fuel taxes are shown in Figure 5.11. From Figure 5.11, it can be seen that, increasing fuel tax rate by either 1 cent or 3 cents in 2010 will only increase the highway revenue in the short run but in the medium to long-term, this approach will not be sustainable. On the other hand, the implementation of a flat VMT fee (VMT Scenario 1) can bring in sufficient revenue in the short to long-term to make highway financing sustainable. Furthermore, should the flat VMT fee be increased annually by at least 1%, then the revenues can be expected to increase even at a faster rate with time.

Inflation indexing of fuel tax rate is expected to generate more revenue than the current fuel tax revenue; however, this result is based on the assumption that inflation would continue to follow the past trend of 3% annual increase (USBEA, 2009). Using the ad valorem tax of 6.5% could also generate more revenue than the current fuel tax structure. However, the assumption underpinning this approach is based on a 3% annual average increase in retail fuel price.

The trend from Figure 5.11 suggests that adopting a new highway revenue scheme such as VMT fee would be desirable as compared to modifications in the current fuel tax structure. This is because expected revenues from modifying the fuel tax structure will still be tied to fuel consumption which is hinged primarily on vehicle fuel efficiency. Since vehicle fuel efficiency will continue to be further enhanced in the future, expected revenues from modifications in the fuel tax structure cannot be expected to keep up with funding needs.

Figure 5.11 Comparative Analysis of Revenue Sources

5.6 Sensitivity Analysis

Sensitivity analysis estimates the impact in an outcome (dependent variable) due to variations in explanatory variables. The impacts on highway revenues from fuel prices were discussed in Section 5.2. In order to estimate how sensitive the prediction models are to the other independent variables (per capita income, gross domestic product and driving age population), elasticity values were computed based on the prediction models (Tables 4.1 and 4.5) and are presented in Tables A.37 to A.40.

Increasing the tax rates (fuel and registration) by a specific amount can increase highway revenue in the short term. The effect of increasing tax rates (fuel and registration) is presented in Table 5.8. For example, a 1-cent increase in the gasoline tax in 2010 could generate an increase of 5.5% (\$32.08 million) in year 2020 as compared to the existing gasoline tax rate revenue; the same increase in special fuel could generate an increase of 6% (\$13.06 million) in year 2020 as compared to the existing tax rate. A \$1 increase in automobile registration fee in year 2010 could generate additional revenue that is on the average, four times more than the extra revenue to be generated by a \$100 increase in 66,000+ lbs truck registration fees in year 2020.

Table 5.8 Effects of Tax Rate Increases on Revenue generated in 2020

Major Parameter	Action	Additional Revenue Generated (in millions of \$)
Gasoline tax	Increase by 1 cent	32.08
Special fuel tax	Increase by 1 cent	13.06
Motor carrier surcharge tax	Increase by 1cent	8.72
Motor carrier fuel use tax	Increase by 1 cent	0.08
Automobile registration fee	Increase by \$1	3.93
Truck (7000 lbs) registration fee	Increase by \$1	1.4
Truck (66,000+ lbs) registration fee	Increase by \$100	0.98

5.7 Software Package

In order to incorporate the forecasting models and procedures discussed in this report, the INDOTREV-1 software package was revised to provide INDOTREV-2. In addition to forecasting highway revenues from existing sources, INDOTREV-2, can be able to predict possible revenues and conduct preliminary impact analysis from alternative highway revenue sources identified in Chapter 5 of this report. The software package was developed in Microsoft Visual Basic.Net platform and it is capable of running on Microsoft Windows Operating System. Attached to this report, is a compact disc containing both the executable software and the user's manual. Screen shots of the software interfaces are presented in Figures B.1 through B.8 of Appendix B.

CHAPTER 6 SUMMARY AND CONCLUSIONS

6.1 Introduction

The principal objectives of this study were to revise the existing highway revenue forecasting models for Indiana, identify alternative revenue sources and possible changes to the existing highway taxation structure. The study also developed the INDOTREV-2 software package to incorporate all the developed models and methodologies for forecasting highway revenues from traditional and alternative sources.

6.2 Statistical Approach

The models developed in this study include vehicle miles of travel, vehicle registrations, and vehicle fleet fuel efficiency. A 10-year dataset (from 1996 to 2005) was used to develop most of the models. The independent variables used included per capita income, real gross domestic product and driving age population in Indiana. These socio-economic variables were found to be reliable, easily available, and relevant to the study and adequate in forecasting highway revenues. INDOTREV-2, the updated software incorporating revised models, provides short- and long-term highway revenue forecasts from 2010 through 2035. The models were validated to ascertain prediction reliability by comparing the estimated values with the actual available dataset from 2006 to 2008. Vehicle registration models were validated using only the 2005 dataset due to the unavailability of data from recent years. Overall estimated fuel tax revenue for 2008 was within 2% difference and that vehicle registration revenue indicated about 4% difference.

6.3 Highway Revenue from Existing Sources

Highway revenues from existing sources were disaggregated into gasoline, special fuel, motor carrier surcharge tax, motor carrier fuel use tax, vehicle registration, driving license and others (international registration plan, state court fees, permits, titles and

miscellaneous). Revenues predicted from these sources were allocated into the various funds using ratios mandated by legislature. The funds include, among others, Highway Road and Street Fund (HRSF); Motor Vehicle Highway Account (MVHA); Motor Carrier Regulation Fund (MCRF); State Highway Fund (SHF); and State Highway Road Construction Improvement Fund (SHRCIF).

From 1996 to 2006, the vehicle miles traveled for automobiles, single unit trucks and buses decreased annually at an average rate 0.11%, 0.20% and 5.37% respectively; with motorcycles, combination trucks and light duty trucks (which consist of minivans, pick-up trucks and sport utility vehicles) increasing annually at an average rate of 4.64%, 1.08% and 3.84% respectively. The decrease in automobile travel could be due to an increased in the VMT share of light duty truck travel, which is also used for personal travel purposes.

The national on-the-road vehicle fleet fuel efficiency, from 1996 to 2006, for automobiles has increased by 5.66% (i.e. from 21.2 to 22.5 mpg) while the corporate average fuel economy (standard for new automobiles and light duty trucks) remained same (27.5 mpg) within the period. The fleet fuel efficiency for buses decreased by 10.6% (from 6.6 mpg in 1996 to 5.9 mpg in 2006). The corporate average fuel economy for light duty trucks increased by 4.35% (from 20.7 to 21.6 mpg), however, the reported national on-the-road vehicle fleet fuel efficiency increased marginally by 3.49% (from 17.2 mpg in 1996 to 17.8mpg in 2006). Over the past decade, fuel efficiencies of automobiles and light duty trucks continued to improve as a result of technological advancement and this trend is expected to continue with the passage of the Energy Independence and Security Act 2007. Increasing fuel efficiencies will adversely affect fuel revenues from automobiles and light duty trucks.

Although gasoline revenue generally increased, on the average, by 0.27% in real terms (from 1996 to 2006), it has decreased annually by 3.35% from 2003 to 2006. Revenue for special fuel increased on the average by 0.91% from 1996 to 2006, but from 2004 to 2006, it has decreased on the average by 1.7%. The recent declining amounts of revenue could be attributed to factors such as increased use of fuel-efficient vehicles and recent decrease in vehicle miles of travel.

Inflation-indexing of fuel tax rates can be considered in the future. The expected fuel revenue generated from inflation-indexing in 2020 could be \$1,185.64 million, 34.2% more than the total fuel revenue from the existing fuel tax structure.

Sensitivity analysis for various input variables was conducted. For example, a 1% increase in gasoline price results in an increase of 0.904% in bus VMT and a reduction of 0.073% in automobile VMT. A 3-cent increase in motor fuel tax rates could also yield 18.11% more revenue in 2015 but from 2016 to 2035, the expected revenue will continue to reduce due to further improvement in vehicle fuel efficiency. Thus, this option was found to be unsustainable in the future. A \$1 increase of automobile registration fee could generate, on the average, four times more revenue than a \$100 increase in the registration fee of trucks weighing 66,000 lbs or more.

6.4 Alternative Highway Revenue Sources

New highway revenue sources such as vehicle miles of travel fee, weight-distance truck fee, tolling, congestion pricing (including cordon pricing) and inflation-indexing can be considered for the medium to long term. The present study developed methodologies for making planning level estimates of these possible future revenues.

Vehicle miles of travel (VMT) fee rate was determined on the assumption that such a fee would replace fuel tax and its implementation would be revenue neutral in the year of implementation. Estimates were made on the assumption of a flat fee as well as under three scenarios of 1%, 2% and 3% annual increase in rate. It was further assumed that existing complementary highway revenue sources (i.e., vehicle registration fees and other revenue sources) will not be discontinued. An appropriate VMT elasticity with respect to VMT fee was considered. Expected revenue from the VMT fee pricing scenarios in 2020, after adjusting for elasticity, would range from 958.79 to 1,284.26 million dollars. In 2020, even the flat VMT fee scenario could generate 8.5% more revenue than the existing fuel tax structure.

The weight-distance truck fee was assumed to apply to only single unit trucks and combination trucks with registered gross vehicle weight class of 26,000 lbs and above. Estimation of the appropriate fee per vehicle weight class requires a highway cost allocation study. The weight-distance truck fee revenue, after adjusting for elasticity, could range in 2020 from 311.36 to 417.58 million dollars. In 2020, even the flat weight-distance truck fee could generate 5.8% more revenue than the existing diesel tax structure from trucks.

Tolling of urban interstates is another possible alternative revenue source considered. Tolling was considered as an additional source of revenue and not to replace any existing sources. The toll rate per vehicle category used for Indiana toll road (I-90/I-80) was considered for motorists with I-Zoom account. In 2020, expected total revenue after adjusting for elasticity, for tolling all urban interstate sections could generate \$558 million on the assumption that all vehicles would use I-Zoom.

Congestion pricing option was also considered for urban interstates. For example, implementing congestion pricing on I-465, during the morning peak periods (7am – 10am) in 2020, could generate, after adjusting for elasticity, on the average, \$468,500 based on a congestion pricing fee of 18 cents per mile.

Cordon tolls are fees paid by drivers for driving in a congested downtown. Assuming the downtown of Indianapolis as the designated area for morning peak periods cordon pricing, the expected revenue in 2020 could be 31.15 million dollars.

6.5 Data Availability

Availability of data is paramount for developing appropriate prediction equations. The data available for the present study had several gaps. For example, no data on recent VMT by vehicle category, monthly gasoline and special fuel revenues could be obtained from INDOT or other agencies for the validation of the model results. Also the data on fuel revenues that was made available from January, 2006 to September, 2008 did not include information on motor carrier surcharge and motor carrier fuel use tax revenues.

Similarly, data on the number of registered vehicles and registration related-items such as the number of licensed drivers and registration revenues from 2006 to 2009, which was to be used to validate vehicle registration and registration-related equations, could not be obtained either from INDOT or the Bureau of Motor Vehicles.

The estimation and validation of alternative highway revenues from proposed sources could be facilitated by the availability of recent traffic distribution information by vehicle category (automobiles, light duty trucks, motorcycles, single unit trucks, buses and combination trucks) within downtown Indianapolis and along all the interstates in Indiana. Data on truck traffic percentage within a traffic mix for each interstate was also not available for the study.

6.6 Future Research Recommendations

Implementation of any of the options presented in the study will require in-depth studies. The INDOTREV-2 software package can be further enhanced with augmented data. The study results should be considered as preliminary. All of the options also require legislative approvals. Future research will be necessary to design properly any of the options considered. For example, before implementation of VMT fee, procedures for collecting the fee and associated technologies should be identified.

The weight-distance truck fee implementation will require a highway cost allocation study to ascertain an equitable fee structure among vehicle weight classes. The necessary technological requirements should also be identified.

Tolling implementation requires identification of candidate interstates and the adoption of appropriate toll fee. Although the Indiana toll road fee structure was used in this present study, the setting of toll fee will require site specific studies.

Congestion pricing implementation will require detailed study of the physical and traffic characteristics of each of the identified roadways. The feasibility study should identify the traffic and traffic mix distribution for the selected interstates. Furthermore, a willingness-to-pay study of road users should also be carried out to determine the fee structure.

Similarly, cordon pricing for downtown Indianapolis will require a study of the actual traffic distribution and traffic mix during peak hours. A willingness-to-pay survey should also be undertaken and procedures for administration of the pricing scheme should be determined.

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Appendix A Data and Intermediate Results

Table A. 1 Historical Economic Data

Year	Consumer Price Index (Midwest Urban)	Producer Price Index (National)	Gross Domestic Product (in billions of \$)	Per Capita Income (\$)
1996	153.0	127.7	7,817	22,368
1997	156.7	127.6	8,304	23,306
1998	159.3	124.4	8,747	24,894
1999	162.7	125.5	9,268	25,615
2000	168.3	132.7	9,817	27,134
2001	172.8	134.2	10128	27414
2002	174.9	131.1	10470	28058
2003	178.3	138.1	10961	28917
2004	182.6	146.7	11686	29982
2005	188.4	157.4	12422	30593
2006	193.0	164.7	13178	32006
2007	198.1	172.6	13,808	33215
2008	205.4	189.6	14,265	34103

Source: USBEA (2009) and USDL (2009)

Table A. 2 Historical Midwest Average Gasoline and Diesel Prices

Year	Diesel Price (\$)	Gasoline Price (\$)
1996	1.22	1.18
1997	1.20	1.17
1998	1.03	1.01
1999	1.14	1.11
2000	1.48	1.47
2001	1.42	1.42
2002	1.35	1.34
2003	1.56	1.52
2004	1.85	1.80
2005	2.27	2.22
2006	2.57	2.52

Source: USEIA(2009)

Table A. 3 Historical Driving Population and Licensed Drivers in Indiana

Year	Driving Population	Licensed Drivers
1996	4340292	1,883,522
1997	4360911	1,999,144
1998	4387849	1,877,967
1999	4413910	1,922,516
2000	4508150	2,015,917
2001	4618508	2,148,614
2002	4565785	1,972,480
2003	4593420	2,132,974
2004	4631060	2,177,070
2005	4675844	2,221,525
2006	4918223	2,266,341

Source: FHWA (2007); BMV

Table A. 4 Vehicle Miles Traveled in Indiana (in millions)

Year	Automobile	Light Duty Truck	Single Unit Truck	Motorcycle	Bus	Combination Truck
1997	49318	11215	2357	349	441	6741
1998	49307	11535	2394	260	376	6823
1999	49679	11963	2403	257	360	6797
2000	50409	12143	2430	261	362	6712
2001	50226	13742	2181	334	292	7322
2002	50467	14176	2314	355	315	7019
2003	50248	14112	2307	354	315	7037
2004	49478	14837	2330	424	296	7175
2005	48850	15080	2302	460	275	7308
2006	48681	15079	2405	459	301	7261

Source: INDOT, Division of Economic and Contract Audit (Mark Ratliff)

Table A. 5 Historical Operational Fleet Fuel Efficiency (FFE)

Year	Automobile FFE	Motorcycle FFE	Bus FFE	Light Duty Truck FFE	Single Unit Truck FFE	Combination Truck FFE
1996	21.2	50.0	6.7	17.2	6.8	5.9
1997	21.5	50.0	6.7	17.2	7.0	6.1
1998	21.4	50.0	6.7	17.2	7.0	6.1
1999	21.4	50.0	6.7	17.0	7.5	5.4
2000	21.9	50.0	6.8	17.4	7.4	5.3
2001	22.1	50.0	6.9	17.6	7.5	5.4
2002	22.0	50.0	6.9	17.5	7.4	5.2
2003	22.2	50.0	6.9	16.2	8.8	5.9
2004	22.5	50.0	7.0	16.2	8.8	5.9
2005	22.1	50.0	5.0	17.7	8.3	5.2
2006	22.4	50.0	6.1	18.0	8.2	5.1

Source: Davis et al. (2009)

Table A. 6 Past Indiana Fuel Revenue Sources

Year	Motor Carrier Fuel Tax Revenue(\$M)	Motor Carrier Surcharge Tax Revenue(\$M)	Gasoline Revenue (\$M)	Special Fuel Revenue (\$M)
1997	7.43	68.13	443.8792	147.5528
1998	9.87	103.42	455.5696	151.245
1999	7.04	100.33	466.4279	161.7794
2000	5.75	84.34	464.1528	186.794
2001	3.73	98.64	493.6842	151.3357
2002	5.07	85.87	480.8089	170.3084
2003	5.19	85.72	518.2956	172.7126
2004	6.76	93.88	582.6107	183.8261
2005	6.03	92.62	579.675	193.1275
2006	3.48	100.04	570.4902	196.8127
2007	-	-	570.6287	196.2094

Source: INDOT; ILSA (2009); FHWA (2007)

Table A. 7 Past “Other Highway Revenue” Sources

Year	International Registration Plan	Permits	State Court Fees	Miscellaneous
2003	95930538	11410743	3615000	23221856
2004	75104042	11972427	3615000	19421425
2005	88615395	12638102	3615000	22869840
2006	95282593	13281781	3615000	17110147
2007	88131939	13367483	3615404	11903684

Source: INDOT, Division of Economic and Contract Audit (Mark Ratliff)

Table A. 8 Driving Age Population and Licensed Drivers in Indiana

Year	Driving Age Population	Year	Driving Age Population	Year	Driving Age Population
2010	4883437	2019	5238244	2028	5593051
2011	4922860	2020	5277667	2029	5632474
2012	4962283	2021	5317090	2030	5671897
2013	5001706	2022	5356513	2031	5711320
2014	5041129	2023	5395936	2032	5750743
2015	5080552	2024	5435359	2033	5790166
2016	5119975	2025	5474782	2034	5829589
2017	5159398	2026	5514205	2035	5869012
2018	5198821	2027	5553628		

Table A. 9 Distribution Factors for Trucks

Vehicle Registered Weight Class	Distribution factor	Vehicle Registered Weight Class	Distribution factor
Truck 7,000 Lbs	0.8489	Truck 66,000 + Lbs	0.0059
Truck 9,000 Lbs	0.0244	Farm Truck 11,000 Lbs	0.0080
Truck 10,000 Lbs	0.0016	Farm Truck 16,000 Lbs	0.0047
Truck 11,000 Lbs	0.0326	Farm Truck 20,000 Lbs	0.0013
Truck 16,000 Lbs	0.0276	Farm Truck 23,000 Lbs	0.0002
Truck 20,000 Lbs	0.0109	Farm Truck 26,000 Lbs	0.0058
Truck 23,000 Lbs	0.0016	Farm Truck 30,000 Lbs	0.0028
Truck 26,000 Lbs	0.0117	Farm Truck 36,000 Lbs	0.0007
Truck 30,000 Lbs	0.0026	Farm Truck 42,000 Lbs	0.0007
Truck 36,000 Lbs	0.0021	Farm Truck 48,000 Lbs	0.0017
Truck 42,000 Lbs	0.0004	Farm Truck 54,000 Lbs	0.0007
Truck 48,000 Lbs	0.0010	Farm Truck 60,000 Lbs	0.0001
Truck 54,000 Lbs	0.0011	Farm Truck 66,000 Lbs	0.0001
Truck 60,000 Lbs	0.0002	Farm Truck 66,000 + Lbs	0.0001
Truck 66,000 Lbs	0.0004		

Derived from Shah (2005)

Table A. 10 Distribution Factors for Tractors

Vehicle Weight Class	Registered	Distribution factor	Vehicle Registered Weight Class	Distribution factor
Tractor 20,000 Lbs		0.0154	Farm Tractor 20,000 Lbs (Semi)	0.0039
Tractor 26,000 Lbs		0.0160	Farm Tractor 26,000 Lbs	0.0030
Tractor 30,000 Lbs		0.0096	Farm Tractor 30,000 Lbs	0.0032
Tractor 36,000 Lbs		0.0132	Farm Tractor 36,000 Lbs	0.0030
Tractor 42,000 Lbs		0.0212	Farm Tractor 42,000 Lbs	0.0028
Tractor 48,000 Lbs		0.0324	Farm Tractor 48,000 Lbs	0.0066
Tractor 54,000 Lbs		0.0951	Farm Tractor 54,000 Lbs	0.0255
Tractor 60,000 Lbs		0.0165	Farm Tractor 60,000 Lbs	0.0061
Tractor 66,000 Lbs		0.0152	Farm Tractor 66,000 Lbs	0.0105
Tractor 72,000 Lbs		0.0207	Farm Tractor 72,000 Lbs	0.0234
Tractor 74,000 Lbs		0.0139	Farm Tractor 74,000 Lbs	0.0220
Tractor 76,000 Lbs		0.0078	Farm Tractor 76,000 Lbs	0.0231
Tractor 78,000 Lbs		0.0116	Farm Tractor 78,000 Lbs	0.0356
Tractor 78,000+ Lbs		0.2094	Farm Tractor 78,000 + Lbs	0.3332

Derived from Shah (2005)

Table A. 11 Distribution Factors for Trailers

Vehicle Weight Class	Registered	Distribution factor	Vehicle Registered Weight Class	Distribution factor
Trailer 3,000 Lbs (1 Yr)		0.6074	Farm Trailer 16,000 Lbs	0.0044
Trailer 5,000 Lbs		0.0569	Farm Trailer 22,000 Lbs	0.0016
Trailer 7,000 Lbs		0.0713	Farm Trailer 22,000+ Lbs	0.0007
Trailer 9,000 Lbs		0.0360	Semi Trailer 1 Year	0.0162
Trailer 12,000 Lbs		0.0199	Permanent Semi-Trailer	0.0463
Trailer 16,000 Lbs		0.0096	Annual Renewal Perm Semi Trailer	0.0956
Trailer 22,000 Lbs		0.0063	Farm Semi Trailer 1 Year	0.0019
Trailer 22,000+ Lbs		0.0063	Permanent Farm Semi Trailer	0.0031
Farm Trailer 12,000 Lbs (1 Yr)		0.0093	Renewal Perm Farm Semi Trailer	0.0073

Derived from Shah (2005)

Table A. 12 Distribution Factors for Buses

Vehicle Registered Weight Class/Activity Type	Distribution factor	Vehicle Registered Weight Class/Activity Type	Distribution factor
Bus A 11,000 Lbs- Commercial	0.0607	Church Bus	0.3941
Bus C (Not for Hire)	0.1148	School Bus	0.4305

Derived from Shah (2005)

Table A. 13 Distribution Factors for Titles

Description	Distribution factor	Description	Distribution factor
Dealers	0.0217	Salvage	0.0047
Non-Dealers	0.5321	Mvin Number	0.0042
Body Change	0.0001	Delinquent Fee	0.0956
Repossession	0.0067	Speed Title Fee	0.0407
Correction/Amendment	0.0418	Admin Fee	0.0410
Mechanic's Lien	0.0003	Sales (Use) Tax (Variable)	0.1893
Duplicate	0.0219		

Derived from Shah (2005)

Table A. 14 Distribution Factors for Drivers' License

Description	Distribution Factor	Description	Distribution Factor
Learner Permit	0.0618	AMND 4-YR CDL	0.0019
Motorcycle Learner	0.0086	Duplicate/Amended License	0.1750
Duplicate/Amended Learner	0.0071	Motorcycle Endorse 3/4 Yr	0.0322
Operator 4 Year	0.4994	Motorcycle Endorse 2 Yr	0.0001
Operator 3 Year	0.0326	Motorcycle Skills Test	0.0000
Chauffeur	0.0059	Identification	0.0919
Public Passenger Chauffeur	0.0019	Dup/Amended Identification	0.0000
Motorcycle Operator 4 Yr	0.0000	Special Identification	0.0063
Motorcycle Operator 3 Yr	0.0000	Dup/Amended Special Id	0.0000
CDL Learner	0.0092	Perm Disability Placard (2)	0.0297
Amended Learner Permit	0.0002	ADDTL / Dup Disability Placard	0.0012
Dup/Amend CDL Learner	0.0004	Temp Disability Placard	0.0051
CDL License 4 Year	0.0295		

Derived from Shah (2005)

Table A. 15 Distribution Factors for Miscellaneous Registration Items

Description	Distribution factor	Description	Distribution factor
Recovery Vehicle 16,000 Lbs	0.0003	Recreational Vehicle	0.0066
Recovery Vehicle 16,000+ Lbs	0.0001	Special Machinery	0.0016
WATERCRAFT REGISTRATIONS			
Registration: New,Renew,Tr (Note: Watercraft Reg's Combined On Branch Report)	0.0047	Additional Excise Variable	0.0000
Validation DNR Fee	0.0182	Administrative Fee	0.0001
Lake Enhancement	0.0223	All Type Titles	0.0031
Dup/Amended Registration	0.0001	Delinquent Fee	0.0006
Replacement Decals	0.0001	Hin Application	0.0000
Excise Variable	0.0222	Sales (Use) Tax Variable	0.0014
Storage Excise Variable	0.0000		
MISCELLANEOUS			
Nuts & Bolts	0.0000	Personalized Plate Order	0.0051
Registration Holders	0.0000	Amateur Radio Plate Order	0.0006
Pull Fees	0.0012	Duplicate Plate	0.0000
Civic Event Plate	0.0002	Replacement Plate	0.0034
Dealer Plate (1st 2 Sets)	0.0012	Redeclared Weight (VAR FEE)	0.0001
ADDTL Dealer Plate (Per Plate)	0.0058	Transfer	0.0413
Motorcycle Dlr Pl (1st 2 Sets)	0.0001	Duplicate Registration	0.0034
Addtl Mc Dlr Pl (Per Plate)	0.0001	Ex-Pow	0.0001
Transport Operator (1st 2 Sets)	0.0001	Children Trust Fee	0.0083
ADDTL Transp Oper (Per Plate)	0.0011	Excise Tax (Variable Fee)	0.4602
Dealer Interim Plate	0.0951	Education Fee	0.0025
Dup/Replacement Plate	0.0003	Amended Registration	0.0091
Permit 48 Hours	0.0013	Special Recognition Fee	0.0299
Permit 30 Days	0.0031	Heritage Trust Fee	0.0084
Permit 90 Days	0.0000	Sur/Wheel Tax (Variable Fee)	0.2362

Derived from Shah (2005)

Table A. 16 Percentage Distribution of Automobile VMT by Age Cohort

Year	Percentage of total VMT by Age Cohort											
	Under 1	1	2	3	4	5	6	7	8	9	10 and older	Total
1987	7.2	11.2	10.6	10.1	6.8	6.1	6.2	6.2	6.4	5.9	23.3	100.0
1989	6.6	11	10.3	10.1	9.3	8.3	6.2	5.2	5.7	4.8	22.5	100.0
1994	6.0	8.2	7.4	7.3	7.2	8.0	8.1	7.7	7.0	6.4	26.7	100.0
1995	6.4	8.1	7.8	7.0	6.9	7.1	7.6	7.6	6.7	6.6	28.2	100.0
1996	6.4	9.0	7.5	7.2	6.4	6.7	6.7	7.2	6.6	6.4	29.9	100.0
1997	6.7	9.8	11.9	10.3	8.3	6.6	5.8	5.3	5.9	5.2	24.2	100.0
1998	7.9	11.3	9.8	9.9	8.8	7.2	5.4	5.2	4.9	3.3	26.3	100.0
1999	8.8	11.1	11.0	8.4	9.0	7.9	6.0	4.9	4.7	3.9	24.3	100.0
2000	7.1	8.1	7.8	7.5	6.6	7.5	6.5	6.1	5.4	5.5	31.9	100.0
2001	6.9	9.4	8.2	7.2	7.2	6.5	7.4	6.3	6.1	5.4	29.4	100.0
Average	7.0	9.7	9.2	8.5	7.7	7.2	6.6	6.2	5.9	5.3	26.7	100.0

Source: Historical Editions of Davis et al. (2009)

Table A. 17 Percentage Distribution of Truck VMT by Age Cohort

Year	Percentage of Total VMT by Age Cohort											
	Under 1	1	2	3	4	5	6	7	8	9	10 and older	Total
1987	11.3	15.7	13.4	10.1	5.9	5	4	3.8	6.2	5.3	19.3	100.0
1989	7.4	13.1	11.8	12.1	9.2	8.2	5.2	4.1	3.4	3.1	22.4	100.0
1994	6.5	9.9	9.2	8.6	8.0	8.9	7.9	6.6	6.7	5.3	22.4	100.0
1995	6.5	11.1	10.6	8.3	7.7	7.2	7.5	6.9	5.8	5.6	22.8	100.0
1996	6.8	11.2	11.4	9.3	7.3	6.8	6.0	6.5	6.1	5.0	23.6	100.0
1997	6.7	9.8	11.9	10.3	8.3	6.6	5.8	5.3	5.9	5.2	24.2	100.0
1998	7.9	11.3	9.8	9.9	8.8	7.2	5.4	5.2	4.9	4.9	24.7	100.0
1999	8.8	11.1	11.0	8.4	9.0	7.9	6.0	4.9	4.7	3.9	24.3	100.0
2000	9.2	12.1	10.7	9.2	7.6	8	6.6	5.4	4.4	3.7	23.1	100.0
2001	6.8	11.2	11.4	9.3	7.3	6.8	6.0	6.5	6.1	5.0	23.6	100.0
Average	7.8	11.7	11.1	9.6	7.9	7.3	6.0	5.5	5.4	4.7	23.0	100.0

Source: Historical Editions of Davis et al. (2009)

Table A. 18 Predicted Age Cohort VMT for Automobile, Motorcycles and Light Duty Trucks

Year	VMT distribution for the ith Age Cohort (%)											Total
	Under 1	1	2	3	4	5	6	7	8	9	10 and older	
2006	7.5	9.7	9.2	8.5	7.6	7.2	6.6	6.1	5.9	5.3	26.5	100.0
2007	6.8	9.7	9.3	8.5	7.7	7.2	6.6	6.2	6.0	5.4	26.7	100.0
2008	6.8	9.7	9.3	8.5	7.7	7.2	6.6	6.2	6.0	5.4	26.7	100.0
2009	7.6	9.7	9.2	8.4	7.6	7.1	6.6	6.1	5.9	5.3	26.5	100.0
2010	8.4	9.6	9.1	8.4	7.5	7.1	6.5	6.1	5.9	5.3	26.3	100.0
2011	8.5	9.6	9.1	8.4	7.5	7.1	6.5	6.1	5.8	5.3	26.3	100.0
2012	7.8	9.6	9.2	8.4	7.6	7.1	6.5	6.1	5.9	5.3	26.4	100.0
2013	6.9	9.7	9.2	8.5	7.7	7.2	6.6	6.2	5.9	5.3	26.7	100.0
2014	6.7	9.8	9.3	8.5	7.7	7.2	6.6	6.2	6.0	5.4	26.8	100.0
2015	7.3	9.7	9.2	8.5	7.6	7.2	6.6	6.2	5.9	5.3	26.6	100.0
2016	8.2	9.6	9.1	8.4	7.6	7.1	6.5	6.1	5.9	5.3	26.3	100.0
2017	8.5	9.6	9.1	8.4	7.5	7.1	6.5	6.1	5.8	5.3	26.2	100.0
2018	8.0	9.6	9.1	8.4	7.6	7.1	6.5	6.1	5.9	5.3	26.4	100.0
2019	7.1	9.7	9.2	8.5	7.6	7.2	6.6	6.2	5.9	5.3	26.6	100.0
2020	6.7	9.8	9.3	8.5	7.7	7.2	6.6	6.2	6.0	5.4	26.8	100.0
2021	7.1	9.7	9.2	8.5	7.6	7.2	6.6	6.2	5.9	5.3	26.7	100.0
2022	7.9	9.6	9.1	8.4	7.6	7.1	6.5	6.1	5.9	5.3	26.4	100.0
2023	8.5	9.6	9.1	8.4	7.5	7.1	6.5	6.1	5.8	5.3	26.2	100.0
2024	8.2	9.6	9.1	8.4	7.5	7.1	6.5	6.1	5.9	5.3	26.3	100.0
2025	7.4	9.7	9.2	8.5	7.6	7.2	6.6	6.1	5.9	5.3	26.6	100.0
2026	6.7	9.7	9.3	8.5	7.7	7.2	6.6	6.2	6.0	5.4	26.7	100.0
2027	6.9	9.7	9.2	8.5	7.7	7.2	6.6	6.2	5.9	5.3	26.7	100.0
2028	7.7	9.6	9.2	8.4	7.6	7.1	6.5	6.1	5.9	5.3	26.5	100.0
2029	8.4	9.6	9.1	8.4	7.5	7.1	6.5	6.1	5.8	5.3	26.3	100.0
2030	8.4	9.6	9.1	8.4	7.5	7.1	6.5	6.1	5.9	5.3	26.3	100.0
2031	7.6	9.7	9.2	8.4	7.6	7.1	6.5	6.1	5.9	5.3	26.5	100.0
2032	6.8	9.7	9.2	8.5	7.7	7.2	6.6	6.2	6.0	5.3	26.7	100.0
2033	6.7	9.7	9.3	8.5	7.7	7.2	6.6	6.2	6.0	5.4	26.7	100.0
2034	7.4	9.7	9.2	8.5	7.6	7.2	6.6	6.1	5.9	5.3	26.5	100.0
2035	8.3	9.6	9.1	8.4	7.5	7.1	6.5	6.1	5.9	5.3	26.3	100.0

NB: Derived from Previous Editions of Literature (Davis et al., 2009)

Table A. 19 Predicted Age Cohort VMT for Single Unit Trucks, Buses and Combination Trucks

Year	VMT distribution for the ith Age Cohort (%)											Total
	Under 1	1	2	3	4	5	6	7	8	9	10 and older	
2006	7.5	15.2	10.7	9.2	7.6	7.0	5.8	5.3	5.2	4.5	22.1	100.0
2007	7.5	15.0	10.7	9.2	7.6	7.0	5.8	5.3	5.2	4.5	22.2	100.0
2008	7.5	14.6	10.8	9.2	7.7	7.0	5.8	5.3	5.2	4.5	22.3	100.0
2009	7.6	14.0	10.8	9.3	7.7	7.1	5.9	5.4	5.3	4.6	22.4	100.0
2010	7.6	13.3	10.9	9.4	7.8	7.1	5.9	5.4	5.3	4.6	22.6	100.0
2011	7.7	12.6	11.0	9.4	7.8	7.2	6.0	5.5	5.4	4.6	22.8	100.0
2012	7.8	12.0	11.1	9.5	7.9	7.2	6.0	5.5	5.4	4.7	23.0	100.0
2013	7.8	11.4	11.1	9.6	7.9	7.3	6.1	5.5	5.4	4.7	23.1	100.0
2014	7.8	11.1	11.2	9.6	8.0	7.3	6.1	5.6	5.5	4.7	23.2	100.0
2015	7.9	10.9	11.2	9.6	8.0	7.3	6.1	5.6	5.5	4.7	23.2	100.0
2016	7.9	10.9	11.2	9.6	8.0	7.3	6.1	5.6	5.5	4.7	23.2	100.0
2017	7.8	11.2	11.2	9.6	7.9	7.3	6.1	5.5	5.4	4.7	23.2	100.0
2018	7.8	11.7	11.1	9.5	7.9	7.3	6.0	5.5	5.4	4.7	23.0	100.0
2019	7.7	12.3	11.0	9.5	7.9	7.2	6.0	5.5	5.4	4.7	22.9	100.0
2020	7.7	12.9	11.0	9.4	7.8	7.2	6.0	5.4	5.3	4.6	22.7	100.0
2021	7.6	13.6	10.9	9.3	7.7	7.1	5.9	5.4	5.3	4.6	22.5	100.0
2022	7.6	14.3	10.8	9.3	7.7	7.0	5.9	5.4	5.3	4.6	22.4	100.0
2023	7.5	14.8	10.7	9.2	7.6	7.0	5.8	5.3	5.2	4.5	22.2	100.0
2024	7.5	15.1	10.7	9.2	7.6	7.0	5.8	5.3	5.2	4.5	22.1	100.0
2025	7.5	15.3	10.7	9.2	7.6	7.0	5.8	5.3	5.2	4.5	22.1	100.0
2026	7.5	15.2	10.7	9.2	7.6	7.0	5.8	5.3	5.2	4.5	22.1	100.0
2027	7.5	14.9	10.7	9.2	7.6	7.0	5.8	5.3	5.2	4.5	22.2	100.0
2028	7.5	14.5	10.8	9.2	7.7	7.0	5.8	5.3	5.2	4.6	22.3	100.0
2029	7.6	13.9	10.8	9.3	7.7	7.1	5.9	5.4	5.3	4.6	22.5	100.0
2030	7.7	13.2	10.9	9.4	7.8	7.1	5.9	5.4	5.3	4.6	22.6	100.0
2031	7.7	12.5	11.0	9.5	7.8	7.2	6.0	5.5	5.4	4.7	22.8	100.0
2032	7.8	11.8	11.1	9.5	7.9	7.2	6.0	5.5	5.4	4.7	23.0	100.0
2033	7.8	11.3	11.2	9.6	7.9	7.3	6.1	5.5	5.4	4.7	23.1	100.0
2034	7.8	11.0	11.2	9.6	8.0	7.3	6.1	5.6	5.5	4.7	23.2	100.0
2035	7.9	10.9	11.2	9.6	8.0	7.3	6.1	5.6	5.5	4.7	23.2	100.0

NB: Derived from Previous Editions of Literature (Davis et al., 2009)

Table A. 20 Estimation of Light Duty Truck Fleet Fuel Efficiency for Year 2010

Age Cohort (i)	Estimated Age Cohort VMT (%)	VMT (x 10 ⁶)	VMT _{IK} (x 10 ⁶)	MYFE (mpg)	α -factor	EFE _{IK}	VMT _{IK} / EFE _{IK}	FFE _K (mpg)
Under 1	8.35	17807.98	1487.24	24.91	1.00	24.91	59.72	19.50
1	9.58		1705.78	24.56	0.98	24.07	70.86	
2	9.10		1619.79	24.22	0.96	23.25	69.66	
3	8.38		1491.68	23.88	0.94	22.45	66.45	
4	7.54		1342.51	23.54	0.92	21.66	61.99	
5	7.09		1261.79	23.20	0.90	20.88	60.43	
6	6.49		1156.49	22.86	0.88	20.12	57.49	
7	6.08		1082.78	22.52	0.87	19.59	55.27	
8	5.85		1042.42	22.18	0.86	19.07	54.66	
9	5.26		937.13	21.84	0.85	18.56	50.49	
10 and older	26.28		4680.37	19.11	0.80	15.29	306.18	
Total	100.00		17807.98				913.18	

Table A. 21 Estimation of Motorcycle Fleet Fuel Efficiency for Year 2010

Age Cohort (i)	Estimated Age Cohort VMT (%)	VMT (x 10 ⁶)	VMT _{IK} (x 10 ⁶)	FE _{IK}	VMT _{IK} /FE _{IK}	FFE _K (mpg)
Under 1	8.35	465.59	38.88	60.40	0.64	55.62
1	9.58		44.60	59.22	0.75	
2	9.10		42.35	59.12	0.72	
3	8.38		39.00	59.01	0.66	
4	7.54		35.10	58.91	0.60	
5	7.09		32.99	57.96	0.57	
6	6.49		30.24	52.50	0.58	
7	6.08		28.31	52.50	0.54	
8	5.85		27.25	52.50	0.52	
9	5.26		24.50	52.50	0.47	
10 and older	26.28		122.37	52.50	2.33	
Total	100.00		465.59		8.37	

Table A. 22 Estimation of Single Unit Truck Fleet Fuel Efficiency for Year 2010

Age Cohort (i)	Estimated Age Cohort VMT (%)	VMT (x 10 ⁶)	VMT _{IK} (x 10 ⁶)	FE _{IK}	VMT _{IK} /FE _{IK}	FFE _K (mpg)
Under 1	7.64	2444.04	186.85	9.00	20.77	8.71
1	13.30		324.94	8.82	36.84	
2	10.91		266.72	8.82	30.24	
3	9.37		229.06	8.82	25.97	
4	7.76		189.72	8.61	22.04	
5	7.12		174.13	8.61	20.22	
6	5.93		144.87	8.61	16.83	
7	5.42		132.40	8.61	15.38	
8	5.32		130.00	8.61	15.10	
9	4.61		112.73	8.61	13.09	
10 and older	22.61		552.62	8.61	64.18	
Total	100.00		2444.04		280.66	

Table A. 23 Estimation of Bus Fleet Fuel Efficiency for Year 2010

Age cohort (i)	Estimated Age Cohort VMT (%)	VMT (x 10 ⁶)	VMT _{IK} (x 10 ⁶)	FE _{IK}	VMT _{IK} / FE _{IK}	FFE _K (mpg)
Under 1	7.64	253.16	19.35	7.63	2.54	7.43
1	13.30		33.66	7.48	4.50	
2	10.91		27.63	7.48	3.69	
3	9.37		23.73	7.48	3.17	
4	7.76		19.65	7.37	2.67	
5	7.12		18.04	7.37	2.45	
6	5.93		15.01	7.37	2.04	
7	5.42		13.71	7.37	1.86	
8	5.32		13.47	7.37	1.83	
9	4.61		11.68	7.37	1.58	
10 and older	22.61		57.24	7.37	7.77	
Total	100.00		253.16		34.09	

Table A. 24 Estimation of Combination Truck Fleet Fuel for Year 2010

Age Cohort (i)	Estimated Age Cohort VMT (%)	VMT (x 10 ⁶)	VMT _{IK} (x 10 ⁶)	FE _{IK}	VMT _{IK} /FE _{IK}	FFE _K (mpg)
Under 1	7.64	7299.15	558.02	6.17	90.43	5.99
1	13.30		970.43	6.05	160.40	
2	10.91		796.55	6.05	131.66	
3	9.37		684.09	6.05	113.07	
4	7.76		566.61	5.94	95.39	
5	7.12		520.05	5.94	87.55	
6	5.93		432.66	5.94	72.84	
7	5.42		395.41	5.94	66.57	
8	5.32		388.25	5.94	65.36	
9	4.61		336.67	5.94	56.68	
10 and older	22.61		1650.41	5.94	277.85	
Total	100.00		7299.15		1217.79	

Table A. 25 Estimated New Vehicle Fuel Efficiency

Year	Auto.	Light Duty Truck	Motorcycle	Bus	Single Unit Truck	Comb. Truck
2010	31.78	24.91	60.40	9.00	7.63	6.17
2011	32.01	25.25	61.61	9.18	7.78	6.17
2012	32.24	25.59	62.84	9.36	7.94	6.17
2013	32.46	25.93	64.10	9.55	8.10	6.23
2014	32.69	26.27	65.38	9.74	8.26	6.29
2015	32.92	26.61	66.69	9.93	8.42	6.29
2016	33.14	26.95	68.03	10.13	8.59	6.33
2017	33.37	27.29	69.39	10.33	8.76	6.39
2018	33.60	27.63	70.77	10.54	8.94	6.42
2019	33.82	27.97	72.19	10.75	9.12	6.44
2020	34.05	28.32	73.63	10.97	9.30	6.48
2021	34.28	28.66	75.11	11.19	9.49	6.53
2022	34.51	29.00	76.61	11.41	9.68	6.56
2023	34.73	29.34	78.14	11.64	9.87	6.59
2024	34.96	29.68	79.70	11.87	10.07	6.64
2025	35.19	30.02	81.30	12.11	10.27	6.68
2026	35.41	30.36	82.92	12.35	10.47	6.70
2027	35.64	30.70	84.58	12.60	10.68	6.75
2028	35.87	31.04	86.27	12.85	10.90	6.79
2029	36.10	31.38	88.00	13.11	11.11	6.82
2030	36.32	31.73	89.76	13.37	11.34	6.86
2031	36.55	32.07	91.55	13.64	11.56	6.90
2032	36.78	32.41	93.38	13.91	11.80	6.94
2033	37.00	32.75	95.25	14.19	12.03	6.98
2034	37.23	33.09	97.16	14.47	12.27	7.02
2035	37.46	33.43	99.10	14.76	12.52	7.06

Table A. 26 Revenues from Existing Fuel Tax Structure under Three Scenarios

Year	No Increase in Tax Rate (\$M)	1 cent Increase in Tax Rate (\$M)	3 cents Increase in Tax Rate (\$M)
2010	887.59	941.76	1,050.10
2011	887.85	941.57	1,048.68
2012	889.11	942.90	1,050.16
2013	890.34	944.20	1,051.61
2014	890.42	944.29	1,051.72
2015	889.56	943.39	1,050.76
2016	887.57	941.29	1,048.45
2017	885.09	938.65	1,045.49
2018	885.25	938.83	1,045.67
2019	885.29	938.87	1,045.71
2020	883.60	937.07	1,043.70
2021	882.01	935.38	1,041.86
2022	879.71	932.95	1,039.20
2023	877.28	930.38	1,036.34
2024	875.92	928.95	1,034.72
2025	875.82	928.83	1,034.58
2026	875.17	928.15	1,033.83
2027	873.29	926.16	1,031.63
2028	870.87	923.60	1,028.82
2029	868.69	921.30	1,026.28
2030	867.16	919.67	1,024.46
2031	866.51	918.99	1,023.68
2032	866.09	918.54	1,023.18
2033	864.69	917.06	1,021.55
2034	862.17	914.40	1,018.62
2035	859.58	911.66	1,015.59

Table A. 27 Revenues from Inflation-Indexing and Existing Flat Tax Rate

Year	Existing Fuel Tax (\$M)	Inflation-Indexing of Fuel Tax (\$M)
2010	887.59	887.59
2011	887.85	913.07
2012	889.11	941.80
2013	890.34	971.39
2014	890.42	1,000.62
2015	889.56	1,029.64
2016	887.57	1,058.16
2017	885.09	1,086.85
2018	885.25	1,119.67
2019	885.29	1,153.31
2020	883.60	1,185.64
2021	882.01	1,219.00
2022	879.71	1,252.29
2023	877.28	1,286.30
2024	875.92	1,322.84
2025	875.82	1,362.36
2026	875.17	1,402.20
2027	873.29	1,441.16
2028	870.87	1,480.28
2029	868.69	1,520.87
2030	867.16	1,563.73
2031	866.51	1,609.44
2032	866.09	1,656.92
2033	864.69	1,703.86
2034	862.17	1,749.87
2035	859.58	1,796.95

Table A. 28 Estimated VMT Fee Revenue

Year	Existing Fuel Revenue (\$M)	Scenario 1 (\$M)	Scenario 2: 1% Annual Increase in Scenario 1 (\$M)	Scenario 3: 2% Annual Increase in Scenario 1 (\$M)	Scenario 4: 3% Annual Increase in Scenario 1 (\$M)
2010	887.59	887.59	887.59	887.59	887.59
2011	887.85	894.86	900.18	910.44	918.46
2012	889.11	902.09	916.54	936.17	953.68
2013	890.34	909.29	933.11	962.53	990.16
2014	890.42	916.45	949.88	989.53	1,027.92
2015	889.56	923.58	966.86	1,017.19	1,067.03
2016	887.57	930.68	984.05	1,045.53	1,107.51
2017	885.09	937.76	1,001.46	1,074.56	1,149.43
2018	885.25	944.80	1,019.08	1,104.29	1,192.83
2019	885.29	951.81	1,036.93	1,134.75	1,237.75
2020	883.60	958.79	1,054.99	1,165.95	1,284.26
2021	882.01	965.74	1,073.28	1,197.90	1,332.40
2022	879.71	972.66	1,091.80	1,230.63	1,382.24
2023	877.28	979.55	1,110.55	1,264.16	1,433.82
2024	875.92	986.42	1,129.53	1,298.49	1,487.21
2025	875.82	993.25	1,148.75	1,333.66	1,542.47
2026	875.17	1,000.06	1,168.20	1,369.67	1,599.66
2027	873.29	1,006.84	1,187.90	1,406.55	1,658.86
2028	870.87	1,013.60	1,207.85	1,444.33	1,720.11
2029	868.69	1,020.33	1,228.04	1,483.01	1,783.50
2030	867.16	1,027.03	1,248.48	1,522.62	1,849.11
2031	866.51	1,033.71	1,269.18	1,563.18	1,916.99
2032	866.09	1,040.36	1,290.14	1,604.72	1,987.23
2033	864.69	1,046.99	1,311.35	1,647.26	2,059.91
2034	862.17	1,053.59	1,332.83	1,690.81	2,135.12
2035	859.58	1,060.17	1,354.58	1,735.41	2,212.93

Table A. 29 Estimated Weight-Distance Truck Fee Revenue

Year	*Truck Fuel Revenue from Existing Scheme (\$M)	Scenario 1: (\$M)	Scenario 2: 1% Annual Increase in Scenario 1 (\$M)	Scenario 3: 2% Annual Increase in Scenario 1 (\$M)	Scenario 4: 3% Annual Increase in Scenario 1 (\$M)
2010	295.56	295.56	295.56	295.56	295.56
2011	295.82	297.14	299.91	302.66	305.43
2012	296.23	298.72	304.51	310.35	316.26
2013	296.56	300.30	309.19	318.23	327.47
2014	296.66	301.88	313.92	326.30	339.07
2015	297.01	303.46	318.72	334.57	351.07
2016	296.76	305.04	323.58	343.04	363.49
2017	295.62	306.62	328.51	351.71	376.33
2018	295.62	308.20	333.51	360.60	389.62
2019	295.60	309.78	338.57	369.69	403.36
2020	294.43	311.36	343.70	379.01	417.58
2021	294.45	312.94	348.90	388.55	432.29
2022	294.40	314.52	354.16	398.32	447.51
2023	293.82	316.10	359.50	408.33	463.25
2024	293.29	317.68	364.91	418.58	479.53
2025	293.30	319.26	370.39	429.08	496.38
2026	293.03	320.84	375.95	439.82	513.80
2027	292.53	322.42	381.58	450.83	531.82
2028	292.32	324.00	387.28	462.10	550.46
2029	292.24	325.58	393.06	473.64	569.73
2030	291.89	327.16	398.92	485.45	589.67
2031	291.54	328.74	404.86	497.56	610.30
2032	291.40	330.32	410.87	509.95	631.63
2033	291.14	331.89	416.96	522.63	653.69
2034	290.72	333.47	423.14	535.62	676.50
2035	290.42	335.05	429.39	548.92	700.10

*Estimated truck fuel revenue was derived using the sum of combination truck special fuel gallons and 5% Single unit truck volume, all multiplied by the their respective tax rates.

Table A. 30 Past VMT Proportional Distribution Per Vehicle Category on Urban Interstates

Year	Auto VMT (x 10 ⁶)	MC (x 10 ⁶)	Bus VMT (x 10 ⁶)	LDT VMT (x 10 ⁶)	SUT VMT (x 10 ⁶)	CombT. VMT (x 10 ⁶)
1994	217174	1420	627	86311	6986	18059
1995	224594	1454	580	89260	7148	18492
1996	210301	1516	598	112908	7301	18955
1997	214016	1509	647	116680	7906	20643
1998	220487	1579	663	121700	8110	22083
1999	224132	1690	752	124399	8494	23792
2000	230510	1692	791	128291	8716	23465
2001	236983	1546	775	127989	8739	23951
2002	243521	1670	803	130174	9119	23921
2003	251904	1962	943	142472	10085	25402
2004	258666	2089	986	155714	9729	28355
2005	266834	2270	1062	160470	10536	29753
2006	267106	2379	1024	166660	10033	30085
2007	267558	2631	1052	170669	10144	31261

Source: FHWA (2007)

Table A. 31 Past Traffic Distribution (%) by Vehicle Category Used for Estimating Tolling Revenue

Year	Automobile	Motor Cycle	Bus	Light Duty Truck	Single Unit Truck	Combination Truck	Total
1994	65.70	0.43	0.19	26.11	2.11	5.46	100
1995	65.76	0.43	0.17	26.14	2.09	5.41	100
1996	59.82	0.43	0.17	32.11	2.08	5.39	100
1997	59.22	0.42	0.18	32.29	2.19	5.71	100
1998	58.86	0.42	0.18	32.49	2.16	5.89	100
1999	58.48	0.44	0.20	32.46	2.22	6.21	100
2000	58.58	0.43	0.20	32.61	2.22	5.96	100
2001	59.25	0.39	0.19	32.00	2.18	5.99	100
2002	59.51	0.41	0.20	31.81	2.23	5.85	100
2003	58.21	0.45	0.22	32.92	2.33	5.87	100
2004	56.78	0.46	0.22	34.18	2.14	6.22	100
2005	56.66	0.48	0.23	34.08	2.24	6.32	100
2006	55.96	0.50	0.21	34.92	2.10	6.30	100
2007	55.36	0.54	0.22	35.31	2.10	6.47	100
Average	59.15	0.44	0.20	32.10	2.17	5.93	100

NB: Derived from FHWA (2007)

Table A. 32 Estimated Percentage Distribution of Traffic by Vehicle Category for
Estimating Tolling Revenue

Year	Auto- mobile	Motor- cycle	Bus	Light Duty Truck	Single Unit Truck	Combination Truck	Total
2007	54.96	0.61	0.27	34.77	2.99	6.39	100.00
2008	54.33	0.62	0.27	35.32	3.00	6.46	100.00
2009	53.70	0.62	0.27	35.86	3.01	6.54	100.00
2010	53.07	0.62	0.28	36.40	3.02	6.61	100.00
2011	52.44	0.62	0.28	36.94	3.04	6.68	100.00
2012	51.81	0.62	0.28	37.48	3.05	6.76	100.00
2013	51.18	0.63	0.28	38.03	3.06	6.83	100.00
2014	50.54	0.63	0.28	38.57	3.07	6.91	100.00
2015	49.91	0.63	0.28	39.11	3.08	6.98	100.00
2016	49.28	0.63	0.28	39.65	3.10	7.05	100.00
2017	48.65	0.64	0.28	40.19	3.11	7.13	100.00
2018	48.02	0.64	0.28	40.74	3.12	7.20	100.00
2019	47.39	0.64	0.28	41.28	3.13	7.28	100.00
2020	46.76	0.64	0.29	41.82	3.14	7.35	100.00
2021	46.13	0.65	0.29	42.36	3.15	7.42	100.00
2022	45.50	0.65	0.29	42.90	3.17	7.50	100.00
2023	44.87	0.65	0.29	43.45	3.18	7.57	100.00
2024	44.23	0.65	0.29	43.99	3.19	7.64	100.00
2025	43.60	0.66	0.29	44.53	3.20	7.72	100.00
2026	42.97	0.66	0.29	45.07	3.21	7.79	100.00
2027	42.34	0.66	0.29	45.61	3.22	7.87	100.00
2028	41.71	0.66	0.29	46.16	3.24	7.94	100.00
2029	41.08	0.67	0.30	46.70	3.25	8.01	100.00
2030	40.45	0.67	0.30	47.24	3.26	8.09	100.00
2031	39.82	0.67	0.30	47.78	3.27	8.16	100.00
2032	39.19	0.67	0.30	48.32	3.28	8.23	100.00
2033	38.56	0.68	0.30	48.87	3.29	8.31	100.00
2034	37.93	0.68	0.30	49.41	3.31	8.38	100.00
2035	37.29	0.68	0.30	49.95	3.32	8.46	100.00

NB: Derived from FHWA (2007)

Table A. 33 Comparing Toll Revenues from Tolling Only Urban Sections along an Interstate.

Location	Length (miles)	I-Zoom Account Revenue (\$M)			
		2010	2020	2030	2035
I-465	50	114.21	141.41	174.75	194.13
I-64	5	8.14	10.07	12.45	13.83
I-65	86	124.34	153.95	190.24	211.34
I-69	38	40.14	49.70	61.42	68.23
I-70	47	68.39	84.62	104.52	116.08
I-74	54	20.20	25.02	30.91	34.34
I-80	16	42.38	52.48	64.86	72.05
I-80 & I-90	5	3.53	4.37	5.40	5.99
I-90	20	16.87	20.88	25.81	28.67
I-94	10	12.82	15.87	19.61	21.79
TOTAL		451.01	558.38	689.97	766.45

Table A. 34 Estimated Congestion Pricing Revenue

Location	Length (miles)	Revenue From Congestion Pricing (x 10 ³ \$)			
		2010	2020	2030	2035
I-465	39	194.31	468.50	1,080.33	1,347.11
I-64	1	0.00	0.00	28.06	30.52
I-65	35	184.30	625.18	892.12	1,018.16
I-69	13	0.00	0.00	196.08	232.49
I-70	12	200.85	301.75	442.92	510.73
I-80	12	210.90	366.20	462.21	502.86
TOTAL		790.35	1,761.64	1,761.64	3,101.73

Table A. 35: Morning Peak Period Traffic in and around Downtown Indianapolis

Location		Morning Peak Periods (7am – 10am) Traffic Volume		
		2010	2020	2035
West St between:	New York and Michigan	4,139	4,572	5,308
	South St and Maryland	4,052	4,476	5,197
	Indiana and St. Clair	3,325	3,672	4,264
	South of South St	1,663	1,836	2,132
Missouri St between:	South of South St	1,745	1,927	2,237
Capitol Ave between:	16th and 21st	2,147	2,372	2,754
	New York and Ohio	2,427	2,681	3,113
Illinois St between:	Ohio and New York	3,017	3,333	3,870
	St. Clair and 10th	1,720	1,900	2,206
Pennsylvania Ave between:	Vermont St. and Michigan	1,962	2,167	2,516
	South of South St	1,582	1,747	2,029
Delaware St between:	South St and Maryland	1,808	1,997	2,318
	Washington and South St	2,619	2,894	3,359
	South of Fall Creek Pkwy	1,111	1,228	1,425
	Central Ave between: 10th and 16th	1,274	1,407	1,633
East Street between	Market and Ohio	1,926	2,128	2,470
	Washington and South St	1,450	1,602	1,859
College Ave between:	Ohio and New York	1,312	1,449	1,683
	Michigan and Massachusetts	1,260	1,392	1,616
Dr. M.L. King between:	16th and 21st	1,971	2,177	2,527
Rural St between:	Michigan and 10th	1,720	1,900	2,206
Washington St between:	Ritter and Arlington	3,383	3,737	4,338
	Alabama and Delaware	1,812	2,002	2,324
Fall Creek Road Pkwy	College and 30th St	4,281	4,728	5,490
	Meridian and Delaware	2,700	2,982	3,462
Total		56,404	62,305	72,335

NB: Original dataset was obtained from Sinha et al. (2004)

Table A. 36: Estimated Cordon Pricing Revenue

Year	Estimated Total Peak Periods (7am - 10am) Traffic Volume	Estimated Revenue (\$)
2010	56,404	28,202,135
2011	56,968	28,484,157
2012	57,538	28,768,998
2013	58,113	29,056,688
2014	58,695	29,347,255
2015	59,281	29,640,728
2016	59,874	29,937,135
2017	60,473	30,236,506
2018	61,078	30,538,871
2019	61,689	30,844,260
2020	62,305	31,152,703
2021	62,928	31,464,230
2022	63,558	31,778,872
2023	64,193	32,096,661
2024	64,835	32,417,627
2025	65,484	32,741,804
2026	66,138	33,069,222
2027	66,800	33,399,914
2028	67,468	33,733,913
2029	68,143	34,071,252
2030	68,824	34,411,965
2031	69,512	34,756,084
2032	70,207	35,103,645
2033	70,909	35,454,682
2034	71,618	35,809,229
2035	72,335	36,167,321

Table A. 37 VMT Elasticity with respect to Economic and Demographic Indicators and Implications

Dependent Variable	Independent Variable	Elasticity Value	Implication
Light Duty Truck VMT	Per Capita Income	4.841	1% increase in PCI results in 4.841% increase in light duty truck VMT
Bus VMT	Per Capita Income	-3.467	1% increase in PCI results in 3.467% decrease in bus VMT
Motorcycle VMT	Indiana Driving Population	0.926	1% increase in driving population within Indiana results in 0.926% increase in motor cycle VMT
Combination Truck VMT	Gross Domestic Product of the USA (in billions)	0.343	1% increase in GDP results in 0.343% increase in combination truck VMT
Automobile VMT	Per Capita Income	0.295	1% increase in PCI results in 0.295% increase in automobile VMT.
Single Unit Truck VMT	Per Capita Income	0.230	1% increase in PCI results in 0.230% increase in single unit truck VMT

NB: Per capita income and gross domestic product are in 2008\$

Table A. 38 Registration Elasticity with respect to Economic and Demographic Indicators and Implications

Dependent Variable	Independent Variable	Elasticity Value	Implication
Motorcycle registration	Driving Age Population in Indiana	5.456	1% increase in driving population within Indiana results in 5.456% increase in motorcycle registration
Watercraft registration	Gross Domestic Product of the USA (in billions)	4.153	1% increase in GDP results in 4.153% increase in water craft registration
Bus registration	Driving Age Population in Indiana	2.879	1% increase in driving population within Indiana results in 2.879% increase in bus registration
Driver License registration	Driving Age Population in Indiana	2.039	1% increase in driving population within Indiana results in 2.039% increase in driving license registration
Trailer registration	Gross Domestic Product of the USA (in billions)	0.766	1% increase in GDP results in 0.766% increase in trailer registration
Truck registration	Gross Domestic Product of the USA (in billions)	0.703	1% increase in GDP results in 0.703% increase in truck registration
Tractor registration	Gross Domestic Product of the USA (in billions)	0.695	1% increase in GDP results in 0.695% increase in tractor registration
Automobile registration	Per Capita Income	0.451	1% increase in PCI results in 0.451% increase in automobile registration

NB: Per capita income and gross domestic product are in 2008\$

Table A. 39 Elasticity of Short-Term Fuel Consumption with respect to Monthly Fuel Price

Month	Elasticity	
	Gasoline	Special Fuel
January	-0.201	-0.653
February	-0.346	-0.683
March	-0.026	-0.046
April	-0.076	-0.068
May	-0.055	-0.142
June	-0.055	-0.390
July	-0.076	-0.448
August	-0.144	-0.272
September	-0.183	-0.841
October	-0.174	-0.294
November	-0.015	-0.002
December	-0.126	-0.155

Table A. 40 Elasticity of Long-Term Fuel Consumption with respect to Fuel Price

Fuel Type	Elasticity
Gasoline	-0.107
Special Fuel	-0.132

Appendix B Interfaces of INDOTREV-2

Figure B.1 Introductory Interface

Figure B.2 Interface of Analysis Type

INDOT Revenue Forecasting System 2.0 - Long Term Estimation

File Edit Data Update Models Update Alternative Revenue Help

Fuel Taxes Registration Fee Other Revenue Existing Revenue Summary Revenue Allocation Alternative Revenue Sources Revenue Summary

Year: 2020

Fuel Tax Revenue Estimation Information

Vehicle Category	VMT (million)	Fleet Fuel Efficiency (mpg)	% of Gasoline Consumed	% of Diesel Consumed	Gasoline Tax Rate (cents/gallon)	Diesel Tax Rate (cents/gallon)	MCFUT Tax Rate (cents/gallon)	MCST Tax Rate (cents/gallon)
Automobiles	52553.35	26.46	100.00	0.00	18.00	16.00	--	--
Light Duty Trucks	23005.53	22.47	95.00	5.00	18.00	16.00	--	--
Buses	184.59	8.38	0.00	100.00	18.00	16.00	--	--
Single Unit Trucks	2492.91	9.88	95.00	5.00	18.00	16.00	--	--
Combination Trucks	7693.40	6.31	0.00	100.00	18.00	16.00	16.00	11.00
Motor Cycles	610.67	65.65	100.00	0.00	18.00	16.00	--	--
Total	86541.00							

Fuel Tax Revenue Estimation

Vehicle Category	Gasoline Tax Revenue (\$million)	Diesel Tax Revenue (\$million)	MCFUT Revenue (\$million)	MCST Revenue (\$million)	Total Fuel Revenue (\$million)
Automobiles	357.53	0.00	0.00	0.00	357.53
Light Duty Trucks	175.09	8.19	0.00	0.00	183.29
Buses	0.00	3.53	0.00	0.00	3.53
Single Unit Trucks	43.15	2.02	0.00	0.00	45.17
Combination Trucks	0.00	195.18	1.32	95.92	292.41
Motor Cycles	1.67	0.00	0.00	0.00	1.67
Total Revenue	577.46	208.91	1.32	95.92	883.60

Notation: MCFUT: Motor Carrier Fuel Use Tax MCST: Motor Carrier Surcharge Tax

Exit

Figure B.3 Interface of Fuel Tax Revenue

INDOT Revenue Forecasting System 2.0 - Long Term Estimation

File Edit Data Update Models Update Alternative Revenue Help

Fuel Taxes Registration Fee Other Revenue Existing Revenue Summary Revenue Allocation Alternative Revenue Sources Revenue Summary

Year: 2020

Registration Fee (\$million)

Description	Registration Fee (\$million)
Passenger Car	87.65
Trucks	85.14
Tractors	10.28
Trailers	20.07
Buses	0.43
Motorcycle	5.87
Titles	43.86
Driver License	22.98
Miscellaneous	52.50

Trucks

Description	Fee Rate (\$)	Frequency	Subtotal (\$million)
TRUCK 7,000 LBS	29.75	1404213	\$41.78
TRUCK 9,000 LBS	49.75	40383	\$2.01
TRUCK 10,000 LBS	79.75	2688	\$0.21
TRUCK 11,000 LBS	84.75	53871	\$4.57
TRUCK 16,000 LBS	144.75	45585	\$6.60
TRUCK 20,000 LBS	184.75	17948	\$3.32
TRUCK 23,000 LBS	244.75	2574	\$0.63
TRUCK 26,000 LBS	244.75	19375	\$4.74
TRUCK 30,000 LBS	304.75	4293	\$1.31
TRUCK 36,000 LBS	422.75	3417	\$1.44
TRUCK 42,000 LBS	515.75	674	\$0.35
TRUCK 48,000 LBS	636.75	1728	\$1.10
TRUCK 54,000 LBS	739.75	1765	\$1.31
TRUCK 60,000 LBS	819.75	397	\$0.33
TRUCK 66,000 LBS	867.95	594	\$0.52
TRUCK 66,000 + LBS	965.75	9766	\$9.43
FARM TRUCK 11,000 LBS	42.75	13198	\$0.56

Total Revenue (\$million) 328.76

Subtotal (\$million) 85.14

Save Changes

Figure B.4 Interface of Vehicle Registration Fee Revenue

INDOT Revenue Forecasting System 2.0 - Long Term Estimation

File Edit Data Update Models Update Alternative Revenue Help

Fuel Taxes Registration Fee Other Revenue Existing Revenue Summary Revenue Allocation Alternative Revenue Sources Revenue Summary

Year 2020

Other Revenue from State

Type	2020 Revenue (\$M)
International Registration Plan	61.64
Permits	20.36
State Court Fees	3.62
Miscellaneous	0.50

Figure B.5 Interface of Other Revenues

INDOT Revenue Forecasting System 2.0 - Long Term Estimation

File Edit Data Update Models Update Alternative Revenue Help

Fuel Taxes Registration Fee Other Revenue Existing Revenue Summary Revenue Allocation Alternative Revenue Sources Revenue Summary

Year 2020

Revenue Summary under Existing Tax Structure

Type	Subtotal (\$million)	Details	Monthly Estimation
Gasoline Tax	\$577.46	Details...	Monthly Estimation
Diesel Tax	\$208.91	Details...	Monthly Estimation
Motor Carrier Fuel Use Tax	\$1.32	Details...	--
Motor Carrier Surcharge Tax	\$95.92	Details...	--
Registration Fee	\$328.76	Details...	Monthly Estimation
International Registration Plan	\$61.64	Details...	--
Permits	\$20.36	Details...	--
State Court Fees	\$3.62	Details...	--
Miscellaneous	\$0.50	Details...	--
Total	\$1,298.48	--	--

Output Results

Figure B.6 Interface of Revenue Summary under Existing Highway Revenue Sources

INDOT Revenue Forecasting System 2.0 - Long Term Estimation

File Edit Data Update Models Update Alternative Revenue Help

Fuel Taxes Registration Fee Other Revenue Existing Revenue Summary Revenue Allocation Alternative Revenue Sources Revenue Summary

Year 2020

Alternative Revenue Sources

Type	2020 Revenue (\$M)	Details
VMT Fee	958.79	<input type="button" value="Update Estimation"/>
Weight Distance Fee	311.36	<input type="button" value="Update Estimation"/>
Ad Valorem Tax	1220.06	<input type="button" value="Update Estimation"/>
Tolling	0.00	<input type="button" value="Update Estimation"/>
Congestion Pricing	0.00	<input type="button" value="Update Estimation"/>
Cordon Pricing	0.00	<input type="button" value="Update Estimation"/>

Alternative Revenue Sources Selection

Alternative Revenue Sources Selection-Group 1

	Fuel Tax	VMT Fee	Weight Distance Fee	Ad Valorem Tax
Automobiles	☒	☐	☐	☐
Light Duty Trucks	☒	☐	☐	☐
Buses	☒	☐	☐	☐
Single Unit Trucks	☒	☐	☐	☐
Combination Trucks	☒	☐	☐	☐
Motor Cycles	☒	☐	☐	☐

Alternative Revenue Sources Selection-Group 2

☐ Tolling ☐ Congestion Pricing ☐ Cordon Pricing

Figure B.7 Interface of Alternative Highway Revenue Sources

INDOT Revenue Forecasting System 2.0 - Long Term Estimation

File Edit Data Update Models Update Alternative Revenue Help

Fuel Taxes Registration Fee Other Revenue Existing Revenue Summary Revenue Allocation Alternative Revenue Sources Revenue Summary

Year 2020

Total Revenue Summary

Type	Revenue (\$million)
Gasoline Tax	\$577.46
Disel Tax	\$208.91
Motor Carrier Fuel Use Tax	\$1.32
Motor Carrier Surcharge Tax	\$95.92
Registration Fee	\$294.63
International Registration Plan	\$20.36
Permits	\$61.64
State Court Fees	\$3.62
Miscellaneous	\$0.50
VMT Fee	\$958.79
Weight Distance Fee	\$311.36
Ad Valorem Tax	\$1,220.06
Tolling	\$0.00
Congestion Pricing	\$0.00
Cordon Pricing	\$0.00
Total Revenue	\$3,754.57

Figure B.8 Interface of Total Revenue Summary