Reseach Report 2008
Project No : A-08 / 003

ATRANS
ASIAN TRANSPORTATION RESEARCH SOCIETY

Transport Demand Elasticity of Bangkok and Nakhon Ratchasima: Effects of Oil Price on Gasoline Consumption and Travel Behavior

Thirayoot Limanond
Sumet Ongkittikul
Duangdao Watthanaklang
Sajjakaj Jomnonkwoa

Transport Demand Elasticity of Bangkok and Nakhon Ratchasima: Effects of Oil Price on Gasoline Consumption and Travel behavior

ATRANS
ASIAN TRANSPORTATION RESEARCH SOCIETY

902/1 9th Floor, Glas Haus Building, Soi Sukhumvit 25 (Daeng Prasert),
Sukhumvit Road, Klongtoey-Nua, Wattana, Bangkok 10110, Thailand
Tel. (66) 02-661-6248 FAX (66) 02-661-6249
http://www.atransociety.com

List of Members

• Project Leaders •

Asst. Prof. Dr. Thirayoot Limanond
Lecture,Department of Transportation Engineering,
Suranaree University of Technology

• Project Members •

Dr. Sumet Ongkittikul
Research Specialist,Humen Resources and Social Development Program,
Thailand Development Research Institute Foundation

Ms. Duangdao Watthanaklang
Research Assistant,
Department of Transportation Engineering,
Suranaree University of Technology

Mr.Sajjakaj Jomnonkwoa
Research Assistant,
Department of Transportation Engineering,
Suranaree University of Technology

• Advisors •

Asst. Prof. Dr. Chamnong Sorapipatana
Energy Division,
The Joint Graduate School of Energy and Environment
King Mongkut's University of Technology Thonburi

Abstract

Due to the recent gasoline price crisis in 2007-2008, we have observed changes on travel behavior of citizens and businesses in a noticeable manner. The purpose of this study is to explore how fuel consumption and transport demand in Thailand had changed at a macroscopic level using the concept of the demand elasticity. The study analyzed the historical data of gasoline price along with economics, demographics, and characteristics of transport system on the demand of various fuels as well as various transport modes over the study period of 10 years. In this study, the fuels are classified into 3 groups: unleaded gasoline/gasohol, liquid petroleum gas/compressed natural gas, and diesel, while he transport demands are represented by the four indicators, traffic volumes on expressway, BMTA bus ridership, BTS skytrian ridership and MRTA subway ridership. This study analyzed the quarterly data of the previous 10 year period (from 1998-2008). It was found that the energy and the transport demand elasticity of Thailand was inelastic (< 1.0), similar to previous studies all over the world; however, the estimated numbers of Thailand tend to be more inelastic than those derived in the developed countries.

Acknowledgements

We would like to express our sincere gratitude to ATRANS for the opportunity and full financial support of this research project. In addition, we would like to thank to a the research committee members of ATRANS for invaluable comments and suggesti on this project, and special thank to Assistant Professor Chumnong Sorapipatana for guidance throughout the course of this research.

Thirayoot Limanond
(Project leader)

Table of Contents

List of Abbreviations

GDP	**Gross domestic product**
ULG	**Unleaded gasoline**
ULG91	**Unleaded gasoline 91**
ULG95	**Unleaded gasoline 95**
LPG	**Liquid petroleum gas**
NGV	**Natural gas of vehicle**
BMTA	**Bangkok Mass Transit Authority**
MRTA	**Mass Rapid Transit Authority of Thailand**
CNG	**Compressed Natural Gas**
SPSS	**Statistical Package for the Social Science**
BTS	**Bangkok Mass Transit System Public Company Limited**
PG95	**Average Octane 95 gasoline unit price in the quarter**
PDS	**Average diesel price in the quarter**
GPP	**Gross Provincial Product**
POPbv	**Number of population in Bangkok&Vicinities and the quarter**
GPPbv	**Gross Provincial Product of Bangkok&Vicinities and the quarter**
EU	**European Union**

CHAPTER I INTRODUCTION

1. Introduction

Transport is one of the crucial sectors that facilitate the economic and social development in any country. It involves all movements of people and goods on roads, on rails, on waterways and in the sky. In Thailand, the transport sector consumes as much as 37 percent of overall energy consumption each year. It is even higher than the industrial sector (accounting for 31 percent) despite the industrial sector produces the largest share of the gross domestic product (GDP) of the country while the transport sector itself produces a minute portion of GDP. From 1981 – 2001, the energy consumption in the transport sector has grown with an average growth rate of 16.6 percent per year, and the growth does not seem to lose its pace in the near-term future. Thus, the energy planning and policy from the government cannot overlook the energy consumption in the transport sector.

1.1 Rationale

The historical gasoline price crisis in the past few years has affected the transport sector in many ways. People as well as transport operators have somehow adjusted their behavior in response to the huge price increase, for example, driving less, carpooling, switching modes to public transit or non-motorized transport, using alternative fuel, or making fewer number of trips after all. We all have witnessed demonstrations from transport operators as well as protests from public all over the world, requesting their government to issue some measures to relieve the problems on them. This is a worldwide crisis. Many European and North American researchers have taken the opportunities to investigate the impacts of oil crisis on travel behavior and consumer behavior in a variety of aspects, to understand the way public reacts to the change. However, such studies are rare in Thailand. Understanding the local transport behavior and its sensitivity to the oil price is greatly useful for engineers and policy makers to understand the public and transport operator's behavior in response to the gasoline price increase, which will be useful to forecast the effectiveness of various proposed gasoline price-related policies in the future.

1.2 Objectives

This study aims to analyze the effects of the gasoline price increase on the transport sector in the Bangkok Metropolitan Area and Nakhon Ratchasima at an aggregate level. In particular, the researchers aim to investigate:

- the changes in gasoline consumption and travel behavior as a result of the recent fuel price increases using the concept of demand elasticity,
- whether the demand elasticity is different between Bangkok and Nakhon Ratchasima, and
- whether the demand elasticity vary across cities in other countries.

1.3 Scope of Work

This study focuses on the demand elasticity analysis particularly in 2 provinces of Thailand: Bangkok and Nakhon Ratchasima. The demand elasticity analyzed in this study can be broadly categorized into two groups. The first group is the fuel demand elasticity: how people/industries change their consumptions of various fuel types in response to the fuel price change. Due to a variety of fuels available, the study will focus on major fuels, as listed below:

- Unleaded gasoline 95 (ULG 95),
- Unleaded gasoline 91 (ULG 91),
- Gasohol 95,
- Gasohol 91,
- Liquid petroleum gas (LPG),
- Compressed natural gas (CNG), and
- Diesel.

The second group is the transport demand elasticity: how people adjust their travel behavior in response to the gasoline price change. This study will cover the following aspects of travel demand:

- Traffic on expressways,
- BMTA bus ridership,
- MRTA subway ridership, and
- Number of registered vehicles.

1.4 Benefit from the study

Information revealed from this study will be the sensitivity of local people in Bangkok and Nakhon Ratchasima to the gasoline price, which will be useful for transport engineers and policy makers to better formulate effective priced-related transport measures in the future. For example, if the government decides to issue a new gasoline tax scheme, the elasticity measures will infer an approximation of the changes in consumption of various fuel types; thus the policy makers can reasonably expect how much the government revenue from gasoline tax will be impacted from the scheme. Simultaneously, they can anticipate how much reduction or increase of the fuel import from overseas. Furthermore, since this study also investigated the fuel price effects on various aspects of travel demand; the information revealed here could explain how the tax scheme would effect the toll collections from vehicles using expressways and how much ridership on buses and subways would be changed, so that the authorized offices can plan/adjust their operations to accommodate the new level of usage/ ridership appropriately. Furthermore, it would infer the impacts to the automobile industry on how much the car sales be altered from the normal situation. This case simply shows an example of benefits from this study; in fact, these benefits can be applied to any situations when the gasoline price has changed.

This chapter provides a description of the demand elasticity concept as well as a review of selected previous researches that are relevant to this study. The concept of demand elasticity that is commonly used to measure the sensitivity of demand due to the price change, is discussed in Section 2.1. The results of elasticity estimates in the past are summarized in Section 2.2. Then, Sections 2.3 to 2.6 specifically discuss the forms and the independent variables of the demand functions, previously developed to estimate the demand for fuel consumption, traffic on expressways, public transit ridership and the number of registered vehicles, respectively. Finally, Section 2.7 provided overall critiques/discussions on the literature review.

2.1 Concept of Demand Elasticity

This study investigates the sensitivity of people and transport operators in Bangkok and Nakhon Ratchsima, in response to the price increase, primarily using the concept of the elasticity. The demand elasticity is regularly used to gauge the responsiveness of demand when the price has changed (Oum *et al*, 1992). More specifically, the elasticity represents the percentage change in consuming of a goods from the one-percent change in price, commonly used in the field of economics. According to Balcombe *et al* (2004), the demand elasticity is defined as follows:

$$e_{X_i} = \frac{\text{The proportional change in demand}}{\text{The proportional change in the explanatory variable}} \quad (1)$$

or

$$= \frac{\Delta y}{y} \Big/ \frac{\Delta x_i}{x_i} \quad (2)$$

where Δy denotes the change in demand, and

Δx_i denotes the change in the explanatory variable x_i

When the change in the explanatory variable Δx_i is very small (or approaches zero), then the elasticity could be rewritten as:

$$e_{X_i} = \underset{\Delta x_i \to 0}{\text{Limit}} \left(\frac{\Delta y}{y} \Big/ \frac{\Delta x_i}{x_i} \right) \quad (3)$$

$$e_{X_i} = \left(\frac{dy}{y} \right) \Big/ \left(\frac{dx_i}{x_i} \right) \quad (4)$$

$$e_{X_i} = \frac{d\,(\ln y)}{d\,(\ln x)} \quad (5)$$

Thus, the demand elasticity can simply be estimated by the derivative of the logarithm of the demand (ln *y*) with respect to the independent variable (ln x_i). If the demand function takes a form of the logarithm, the coefficient of the independent variable x_i (or ln x_i) will then become the demand elasticity measure. Please refer to Sections 2.3 to 2.6 for a review of the demand functions successfully developed in the past.

In theory, the value of the elasticity can have either positive or negative sign. The positive value shows that the change in demand and price go in the same direction. That is, when the price increases, the demand will also increase, or if the price decreases, the demand will decrease as well. The negative value represents the case where the changes go into the opposite direction, i.e., when the price increases, the demand will decrease, or vice versa. This is sometimes called 'cross-elasticity.' The demand elasticity in transport can have either negative or positive sign, depending on the issue of interest.

2.2 Review of demand elasticity estimates

The elasticity measures of road traffic and fuel consumption with respect to gasoline price had been intensively studied in North America and Europe for a few decades. Oum *et al* (1992) reviewed empirical elasticity estimates for both passenger and freight demand studied during the period of 1970's and 1980's. It was found that the demand elasticity of automobile usage calculated by the previous studies ranged from -0.09 to -0.52. The study also found that the elasticity estimates for the long-run is generally higher than those for the short-run; nevertheless, they are not statistically different. Table 2-1 below shows the summary of the demand elasticity of automobile usage as summarized by Oum *et al* (1992).

Table 2-1. Demand Elasticity of Automobile Usage

(all values are negative)

	Short Run	Long Run	Unspecified
United States	0.23	0.28	0.31-0.26, 0.15-0.45
Australia	0.09-0.24	0.22-0.31	0.22-0.52, 0.25-0.34
United Kingdom	n.a.	n.a.	0.14-0.36

Source: Oum *et al* (1992)

Table 2-2 summarized the demand elasticity estimates of urban transit as collected by Oum *et al* (1992). As shown, the elasticity estimates ranged between -0.01 to -0.78, as they were estimated by various data types.

Table 2-2. Demand Elasticity of Urban Transit

(all values are negative)

Data types	Elasticity Estimates
Time series	0.01-0.62, 0.17-0.59, 0.18-0.22, 0.23-0.25, 0.23-0.27, 0.27-0.78, 0.29-0.34, 0.36-1.32
Cross-section	0.05-0.34
Pooled data	0.06-0.44
Before/after data	0.10-0.60, 0.70

Source: Oum *et al* (1992)

Goodwin (1992) also reviewed the demand elasticity from the previous studies, and developed a summary table of the elasticity of petrol consumption and traffic level with respect to gasoline price, on Tables 2-3 and Table 2-4, respectively. It was found that the short-term elasticities of gasoline consumptions vary from -0.27 to -0.28, while the long-term ones are 3 times as higher (see Table 2-3), ranging from -0.71 to -0.84. These elasticity estimates seem to be higher than the elasticity of traffic demand with respect to the gasoline price (Table 2-4), which was -0.16 for the short-term period, and in between -0.29 to -0.33 for the long-term period.

Table 2-3. Summary of evidence from studies of elasticity of Petrol consumption with respect to price

	Explicit		Ambiguous
	Short-term	Long-term	
Time-series	-0.27 (0.18, 51)	-0.71 (0.41, 45)	-0.53 (0.47, 8)
Cross-section	-0.28 (0.13, 6)	-0.84 (0.18, 8)	-0.18 (0.10, 5)

*Figures in parenthesis are one standard deviation, and the number of quoted elasticities in the average.

Source: Goodwin (1992)

Table 2-4. Summary of evidence from studies of elasticity of traffic levels with respect to petrol price

	Explicit		Ambiguous
	Short-term	Long-term	
Time-series	-0.16 (0.08, 4)	-0.33 (0.11, 4)	-0.46 (0.40, 5)
Cross-section	-	0.29 (0.06, 2)	-0.5 (n.a., 1)

*Figures in parenthesis are one standard deviation, and the number of quoted elasticities in the average.

Source: Goodwin (1992)

A recent study by Goodwin *et al* (2004) had summarized the 69 demand elasticity studies/reports issued after his previous work in 1992, and reached the following interesting findings as summarized in Table 2-5.

Table 2-5. Short-term and long-term impacts from 10% increase in fuel price

	Impact	
	Short-term	Long-term
Traffic volume	decreases around 1%	decreases about 3%
Fuel Consumption	decreases by 2.5%	decreases by 6.0%
Fuel use efficiency	improves by 1.5%	improves by 2.5%
No. of vehicle ownership	Decreases by 1%	decreased by 2.5%

2.3 Review of demand functions of gasoline consumptions

Rattapan (1996) conducted a research on influencing factors on demand and supply of fuel and the substitution of the fuel imports from 1995 to 2000. This study aims to analyze the structure of the demand, the production and the import of fuel from abroad, and the factors that affect the demand and the amount of the fuel distillation within the country, as well as forecast the gasoline demand in the future. In this study, the researchers categorized fuel into five groups, including, Gasoline, Aviation Fuel, Diesel, Tar, and Liquid Gas, and analyzed the demand functions of fuel usage of these five groups separately using a regression analysis.

The proposed demand functions used in the study had the following form:

$$QD_i = a_i + b_i GDP + c_i POP + d_i P_i + en_i EFFn_i + U_i \quad (6)$$

where a_i - the constant for fuel i

b_i - the coefficient of Gross Domestic Product

c_i - the coefficient of population

d_i - the coefficient of unit price of fuel i

en_i - the coefficient of Factor n that affects the demand of fuel i

U_i - the error term

The usages of the five different fuels were regressed on the gasoline price, and socio-economic data, using the database collected from 1983 to 1994. The final demand functions of gasoline, diesel and liquid petroleum usage were as follow:

Gasoline demand function

$$QDMG = 906.66 + 4.644 \times 10^{-4} CARMG \quad (7)$$

Diesel demand function

$$\ln QDDS = -7.14 + 1.17 \ln GDP - 0.37 \ln PDS \quad (8)$$

Liquid petroleum demand function

$$\ln QDLPG = -1148.166 + 7.67 \times 10^{-4} GDP + 0.02 POP \quad (9)$$

where CARMG - number of registered vehicles in the country.
GDP - Gross Domestic Product
PDS - price of diesel
POP - number of population

The study found that the number of registered vehicles is the only factor that appeared to significantly affect the gasoline usage. For diesel, however, the significant influencing factors included the country gross domestic product and the unit price of diesel. In determining the demand of liquid petroleum, the number of population and the country GDP were the significant independent factors.

Pongpaew (2002) conducted a similar study to analyze the fuel consumption as well as the fuel demand forecasting for Thailand. This study focused on 3 types of major fuels used in the country: liquid petroleum, gasoline and diesel. Quarterly data of fuel consumption, socio-economics, fuel price and other important factors collected between Year 1993 to 2001 were used to developed demand functions. The coefficients were estimated using an ordinary least square method. The final fuel demand models took forms below:

Overall gasoline consumption:

$$\ln GT = \alpha_0 + \alpha_1 \ln PGT + \alpha_2 \ln GDP + \alpha_3 \ln GT_{t-1} \quad (10)$$

where GT = overall gasoline consumption (million liters)
PGT = average gasoline unit price (baht/liter)
GDP = gross domestic products (million baht)
GT_{t-1} = overall gasoline consumption in the previous quarter (million liters)

Consumption of Octane 95:

$$\ln G95 = \alpha_0 + \alpha_1 \ln PG95 + \alpha_2 \ln GDP + \alpha_3 \ln G95_{t-1} + \alpha_4 \ln CAR + \alpha_5 DUM \quad (11)$$

where G95 = consumption of Octane 95 gasoline (million liters)
PG95 = average Octane 95 gasoline unit price in the quarter (baht/liter)
GDP = gross domestic products (million baht)
$G95_{t-1}$ = consumption of Octane 95 gasoline in the previous quarter (million liters)
CAR = number of registered vehicles (vehicles)
DUM = represents the government campaign to promote Octane 95 gasoline in replacing Octane 91 gasoline. (1993:1-1999:4=0 และ 2000:1-2001:4=1)

Consumption of Octane 91:

$$\ln G91 = \alpha_0 + \alpha_1 \ln PG91 + \alpha_2 \ln GDP + \alpha_3 \ln G91_{t-1} + \alpha_4 \ln CAR + \alpha_5 DUM \qquad (12)$$

where G91 = consumption of Octane 91 gasoline (million liters)

PG91 = average Octane 91 gasoline unit price in the quarter (baht/liter)

GDP = gross domestic products (million baht)

$G91_{t-1}$ = consumption of Octane 91 gasoline in the previous quarter (million liters)

CAR = number of registered vehicles (vehicles)

DUM = represents the government campaign to promote Octane 95 gasoline in replacing Octane 91 gasoline. (1993:1-1999:4=0 และ 2000:1-2001:4=1)

The demand model produced small errors for the prediction given that the root mean squared error (RMSE) and the error terms were small and approached zero. Thus, the factors used were the good determinants of gasoline consumption.

Eltony (1996) analyzed the structure of gasoline demand for the six country members of Gulf Cooperation Council, comprising of Bahrain, Kuwait, Oman, Katar, Saudi Arabia, United Arab Emirate. The objective of his study was to estimate the elasticity of gasoline price and income on the gasoline consumption in the short-term and the long-term periods. The demand function took a form of:

$$Ln\ GS = A_i + B_1 LnP_g + B_2 LnY + B_3 LnS + B_4 Ln\ GS_{t-1} + e \qquad (13)$$

where

GS = per capita gasoline consumption

P_g = real price of gasoline

Y = real capita real personal disposable income

S = per capita stock of automobile

GS_{t-1} = first order lagged consumption of gasoline

e = error term

All of the estimated coefficients of the model were found to have a rationale sign and were significant at a 95% confident interval. The coefficient of the determination (r^2) of the model was also high. From the final form of the model, it was found that the short-term elasticity appeared sound, having a negative value and being inelastic.

Long-run elasticity of gasoline consumption were estimated to be 0.17, which is larger than the short-run elasticity of 0.11. The gasoline consumption was found to be inelastic for both short-run and long-run.

2.4 Review of demand functions of traffic on expressway

Matas and Raymond (2003) analyzed a demand function of traffic on expressways in Spain with an ultimate goal of estimating the expressway traffic elasticities. The research team collected the information of expressway traffic, expressway tolls, socio-economics and other relevant data from year 1981 – 1998, and analyzed the data based on a yearly basis using a regression analysis. The demand function obtained from the research took the following form:

$$\Delta\ln(Y_{it}) = \beta_1\Delta\ln(GDP_t) + \beta_2\Delta\ln(PP_t) + \beta_{3i}\Delta\ln(MT_{it}^{m}) + \varphi\Delta\ln(Y_{it-1}) + \gamma'\Delta Z_{it} + \varepsilon_{it} \quad (14)$$

where

- Y_{it} = traffic volume at the motorway section i and period t
- GDP_t = level of economic activity in period t
- PP_t = petrol price in period t
- MT_{it}^{m} = motorway toll in section i and period t
- Y_{it-1} = amount of traffic on expressway i in the time period t-1
- ΔZ_{it} = vector of the dummy variables
- ε_{it} = error term

It was found that the short-term elasticity of traffic on expressways due to gasoline prices, on average, was -0.3, which varies from -0.21 to -0.83 depending on the sections of the expressway. The long-term elasticity, on average, was -0.53 for the whole expressway, varying within the range of -0.33 and -1.31, depending on the section of the expressway.

Hirschmand *et al* (1995) investigated the elasticity of traffic on tolled bridges or tolled tunnel in New York. They collected all of the relevant data between 1979 to 1990, and analyzed them on a monthly basis, using a multiple regression model. The final model took the form of:

$$\ln Crossing = f(\ln Toll_t + \ln Employment_t + \ln MVR_t + \ln Fare_t + \ln Gas_t + Strike_t + \ldots\text{monthly dummy variables for Jan. through Nov.}) \quad (15)$$

where

- Crossing = monthly automobile crossing
- $Toll_t$ = real auto toll in that month
- $Employment_t$ = employment weighted by trip destination in that month
- MVR_t = motor vehicle registrations weighted by trip origins in that month
- $Fare_t$ = real subway fare in that month
- Gas_t = real retail gasoline price in that month

Strike $_t$ = dummy variable *for TA strike month*

Monthly variables = a series of eleven 0/1 dummy variable *for January through November*

Odeck and Brathen (2008) studied the elasticity of travel demand and public attitudes on the toll project in Norway. The study aimed to investigate the short-term elasticity of travel demand for the 19 tolled road projects, and the long-term elasticity for another 5 projects. The study site included selected tolled roads in 3 major cities: Oslo, Bergen and Trondheim. The research was based on the before and after study. The data were collected between 1987 and 2002.

The demand function took the form of:

$$\Delta x_t = \gamma \Delta x_{t-1} + \alpha_1 \Delta gc_t + \alpha_2 \Delta w_t + \delta_1 \lambda + U_t \quad (16)$$

where

Δx_t= change register volume of traffic per year

Δx_{t-1}= change register volume of traffic per year in the time period t-1

Δgc_t=change generalized transport costs per year

Δw_t= change household in come per year

λ=dummy variable

U_t=residual

It was found that the elasticity was sensitive to tolls more than household income. The short-term elasticity of traffic due to toll were -0.56 on average, varying within a range from -0.03 to -2.26 depending on the characteristics of the project such as, the level of the tolls, the location of the project. The long-term elasticity was estimated to be -0.82, higher than the short-term one, which is rationale given that some people need more time to change their behavior.

2.5 Review of demand functions of public transit ridership

Mattson (2008) studied the effects of the recent gasoline price hike on the bus patronages in small cities and rural area. He used dynamic polynomial distributed lag model to analyze the short-term and the long-term elasticity of bus ridership. All of the public bus system under investigation were divided into 4 groups depending on the number of population in the city that the bus system serves. The model was developed based on monthly data collected between 1997 and 2007, and took the form of:

$$\ln R_t = \alpha_0 + \beta_0 \ln PG_t + \beta_1 \ln PG_{t-1} + \beta_{21} \ln PG_{t-2+...} \beta_m \ln PG_{t-m} + \sum \gamma_i M_i + U_t \quad (17)$$

where

R_t = ridership in time t

PG_t = price of gas in time t

PG_{t-1} = price of gas in time t-1

M_i = monthly dummy variable for month i

U_t = error term

The study found that the elasticity of bus ridership due to the gasoline price was in a range of 0.08 to -0.16, which is statistically significant at 0.1. It also found that the elasticity in larger cities tend to be larger than smaller cities.

Piro (2006) investigated the fare structure of public and the ridership demand for public transit in New York. It aimed to analyze how the changes in fares affect the sensitivity and usage as well as response from users. The regression analysis used in this study took the generalized form of:

$$\frac{RIDERSHIP}{POP} = \beta_0 + \beta_1 (1\text{-}UNLIMITED)^*BASEFARE + \beta_2 (UNLIMITED)^*BASEFARE$$
$$+ \beta_3 (UNLIMITED)^*MONTHPI + \beta_4 (UNLIMITED) + \beta_5 UNEMP + \beta_6 \left(\frac{OBSNUM}{100}\right)$$
$$+ \beta_7 \left(\frac{OBSNUM^2}{100}\right) + \beta_8 (1\text{-}UNLIMITED)^*CAB + \beta_9 (UNLIMITED)^*CAB$$
$$+ \beta_{10} FEB + ... + \beta_{20} DEC \quad (18)$$

where

$\frac{RIDERSHIP}{POP}$ = Per capita monthly ridership :the aver monthly weekday ridership divided by the population of New York city

$(1\text{-}UNLIMITED)^*BASEFARE$ =Real base fare for mass transit before the introduction of unlimited pass

$(UNLIMITED)^*BASEFARE$ = Real base fare for mass transit after the introduction of unlimited pass

$(UNLIMITED)^*MONTHPI$ = Real price of the monthly unlimited pass

$(UNLIMITED)$=Dummy variable equal to 1 after the introduction of the unlimited pass

$UNEMP$ =Unemployment rate for New York City

$\left(\frac{OBSNUM}{100}\right), \left(\frac{OBSNUM^2}{100}\right)$=Quadratic time trend :Observation number rescaled for convenience

$(1\text{-}UNLIMITED)^*CAB$ = Real average cab fare before the introduction of the unlimited pass

$(UNLIMITED)^{*}CAB$ = Real average cab fare after the introduction of the unlimited pass
FEB-DEC=Monthly dummy variable

It was found that the coefficient estimate of the taxi cost has a positive sign as expected. The average value of the coefficient is 0.5. The dummy variables of September and August has a negative sign, which represent the condition when the school close.

Before the employment of the unlimited passes, the relationship between the transit fare and the number of ridership was -0.43. When the unlimited passes are initiated, the elasticity of the number of ridership due to public transit become 0.09, which is statistically insignificant.

Jones and Nicole (1983) analyzed the ridership demand of intercity public transit in the UK. They gathered monthly data of ridership, socioeconomic as well as relevant information from 1970 to 1976 to construct a ridership demand model using an ordinary least square method. The model took the form of:

$$Q_t = \beta_0 P_t^{\beta_1} JT_t^{\beta_3} EA_t^{\beta_4} GDP_t^{\beta_5} PP_t^{\beta_6} e(\beta_7 S_t + \sum_{i=0}^{20} \beta_i D_{it}) \varepsilon_t \qquad (19)$$

where

P_t =fare bus in period t

JT_t =Journey time by rail

EA_t =index of cyclical activity

GDP_t =index of real GDP

PP_t =index of petrol prices

S_t=service level on non-rail modes

D_{it}=seasonal dummy variable

ε_t=a random error

It was found that the estimated elasticity of ridership due to the fare level all had a negative sign as expected, with an average value of -0.64. In particular, two lines had high elasticity, that is, London-Glasgow (-1.18) and London-Newcastle (-1.03). The elasticity of ridership demand due to travel time can be broadly categorized into 2 groups: the high elasticity group (-0.8 to -1.0) and the low elasticity group (-0.3 to -0.5).

2.6 Review of demand functions of the number of vehicles registered

Lee and Kang (2008) analyzed the influencing factors on the automobile demand in Brazil using a regression analysis. Their model took the form of:

$$\ln Y_t = \beta_0 + \beta_1 \ln X_{1t} + \beta_2 \ln X_{2t} + \beta_3 \ln X_{3t} + \beta_4 \ln X_{4t} + \mu_t \quad (20)$$

where

Y = Brazilian demand for automobiles

X_{1t}=the price index of durable goods

X_{2t}=the price of fuels

X_{3t}=the lending rate

X_{4t}=GDP

μ_t=the stochastic disturbance item

The analysis utilized the monthly data gathered from January 2001 to December 2006. It was found that the price elasticity of demand is 0.006477, which is rather insignificant. It virtually has no impact on the decision of buying a new vehicle. Thus, the gasoline price was not the main influencing factors to automobile purchase. The elasticity due to GPD is 1.82 which is statistically significant to the buying of a new vehicle.

Chen *et al* (1999) analyzed the demand for new vehicles in the United States to specify any factors that seems to influence the new vehicle demand. Their research gathered relevant information base on quarterly basis from 1988 to 1999. The final model took the form of

Demand New Car(million)=43.868+0.00007485(retail_Sales)-0.851(Fed_Funds_Rate)
-3.110(Unemployment_Rate)-0.250(CPI_New_Cars)+2.808(Quarter_1) (21)

where

Demand New Car =demand new car (million)

retail_Sales =Sale Retail(billion)

Fed_Funds_Rate =Federal funds Rate(%)

Unemployment_Rate =Unemployment Rate(%)

CPI_New_Cars =Price of new cars

Quarter_1=demand for car in first Quarter impact

It was found that the demand elasticity of retail price was -0.00007485 and the elasticity of loan interest was -0.851, the elasticity of unemployment rate was -3.110.

2.7 Summary

From the literature review, there are a few studies in the past that investigate the responsiveness of gasoline consumption and travel demand due to the gasoline price as well as other factors using a demand model. Most of the studies employed a regression analysis technique on a historical data based on a monthly, quarterly or yearly basis. Most of them took a logarithm form. As summarized previously, there are a few researches that particular focusing on specific topic of interest, including

Gasoline consumption,
Traffic on expressways,
Public transit ridership,
No. of vehicle registered.

The independent variables commonly used for the demand models can be broadly categorized into four groups. The first is the socio-economic data, such as, gross domestic product, the number of population, the number of vehicle registered, per-capita income, the unemployment rate, etc. This group of variables in general has apparent relationship with the demand; that is, as the GPD increases, the city grows, or per-capita income raises, then the demand of gasoline consumption or travel tend to increase. The second is related to the cost of travel or the cost of gasoline that could affect the decision choice of what modes or which type of gasoline to be used. This group comprises of bus fare, subway fare, tolls, and gasoline price. The third group is the lagged value of the dependent variable. Given that the public responsiveness to any change is a dynamic process, and the effect could be gradually change toward after some time, the lagged variable is a crucial factor for us to check the long-term responsiveness on various aspect of travel demand or gasoline consumption. The forth group include other important information that is unique to issue of interest; for example, dummy variables to represent a government campaign to promote specific use of any modes of travel, variables explaining the rail network or the expressway network expansion over the years, or variables that used to capture the effect of seasonal usage of particular thing.

CHAPTER 3 Methodology

In this study, the researchers attempt to investigate the public reactions on gasoline consumption as well as on travel demand due to the change in gasoline price in the past 10 years. Section 3.1 shows key graphical presentation of the historical data of gasoline consumption, gasoline price and travel demand in the past 10 years. In addition, it will first propose appropriate demand functions to be used to explain the demand of gasoline price and travel demand of particular interest. Section 3.2 explains the list of variables needed for the analysis, and the source of such data.

3.1 Proposed Demand Functions

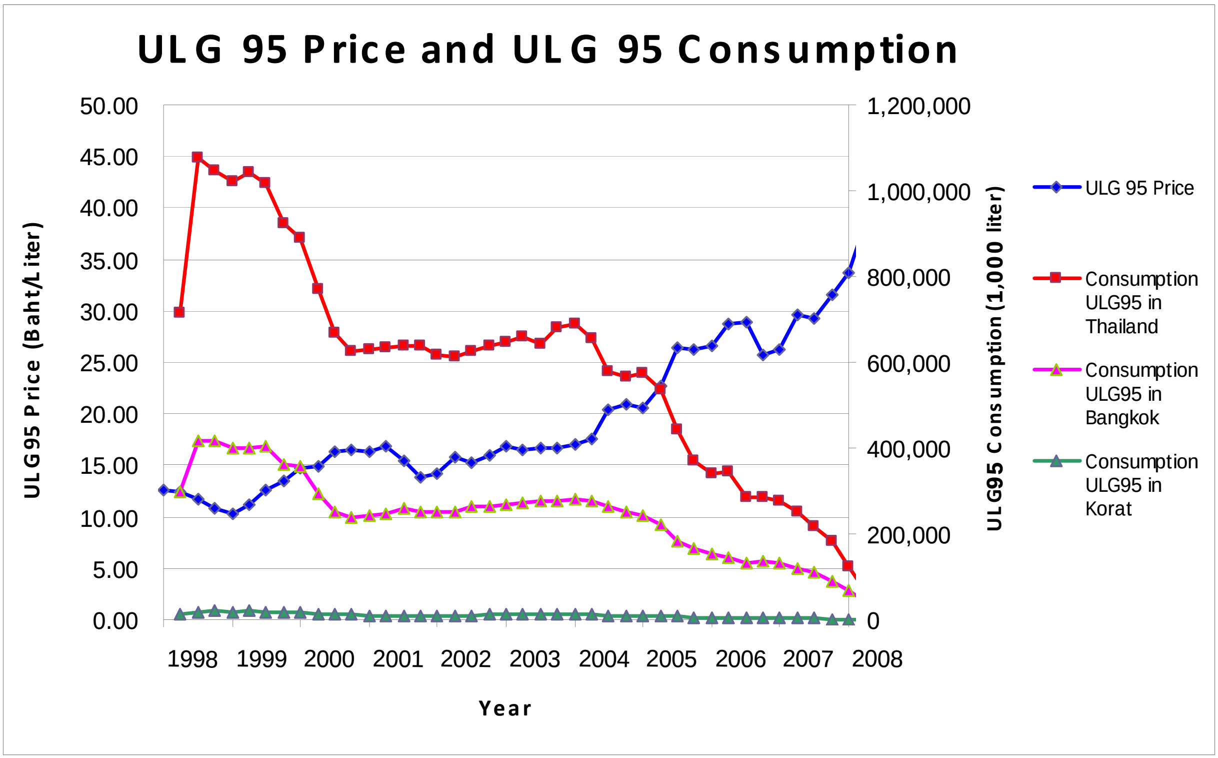
The proposed demand functions of fuel consumption as well as travel demand are listed below. It should be noted that these demand functions was developed based on the literature review, critical thinking and personal familiarity with the area.

<u>Fuel demand function</u>

3.1.1 Consumption of ULG 95:

Figure 3-1 below shows the historical trends of the ULG 95 price, and the ULG 95 consumptions for the whole country, for Bangkok and for Nakhon Ratchasima (Korat) from 1998 to 2008. As shown, the ULG95 price was relatively stable around 15 to 16 baht per liter during 2000 to 2004, and had been increasingly since 2004 to reach 35 baht per liter in 2008. In 1998, the consumptions of ULG 95 were over 1 billion liters per quarter, and shapely dropped to 600 million liters per quarter in 2000, perhaps due to the major economic crisis in Thailand during the period. From 2004 onward, the introduction of an alternative fuels, Gasohol 95, causes the declining trend in ULG 95 consumptions until today.

Figure 3-1. Historical price and consumptions of ULG 95 between 1998 and 2008



The proposed demand function for ULG 95 consumption is:

$$\ln G95 = \alpha_0 + \alpha_1 \ln PG95 + \alpha_2 \ln GDP + \alpha_3 \ln POP + \alpha_4 G95_{t-1} + \alpha_5 \ln CAR + \alpha_6 \ln PLPG + \alpha_7 \ln SNGV + \alpha_8 \ln PGAS95 + \alpha_9 DUM \quad (22)$$

where

G95 = consumption of Octane 95 gasoline (thousand liters)

PG95 = average Octane 95 gasoline unit price in the quarter (baht/liter)

GDP = gross domestic products (million baht)

POP = population in thailand

$G95_{t-1}$ = consumption of Octane 95 gasoline in the previous quarter

CAR = number of registered vehicles (vehicles)

PLPG = price of LPG

SNGV = station of NGV

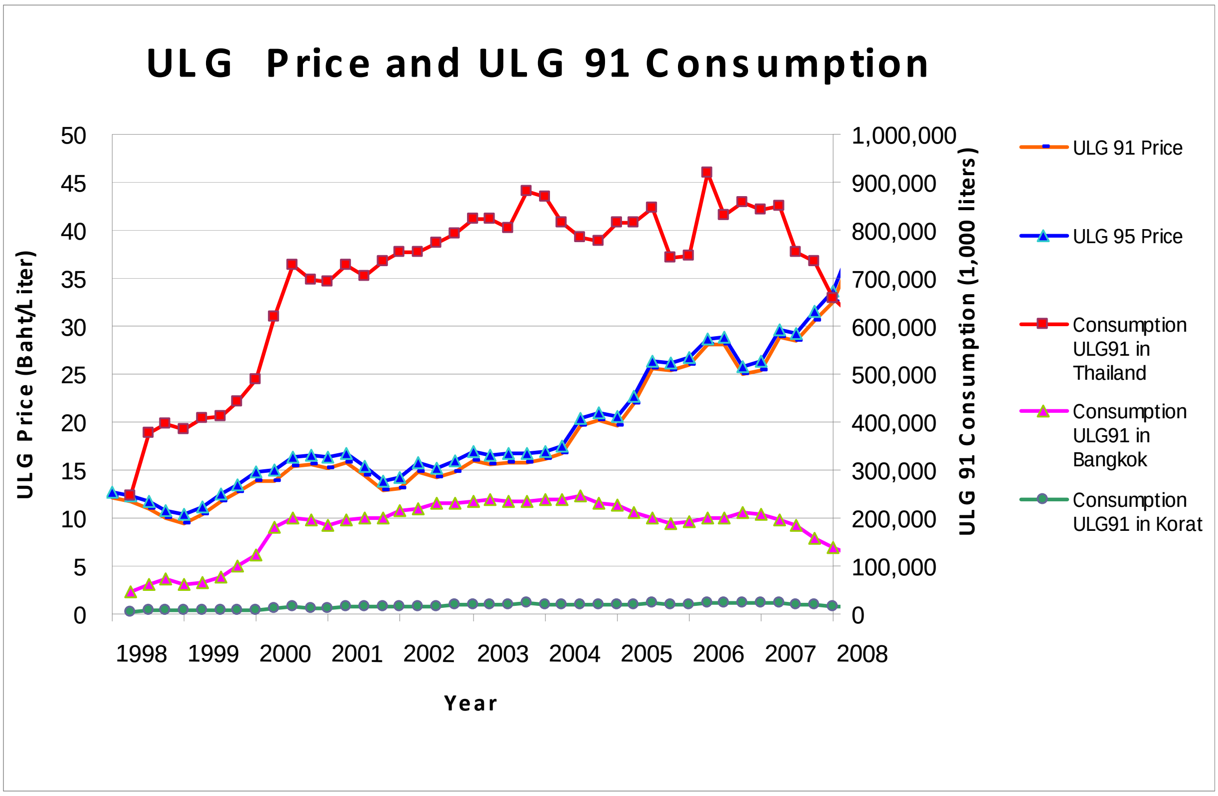
PGAS95 = price of gasohol 95

DUM = represents the government campaign to promote Octane 91 gasoline in replacing Octane 95 gasoline.

3.1.2 Consumption of ULG 91:

Figure 3-2 below shows the historical trends of the ULG prices, and the ULG 91 consumptions for the whole country, for Bangkok and for Nakhon Ratchasima (Korat) from 1998 to 2008. Similar to ULG 95, the price of ULG 91 was relatively stable around 15 to 16 baht per liter during 2000 to 2004, and had been increasingly since 2004 to reach 35 baht per liter in 2008. In 1998, the consumptions of ULG 91 were around 250 million liters per quarter, and had increased to 700 million liters per quarter in 2000. From 2000 onward, the consumption of ULG 91 had gradually increased to 850 million liters per quarter in 2005. From 2007, the consumption has declined due to 2 main reasons: the skyrocketing increase of gas price and the promotion of the alternative fuel: gasohol 91.

Figure 3-2. Historical price and consumptions of ULG 91 between 1998 and 2008



The proposed demand function for ULG 91 consumption is:

$$\ln G91 = \alpha_0 + \alpha_1 \ln PG91 + \alpha_2 \ln GDP + \alpha_3 \ln POP + \alpha_4 \ln G91_{t-1} + \alpha_5 \ln CAR + \alpha_6 \ln PLPG + \alpha_7 \ln SNGV + \alpha_8 \ln PGAS95 + \alpha_9 DUM \quad (23)$$

where

G91 = consumption of Octane 91 gasoline (thousand liters)

PG91 = average Octane 91 gasoline unit price in the quarter (baht/liter)

GDP = gross domestic products (million baht)

POP = population in thailand

$G91_{t-1}$ = consumption of Octane 91 gasoline in the previous quarter

CAR = number of registered vehicles (vehicles)

PLPG = price of LPG

SNGV = station of NGV

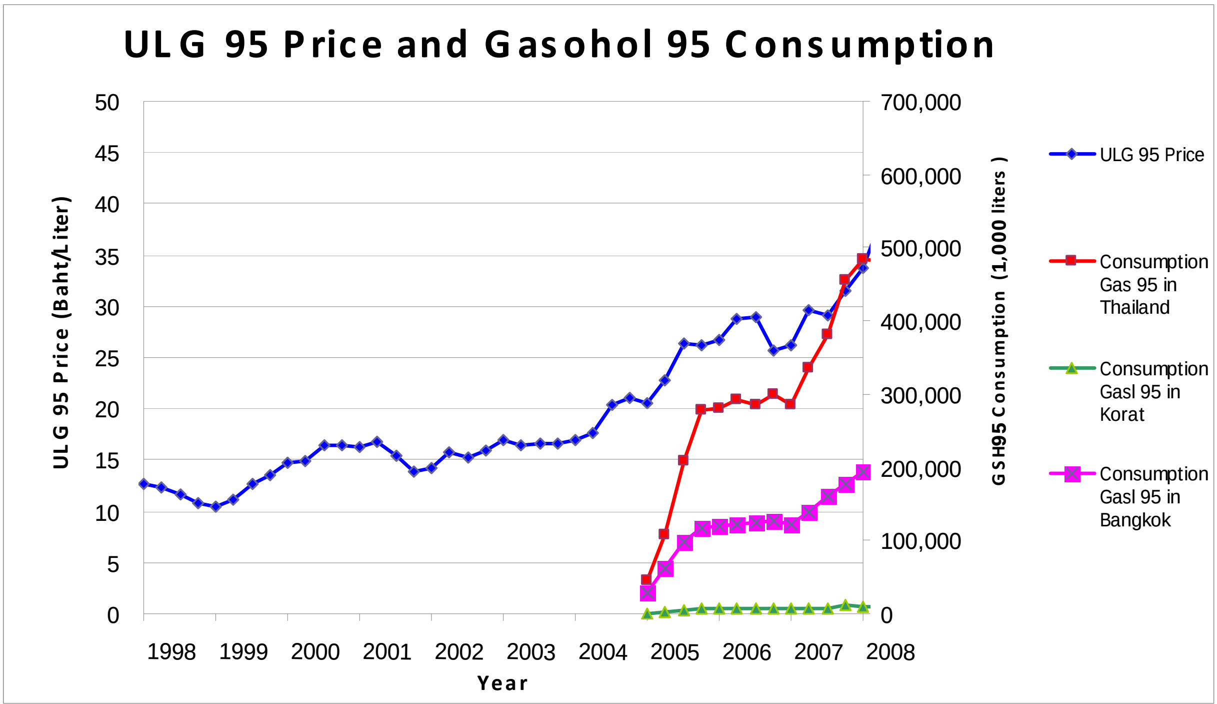
PGAS95 = price of gasohol 95

DUM = represents the government campaign to promote Octane 91 gasoline in replacing Octane 95 gasoline

3.1.3 Consumption of gasohol 95:

Figure 3-3 below shows the historical trends of the fuel price, and the consumptions of Gasohol 95 for the whole country, for Bangkok and for Nakhon Ratchasima (Korat) since the introduction of Gasohol 95 in 2005 until 2008. Since its introduction to the market, the demand of gasohol 95 has continuously increased to reach 500 million liters per quarter in 2008.

Figure 3-3. Historical fuel price and consumptions of Gasohol 95 between 2004 and 2008



The proposed demand function for Gasohol 95 consumption is:

$$\text{n } GAS95 = \alpha_0 + \alpha_1 \ln PGAS95 + \alpha_2 \ln GDP + \alpha_3 \ln POP + \alpha_4 \ln GAS95_{t-1} + \alpha_5 \ln CAR + \alpha_6 \ln PLPG + \alpha_7 \ln SNGV + \alpha_8 SGAS95 + \alpha_8 DUM \quad (24)$$

where

GAS95 = consumption of gasohol 95 (thousand liters)

PGAS95 = average gasohol 95 unit price in the quarter (baht/liter)

GDP = gross domestic products (million baht)

POP = population in Thailand.

$GAS95_{t-1}$ = consumption of gasohol 95 in the previous quarter.

CAR = number of registered vehicles (vehicles),

PLPG = average LPG unit price in the quarter(baht/kg).

SNGV = station of NGV.

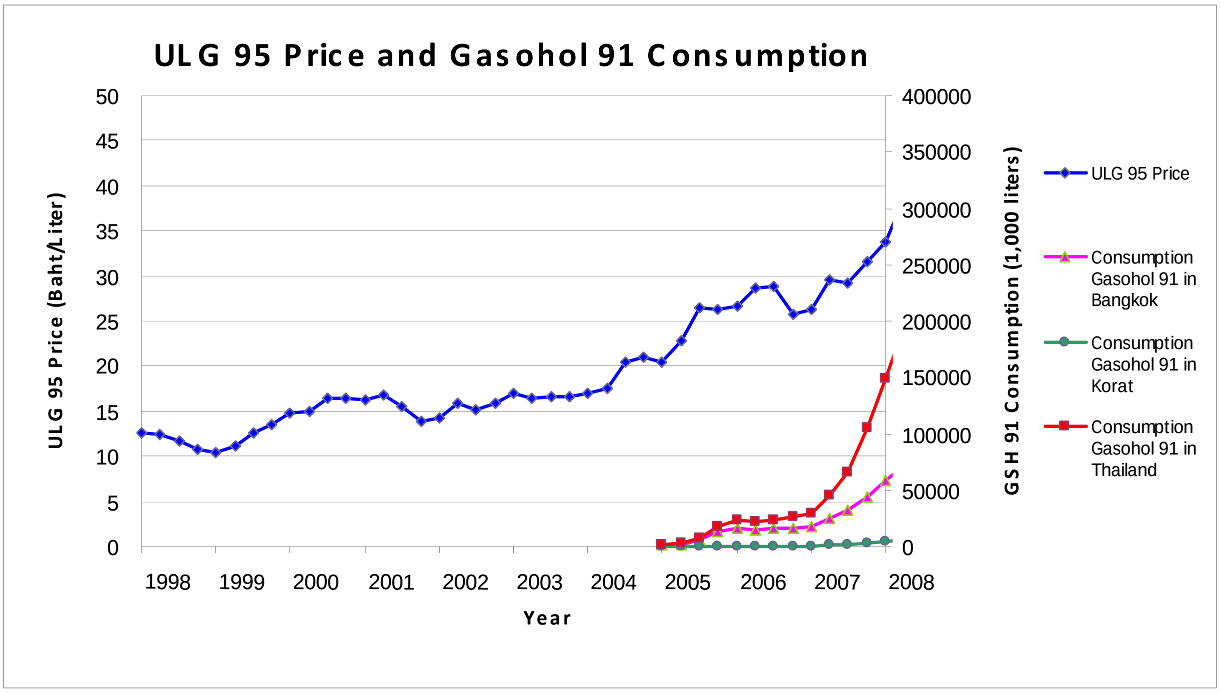
SGAS95 = station of Gasohol 95.

DUM = represents the government campaign to promote gasohol in replacing gasoline.

3.1.4 Consumption of gasohol 91:

Figure 3-4 below shows the historical trends of the fuel price, and the consumptions of Gasohol 91 for the whole country, for Bangkok and for Nakhon Ratchasima (Korat) since the introduction of Gasohol 91 in 2005 until 2008. Since its introduction to the market, the demand of gasohol 91 has continuously increased to reach 150 million liters per quarter in 2008.

Figure 3-4. Historical fuel price and consumptions of Gasohol 91 between 2004 and 2008



The proposed demand function for Gasohol 91 consumption is:

$$\ln GAS91 = \alpha_0 + \alpha_1 \ln PGAS91 + \alpha_2 \ln GDP + \alpha_3 \ln POP + \alpha_4 \ln GAS91_{t-1} + \alpha_5 \ln CAR + \alpha_6 \ln PLPG + \alpha_7 \ln SNGV + \alpha_8 SGAS91 + \alpha_8 DUM \quad (25)$$

where

GAS91 = consumption of gasohol 91 (thousand liters)

PGAS91 = average gasohol 91 unit price in the quarter (baht/liter)

GDP = gross domestic products (million baht)

POP = population in Thailand.

$GAS95_{t-1}$ = consumption of gasohol 95 in the previous quarter.

CAR = number of registered vehicles (vehicles)

PLPG = average LPG unit price in the quarter(baht/kg).

SNGV = station of NGV.

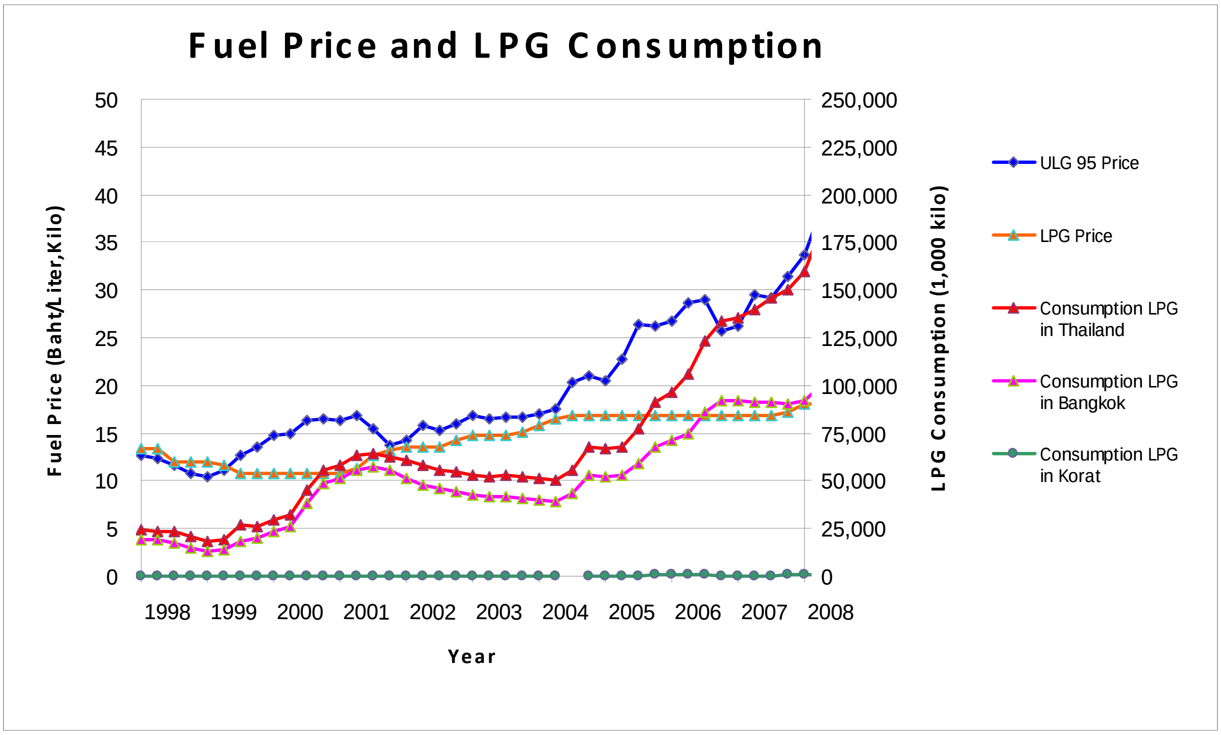
SGAS91 = station of Gasohol 91.

DUM = represents the government campaign to promote gasohol in replacing gasoline.

3.1.5 Consumption of LPG:

Figure 3-5 shows the historical trends of the fuel prices, and the consumptions of LPG for the whole country, for Bangkok and for Nakhon Ratchasima (Korat) from 1998 to 2008. The price of LPG was gradually increased from 10 baht/kilogram in 2000, to 17 baht/kilogram in 2004, and maintains this price until 2008. The LPG consumption shows a significant increase since 2004 onward, perhaps due to the continuing increase of gasoline price from 2004 to 2008.

Figure 3-5. Historical fuel price and consumptions of LPG between 1998 and 2008



The proposed demand function for LPG consumption is:

$$\ln LPG = \alpha_0 + \alpha_1 \ln PLPG + \alpha_2 \ln GDP + \alpha_3 \ln POP + \alpha_4 \ln LPG_{t-1} + \alpha_5 \ln CAR + \alpha_6 \ln PGAS95 + \alpha_7 \ln SLPG \quad (26)$$

where

LPG = consumption of LPG (thousand kilo)

PLPG = average LPG price unit price in the quarter (baht/kilo).

GDP = gross domestic products (million baht)

POP = population in Thailand.

LPG_{t-1} = consumption of LPG in the previous quarter.

CAR = number of registered vehicles (vehicles).

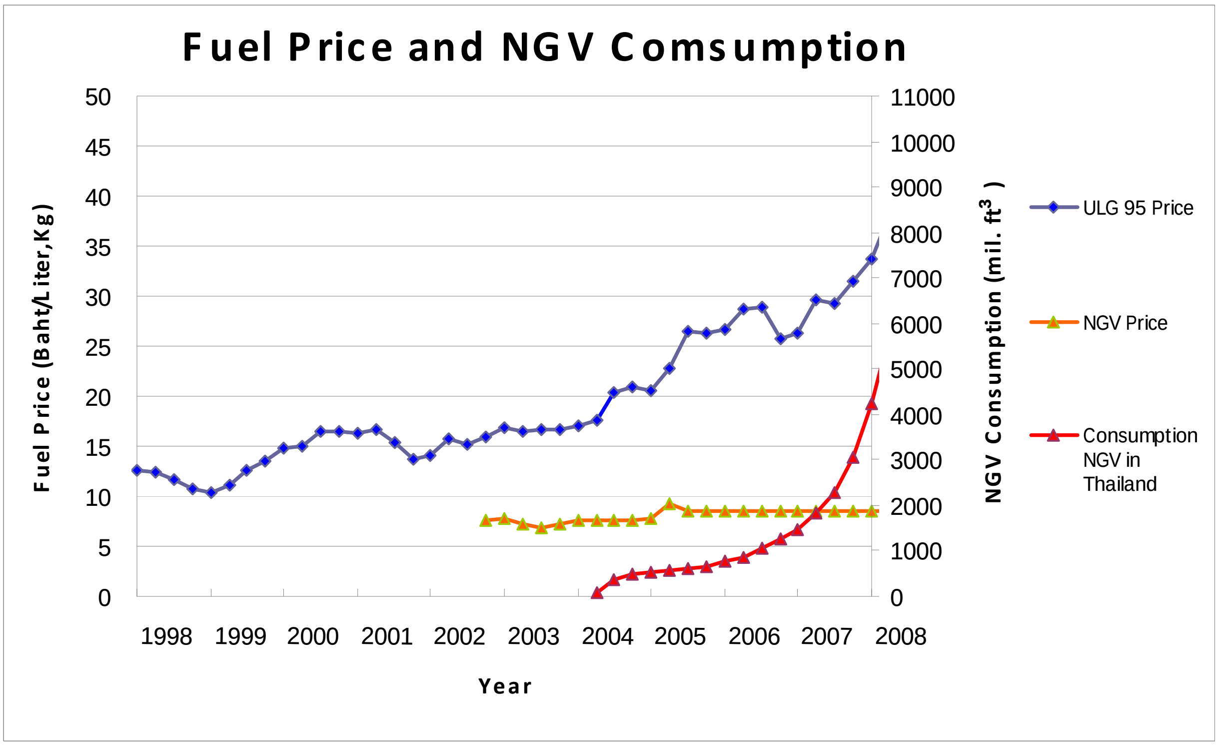
PGAS95 = average gasohol 95 unit price in the quarter (baht/liter).

SLPG = station of LPG.

3.1.6 Consumption of NGV:

Figure 3-6 shows the historical trends of the fuel prices, and the consumptions of NGV for the whole country since its introduction in 2004. The price of NGV was relative stable from 7-8 baht/liter between 2004 and 2008. The NGV consumption has however shapely increased since 2004 onward to reach 4 billion cubic feet in 2008, perhaps due to the continuing increase of gasoline price during that period.

Figure 3-6. Historical fuel price and consumptions of NGV between 2004 and 2008



The proposed demand function for NGV consumption is:

$$\ln NGV = \alpha_0 + \alpha_1 \ln PNGV + \alpha_2 \ln GDP + \alpha_3 \ln POP + \alpha_4 \ln NGV_{t-1} + \alpha_5 \ln CAR + \alpha_6 \ln PGAS95 + \alpha_7 DUM \quad (27)$$

where

NGV = consumption of natural gas for vehicle (thousand liters)

PNGV = average LPG price unit price in the quarter (baht/kilo).

GDP = gross domestic products (million baht)

POP = population in Thailand.

NGV_{t-1} = consumption of NGV in the previous quarter.

CAR = number of registered vehicles (vehicles),

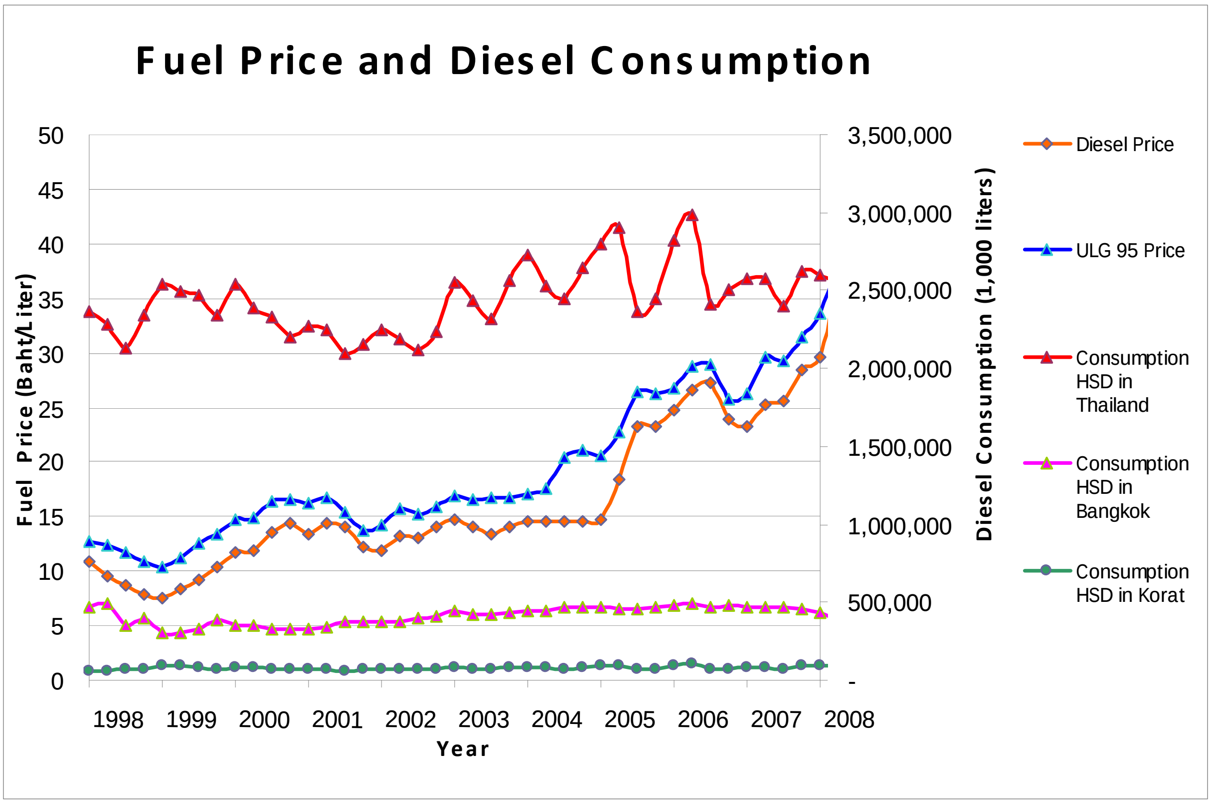
PGAS95 = gasohol 95 price.

DUM = represents the government campaign to promote NGV in replacing gasoline.

3.1.7 Consumption of diesel for transport:

Figure 3-7 shows the historical trends of the fuel prices, and the consumptions of diesel for the whole country, Bangkok and Nakhon Ratchasima from 1998 to 2008. The price of diesel has a similar pattern to the price of ULG 95, which continuingly increase since 2004. The consumption of diesel was 200 billion liters/quarter in 1998, and was slightly increase to approximately 250 billion liters/quarter in 2008. It should be noted that the diesel consumption for the whole country shows a cyclic trend, which implies that consumption vary by seasons of the year.

Figure 3-7. Historical fuel prices and consumptions of diesel between 1998 and 2008



The proposed demand function for Diesel consumption is:

$$\ln DS = \alpha_0 + \alpha_1 \ln PDT + \alpha_2 \ln GDP + \alpha_3 \ln POP + \alpha_4 \ln DT_{t-1} + \alpha_5 \ln TRUCK + \alpha_6 \ln BUS \quad (28)$$

where

DS = consumption of diesel (thousand liters)

PDS = diesel price.

GDP = gross domestic products (million baht)

POP = population in Thailand.

DS_{t-1} = consumption of diesel in the previous quarter.

TRUCK = number of truck registered (vehicles).

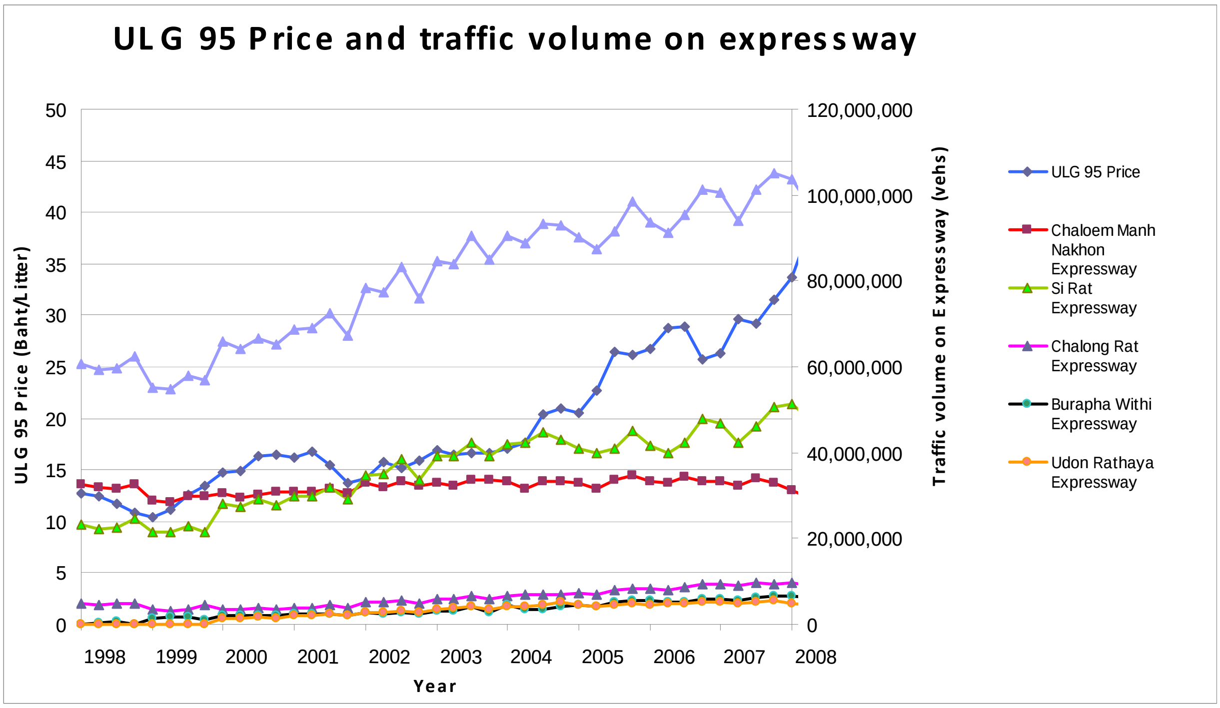
BUS = number of registered buses (vehicle).

Travel demand function

3.1.8 demand function of traffic on expressway

Figure 3-8 shows the historical trends of the fuel prices, and the traffic volume on the 5 expressways in Bangkok. The total volumes on the 5 expressway combined was 60 million vehicles per quarter in Year 1998, and had generally increased to 100 million vehicles per quarter in Year 2008. It should be noted that the trend of traffic on expressways has a cyclic pattern, which implies that travel activities vary by seasons of the year. This is perhaps due to the fewer travel activities during the summer time when schools close.

Figure 3-8. Historical fuel prices and traffic volumes on expressways between 1998 and 2008



The proposed demand function for traffic on expressways is:

$$\Delta \ln(Y_{it}) = \beta_1 \Delta \ln(GDP_t) + \beta_2 \Delta \ln(PG95_t) + \beta_3 \Delta \ln(INC_t) + \beta_{4i} \Delta \ln(MT_{it}^{m}) + \beta_5 \Delta \ln(CAR_t)$$

$$+ \varphi \Delta \ln(Y_{it-1}) + \beta_6(Cycle) \qquad (29)$$

where Y_{it} = traffic volume at the expressway section i and period t.

GDP_t = gross domestic products (million baht) in period t.

$PG95_t$ = average gasohol 95 unit price in the quarter (baht/liter)

INC_t = personal income in period t.

MT_{it}^{m} = motorway toll in section i and period t.

CAR_t = number of registered vehicles (vehicles) and period t.

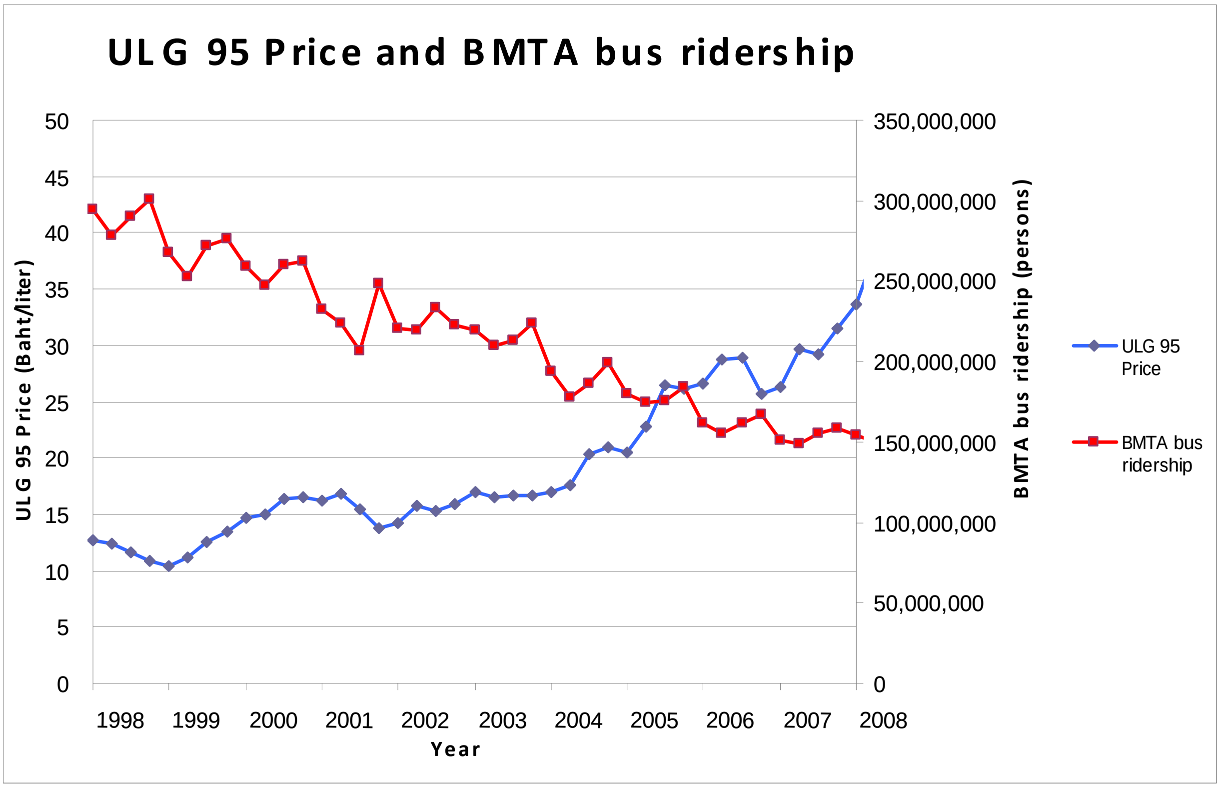
Y_{it-1} = first order lagged traffic volume of expressway.

Cycle = seasonal variable.

3.1.9 Demand function of bus ridership

Figure 3-9 shows the historical trends of the ULG95 prices, and the total BMTA bus ridership in the greater Bangkok area. The number of ridership has declined over the years, reducing from 300 million person-trips in 1998 to 150 million person-trips in 2008. Similar to traffic on expressway, the trend of BMTA bus ridership has a cyclic pattern, which implies that travel activities varies by seasons of the year. This is perhaps due to the fewer travel activities during the summer time when schools close.

Figure 3-9. Historical fuel prices and BMTA bus ridership between 1998 and 2008



The proposed demand function for BMTA bus ridership is:

$$\ln Rb_t = \alpha_0 + \alpha_1 \ln GDP_t + \alpha_2 \ln POP_t + \alpha_3 \ln PG95_t + \alpha_4 \ln Rb_{t-1} + \alpha_5 \ln Fbus_t + \alpha_6 \ln QS_t + \alpha_7 \ln U_t + \alpha_8 \ln CAR_t + \alpha_9 (Cycle) + \alpha_{10} DUM \quad (30)$$

where

Rb_t = ridership for bus in period t.

GDP_t = gross domestic products (million baht) in period t.

POP_t = population in Thailand.

$PG95_t$ = average gasohol 95 unit price in the quarter (baht/liter)

Rb_{t-1} = first order lagged ridership of bus.

$Fbus_t$ = fares for bus in period t.

QS_t = Quantity of service for bus in period t.

U_t = unemployment rate in period t.

CAR_t = number cars in Thailand and period t.

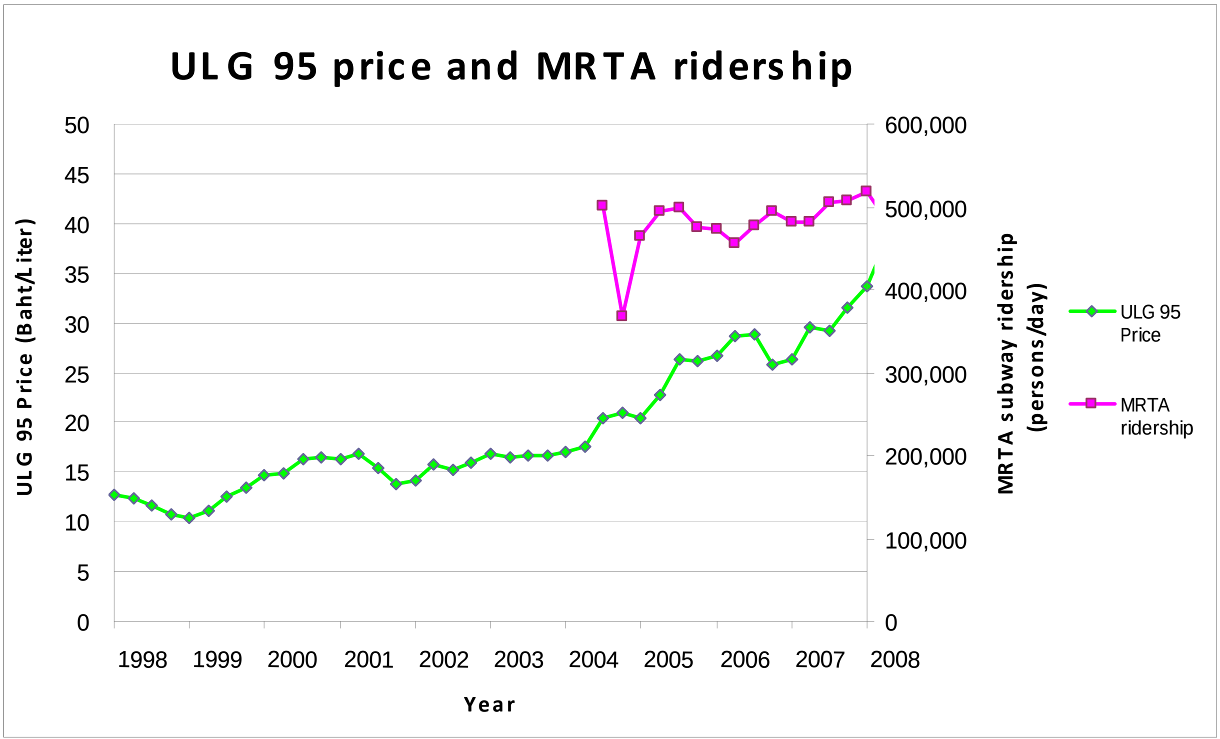
DUM = policy bus free for BMTA.

Cycle = seasonal variable.

3.1.10 Demand function of bus MRTA ridership

Figure 3-10 shows the historical trends of the ULG95 prices, and the total MRTA subway ridership in Bangkok from 2004 to 2008. Since the beginning of the operation in 2004, the number of subway ridership has a slight increasing trend until 2008. Unlike to the traffic volume on expressway nor the BMTA bus ridership, the trend of BMTA bus ridership has no obvious cyclic pattern, which implies that MRTA ridership does not much related to school trips.

Figure 3-10. Historical fuel prices and MRTA subway ridership between 2004 and 2008



The proposed demand function for MRTA subway ridership is:

$$\ln Rm_t = \alpha_0 + \alpha_1 \ln GDP_t + \alpha_2 \ln POP_t + \alpha_3 \ln PG95_t + \alpha_4 \ln Rm_{t-1} + \alpha_5 \ln FMRTA_t + \alpha_6 \ln Fbus_t + \alpha_7 \ln QS_t + \alpha_8 \ln U_t + \alpha_9 (Cycle) \quad (31)$$

where

Rm_t = ridership for MRTA in period t.

GDP_t = gross domestic products (million baht) in period t.

POP = population in Thailand.

$PG95_t$ = average gasohol 95 unit price in the quarter (baht/liter)

Rm_{t-1} = first order lagged ridership of MRTA.

$FMRTA_t$ = fares for MRTA in period t.

$Fbus_t$ = fares for bus in period t.

QS_t = Quantity of service for MRTA in period t.

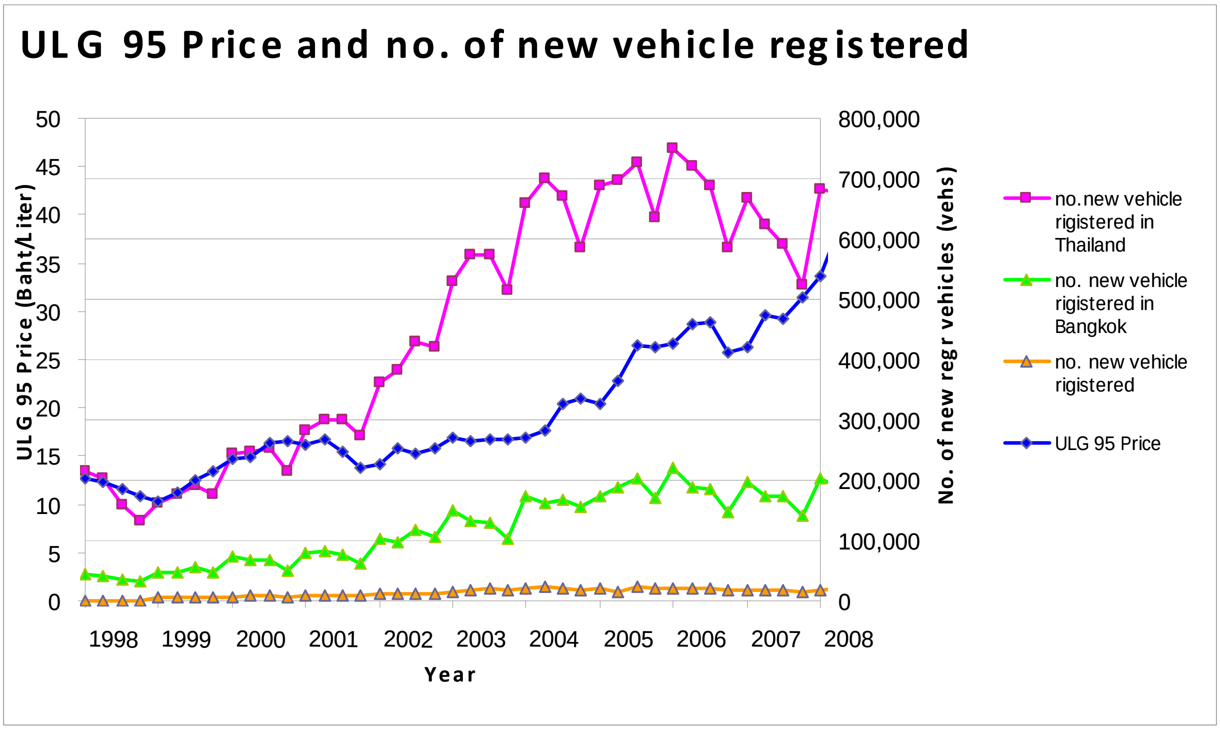
U_t = unemployment rate in period t.

Cycle = seasonal variable.

3.1.11 Demand function of no. of new vehicles registered

Figure 3-11 shows the historical trends of the ULG95 price, and the total number of new vehicles registered in Thailand, Bangkok and Nakorn Ratchasima from 1998 to 2008. The number of new vehicles registered were approximately 150 – 200 thousand vehicles/quarter in 1998, and continuingly increase to its peak around 700 thousand vehicles/quarter in 2005/2006. Since 2006, the number of new vehicles show a slight declining trend.

Figure 3-11. Historical fuel prices and the number of new vehicle registered between 1998 and 2008



The proposed demand function of the number of new vehicles registered is:

$$VRt = \alpha_0 + \alpha_1 \ln GDP_t + \alpha_2 \ln POP_t + \alpha_3 \ln PG95_t + \alpha_4 \ln INC_t + \alpha_5 \ln Pnc_t + \alpha_6 \ln U_t \quad (32)$$

where

VR_t = demand of no.of new vehicles registered in period t.

GDP_t = gross domestic products (million baht) in period t.

POP = population in Thailand.

$PG95_t$ = average gasohol 95 unit price in the quarter (baht/liter)

INC_t = personal income in period t.

Pnc_t = price new car in period t.

U_t = unemployment rate in period t.

Cycle = seasonal variable.

3.2 Data Collection

Data used in this study include the consumption of various fuels in the transport sectors, the historical gasoline price data, traffic volumes on major streets, subway ridership, bus ridership, the number and type of new vehicles registered, etc. Some of these data are readily available from the government agencies from the two ministries: the ministry of

energy (department of energy business, energy policy and planning office) and the ministry of transport (office of traffic and transport policy and planning, department of land transport, mass rapid transit authority, Bangkok mass transit authority, department of highway). Table 3-1 shows the list of data (all of the dependent and the independent variables) needed for the analysis, including the acquisition status of these data.

Table 3-1 List of variables used in this study

No	List	Quarter	Period	Acquired
Dependent variabls				
1	Consumption of ULG* 95	/	1998-2008	/
2	Consumption of ULG* 91	/	1998-2008	/
3	Consumption of Gasohol 95	/	2005-2008	/
4	Consumption of Gasohol 91	/	2005-2008	/
5	Consumption of LPG	/	1998-2008	/
6	Consumption of CNG	/	2003-2008	/
7	Consumption of Diesel	/	1998-2008	/
8	Traffic volume on expressway	/	1998-2008	/
9	BMTA bus ridership	/	1998-2008	/
10	MRTA subway ridership	/	2005-2008	/
11	No.and type of new vehicles registered	/	1998-2008	/
12	Vehicle kilometers of travel (VKT)	Yearly	2001-2008	/
Independent variables				
13	ULG* 95 unit price	/	1998-2008	/
14	ULG* 91 unit price	/	1998-2008	/
15	Gasohol 95 unit price	/	2005-2008	/
16	Gasohol 91 unit price	/	2007-2008	/
17	LPG unit price	/	1998-2008	/
18	CNG unit price	/	2004-2008	/
19	Diesel unit price	/	1998-2008	/
20	Tolls on expressway	date of change	1998-2008	/
21	Bus fare	date of change	1998-2008	/
22	MRTA subway fare	date of change	2004-2008	/
23	Median price of new cars	-	-	-
24	No. of Gasohol 95 stations	/	2005-2008	/
25	No. of Gasohol 91 stations	/	2005-2008	/
26	No. of LPG Stations	/	1998-2008	/
27	No. of NGV stations	/	2004-2008	/
28	Gross Domestic Product	/	1998-2008	/
29	Personal Income	-	-	-
30	Unemployment rate	/	2001-2008	/
31	No. of Population	/	1998-2008	/
32	No. of registered vehicles	/	1998-2008	/
33	No. of registered trucks	/	1998-2008	/
34	No. of registered buses	/	1998-2008	/
35	Expansion of expressway	date of change	1998-2008	/
36	Service expansion for BMTA buses	-	-	-
37	Service expansion of MRTA subway	-	-	-

*ULG – Unleaded gasoline

CHAPTER 4 Analysis Results

This section presents the results from the development of a suitable demand function for the gasoline consumption indicators and the transport demand indicators. In the gasoline demand analysis portion, there are a number of common fuel types available, and from the preliminary analysis found that it was inefficient to develop a separate model for each of the fuel types. Thus, we aggregated fuel types with similar usage characteristics into larger categories. Section 4.1 describes the categories of the fuels in this analysis. Section 4.2 provides a summary of model development for the demand functions. Then, the specifications of the selected demand models along with the implications on short-term and long-term elasticity are provided in Section 4.3.

4.1 Grouping of fuel types for analysis

In Thailand, there are a variety of fuel types commonly available for the transportation sector, including unleaded gasoline 95 (ULG95), unleaded gasoline 91 (ULG91), Gasohol 95, Gasohol 91, Liquid Petroleum Gas (LPG), Compressed Natural Gas (CNG or NGV), Diesel and Bio diesel. The demand function development for each of the fuel types is a cumbersome process, and might not be able to provide meaningful results given that certain fuel types are exchangeable without any engine modifications, for example, recent automobile make/models are able to use either ULG or its counterpart Gasohol. In fact, we initially attempted to develop a separate demand function for each, but were not successful. Therefore, the researchers had aggregated a variety of fuel types with similar usage characteristics into 3 main groups. The first group includes regular fuels for passenger vehicles, as well as the alternative fuels that such vehicles can take without any major engine modification, nor a special fuel system needed. This fuel group includes ULG95, ULG91, Gasohol 95 and Gasoline 91. The second group represents the alternative fuels passenger vehicles consume that require engine modification or special fuel system installations: they are LPG and CNG. Note that the government regulates the price of LPG and NGV such that its real price remains stable during the gasoline price crisis, thus, they had attracted a large number of drivers to install a special fuel system and modify their automobile engine in order to use LPG or NGV. Such vehicles become a hybrid system, since they are able to use either ULG, Gasohol or LPG or NGV, depending on the system installed. It costed approximately 20,000 baht for installing the LPG fuel system, while approximately 50,000 baht for installing the NGV fuel system on a vehicle. The last group is the fuel that is typically consumed by trucks or large vehicles. It is a diesel. Although Bio-diesel is currently available on market during the study, but it is a new type of fuel that has a short history. It was only introduced to public in 2007.

The number of data was inadequate for the development of a demand function, thus this type of fuel was not included in this analysis.

The aggregation of various fuel types is not a straightforward task. Each fuel type has different mega joules which result in different gasoline consumption (km/liter or km/kg). For example, one liter of gasohol 95 could fuel a vehicle to travel 10 kilometers, while the same amount of ULG 95 could provide up to 12 kilometers on the same vehicle. Thus, the simple aggregation of various fuel types is illogical. In this study, all of the various fuel types in the first group were converted into a unit of equivalent ULG95 liter using the information of its mega joules against the mega joules of ULG 95. Similarly, the unit sale of LPG and NGV was converted into a unit of equivalent ULG liter using the similar mega joule info. The third fuel group include only diesel, thus it does not require any conversion for the aggregation process.

4.2 Demand Function Development

In this study, the demand models were developed using regression analysis using a commercial available software, SPSS. The initial form of the demand functions was described in Section 4.2. Basically, both dependent and independent variables of the model were secondary data available from various sources, collected in the past 10 years, starting from 1998 – 2008. We used the quarterly data (every three months); each year will have 4 data points, and the 10-year analysis period will provide a total of 40 data points. The demand function was developed using a least squared method. For each of the model, the researchers verified the logic of the estimated coefficients for each variable in the model, as well as avoided the multicollinearity problem among the independent variables. A few alternatives of the model is provided in Section 4.3, and the final one are selected based on its logic and free of statistical problems.

The demand functions would take a general form of

$$\ln Yt = \alpha + \beta \ln PG_t + \gamma \ln Z_t + \delta \ln Y_{t-1} \quad (4.1)$$

Where

Y_t = fuel demand or travel demand in the period t

PG_t = fuel price in the period t

Z_t = a set of the key independent variables that influence the demand, for the period t

Y_{t-1} = lagged fuel demand or travel demand in the period t – 1

Once the demand function has been developed, we can obtain the demand elasticity with respect to fuel price as:

Short-term elasticity = β (4.2)

long-term elasticity = β /(1-δ) (4.3)

where β is the estimated coefficient of the fuel price in the demand equation, and δ is the estimated coefficient of the lagged fuel demand or travel demand.

4.3 Demand Function and elasticity

The consumptions of various fuel types were groups into 3 main categories as listed below. Note that the researchers developed a separate demand function for the three categories, and some categorizes were analyzed not only for the entire nation, but specific for Bangkok and Nakhon Ratchasima as well.

- Unleaded Gasoline and Gasohol
  (analyzed for the entire country, Bangkok and Nakhon Ratchasima)
- LPG and NGV
  (analyze for the entire country only)
- Diesel
  (analyzed for the entire country, Bangkok and Nakhon Ratchasima)

For the travel demand analysis part, we focus on 4 indicators.

- Traffic volumes on the expressway system
  (analyzed for the Expressway Stage 1 – 5, in the greater Bangkok area)
- Ridership on the BMTA bus system
  (analyzed for all of the BMA-operating routes, in the greater Bangkok area)
- Ridership on the MRTA subway system
  (analyzed for the heavy rail – blue line, in Bangkok)
- Ridership on the BTS skytrain system
  (analyzed for the heavy rail – green line, in Bangkok)

4.3.1 Consumptions of ULG 95, ULG 91, Gasohol 95, Gasohol 91

The demand of ULG 95, ULG 91, Gasohol 95 and Gasohol 91 were aggregated as a single group, which represents the fuel types that are commonly used in regular passenger cars without engine modifications. The dependent variable of the demand function is in the unit of equivalent ULG-95 liters per quarter (converted using the information of mega joule of each fuels). The independent variables analyzed include the price of ULG95, the Gross Domestic Product (GDP), the Population (POP), the number of registered vehicles (CAR), the number of NGV stations (SNGV), the number of gas stations that serve gasohol (SGAS), the number of gas stations that serve LPG (SLPG), and the lagged demand of these fuels in the previous quarter. In this fuel category, we used the actual price of ULG95 (represents as

"PG95") to represent the general gasoline price trend during the 10-year analysis period. The price of other fuel types in the same group fluctuates in the similar pattern of PG95's.

Table 4.1 illustrated a few selected alternatives for the demand function of the ULG and Gasohol consumptions. Perhaps, the best demand model for the ULG and Gasohol consumption is Model 5:

$$\ln G = 12.599 - 0.058 \ln PG95 + 0.389 \ln G_{t-1} + 0.044 \ln CAR$$

Adjusted R^2 =0.672

Where

G = consumption of ULGs and Gasohols in the quarter(liters)

PG95 = average Octane 95 gasoline unit price in the quarter (bath/liter)

G_{t-1} = consumption of ULGs and Gasohols in the previous quarter(liters)

CAR= the number of registered vehicles for the entire nation (vehicle)

As shown, the selected independent variables include the actual price of ULG95, the lagged fuel demand in the previous quarter and the number of registered vehicles. All estimated coefficients appear to have a logical sign. The negative sign of the PG95 variable implies that as the gasoline price increases, drivers will somehow adjust their travel behavior such that the demand for this fuel group reduces. The positive sign of the CAR variable implies that as the number of registered vehicles increases, the demand for this fuel group would rise. The adjusted r^2 of this demand function is 0.672.

From the demand function, we can estimate the elasticity of this fuel group using the estimated coefficient of the PG95 variables and of the lagged demand of the previous quarter. That is, the short-term elasticity of ULG & Gasohol consumption is simply the coefficient of the PG95 variable or -0.06. To estimate the long-term elasticity, we have to analyze the short-term elasticity with the coefficient of the lagged demand according to EQ4.1-4.3. Thus the long-term elasticity is estimated to be -0.09. Note that the long-term elasticity is usually higher in magnitude than its short-term counterpart as some people would need some time to overcome technical barrier, institutional barrier and behavioral barrier and change their behavior to react to the gasoline price change.

Table 4.1 Selected alternatives of the demand model for ULG & Gasohol

Variable	Model 1		Model 2		Model 3		Model 4		Model 5	
	β	t-stat	β	t-stat	β	t-stat	β	t-stat	β	t-stat
Constant	25.207	.083	27.230**	4.908	12.096**	11.642	10.310**	7.915	12.599**	12.264
PG95	-.162	-1.614	-.094	-2.123	-.014	-.777	-.134*	-2.27	-.058*	-2.127
GDP	-.495*	-2.393					.206*	2.129		
POP	.464	.028								
Gt-1	-.156	-.420	-.149	-.577	.433**	8.762	.396**	7.837	.389**	7.478
CAR	-.149*	-2.678	-.182**	-3.485					.044*	2.079
SNGV	.009	.163								
SGAS	.022	.279	-.008	-.468						
SLPG	.097	.354								
Adjusted R^2	.678		.512		.645		.645		.672	
F-test	4.945		4.941		39.182		29.938		29.732	
Conclusion	Method :Enter Correlated among: PG95 and GDP PG95 and POP PG95 and CAR PG95andSNGV PG95andSGAS PG95andSLPG		Method :Enter Correlated among: PG95 and GDP PG95 and CAR PG95andSGAS		Method :Enter Predictor Variable are Uncorrelated		Method :Enter Correlated among: PG95 and GDP		Method :Enter Correlated among: PG95 and CAR Best model	

* denotes significance at the 0.05 level

* * denotes significance at the 0.01 level

In this study, we also developed separate fuel consumptions for Bangkok and Nakhorn Ratchasima, and estimated the short-term and long-term elasticity specifically for these two provinces (as described in the following sub-sections).

4.3.1.1 ULG 95, ULG 91, Gasohol 95, Gasohol 91 consumption in Bangkok

The estimation of the fuel demand specifically for Bangkok employed similar procedure to the model development for the entire country, except for using data that are specific to particular province rather than for the whole country. That is, we used the information of the Gross Provincial Product of Bangkok (GPPb), the population of Bangkok (POPb), the number of registered vehicles in Bangkok (CARb), the number of gas stations that serve CNG in Bangkok (SNGVb), and the number of gas stations that serve LPG in Bangkok (SGASb) as independent variables, along with the actual price of ULG95 (PG95) and the lagged demand in the previous quarter.

Table 4.2 illustrated a few selected alternatives for the demand function of the ULG and Gasohol consumptions. Perhaps, the best demand model for the ULG and Gasohol consumption is Model 5:

$$\ln Gb = 13.659 - 0.090 \ln PG95 + 0.293 \ln Gb_{t-1} + 0.081 \ln CARb$$

Adjusted R^2=0.603

Where

Gb = consumption of ULG and Gasohol of Bangkok in the quarter(liters)
PG95 =average Octane 95 gasoline unit price in the quarter (bath/liter)
Gb_{t-1} = consumption of ULG and Gasohol of Bangkok in the previous quarter(liters)
CARb = the number of registered vehicles in Bangkok (vehicle)

As shown, the included independent variables are the same as the fuel demand for the entire country. All of the estimated coefficients have a logical sign and are significant to the model at a significant level of 0.05. The adjusted r^2 of this demand function is 0.603. From the demand function, the short-term elasticity of ULG/Gasohol consumption in Bangkok is estimated to be -0.09, while long time elasticity of ULG/Gasohol consumption is estimated to be -0.13.

Table 4.2 Selected alternatives of the demand model for ULG & Gasohol consumption in Bangkok

VARIABLE	Model 1		Model 2		Model 3		Model 4		Model 5	
	β	t-stat	β	t-stat	β	t-stat	β	t-stat	β	t-stat
Constant	-76.40	-.966	18.055**	29.256	12.261**	5.330	10.168**	4.322	13.659**	13.242
PG95	-.654*	-3.149	-.170	-1.559	-.200	-1.839	-.136	-1.179	-.090*	-2.293
GPPb	.273	.530			.170	.706	.335	1.322		
POPb	6.861	1.344								
Gbt-1	-.606	-2.080			.259**	3.820	.303**	4.257	.293**	5.172
CARb	.087	.657	.233**	3.186	.099*	2.699			.081*	2.716
SNGVb	.128	1.556								
SGASb	-.083	-.686								
Adjusted R^2	0.554		0.204		0.625		0.557		0.603	
F-test	2.950		6.499		16.822		16.957		22.270	
Conclusion	Method :Enter Correlate among: PG95 and GPP PG95 and CAR PG95andSNGV		Method :Enter Correlate among: PG95 and CAR		Method :Enter Correlate among: PG95 and CAR PG95 and GPP GDP and CAR		Method :Enter Correlate among: PG95 and GPP		Method :Enter Correlate among: PG95 and CAR Best model	

* denotes significance at the 0.05 level

* * denotes significance at the 0.01 level

4.3.1.2 ULG 95, ULG 91, Gasohol 95, Gasohol 91 consumption in Nakhon Ratchasima

The estimation of the fuel demand specifically for Nakhon Ratchasima employed similar procedure to the model development for the entire country and for Bangkok, except for using particular data for the province. That is, we used the information of the Gross Provincial Product of Nakhon Ratchasima (GPPn), the population of Nakhon Ratchasima (POPn), the number of registered vehicles in Nakhon Ratchasima (CARn), and the number of gas stations that serve CNG in Nakhon Ratchasima (SNGVn) as independent variables, along with the actual price of ULG95 (PG95) and the lagged demand in the previous quarter.

Table 4.3 illustrated a few selected alternatives for the demand function of the ULG and Gasohol consumptions. Perhaps, the best demand model for the ULG and Gasohol consumption is Model 5:

$$\ln Gn = 3.108 - 0.070 \ln PG95 + 0.468 \ln GPPn + 0.559 \ln Gn_{t-1}$$

Adjusted R^2=0.845

Where

Gn= consumption of ULG and Gasohol of Nakhon Ratchasima in the quarter(liters)

PG95 = average Octane 95 gasoline unit price in the quarter(bath/liter)

GPPn =the Gross Provincial Product of Nakhon Ratchasima (million bath)

Gn_{t-1}= consumption of ULG and Gasohol of Nakhon Ratchasima in the previous quarter(liters)

As shown, the included independent variables are similar to the fuel demand for the entire country and for Bangkok. Only the gross provincial product data was used instead of the number of registered vehicles. All of the estimated coefficients have a logical sign, but some are not significant to the model at a significant level of 0.05. The adjusted r^2 of this demand function is quite high 0.845. From the demand function, the short-term elasticity of ULG/Gasohol consumption in Nakhon Ratchasima is estimated to be -0.07, while long time elasticity of ULG/Gasohol consumption is estimated to be -0.16.

Table 4.3 Selected alternatives of the demand model for ULG & Gasohol consumption in Nakhon Ratchasima

Variable	Model 1		Model 2		Model 3		Model 4		Model 5	
	β	t-stat	β	t-stat	β	t-stat	β	t-stat	β	t-stat
Constant	-155.69**	-3.401	1.185	.892	1.843	.873	7.283**	2.890	3.108	1.933
PG95	.153	1.399			.012	.100	-.193	-1.269	-.070	-.707
GPPn	.456	1.872			.240	.878	.991**	3.096	.468*	2.456
POPn	10.95**	3.444								
Gnt-1	.424*	2.705	.933**	12.182	.760**	5.337			.559*	7.285
CARn	-.099	-1.863			-.016	-.285	.058	.795		
SNGVn										
Adjusted R^2	.859		.808		.810		.646		.845	
F-test	43.700		148.398		38.256		22.331		70.043	
Conclusion	Method :Enter Correlated among: PG95 and GPP PG95 and CAR GPP and CAR PG95 and Gt-1		Method:Stepwise model doesn't have PG95		Method:Enter Correlated among: PG95andGPP PG95andCAR GPP and CAR PG95 andGt-1		Method :Enter Correlated among: PG95 and GPP GPP and CAR PG95 and CAR		Method :Enter Correlated among: PG95and GPP PG95 and Gt-1 Best model	

* denotes significance at the 0.05 level

* * denotes significance at the 0.01 level

4.3.2 Consumption of Liquid Petroleum Gas (LPG) & Compressed Natural Gas (CNG)

The demand of liquid petroleum gas (LPG) and compressed natural gas (CNG) were aggregated as a single group, which represents the fuel types regular passenger cars can not take directly, but need a special equipment installation. The dependent variable of the demand function is in the unit of equivalent ULG-95 liters per quarter (converted using the information of Mega Joule of each fuels). The independent variables analyzed include the price of ULG95, the Gross Domestic Product (GDP), the Population (POP), the number of registered vehicles (CAR), the number of NGV stations (SNGV), the number of gas stations that serve gasohol (SGAS), the number of gas stations that serve LPG (SLPG), and the lagged LPG and NGV demand in the previous quarter. In this fuel category, we used the actual price of ULG95 (represents as "PG95") to represent the general gasoline price trend during the 10-year analysis period.

Table 4.4 illustrated a few selected alternatives of the demand function for the LPG and CNG consumptions. Perhaps, the best demand model for the LPG and NGV consumption is Model 5:

$$\ln G1 = -0.265 + 0.316 \ln PG95 + 0.963 \ln G1_{t-1} + 0.017 \ln CAR$$

Adjust R^2=0.990

where

G1 = consumption of LPG and CNG in the quarter(liters)

PG95 = average Octane 95 gasoline unit price in the quarter(bath/liter)

$G1_{t-1}$ = consumption of LPG and CNG in the previous quarter(liters)

CAR = the number of registered vehicles(vehicle)

As shown, the selected independent variables include the actual price of ULG95, the lagged fuel demand in the previous quarter and the number of registered vehicles. All estimated coefficients appear to have a logical sign. The positive sign of the PG95 variable implies that as the gasoline price increases, drivers will somehow adjust their travel behavior such that the demand for alternative fuels increases. The adjusted r^2 of this demand function is quite high 0.990

From the demand function, the short-term elasticity of the LPG & NGV consumption is estimated to be 0.32, while long time elasticity is estimated to be 8.54.

Table 4.4 Selected alternatives of the demand model for LPG & CNG

VARIABLE	Model 1		Model 2		Model 3		Model 4		Model 5	
	β	t-stat	β	t-stat	β	t-stat	B	t-stat	β	t-stat
Constant	-72.935	-.150	-12.150**	-3.642	-.011	-.016	-2.284	-0.618	-.265	-.213
PG95	.829*	2.747			.359	1.894	.283	1.252	.316	1.224
GDP	1.383*	3.045	.852*	2.923			.194	.626		
POP	3.362	.124								
G1t-1	.591**	4.792	.998**	27.036	.956**	16.99	.944**	15.718	.963**	15.002
CAR	-.028	-.209							.017	.246
SNGV	.083	.611								
SGAS	-.308	-1.818								
SLPG	.302	.709								
Adjusted R^2	0.998		0.996		0.991		0.991		0.990	
F-test	1133		1941		2232		1465		1453	
Conclusion	Method :Enter Correlated among: PG95 and GDP PG95 and POP PG95 and G1t-1 PG95 and CAR PG95 and SNGV PG95 and SGAS PG95 and SLPG		Method:Stepwise Correlated among: GDP and G1t-1 And model doesn't have PG95		Method :Enter Correlated among: PG95 and Gt-1		Method :Enter Correlated among: PG95 and Gt-1 PG95 and GDP		Method :Enter Correlated among: PG95 and Gt-1 PG95 and CAR Best model	

* denotes significance at the 0.05 level

* * denotes significance at the 0.01 level

4.3.3 Consumption of Diesel

The fuel group includes only diesel, and represents the demand of fuel that large and hi-powered vehicles, such as trucks or buses, normally used. The dependent variable of the demand function is in the unit of liters per quarter. The independent variables analyzed include the price of diesel (PDS), the Gross Domestic Product (GDP), the Population (POP), the number of registered trucks (TRUCK), the number of registered buses (BUS), the number of gas stations that serve bio-diesel (SB5), and the lagged demand of diesel in the previous quarter. In this fuel category, we used the actual price of diesel (represents as "PDS") to represent the general price trend during the 10-year analysis period.

Table 4.5 illustrated a few selected alternatives of the demand function for the diesel consumptions. Perhaps, the best demand model for the Diesel consumption is Model 5:

$$\ln DS = -3.078 - 0.260 \ln PDS + 0.375 \ln GDP + 0.930 \ln DS_{t-1}$$

Adjusted R^2 =0.774

Where

DS = consumption of Diesel in the quarter(liters)

PDS =average diesel unit price in the quarter (bath/liter)

GDP = the Gross Domestic Product (million bath)

$DS1_{t-1}$= consumption of diesel in the previous quarter (liters)

As shown, the selected independent variables include the actual price of diesel, gross domestic product and the lagged fuel demand in the previous quarter. All estimated coefficients appear to have a logical sign. The negative sign of the PDS variable implies that as the diesel price increases, the demand for diesel will decrease. The coefficient of the GDP variable is positive, implying that as economic in the country prospers, the gasoline demand would also increase. The adjusted r^2 of this demand function is quite high 0.774.

From the demand function, the short-term elasticity of Diesel is estimated to be -0.26, while long time elasticity is estimated to be -3.71.

Table 4.5 Selected alternatives of the diesel demand model

VARIABLE	Model 1		Model 2		Model 3		Model 4		Model 5	
	β	t-stat	β	t-stat	β	t-stat	β	t-stat	β	t-stat
Constant	924.622	1.183	-.359	-.124	.620	.308	3.244	1.552	-3.078	-1.387
PDS	-.692	-2.249	-.246**	-3.485	-.062*	-2.201	-.141**	-3.658	-.260**	-3.659
GDP	2.675	3.092	.259	1.755					.375**	2.986
POP	-53.102	-1.225								
Dst-1	1.087*	5.746	.860**	8.812	.979**	10.621	.838**	8.436	.930**	10.824
TRUCK	-1.008	-.991	.049	1.439			.081**	2.782		
BUS	-.014	-.113								
SB5	.010	.133								
Adjusted R^2	.990		.781		.730		.769		.774	
F-test	42.201		38.341		57.740		47.558		49.083	
Conclusion	Method : Enter Correlated among: PDS and GDP PDS and POP PDS and TRUCK PDS and BUS		Method: Enter Correlated among: PDS and GDP PDS and TRUCK		Method : Enter Predictor Variable are uncorrelated		Method : Enter Correlated among: PDS and TRUCK		Method : Enter Correlated among: PDS and GDP Best model	

* denotes significance at the 0.05 level

* * denotes significance at the 0.01 level

In this study, we also develop separate diesel consumptions for Bangkok and Nakhorn Ratchasima, and estimate the short-term and long-term elasticity specifically for these two provinces (as described in the following sub-sections).

4.3.3.1 Diesel consumption in Bangkok

The estimation of the diesel demand specifically for Bangkok employed similar procedure to the model development for the entire country, except for using data that are specific to particular province rather than for the whole country. That is, we used the information the Gross Provincial Product of Bangkok (GPPb), the population of Bangkok (POPb), the number of registered trucks in Bangkok (TRUCKb), and the number of registered buses in Bangkok (BUSb) as independent variables, along with the actual price of diesel (PDS) and the lagged diesel demand in the previous quarter.

Table 4.6 illustrated a few selected alternatives for the demand function of the diesel consumptions. Perhaps, the best demand model for the diesel consumptions consumption is Model 5:

$$\ln DSb = -2.875 - 0.090 \ln PDS + 0.430 \ln GPPb + 0.824 \ln DSb_{t-1}$$

Adjusted R^2=0.898

Where

DSb = consumption of Diesel in Bangkok in the quarter(liters)

PDS = average diesel unit price in the quarter(bath/liter)

GPPb = the Gross Provincial Product of Bangkok(million bath)

DSb_{t-1} = consumption of diesel in the previous quarter(liters)

As shown, the included independent variables are the same as the diesel demand for the entire country. All of the estimated coefficients have a logical sign, and some are significant to the model at a significant level of 0.05. The adjusted r^2 of this demand function is quite high 0.898. From the demand function, the short-term elasticity of diesel consumption in Bangkok is estimated to be -0.09, while long time elasticity of diesel consumption is estimated to be -0.51.

Table 4.6 Selected alternatives of the demand model for Diesel consumption in Bangkok

VARIABLE	Model 1		Model 2		Model 3		Model 4		Model 5	
	β	t-stat	β	t-stat	β	t-stat	β	t-stat	β	t-stat
Constant	-27.56	-1.231	1.810*	2.173	.362	.401	.762	.848	-2.875	-1.010
PDS	-.112	-1.141			-.052	-1.258	-.096*	-2.075	-.090	-.909
GPPb	.422	1.525							.430	1.541
POPb	1.668	1.173								
Dst-1	.699**	6.231	.821**	11.085	.984**	14.356	.914**	12.049	.824**	9.117
TRUCKb	.076	1.584	.095*	2.252			.095	1.926		
BUSb	.016	.777								
Adjusted R^2	.907		.905		.863		.871		.898	
F-test	62.592		182.995		132.837		95.797		112.263	
Conclusion	Method: Enter Correlated among: PDS and GPP		Method: Stepwise Model doesn't have PDS		Method : Enter Predictor Variable are uncorrelated		Method : Enter Predictor Variable are uncorrelated		Method : Enter Correlated among: PDS and GPP Best model	

* denotes significance at the 0.05 level

* * denotes significance at the 0.01 level

4.3.3.2 Diesel consumption in Nakhon Ratchasima

The estimation of the diesel demand specifically for Nakhon Ratchasima employed similar procedure to the model development for the entire country and for Bangkok, except for using particular data for the province. That is, we used the information of the Gross Provincial Product of for Nakhon Ratchasima (GPPn), the population of Nakhon Ratchasima (POPn), the number of registered trucks in Nakhon Ratchasima (TRUCKn), and the number of registered buses in Nakhon Ratchasima (BUSn) as independent variables, along with the actual price of diesel (PDS) and the lagged diesel demand in the previous quarter.

Table 4.7 illustrated a few selected alternatives for the demand function of the diesel consumptions. Perhaps, the best demand model for the diesel consumptions consumption is Model 5:

$$\ln DSn = 3.955 + 0.00 \ln PDS + 0.372 \ln GPPn + 0.344 \ln DSn_{t-1}$$

Adjusted R^2=0.538

Where

DSn = consumption of Diesel in Nakhon Ratchasima in the quarter(liters)

PDS=average diesel unit price in the quarter(bath/liter)

GPPb=the Gross Provincial Product of Nakhon Ratchasima (million bath)

DSn_{t-1}= consumption of diesel in Nakhon Ratchasima in the previous quarter(liters)

As shown, the included independent variables are the same as the fuel demand for the entire country and for Bangkok. All of the estimated coefficients have a logical sign, but some are not significant to the model at a significant level of 0.05. The adjusted r^2 of this demand function is 0.538. From the demand function, the short-term elasticity of diesel consumption in Nakhon Ratchasima is estimated to be 0, while long time elasticity is estimated to be 0.

Table 4.7 Selected alternatives of the demand model for Diesel consumption in Nakhon Ratchasima

VARIABLE	Model 1		Model 2		Model 3		Model 4		Model 5	
	β	t-stat	β	t-stat	β	t-stat	β	t-stat	β	t-stat
Constant	67.765	.909	7.137**	9.113	7.823**	3.910	6.461**	3.765	3.955	1.709
PDS	-.024	-.227			.135	1.263	.072	.242	.000	-.004
GPPn	.427	1.505	.459**	5.984	.353	1.600			.372	1.995
POPn	-4.054	-.819								
Dst-1	-.053	-.320					.436**	2.814	.344*	2.298
TRUCKn	.041	.773								
BUSn	-.007	-.322								
Adjusted R^2	.437		.499		.450		.363		.538	
F-test	5.526		35.803		16.970		12.979		15.574	
Conclusion	Method : Enter Correlated among: PDS and GPP POP and TRUCK		Method: Stepwise Model doesn't have PDS		Method : Enter Correlated among: PDS and GPP		Method : Enter Predictor Variable are Uncorrelate		Method: Enter Correlated among: PDS and GPP Best model	

* denotes significance at the 0.05 level

* * denotes significance at the 0.01 level

4.3.4 Traffic volumes on the expressway system

This study also investigates how gasoline price change impact the demand on the expressway system. The expressway system Stages 1-5 in the greater Bangkok area covers a total length of 173.2 kilometers of limited access freeway. It is one of the attractive options for travelers who would like to bypass traffic on normal streets and signalized intersections and reach the destination faster with a fee. During 2008 when the gasoline price at its peak (43.89 baht/liter), it is noticeable that traffic volumes on expressway reduces, traffic conditions on the expressway system improve in a noticeable manner. One of the plausible reasons is that, due to the high gasoline price, travelers adjusted their travel behavior to minimize travel cost. Thus, travelers might decide to generate fewer trips, to travel to a nearer destination, to switch mode of travel, or might even switch routes for a less expensive routes. These would result in a reduction of the traffic demand on the expressway system.

The dependent variable of the demand function is the accumulated total volumes on the expressway system (Stages I – V) in the unit of trips per quarter. The independent variables analyzed include the price of ULG95 (PG95), the Gross Provincial Product of Bangkok & vicinities (GPPbv), the number of registered vehicles in Bangkok & vicinities(CARbv), the expressway toll (MT), and the seasonal factor during the summer time (CYCLE), and the lagged traffic volume on the expressway system in the previous quarter. We used the actual price of ULG95 (represents as "PG95") to represent the general gasoline price trend during the 10-year analysis period. The price of other fuel types in the same group fluctuates in the similar pattern of PG95's.

Table 4.8 illustrated a few selected alternatives for the demand function of the expressway usage. Perhaps, the best demand model for the expressway usage is Model 5:

$$\ln Y = 6.369 - 0.043 \ln PG95 + 0.350 \ln GPPbv + 0.271 \ln Y_{t-1} + 0.199 \ln CARbv$$

Adjust R^2=0.941

Where

Y = traffic volume at the expressway in the quarter(vehicle)

PDS = average diesel unit price in the quarter(bath/liter)

GPPbv = gross provincial products of Bangkok& Vicinities in the quarter(million bath)

Y_{t-1} = first order lagged traffic volume of expressway(vehicle)

CARbv= the number of registered vehicles in Bangkok & Vicinities (vehicle)

As shown, the selected independent variables include the actual price of ULG95, Gross Provincial Product of Bangkok and vicinities, the number of registered vehicles in the area, and the lagged fuel demand in the previous quarter. All estimated coefficients appear to have a logical sign. The gasoline price has a negative, as expected since traffic demand on the expressway system would be reduced when the gasoline price increases. The positive sign of the GPP coefficient, simply implying that the traffic volumes increase as the economics in the area grows. Similarly, it is expected that the number of vehicles would provide a direct impact to the traffic demand on the expressway system with a presumed positive sign. The adjusted r^2 of this demand function is 0.941. Note that the gasoline price and the gross provincial product are not significant to the model at a significance level of 0.05, implying that both gasoline price and the gross provincial products are not a good predictor of the demand volume on the expressway. However, the researchers decided to have these variables into the model for the estimation of the short-term elasticity.

From the demand function, we can estimate the elasticity of traffic volumes on the expressway system using the estimated coefficient of the PG95 variables and of the lagged demand of the previous quarter. That is, the short-term elasticity of travel demand on the expressway is simply the coefficient of the PG95 variable or -0.04. To estimate the long-term elasticity, we have to analyze the short-term elasticity with the coefficient of the lagged demand according to EQ4.1-4.3. Thus the long-term elasticity is estimated to be -0.06. Note that the long-term elasticity is usually higher in magnitude than its short-term counterpart as some people would need some time to overcome technical barriers, institutional barriers or behavioral barriers and adjust their behavior to react to the gasoline price change.

Table 4.8 Selected alternatives of the demand model for traffic volumes on the expressway system

VARIABLE	Model 1		Model 2		Model 3		Model 4			Model 5
	β	t-stat	β	t-stat	β	t-stat	β	t-stat	β	t-stat
Constant	8.055**	3.236	7.049**	5.212	4.656	1.769	2.787	1.316	6.369**	3.183
PG95	.008	.088			.032	.241	.074	.717	-.043	-.467
GPPbv	.303	1.338	.267*	2.395	1.005**	4.510	.270	1.194	.350	1.668
Yt-1	.191	1.390	.290*	2.333			.638**	4.948	.271*	2.038
CARbv	.221**	4.436	.194**	5.134					.199**	5.016
MT	-.032	-1.563			-.069*	-2.383	-.035	-1.397		
Cycle	.023	.926								
Adjusted R^2	.944		.943		.860		.914		.941	
F-test	100.15		192.82		80.84		101.95		141.13	
Conclusion	Method :Enter Correlated among: PG95 and GPP PG95 and Yt-1 PG95 and CAR GPP and CAR		Method:Stepwise Correlated among: GPP and CAR GPP and Yt-1		Method:Enter Correlated among: PG95 and GPP		Method:Enter Correlated among: PG95 and GPP PG95 and Yt-1 PG95and CAR GPP and CAR		Method:Enter Best model	

* denotes significance at the 0.05 level

* * denotes significance at the 0.01 level

4.3.5 Ridership on the BMTA bus system

This project also analyzes how gasoline price change impact the number of patronage on the BMTA bus system. Bangkok Metropolitan Transit Authority (BMTA) currently operated 3,526 AC and non-AC buses on 113 bus routes covering the area of Bangkok and the vicinity provinces. During 2008 when the gasoline price at its peak (43.89 baht/liter), one can reasonably assume that some travelers would switch from driving their vehicle to use buses instead, thus increase the number of ridership on BMTA system.

The dependent variable of the demand function is the accumulated total number of ridership on the BMTA-operated bus route system, in the unit of passengers per quarter. The independent variables analyzed include the price of ULG95 (PG95), the Gross Provincial Product of Bangkok and vicinities (GPPbv), the number of population in the area (POPbv), the number of registered vehicles in the area (CARbv), the base bus fare (Fbus), and the seasonal factor during the summer time (CYCLE), and the lagged bus ridership on the BMTA bus system in the previous quarter. We used the actual price of ULG95 (represents as "PG95") to represent the general gasoline price trend during the 10-year analysis period. The price of other fuel types in the same group fluctuates in the similar pattern of ULG95's.

Table 4.9 illustrated a few selected alternatives for the demand function of the ridership on the BMTA bus system. Perhaps, the best demand model for the ridership on the BMTA bus system is Model 3:

$$\ln Rb = 25.769 + 0.057 \ln PG95 - 0.904 \ln GPPbv + 0.278 \ln Rb_{t-1} + 0.117 Cycle$$

Adjusted R^2=0.961

Where

Rb= ridership for BMTA bus in the quarter (person)

PG95=average Octane 95 gasoline unit price in the quarter (baht/liter)

GPPbv=gross provincial products of Bangkok&Vicinities in the quarter(million bath)

Rb_{t-1}=first order lagged ridership for BMTA bus (person)

Cycle= the seasonal factor during the summer time

As shown, the selected independent variables include the actual price of ULG95, Gross Provincial Product of the area, and the lagged BMTA ridership in the previous quarter. All estimated coefficients appear to have a logical sign. The gasoline price has a positive sign, as one can reasonably assume that bus ridership increases when the gasoline price increases. The negative sign of the GPP coefficient, simply implying that as the economics in the area grows, travelers tend to earn more, thus would be able to afford driving a vehicle, resulting in a reduction in the bus ridership. The adjusted r^2 of this demand function is 0.961. Note that the gasoline price is not significant to the model at a significance level of 0.05,

implying that it is not a good predictor of the number of ridership on the BMTA bus system. However, the researchers decided to have this variable into the model for the estimation of the short-term elasticity.

From the demand function, we can estimate the elasticity of ridership on the BMTA bus system using the estimated coefficient of the PG95 variables and of the lagged demand of the previous quarter. That is, the short-term elasticity is simply the coefficient of the PG95 variable or 0.06. To estimate the long-term elasticity, we have to analyze the short-term elasticity with the coefficient of the lagged demand according to EQ4.1-4.3. Thus the long-term elasticity is estimated to be 0.08.

Table 4.9 Selected alternatives of the demand model for ridership on the BMTA bus system

VARIABLE	Model 1		Model 2		Model 3		Model 4		Model 5	
	β	t-stat	β	t-stat	β	t-stat	β	t-stat	β	t-stat
Constant	43.068*	2.716	25.873**	7.120	25.769**	7.451	34.138**	14.941	26.451**	6.94
PG95	.004	.036			.057	.714	.021	.232	.080	.900
GPPbv	-.833**	-2.931	-.858**	-6.822	-.904**	-5.916	-1.095**	-5.341	-.928**	-4.57
POPbv	-1.016	-1.034								
Rbt-1	.203	1.639	.249*	2.385	.278*	2.658			.267*	2.43
Fbus	-.017	-.187								
Ub	-.067	-1.529								
CARbv	-.022	-.425					-.032	-.884	-.019	-.563
Cycle	.093**	3.059	.116**	6.877	.117**	7.075	.118**	5.099	.115**	5.303
Adjusted R^2	.952		.954		.961		.946		.953	
F-test	88.644		242.144		237.747		152.897		142.803	
Conclusion	Method : Enter Correlated among: PG95 and GPP PG95and POP PG95 andRbt-1 PG95 and Fbus PG95 and Ub PG95 and CAR		Method:Stepwise Correlated among: PG95andRbt-1		Method : Enter Best Model PG95 and GPP PG95 and Rbt-1 GPP and Rbt-1 GPP and CAR Best Model		Method : Enter Correlated among: PG95 and GPP PG95 and Rbt-1 GPP and CAR		Method : Enter Correlated among: PG95 and GPP PG95 andRbt-1 GPP and Rbt-1	

* denotes significance at the 0.05 level

* * denotes significance at the 0.01 level

4.3.6 Ridership on the MRTA subway line

We also analyzed how gasoline price change impact the number of patronage on the MRTA subway system. Currently, the MRTA subway (blue line) line is approximate 20 kilometers, connecting the high-density residential areas (Bang Sue, Lad Prao, Sutthisarn) to the commercial areas (Ratchadapisek) and center business districts (Petchburi, Sukhumbit, Rama V, Sathorn, Silom and Hua Lamphong). The line operates from 6:00 am to midnight with the frequent and reliable service. Since its operation in July, 2004 , it quickly gains popularity among Bangkokians. During 2008 when the gasoline price at its peak (43.89 baht/liter), one can reasonably assume that some travelers would switch from driving their vehicle to use subways instead, thus increase the number of ridership on the MRTA subway system.

The dependent variable of the demand function is the accumulated total number of ridership on the MRTA subway system, in the unit of passengers per quarter. The independent variables analyzed include the price of ULG95 (PG95), the Gross Provincial Product of Bangkok & vicinities (GPPbv), the number of population in the area (POPbv), the base subway fare (FMRTA), the base bus fare (Fbus), and the seasonal factor during the summer time (CYCLE), and the lagged bus ridership on the MRTA subway system in the previous quarter. We used the actual price of ULG95 (represents as "PG95") to represent the general gasoline price trend during the 10-year analysis period. The price of other fuel types in the same group fluctuates in the similar pattern of ULG95's.

Table 4.10 illustrated a few selected alternatives for the demand function of the ridership on the MRTA subway system. Perhaps, the best demand model is Model 4:

$$\ln Rm = -4.554 + 0.024 \ln PG95 + 0.912 \ln POPbv + 0.220 \ln Rm_{t-1}$$

Adjusted R^2=0.176

Where

Rm = ridership for MRTA in the quarter(person/day)

PG95 = average Octane 95 gasoline unit price in the quarter (baht/liter)

POPbv = number of population in Bangkok& Vicinities and the quarter(person)

Rm_{t-1} = first order lagged ridership for MRTA (person/day)

As shown, the selected independent variables include the actual price of ULG95, population of Bangkok & vicinities, and the lagged subway ridership in the previous quarter. All estimated coefficients appear to have a logical sign. The gasoline price has a positive sign, as one can reasonably assume that subway ridership increases when the gasoline price increases. The positive sign of the POPb coefficient, simply implying that the more people live in Bangkok, the higher ridership on the subway system. The adjusted r^2 of this demand function is 0.176. Note that the gasoline price is not significant to the model at a significance level of 0.05, implying that it is not a good predictor of the number of ridership on the MRTA subway system. However, the researchers decided to include this variable into the model for the estimation of the short-term elasticity.

From the demand function, we can estimate the elasticity of ridership on the MRTA subway system using the estimated coefficient of the PG95 variables and of the lagged demand of the previous quarter. That is, the short-term elasticity is simply the coefficient of the PG95 variable or 0.02. To estimate the long-term elasticity, we have to analyze the short-term elasticity with the coefficient of the lagged demand according to EQ4.1-4.3 Thus the long-term elasticity is estimated to be 0.03.

Table 4.10 Selected alternatives of the demand model for ridership on the MRTA subway line.

VARIABLE	Model 1		Model 2		Model 3		Model 4		Model 5	
	β	t-stat	β	t-stat	β	t-stat	β	t-stat	β	t-stat
Constant	-122.900	-1.826	9.235*	2.279	10.738*	2.505	-4.554	-.236	9.471*	2.422
PG95	-.347	-.487	.072	1.109	.125	1.457	.024	.261	.107	1.318
GPPbv	.654	.155								
POPbv	8.767	2.913					.912	.737		
Rmt-1	-.750	-.447	.270	.865	.159	.475	.220	.712	.258	.842
FMRTA	-.913	-1.229	.033	.185						
Fbus	-.430	-.709			-.079	-.691			-.057	-.520
Ub	.097	.156								
Cycle	.042	1.295			.019	.794				
Adjusted R^2	.568		.138		.127		.176		.156	
F-test	2.643		1.746		1.507		1.996		1.862	
Conclusion	Method: Enter Correlated among: PG95 and GPP PG95 and POPB PG95 and Fbus PG95 and Ub		Method:Enter Adjusted R^2 is low value		Method: Enter Correlated among: PG95and Fbus		Method:Enter Correlated among: Best Model		Method: Enter Correlated among: PG95 and Fbus	

* denotes significance at the 0.05 level

* * denotes significance at the 0.01 level

4.3.7 Ridership on the BTS skytrain

We also analyzed how gasoline price change impact the number of patronage on the BTS skytrain. Currently, the BTS skytrain (green line) line extends approximate 23.3 kilometers, connecting the high-density residential areas (Mohr Shit, Sukhumvit) to the center business districts (Sathorn, Silom and Siam Square). The line operates from 6:00 am to midnight with the frequent and reliable service. Since its operation in December, 1999 , it gains popularity among Bangkokians. During 2008 when the gasoline price at its peak (43.89 baht/liter), one can reasonably assume that some travelers would switch from driving their vehicle to use skytrain instead, thus increase the number of ridership on the BTS skytrain system. The dependent variable of the demand function is the accumulated total number of ridership on the BTS skytrain system, in the unit of passengers per quarter. The independent variables analyzed include the price of ULG95 (PG95), the Gross Provincial Product of Bangkok and vicinities(GPPbv),the number of population in the area (POPbv), the base skytrain fare (Fbts), the base bus fare (Fbus), and the seasonal factor during the summer time (CYCLE), and the lagged bus ridership on the BTS skytrain system in the previous quarter (Rbts t-1). We used the actual price of ULG95 (represents as "PG95") to represent the general gasoline price trend during the 10-year analysis period. The price of other fuel types in the same group fluctuates in the similar pattern of ULG95's.

Table 4.11 illustrated a few selected alternatives for the demand function of the ridership on the BTS skytrain system. Perhaps, the best demand model is Model 5:

$$\ln Rbts = 4.081 + 0.159 \ln PG95 + 0.936 \ln GPPbv - 1.118 Fbts$$

Adjusted R^2=0.914

Where

Rbts = bus ridership on the BTS skytrain system in the quarter(person/day)

PG95 =average Octane 95 gasoline unit price in the quarter (baht/liter)

GPPbv = the Gross Provincial Product of Bangkok& Vicinities and the quarter (million bath)

Fbts = the base skytrain fare (Bath)

Cycle = the seasonal factor during the summer time

As shown, the selected independent variables include the actual price of ULG95, the gross provincial product of Bangkok& Vicinities, the seasonal factor for Summer (during school break), and the base skytrain fare . All estimated coefficients appear to have a logical sign. The gasoline price has a positive sign, as one can reasonably assume that skytrain riderhip would increase when the gasoline price increases. The positive sign of the GPPbv coefficient, simply implying that the growth in the economic would result in a higher number of ridership on the subway system. The negative sign of the seasonal factor infers that the ridership on the skytrain system reduces during the summer time when all schools close. The adjusted r^2 of this demand function is 0.914. Note that the gasoline price is not significant to the model at a significance level of 0.05, implying that it is not a good predictor of the number of ridership on the BTS skytrain system. However, the researchers decided to include this variable into the model for the estimation of the short-term elasticity.

From the demand function, we can estimate the elasticity of ridership on the BTS skytrain system using the estimated coefficient of the PG95 variables and of the lagged demand of the previous quarter. That is, the short-term elasticity is simply the coefficient of the PG95 variable or 0.16. To estimate the long-term elasticity, we have to analyze the short-term elasticity with the coefficient of the lagged demand according to EQ4.1-4.3. Thus the long-term elasticity is not estimated because the lagged bus ridership on the BTS skytrain system in the previous quarter ($Rbts_{t-1}$) is not included model.

Table 4.11 Selected alternatives of the demand model for ridership on the BTS skytrain system

VARIABLE	Model 1		Model 2		Model 3		Model 4		Model 5	
	β	t-stat	β	t-stat	β	t-stat	β	t-stat	β	t-stat
Constant	9.715	.305	-.213	-.159	15.519**	83.119	15.722**	90.634	4.081	1.492
PG95	-.139	-.634			.553**	9.049	.483**	8.684	.159	1.500
GPPb	1.907**	3.461	1.290**	12.991					.936**	4.177
POPb	-.633	-.333								
$Rbts_{t-1}$	-.459	-1.766								
Fbts	-.405**	-3.391	-.332**	-5.190	-.071	-2.071			-1.118**	-4.388
Fbus	.138	.792								
Ub	.043	.527								
Cycle	-.046	-1.615	-.042*	-2.176	.033	.238	.037	1.264		
Adjusted R^2	.905		.915		.837		.805		.914	
F-test	22.423		65.672		33.409		40.188		68.695	
conclusion	Method :Enter Correlated among: PG95 and GPP PG95 and POP PG95and $Rbts_{t-1}$ PG95 and Ub		Method :Stepwise Model doesn't have PDS		Method: Enter Predictor Variable are Uncorrelated		Method: Enter Predictor Variable are Uncorrelated		Method: Enter Correlated among: PG95 and GPP Best model	

* denotes significance at the 0.05 level

* * denotes significance at the 0.01 level

CHAPTER 5 Conclusion

This study successfully developed demand functions for various fuel types for transportation as well as travel patterns on the transport system, in order to investigate the short- and long-term elasticity of gasoline consumption and travel demand with respect to gasoline price. In this research, the demand functions were developed for three groups of fuel categories (ULG/Gasohol, LPG/CNG, Diesel) and four groups of travel demand (volumes on expressways, riderships on BMTA buses, on MRTA subways, and on BTS skytrains). The independent variables for the demand function include major socio-economic factors (gross domestic products, gross provincial products, no. of population, numbers of registered vehicles, trucks, buses) that seem to be the main influencing factors as suggested in the literature, along with gasoline price. Given that new fuel types had been introduced to Thai market in the past few years, the level of market penetrations might play an important role on the fuel consumption. Thus, we collected and incorporated such data as the number of gasoline stations that serve LPG, CNG as well as Biodiesel into the model. Furthermore, a seasonal factor that represents the fluctuation of travel demand throughout the year was also included into some of the travel demands that possess an obvious cyclic pattern. The demand functions were developed using the regression analysis on the quarterly data for the 10-year periods from 1998 -2008.

The final demand functions for gasoline consumptions and for the travel demand on various transportation systems are summarized in Tables 5.1 to 5.2, respectively.

Table 5.1 Demand functions for gasoline consumptions

List of variables (include only the significant ones)	ULG/Gasohol Whole nation		ULG/Gasohol Bangkok		ULG/Gasohol Nakhon Ratchasima		LPG/CNG Whole nation	
	beta	t-stat	beta	t-stat	beta	t-stat	beta	t-stat
constant	12.599**	12.264	13.659**	13.242	3.108	1.933	-0.265	-0.213
PG95	-0.058*	-2.127	-0.090**	-2.293	-0.070	-0.707	0.316	1.224
CAR	0.044*	2.079	0.081*	2.716			0.017	0.246
GPP					0.468*	2.456		
Gt-1	0.389**	7.478	0.293**	5.172	0.559*	7.285	0.963**	15.002
Adjusted- r^2	0.672		0.603		0.845		0.990	

* denotes significance at the 0.05 level

* denotes significance at the 0.01level

***PG95 – The price of ULG 95

CAR– the number of registered vehicles

GPP– the Gross Provincial Product

G_{t-1}– first order lagged of fuel demand

Table 5.1 Demand functions for gasoline consumptions (Cont'd)

List of variables (include only the significant ones)	Diesel Whole nation		Diesel Bangkok		Diesel Nakhon Ratachsima	
	beta	t-stat	beta	t-stat	beta	t-stat
constant	-3.078	-1.387	-2.875	-1.010	3.955	1.709
PDS	-0.260**	-3.659	-0.090	-0.909	0.00	-0.004
GDP/GPP	0.375**	2.986	0.430	1.541	0.372	1.995
DS_{t-1}	0.930**	10.824	0.824**	9.117	0.344*	2.298
Adjusted r2	0.774		0.898		0.538	

* denotes significance at the 0.05 level

**denotes significance at the 0.01level

***PDS – The price of Diesel

GDP/GPP– the Gross Domestic Product/ the Gross Provincial Product

DS_{t-1}– first order lagged of fuel demand

Table 5.2 Demand functions for travel demand

List of variables (include only the significant ones)	Traffic volumes on expressways		Ridership on BMTA bus system		Ridership on MRTA subway system		Ridership on BTS skytrain system	
	beta	t-stat	beta	t-stat	beta	t-stat	beta	t-stat
constant	6.369**	3.183	25.769**	7.451	-4.554	-0.236	4.081	1.492
PG95	-0.043	-0.467	0.057	0.714	0.024	0.261	0.159	1.500
POPbv					0.912	0.737		
GPPbv	0.350	1.668	-0.904**	-5.916			0.936**	4.177
Yt-1	0.271*	2.038	0.278**	2.658	0.220	0.712		
Fbts							-1.118**	-4.388
CARbv	0.199*	5.016						
Cycle			0.117**	7.075				
Adjusted- r2	0.941		0.961		0.176		0.914	

* denotes significance at the 0.05 level

** denotes significance at the 0.01level

***PG95 – The price of ULG 95

POPb – number of population in Bangkok& Vicinities

GPPb – the Gross Provincial Product of Bangkok& Vicinities

Y_{t-1} – first order lagged of travel demand

Fbts – the base skytrain fare

CARb – the number of registered vehicles in Bangkok & Vicinities

Cycle – the seasonal factor during the summer time

The short- and long-term elasticity of various gasoline consumption and travel demand on various transport system, can be obtained directly from the specifications of the developed demand functions. The estimated coefficient of the variable, price of gasoline (PG95 or PD) in the demand function is in fact the short-term elasticity. To estimate the long-term elasticity, the estimated coefficient of the variable, price of gasoline, has to be adjusted by (1 – x), where x is the estimated coefficient of the lagged demand in the previous quarter. The estimated short- and long-term elasticity of gasoline consumption and travel demand are summarized in Table 5-3.

TABLE 5-3 SHORT RUN AND LONG RUN ELASICITY OF FUEL CONSUMPTION AND TRANSPORT DEMAND

	Elasticity	
	SHOT RUN	LONG RUN
Gasoline consumption elasticity		
1.Gasoline &Gasohol Consumption (Nationwide)	-0.06*	-0.09
- Bangkok	-0.09**	-0.13
- Nakhon Ratchasima	-0.07	-0.16
2.NGV&LPG Consumption elasticity (Nationwide)	0.32	8.54
3.Diesel Consumption elasticity (Nationwide)	-0.26**	-3.71
- Bangkok	-0.09	-0.51
- Nakhon Ratchasima	0.00	-
Travel Demand elasticity		
4.Traffic on expressway (Greater Bangkok Area)	-0.04	-0.06
5.BMTA Bus ridership (Greater Bangkok Area)	0.06	0.08
6.MRTA ridership (Bangkok)	0.02	0.03
7.BTS ridership (Bangkok)	0.16	-

* denotes significance at the 0.05 level in the demand function

* * denotes significance at the 0.01 level in the demand function

As shown in Table 5.3, the price elasticity of gasoline demand and travel demand is inelastic, similar to the same elasticity revealed in other cities or other countries. The absolute magnitude of the elasticity is less than 1.0, which implies that when the gasoline price increase by 100 percent, the gasoline consumption and travel demand functions would change less than 100 percent, depending on the sign and the magnitude of the elasticity. Long-term elasticities are typically higher than short-term elasticities, as a typical trend worldwide, since it would take some times for some people to overcome the institutional barriers, technical barriers and financial barriers and adjust their travel behavior.

The nationwide short-term demand elasticities of fuel consumption are in the magnitude of -0.06 to -0.26, for gasoline and diesel. That is, when the gasoline price increases by 100 percent (for example; from 25 baht/liter to 50 baht/liter), the overall consumption of transport fuel (ULG & Gasohol as well as Diesel) would decrease by 6 to 26 percent from the original level. The reduction in fuel consumption was a result from behavior adjustment, from people and industries, on their travel and logistics in order to react to the gasoline price increase in a short term. However, the long-term elasticity of diesel consumption (-3.71) seem to be four times as much as the gasoline consumption (-0.09). One of the plausible explanations is that industries have to constantly improve their supply chain and operations in order to remain competitive in the businesses; otherwise they will soon lose market share. Thus, they intend to develop a substitute plan in order to reduce transport costs as much as possible; for example, using cheaper alternative fuels, switching to cheaper transport modes, employing new technology system in order to reduce travel cost, or even relocate their office/factory etc. The bus operators also plan to minimize their travel cost, by using larger buses, reduce empty bus trips. They all have to adjust themselves in order to stay competitive. Thus, the long-term elasticity of diesel consumption would reduce much more substantially in reaction to the gasoline price increase, compared to the long-term elasticity of gasoline consumption.

The nationwide elasticities of LPG/CNG consumption in Thailand are rather high. As shown, the short- and long-term elasticities were estimated to be 0.32 and 8.54, respectively. It should be noted that CNG has recently been introduced in Thailand, and it quickly gains popularities in Thailand due to several promotion packages issued by the national government. The demand function was developed based on the data during the introduction and the initial growth of the CNG, which could potentially attenuate the effect of gasoline price. Thus, care should be taken when using these numbers.

The elasticity of expressway traffic was found to be -0.04 and -0.06 for short- and long-term, respectively. That is, as the gasoline price increases by 100 percent, the amount of traffic on expressways will be reduced by 4% in the short term and by 6% in the long run. This is the most inelastic among all of the indicators analyzed. Recall that the expressway system offers a fast and reliable route for private vehicles traveling to the various destinations with minimal delay. Most drivers will have no other choices to do except for using the expressway system. The expressway toll generally costs 25-50 baht per trips, which is approximately 25-50% of the cost of an hour of travel delay of typical Bangkokians. That is, if the expressway would pay off if they save 25% or 50% of their travel time, which they typically do already. Moreover, most of the business/working trips can get a reimbursement on the expressway tolls, thus the toll would not affect to their route choice decision. This is why traffic volumes on expressway are very inelastic to the gasoline price increases.

The elasticities of the three transit systems in the Bangkok area are also inelastic, approximately in the range of 0.02 – 0.16 short-term, and 0.03 – 0.08 long-term. This reveals that the gasoline price increase has relatively small impacts on mode switching in Bangkok. That is, when the gasoline price increases by 100 percent, the number of ridership on buses, skytrains and subways increase by 2 – 16 percent only. This is perhaps due to the low quality of the current bus systems that people are reluctant to use even though the gasoline price increase considerably, and due to the limited coverage area of the current subways and skytrains that people are not able to use to access many destinations. Thus, both short- and long-term of these public transit services are rather inelastic to the gasoline price.

<u>Comparison within Thailand</u>

A comparison of gasoline (ULG/Gasohol) demand elasticities between the two provinces in Thailand reveals that gasoline consumption in Bangkok (-0.09) is more elastic than the gasoline consumption in Nakhon Ratchasima (-0.07). The Bangkok's elasticity is also higher than the nationwide number (-0.06). There are a few plausible explanations for this phenomenon. First, Bangkok has a number of alternative modes of transport available. With an extensive coverage of transit system, a fast and reliable service of skytrains and subways, a plenty services of taxis, motorcycle taxis, tuk tuk, ferry service, Bangkokians have plenty of readily available alternative modes to use as a substitute of personal transport to use when the gasoline price increases. Second, there are also several gasoline stations that serve alternative fuels, such as LPG and NGV, with a reasonable price. Lastly, thanks to good telecommunication system in Bangkok, some of the works and shopping could be completed without making unnecessary trips everyday. Bangkokians are luxurious to enjoy these benefits, thus they are readily to adjust their travel behavior in reaction to the gasoline price crisis. Nakhon Ratchasima, as of other regional large municipalities outside Bangkok, has only limited-route transit system available and only few gasoline stations that serves alternative fuels, such as LPG and CNG, thus citizens would not have much choices to react to the gasoline price increase. Thus, the gasoline consumption in Nakhon Ratchasima tends to be inelastic when compared to the Bangkok area, both in the short run and the long run.

The estimated elasticities of diesel consumption reveal a different story. It was found that the short-term elasticity of diesel consumption in Bangkok is more than that in Nakhon Ratchasima. As commonly accepted, as gasoline price increases, general people tend to save up money by reducing spending on other expenditures, thus it tends to slow down the activities in the area. Furthermore, businesses want to stay competitive in the business by reducing some operating costs, and they tend to pay more attention on the reduction of costly trips, such as a long trip to other provinces. Thus, the diesel consumption in regional provinces will be affected by the gasoline price increase more than those in Bangkok during the short term. However, in the long term, the elasticity of diesel consumptions in Bangkok become higher than in Nakhon Ratchasima, plausibly with the same reasons above that Bangkok has alternative fuels with reasonable price as well as the availability of professional delivery services that make the entire diesel consumption reduce in the higher magnitude in the long run.

Comparisons with other cities around the world

Table 5-4 illustrates the estimated elasticity from this study along with the estimated elasticity of gasoline consumption in other countries. As shown, the gasoline consumption elasticity in Thailand is rather inelastic, compared with the numbers of other countries as summarized by Goodwin (1992) and Goodwin et al (2004), except for the gulf countries (Eltony, 1996). One plausible explanation would be that the restricted public transit service in Thailand, would resembles the transit condition on the gulf countries. People would leave with no choices but drive private vehicles to reach various destinations, unlike citizen in EU and north America that enjoy various quality transit systems. Furthermore, citizens in EU and north America are keen on environment than people in Gulf countries, and Thailand, thus they invented a number useful program to reduce gas consumption (e.g., telecommuting centers, car-pools, bicycle lanes) that turns successful after it adopted.

TABLE 5-4 Demand Elasticity of Fuel consumption with respect to fuel price per litre.

Country	Short Run	Long Run
Thailand(2009)	-0.06	-0.09
Goodwin *et al.*(2004)	-0.25	-0.64
M. Nagy Eltony ,Gulf Cooperation Council(1996)	-0.11	-0.17
Goodwin(1992)	-0.27	-0.73

Table 5-5 summarized the estimated demand elasticity of traffic on expressway in Thailand comparing with the demand elasticity of traffic on tolled roads in other countries. As shown, traffic volumes on the expressway system in Bangkok are very inelastic when comparing with international numbers. This is perhaps, the expressway system in Thailand is the only fast and reliable routes for private vehicles, and Bangkok drivers have no choice but to use the expressway system, or use normal street system that traffic are very congested. In other country/studies, drivers have a few parallel routes that can be used. Thus, the elasticity revealed in the Bangkok case was rather inelastic.

TABLE 5-5 Demand Elasticity of traffic on expressway with respect to fuel price per litre.

Country	Short Run	Long Run
Thailand(2009)	-0.04	-0.06
James Odeck,Norway(2008)	-0.56	-0.82
Anna Metas *et al*.,Spain(2002)	-0.30	-0.53
Ira Hirschman *et al*.,New York(1995)	-0.09	-0.5

References

Balcombe R, Mackett R, Paulley N, Preston J, Shires J, Titheridge H, Wardman M, White P (2004), The demand for pubic transport: a practical guide, TRL Report TRL 593, 2004.

Eltony M.N. (1996),Demand for gasoline in the GCC: an application of pooling and testing procedures,Energy Economic18(1996),pp. 2003-2009.

Goodwin PB (1992), A review of new demand elasticities with special reference to short and long run effects of price changes. Journal of transport economics and policy, May 1992, pp. 155-169.

Goodwin PB, Dargay J and Hanly M (2004), Elasticities of road traffic and fuel consumption with respect to price and income: an review. Transport Reviews, Vol. 24, No. 3, pp. 275-292, May 2004.

Hirschmand I, McKnight C, Pucher J, Paaswell RE, Berechman J (1995). Bridge and Tunnel Toll Elasticities in New York:Some recent evidence,Transportation 22:2,pp.97-113.

Jones IS, Nicole AJ (1983),The demand for inter-city rail travel in the United Kingdom, Journal of transport economics and policy,May 1983,pp. 133-153.

Lee HY, Kang HH (2008) The study of Brazilian automobile demand, National Cheng Kung University,Taiwan. Proceedings of Decision Sciences Institute 2008 Annual Meeting – Baltimore, 2008.

Matas A, Raymond JL (2003).The demand elasticity on tolled motorways. Journal of Transportation and Statistics, Vol. 6, N 2/3, pp. 91-108.

Mattson J (2008),Effects of Rising Gas Prices on Bus Ridership for Small Urban and Rural Transit System,Small Urban and Rural Center Upper Great Plains transportation Institute North Dakota State University.

Odeck J, Brathen S (2008),Travel demand elasticities and users attitudes: A case study of Norwegian toll projects,Transport Research Part A 42,pp. 77-94.

Oum TH, Waters II WG, and Yong JS (1992), Concepts of price elasticities of transport demand and recent empirical estimates: an interpretative survey. Journal of transport economics and policy, May 1992, pp. 139-154.

Piro K (2006),Changes in Transportation Fare Structures:The Demand for Mass Transit in New York city. In Sixth Annual Missouri Economic Conference, March 31 and April 1, 2006, at University of Missouri-Columbia.

Pongpaew O (2002),Factor Affecting and Forecast Demand for oil in Thailand,Master of Economic,Ramkhamhaeng University.

Rattapan K. (1996) , Factors Affecting Thailand's Demand for and Supply of Oil and Import, substitution , 1995 to 2000. Master of Science(Economic),Kasetsart University.

Final Report

Research Grant 2008

ATRANS