Final Report

Research Grant 2011

ATRANS

ASIAN TRANSPORTATION RESEARCH SOCIETY

Marginal Cost of Road Transport: Conceptual Framework and Implication for Bangkok

Sumet Ongkittikul
Kannika Thampanishvong
Thirayoot Limanond

Marginal Cost of Road Transport: Conceptual Framework and Implication for Bangkok

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**
  Dr. Sumet Ongkittikul

- **Project Members**
  Dr. Kannika Thampanishvong
  Asst. Prof. Dr. Thirayoot Limanond

- **Advisors**
  Prof. Dr. Harry Geerlings

Table of Contents

CHAPTER I INTRODUCTION

1.1 Background

Transport creates benefits but also costs. It is widely accepted that external impacts of transport are enormous. Transport activities post both environmental and social damages, especially in the road transport sector. Making road users pay for the external costs they cause has become an important principle in transportation economics (Button, 1990).

Normally, in the context of transport, the following main external cost categories are distinguished: congestion, environmental effects, noise annoyance, and accidents. Road transport is generally identified as the most important inland transport mode in terms of external cost generation (Verhoef, 2001).

In European countries, the issue of the marginal cost pricing was discussed extensively in the past two decades. A number of research papers and reports are published such as 'Fair Payment from Road Users: A Review of the Evidence on Social and Environmental Cost (Newbery, 1998)', 'Surface Transport Costs and Charges: Great Britain 1998 (Samson et al, 2001)', and 'Handbook on Estimation of External Cost in the Transport Sector (Maibach et al, 2007). This emphasizes the importance of the issue and its implication to the transport policy in the developed countries.

Although a number of research in Thailand dealing with the environmental effect and accident impact, a few, if any, addresses a marginal cost pricing concept. Road transport users in Thailand are heavily subsidized by the government budget, with only a few toll roads. The question is the road users in Thailand pay more or less on what they impose to the society at large. Furthermore, the ASEAN Economic Community (AEC) is on the way and Thailand has to accept the traffic from neighboring countries. This means if Thailand does not have a proper measure to mitigate the external effects of the international traffic, only Thai society will bear the costs incur.

1.2 Objective

This research proposal aims to shed some lights on the issue of the marginal cost of road transport by setting up a conceptual framework and give some implications for Thailand in order to understand the magnitude of the external costs that road users impose for the society. Thus, the objectives of this research are:

1. To review the concept of marginal cost of road transport including the external costs.
2. To define the categories of costs and revenues of road transport in Bangkok.
3. To compare the marginal costs and the price of road users pay.
4. To recommend a measure for efficient pricing mechanism.

1.3 Project Timeframe

This research will be conducted within 12 months and the research schedule of this project by activities is presented below.

Activity	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
1. Literature review on marginal cost of road transport and related issue	■	■										
2. Defining the marginal costs and revenues definition for Bangkok			■									
3. Collect secondary data on costs and revenues				■	■	■						
4. Analyze data							■	■	■			
5. Formulate the recommendations										■		
6. Writing a report											■	■

1.4 List of Members

The members of this project are as follows.

1. PROJECT LEADER

   Dr. Sumet Ongkittikul, Thailand Development Research Institute (TDRI)

2. PROJECT MEMBERS

   Dr. Kannika Thampanishvong, Thailand Development Research Institute (TDRI)

   Asst. Prof. Dr. Thirayoot Limanond, Asian Institute of Technology (AIT)

3. PROJECT ADVISORS

   Prof. dr. Harry Geerlings, Erasmus University Rotterdam, the Netherlands

   Prof. Paibul Suriyawongpaisal, Faculty of Medicine, Ramathibodi Hospital, Mahidol

University

CHAPTER 2 LITERATURE REVIEWS

2.1 Introduction

There are a number of researches on the cost of transport, especially the marginal cost of transport. A long list of research can be drawn since the work of Walters (1961) to Carbajo (1991) and Verhoef (1994). The marginal cost studies stem mainly from the field of research in economics. Characteristics of transport are unique. We cannot mention costs without touch upon the benefits of transport. This uniqueness has been highlighted in Lakshmanan et al (2001) that there are three characters to be considered. First, transport is a derived demand. It is serving to satisfy spatial mismatches between demand and supply on various markets: goods markets for freight transport; labour and housing markets for peak-hour commuters' traffic, etc. Second, the costs and benefits of the entire transport system arise both through the supply and existence of infrastructure, and through its usage. Finally, transport activities themselves often give rise to a variety of costs, which can be internal (fuel, time) or external ('inter-sectoral': pollution, noise, accidents; and 'intra-sectoral': accidents, congestion) in nature; which can be variable (fuel) or fixed (purchase of cars, vehicle taxes) for individual trips; which can be instantaneous (congestion) or cumulative (CO2), which can have a local (noise) or a global (CO2) impact, and so forth.

The main issues in the marginal cost aspect are the direct costs and the indirect costs or externalities created by the transport activities. The direct costs concern with the infrastructure cost and user cost of transport (Button, 1992). The externalities include undesirable effects of the transport activities. In terms of economics, it is commonly recognized that externalities are an important form of market failure. In presence of externalities, market prices do not reflect full social costs (or benefits), and additional taxes (or subsidies) are called for to restore the efficient working of the market mechanism (Verhoef, 1994).

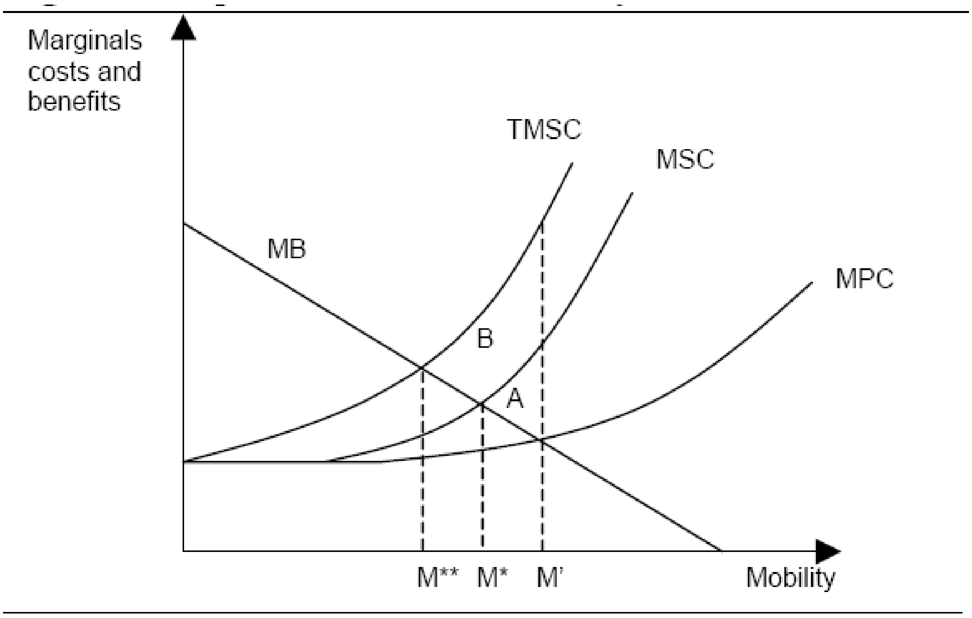
This chapter reviews a concept of marginal cost that relevant to the research methodologies that we will use later in this research. First, we review the concept of marginal cost and external cost of transport. We then discuss on the marginal cost of infrastructure. Section 2.4 reviews the literature of the marginal accident cost. Finally, the marginal cost of environment is discussed.

2.2 Concept of Marginal Cost and External Cost of Transport

Verhoef (2001) gives an important distinction regarding the external costs of road transport that is between 'intra-sectoral externalities' on the one hand, which are, like congestion and part of the external accident costs, posed upon one-another by road users, and 'intersectoral externalities' on the other, which are posed upon society at large. The latter include environmental externalities, noise annoyance, and another part of the external accident costs. This distinction may sometimes give rise to confusion on the question of exactly what is an externality. For instance, it is sometimes argued that congestion would not be an externality, because it is internal to the road transport sector (road users only hinder each other, and no-one else suffers). However, it is important to bear in mind that for a correct welfare analysis, the relevant level of disaggregation is of course the individual level. At least from a welfare economic viewpoint, therefore, both intra-sectoral and inter-sectoral externalities are Pareto-relevant.

We can give a simple explanation of the marginal cost concept as given in Ruta (2002). Consider the case of urban transport. Motor vehicle use conveys important benefits, such as ease of communication, time saving, comfort and privacy. A simple graph will allow us to set the stage. On the horizontal axis of Figure 2-1 we measure the number of vehicles at a certain hour in an urban area, a variable we call 'mobility'. On the vertical axis we measure marginal benefits and costs of mobility. The graph represents a demand and supply framework. The marginal benefits curve is indeed a demand curve for mobility. Given a certain number of vehicles, it gives the maximum price the marginal road user is willing to pay for driving. The marginal benefits curve is decreasing assuming that different individuals receive different level of utility from driving. For a very high price of transport, only those individuals with a high marginal benefit will drive, but as the cost of transport decreases, the number of individuals finding it worthwhile to drive will presumably increase.

Figure 2-1: Optimal amount of mobility



Source: Ruta (2002)

The marginal private costs (MPC) curve is the equivalent of a supply curve. Using a vehicle to commute at a certain time involve costs; first of all the necessary expenses to operate (gasoline, oil, etc.) and to maintain the vehicle. If these were the only costs of using a vehicle, the marginal cost curve would be practically horizontal: any additional user would spend on average the same to use a certain road at a certain time. As the number of vehicles increase, however, the time to commute increases. Road space is a resource common to road users and is limited in amount. As road use increases, congestion costs will be the same, but as the number of vehicles turns to be very high, the cost experienced by each new road user will be higher than the cost privately incurred by those before her. This is why the marginal cost curve is shown to be increasing.

It has been noticed that road space is commonly used by the drivers. As mobility increases, not only each new driver pays a higher congestion cost compared to previously present drivers, but she also reduces the road space available to other drivers. This cost is external to the marginal driver. The marginal social cost (MSC) of mobility is thus represented as an increasing curve above the marginal private cost of mobility, to take into account the congestion externality.

Microeconomic analysis suggests that the optimal mobility level should be determined by the intersection of the marginal benefit curve and the marginal social cost curve. In practice, individual users will disregard the cost imposed on others and will be using the road space beyond point M* in Figure 2-1, until the level at which the marginal private cost curve intersects the marginal benefit curve. A policy that allows to reduce mobility from M' to M* would increase social welfare. This change is represented by area A in Figure 2-1. For levels of car use higher than M*, marginal social costs are higher than marginal benefits and car use beyond M* causes a net welfare loss to society.

We may also account for the costs that road used causes to the non-driving urban population, i.e. noise, air pollution, health threats and risk of accidents. Adding these external costs lead to a 'total' marginal social cost curve (TMSC) which implies an optimal level of mobility even lower. When environmental external costs are taken into account, the social costs avoided by reducing mobility to the new optimal level M** is represented by area A+B in Figure 2-1.

Given the above concept, the economic efficiency perspective derives from a simple proposition that society's economic welfare will be maximized when each transport user pays the marginal external cost of each trip (Samson et al, 2001). If an individual or firm's benefit from a trip is less than marginal external cost society as a whole will be better off if the trip is not made. Conversely, if the benefit exceeds marginal external costs, there is a net gain to society from the trip being made.

Samson et al (2001) gives a framework on the definition of the marginal costs and revenues categories for the purpose of calculating the surface transport cost. Table 2-1 shows the categories given in their research report.

Table 2-1: Definition of the Marginal Costs and Revenues Categories

Category	Marginal Cost Basis
Cost of capital	Not relevant
Infrastructure costs	Mainly wear & tear costs that can be related to increase vehicle km.
Vehicle operating costs (public transport)	Cost of an additional vehicle km.
Congestion	Costs imposed by one user on all other users of the transport system.
Scarcity	Opportunity cost of providing a service that precludes other services being run.
Mohring effect	Benefits of increased service frequencies due to additional vehicle km.
Accidents	External costs of an additional vehicle km, including the increase/decrease in accident risk due to increased traffic.
Environmental costs	Cost of an additional vehicle km
Fuel duties	Revenue associated with an additional vehicle km
Vehicle excise duty	Revenue relating to an additional vehicle km – only for those vehicles where an increase in vkm would result in an expansion of vehicle fleet (e.g. HGVs, PSVs, but not cars, LDVs).
Value added tax	On fuel duties
Fares, freight tariffs	Associated with an additional vehicle km

Sources: Samson et al (2001)

For this research, we will explore the infrastructure cost, accident cost, and environmental cost. The literature review of each category is described as follows.

2.3 Marginal Infrastructure Cost

2.3.1 Background

Not many theoretical and empirical studies analyzing on cost functions purely for infrastructure network and terminals. Generally, background for all existing studies has rarely been question of estimating cost functions for pure infrastructure, most of them usually been question of regulating or deregulating industries.

Previous studies on marginal infrastructure costs can be classified by three criteria; functional form, type of cost functions estimation, and type of information used. Many forms of it were used to analyze to understand the theory and conceptual foundations for multiproduct cost functions with scope economies, however, some studies focus on how to measure and compare productivity across firms over time by applying cost function study with other conventional approaches of firm and time effect model.

Empirical studies on transport infrastructure costs were only performed in central European countries; Germany, Austria, Switzerland and France. These studies were full cost studies and included only in a few cases regression analysis with mainly longitudinal data on costs and on traffic volume. However, there was not many infrastructure cost study since policy documents assume that marginal infrastructure costs refer mainly to cost elements such as maintenance and repair of infrastructure, then, congestion costs, environment costs, and accident costs play the major role in the road sector. Moreover, these costs are the relevant components of setting prices for infrastructure use in the road sector.

2.3.2 Literature Review

According to UNITE (2002), one possible category of study on infrastructure cost function analysis is the distinction between bottom-up and top-down estimation. Due to type of information and data used, costs function can be estimated by using observed data and by applying theoretical and experimental relations.

The bottom-up approaches is the costs of so-called basic packages such as construction costs of infrastructure for the least demanding vehicle category. Besides, in the stepwise approach, the additional cost caused by successor categories are added and if they are defined in a sufficiently detailed way, the bottom-up approach could be considered as an incremental approach to the first derivative of a cost function or to the marginal cost function (TRL et al., 1996). The top-down approaches start from observed total costs or total cost components and try to identify a functional form for the total costs and marginal costs (BMV, 1969 and Johansson and Nilsson, 1998) while the previous ones typically analyze single infrastructure sections or lines and generalize the result afterwards.

Moreover, empirical observed information on cost behavior in cost function analysis can be based either on cross section analysis and regression analysis based on time series. For cross section analysis different sections of infrastructure are compared and infrastructure costs are analyzed according to traffic volumes, vehicle weight, design parameter, etc. (BMV, 1969 and Johansson and Nilsson, 1998) While time series regression analyzes the change of traffic volumes and weights and the related development of costs and time.

2.4 Marginal Accident Cost

2.4.1 Background

Traffic accident is the cause of inopportunely deaths, injuries, damage of properties, and loss of productivity; moreover, it leads to economic losses as a social component since victims and their families are often beset with grief, hardship, and even a degraded quality (Department of Highways, 2007). Therefore, to estimate the value of accident losses is significant in order to highlight on the damage occurred from road accident which can lead to the effectiveness of road safety programs or prevention plans for the country.

According to Department of Highways (2007), determination of road accident costs for the whole country can increase the awareness of the losses from road crashes. Hence, to categorize road accident losses by level of bodily severity provides a basis for the analysis and comparison of the effectiveness of prevention measures and related investments in the campaign to reduce road accidents.

However, according to UNITE (2003a), the increasing of total accident costs does not imply that the marginal external accident costs is high because we are only interested in the cost not already borne by the user and examine the change in cost at the margin when the user takes a decision. Hence, the decision of making trip or the external marginal accident cost is related to distance in kilometer.

2.4.2 Literature Review

UNITE (2003a) assumes that the marginal external accident cost is estimated and introduced as a distance based charge which a large part of the accident cost is already internalized in the driver's decision, hence, the principle of congestion pricing is adopt which means that driver will be aware of the expected accident cost that will arise due to his trip decision. Besides, there is no need to charge the users for accidents that they do not create if the number of accidents will not change due to the trip decision, however, the number of accidents usually increase which means that the marginal effect occurs.

The increase in the number of accidents may be in proportion to the increase in traffic, which means that the accident risk (number of accidents per vehicle kilometer) is constant. However, the risk may also decline or increase and the actual change in risk will have a strong impact on the marginal external accident cost. The driver will consider all the socio-economic consequences in his private decision and other safety related decisions will be socioeconomic efficient.

According to marginal cost based pricing, the charge should be based on the expected accident cost, caused by his trip decision, which the driver or the operator does not already bear. The charge based on marginal cost will only directly affect the trip decision, and not the choice of technology or behavior. The external marginal accident cost has two distinct characteristics: a division between internal and external cost and congestion like effect.

Moreover, the average accident cost, as the result of dividing total accident cost during one year by the annual traffic volume, has been labeled as the accident cost that should be charged to the road user or driver. However, UNITE (2003a) provides two assumptions; all accident cost is external and the risk is constant, in order to indicate that the average accident cost is equal to relevant marginal external accident cost.

For the policy instrument, UNITE (2003a) suggests that traffic safety policy is not mainly, about optimal traffic volumes but will be focused more on a safe behavior while driving. However, this will not be influenced by a charge based on the external marginal accident cost measured related to driven distance. Moreover, more sophisticated system may either observe the actual behavior of the driver and can differentiate the charge appropriately or be differentiated according to some of the factors above such as vehicle regulations.

2.5 Marginal Cost of Environment

2.5.1 Background

Transportation activities inflict a wide range of damages and impose considerable costs on the environment, including the impacts of noise emissions, impacts from global warming, as well as the impacts of a large number of airborne pollutants on human health, amenity, materials, and ecosystems. Whereas airborne pollutants cause damages at the local and regional scales, the effects of greenhouse gas emissions are global in nature. The impacts from noise are restricted to the very local scale, i.e. it could be ranging from several hundred meters to a few kilometers from the emitting source (Bickel et al., 2005).

These environmental costs are not reflected in the price paid by the transport users and are not embedded in their decision making process (Bickel et al., 2005). From the perspective of economic efficiency, to ensure that the society's economic welfare is maximized, each transport user must internalize the above and other impacts by paying the marginal external costs of each trip. If an individual's benefit from a trip is less than marginal external costs, society as a whole will be better off if the trip is not made.

In this section, we only focus on quantifying the effects of air pollution from road transport. Road transport is one of the major sources of air pollution in Thailand. The key pollutants include Carbon dioxide (CO2), Sulfur dioxide (SO2), Carbon monoxide (CO), Nitrogen Oxides (NOx), Particulate matter (PM), Hydrocarbon (HC), Volatile Organic Compounds (VOCs) and air toxics. The air pollution from road transport is higher in towns and cities as more traffic often leads to higher level of nitrogen dioxide, carbon monoxide, hydrocarbons and particulate matters.[1] Air pollution from on-road vehicles could cause adverse impact on human health, building soiling, material corrosion, damages on crop yields, etc. (UNITE, 2003b).

2.5.2 Literature Review

In the early studies on the assessment of transport externalities, the top-down approach was applied and the results yielded average costs for the whole country rather than marginal costs for specific circumstances (UNITE, 2003b). The basis for calculation under such approach is a whole geographical unit (a country for example). For such a unit, the total cost due to a burden is calculated. This is then allocated based on the shares of total pollutant emissions, by vehicle mileage, etc. (Bickel et al., 2005). Provided that the marginal environmental costs of transportation

[1] However, this does not mean that rural areas do not have the same problem.

vary with the technology of a vehicle and site/route characteristics, this top-down approach does not seem to be appropriate. The previous studies suggested that the bottom-up calculation should be adopted as it allows us to incorporate site- and technology dependence (see Friedrich and Bickel, 2001 for results of recent bottom-up calculations); thus, it is marginal external environmental costs that are important for transport pricing purposes.

In European Commission (1999a,b) and Friedrich and Bickel (2001), the impact pathway approach (IPA), one of the bottom-up approaches, was developed. This approach enables us to quantify and value the impacts due to airborne emissions (Sansom et al., 2001). To assess impacts due to airborne emissions under the IPA, information is generated on three levels (Bickel et al., 2005): (i) the increase in burden (i.e. additional emissions) due to an additional activity (i.e. one additional trip on a specific route with a specific vehicle); (ii) the associated impact (e.g. additional hospital admissions in cases); and (iii) the monetary valuation of this impact (e.g. willingness-to-pay (WTP) to avoid the additional hospital admissions).

A number of research projects applied the ExternE IPA to assess impacts due to airborne emissions (INFRAS/IWW, 2000; AEA, 1997). The studies conducted by WHO (1999) and McCubbin and Delucchi (1996) also looked at the chain of ambient pollutant concentrations due to the transport sector.

The research on calculation of air pollution emission from on-road vehicular traffic in Thailand is limited, with exception to the study conducted by Thailand's Pollution Control Department. Warapetcharayut and Paw-armart (2004) used the mobile source emission inventory for Bangkok Metropolitan Region (BMR), which includes the 5 surrounding provinces (Nakhonpathom, Nonthaburi, Pathumthani, Samutprakarn and Samutsakorn) to estimate emissions from on-road vehicle fleets. They obtained emission estimates by multiplying an estimate of the distance traveled by a given class of vehicles by an appropriate emission factor based on the final version of the U.S. EPA MOBILE6.2 The model was customized to the conditions in BMR by taking into account local factors such as characterization of vehicle fleet, fuel characteristics, vehicle operating characteristics, ambient characteristics, existing inspection/maintenance programs and tampering and misfuelling (Warapetcharayut and Paw-armart, 2004). Motorcycle, light duty

[2] MOBILE6 generates emission factors in terms of grams/mile of travel. Emission calculations were made for the base year of 2003 and for future years out to 2013 and included the effects of all promulgated on-road mobile source emission standards. The effect of Inspection and Maintenance programs on emission was also included (Warapetcharayut and Paw-armart, 2004).

gasoline vehicles, light duty diesel vehicles and heavy duty diesel vehicles were tested using the dynamometer and constant volume sampler system (CVS).

CHAPTER 3 RESEARCH METHODOLOGY

3.1 Research Framework

This research will be based on the study of Samson et al (2001) in developing the cost and revenue categories of the marginal cost. The research steps can be described as follows:

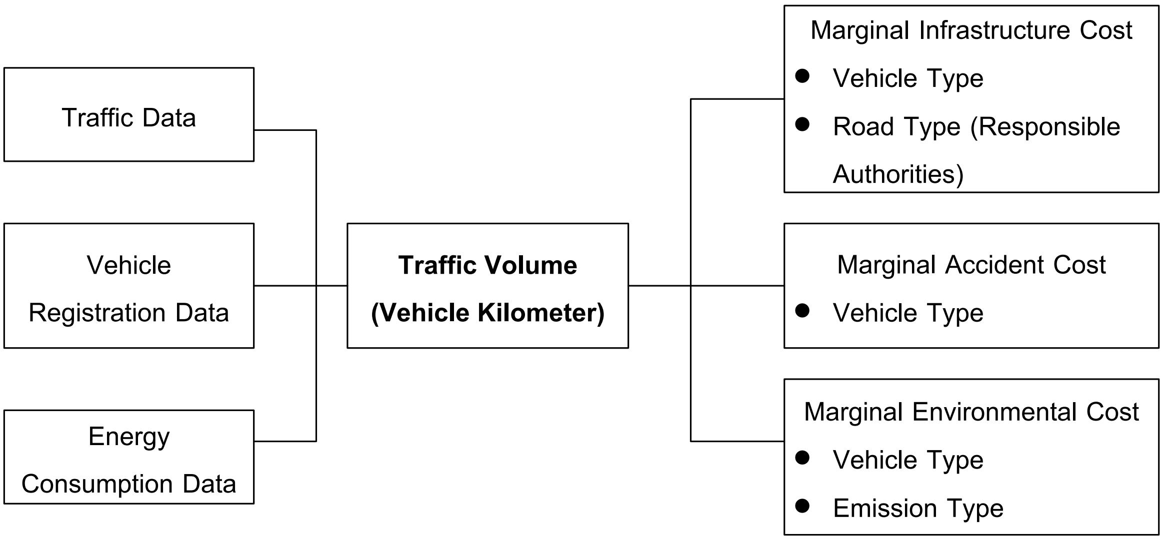
First, the research team will review the relevant literature on the marginal cost of transport as shown in Section 2. The concept of marginal cost is commonly known to any economist but it is not easy to the practical use of the concept. The literature review will help us to understand in detail of this concept.

Secondly, for illustration purpose of the concept, the research team will define the marginal costs and revenues categories for Thailand. As mentioned above, the categories that will be used are based on the study of Samson et al (2001). The categories are described in Table 2-1. For marginal costs analysis, the research team is focusing on infrastructure cost, accidents, and environmental costs while paying attention on fuel duties, vehicle excise duty, and value added tax for revenues analysis.

The third step is the data collection. This research is based on secondary data only. The likely data sources are the Ministry of Transport (for road, vehicle data, accident data), the Ministry of Natural Resource and Environment (for environmental impact), the Ministry of Energy (fuel data), and the Ministry of Finance (tax data). It should be noted that the research team will analyze at least the Bangkok and vicinity provinces for the case studies. This will cover different road types (highway, local road) and different vehicle types (car, public vehicles, and trucks).

Finally, the data will be analyzed and the recommendations will be formulated based on the results. The research team hopes to shed some lights on the issues of the external costs and contribution of the road users for these costs.

Figure 3-1: Main Research Framework



Source: Authors

3.2 Methodology

The methodology of the study cost and revenue analyses which are consists of methodology for marginal infrastructure cost, accident cost, environmental cost, and revenues.

3.2.1 Methodology for Marginal Infrastructure Cost

To estimate the marginal infrastructure costs for road transport, the research team applies simple log-linear cost function from UNITE (2002) as shown in (3.1). Then, the research team employs the panel data analysis of infrastructure cost and traffic volume for 10 years from 3 sections of Expressway Authority of Thailand (EXAT).

$$\ln(Cost_{it}) = a + b \ln(VT_{it}) \qquad (3.1)$$

where:

$Cost_{it}$	=	infrastructure cost of sector i in year t (Baht)
VT_{it}	=	traffic Volume of road transport (Million vehicles/Km.)

The estimated parameter can be demonstrated in Table 3-1.

Table 3-1 Log-Linear Regression Result

Variable	Coefficients	Standard Error	T-Statistics	P-Value
VT_{it}	1.0128***	0.205	4.935	0.00
Constant	-1.6361	3.619	-0.452	0.651
R-Square = 0.5592				

Note: *** denotes statistically significant at 99 percent

Source: Authors' own calculations

Hence, we can estimate marginal infrastructure cost using equation (3.2) as follows.

Marginal Infrastructure Cost = 1.10128 (Average Infrastructure Cost) (3.2)

In order to apply the estimated parameter to calculate the marginal infrastructure costs for road transport, we have to estimate traffic volume and infrastructure costs by following these steps:

(1) Estimate traffic volume of all types of vehicle in Bangkok and vicinities in term of million vehicles per kilometer. To estimate traffic volume, we estimate number of vehicle per kilometer of travel (VKT) in target areas, by type of vehicle, from two data sources which are i) number of registered vehicles and ii) number of vehicles classified by types of energy consumption.

Table 3-2 shows types of data used to estimate traffic volume, in term of VKT, classified by type of vehicle while Table 3-3 shows number of vehicle per kilometer in Bangkok and vicinities as the traffic volume result from the estimate.

Table 3-2 Estimating Traffic Volume Data

Output Data	Input Data	
VKT by type of vehicle	**Registered Vehicles**	**Energy Consumption**
- Passenger Car	- By type of vehicle	- Benzene 95
- Taxi		- Benzene 91
- Pick Up Truck		- Diesel
- Truck		- Gasohol 95
- Motorcycle		- Gasohol 91
		- E20
		- LPG
		- NGV

Source: Authors

Table 3-3 Traffic Volume Result

Type of Vehicle	2007	2008	2009	2010	2011
Car	71,918	75,331	79,752	85,395	93,808
Pick Up	31,352	31,350	31,397	31,476	32,640
Motorcycle	8,653	8,926	9,163	9,471	9,994
Taxi	8,345	8,795	9,407	10,104	10,523
Motorcycle Taxi	3,053	3,014	2,889	2,568	2,457
Bus	2,048	2,114	2,227	2,418	2,525
Truck	6,195	6,346	6,310	5,959	6,358

Source: Estimate from data of Department of Land Transport (DLT)

(2) Estimate infrastructure cost of transport in Bangkok and vicinities from data of the three involving authorities; Department of Highways (DOH), Department of Rural Highways (DRH), and Bangkok Metropolitan Administration (BMA). Since the first two authorities provide the data for the whole country, we have to estimate the cost only in Bangkok and vicinities as shown in Table 3-4.

Table 3-4 Infrastructure Cost Estimated for Bangkok and Vicinities

Year	Department of Highways (Million Baht)		Department of Rural Highways (Million Baht)		Bangkok Metropolitan Administration (Million Baht)	Total in BKK & Vicinities (Million Baht)
	Whole Country	BKK & Vicinities	Whole Country	BKK & Vicinities		
2004	31,329	6,266	15,149	3,030	472	9,767
2005	44,388	8,878	15,587	3,117	264	12,259
2006	39,053	7,811	18,886	3,777	252	11,839
2007	45,179	9,036	17,864	3,573	290	12,899
2008	40,583	8,117	17,304	3,461	306	11,883
2009	40,512	8,102	22,370	4,474	467	13,043
2010	26,386	5,277	20,436	4,087	392	9,757
2011	47,445	9,489	20,769	4,154	842	14,484

Source: Estimate from data of DOH, DRH, and BMA

(3) Apply the traffic volume results and infrastructure cost estimated, from Table 3-3 and 3-4, in to (3.2) and the results of marginal infrastructure cost can be shown in Table 3-5.

Table 3-5 Results of Marginal Infrastructure Cost for road transport in Bangkok and Vicinities

Year	Infrastructure Cost (Million Baht)	VKT (Million Veh-km)	Average Cost (Baht/Veh-km.)	Marginal Cost (Baht/Veh-km.)
2007	12,899	131,564	0.0980	0.0993
2008	11,883	135,876	0.0875	0.0886
2009	13,043	141,145	0.0924	0.0936
2010	9,757	147,391	0.0662	0.0670
2011	14,484	158,306	0.0915	0.0927

Source: Authors' own calculations

3.2.2 Methodology for Marginal Accident Cost

To quantify costs due to road accident, we apply accident-risk analysis or value of statistical life (VSL) from UNITE (2003a) which indicates accident cost into 4 types; costs for fatality, serious injury, minor injury, and property damage.

The research team obtains number of accident cases occurred in 2007-2011, as shown in Table 3-6, from the Royal Thai Police, then, we obtain average accident value as shown in Table 3.7 from the study of traffic accident cost in Thailand of the Department of Highways (2007).

Table 3-6 Number of Accident Cases Occurred in 2007-2011

Year	2007	2008	2009	2010	2011
Number of injuries and fatalities					
Fatalities	652	602	579	454	336
Seriously Injuries	2,193	1,304	1,019	841	288
Minor Injuries	20,293	19,448	17,073	13,109	7,416
No. of Accidents	50,633	49,093	41,936	37,051	40,784
Property Damage (Baht)	70,686,010	357,959,489	2,305,444,733	1,061,187,103	767,535,323

Source: Royal Thai Police

Table 3-7 Average Accident Value in 2007

Types of injury	Average Accident Value in 2007 (Baht/case)
Fatalities	6,190,590
Seriously Injuries	253,098
Minor Injuries	135,014
Property Damage	127,693

Source: Department of Highways (2007)

By analyzing all data from Table 3-6 and 3-7, hence, we can calculate accident costs in 2007-2011 as in Table 3-8.

Table 3-8 Total Costs from Accidents in 2007-2011

Types of Costs	2007	2008	2009	2010	2011
Fatalities (Million Baht)	4,036	3,727	3,584	2,811	2,080
Seriously Injuries (Million Baht)	555	330	258	213	73
Minor Injuries (Million Baht)	2,740	2,626	2,305	1,770	1,001
Property Damage (Million Baht)	6,465	6,269	5,355	4,731	5,208
Total Costs (Million Baht)	**13,797**	**12,951**	**11,502**	**9,524**	**8,362**

Source: Authors' own calculations

3.2.3 Methodology for Marginal Environment Cost

To quantify the costs due to airborne pollutants, we apply the Impact Pathway Approach. This approach comprises the following steps:

(1) Calculation of emissions from an additional vehicle on specific routes in BMR.[3]

(2) Calculation of the changes in the concentration and deposition of primary and secondary pollutants due to the additional emissions caused by the additional vehicle.

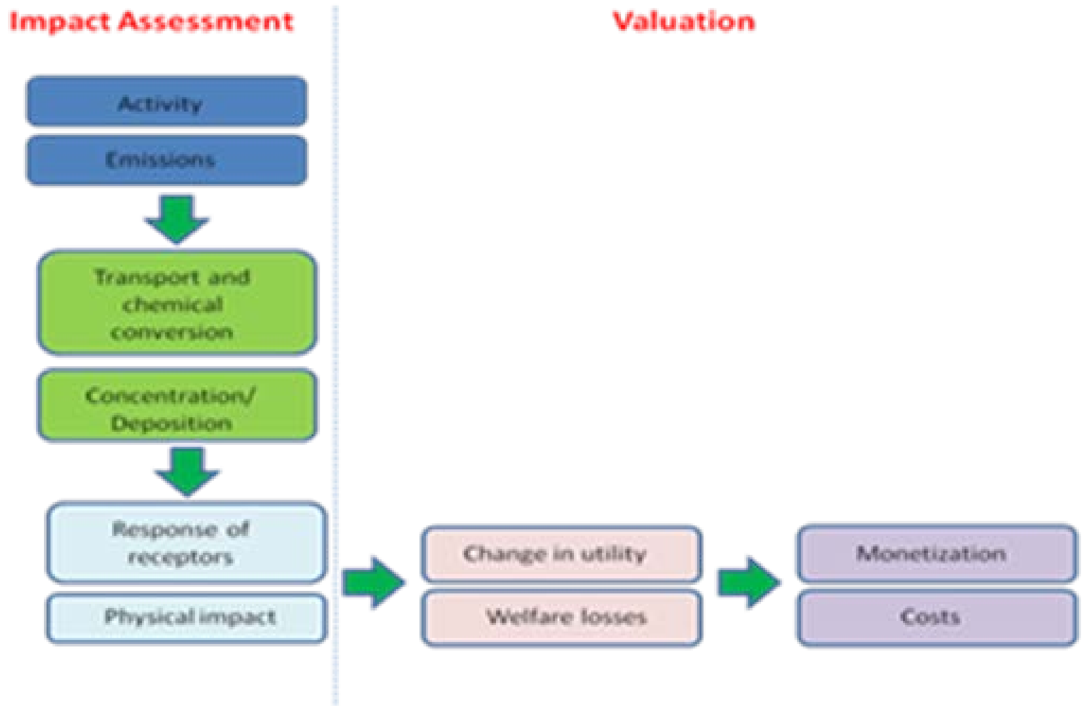
(3) Calculation of impacts on human health.

(4) Monetary valuation.

Figure 3-2 illustrates how the Impact Pathway Approach can be applied to quantify the marginal external costs caused by air pollution.

[3] According to Bickel et al. (2005), the starting point for assessing the marginal damages of transport activities is at the micro level, i.e. the transportation activity on a particular route. Thus, the marginal external costs of one additional vehicle are calculated for a single trip.

Figure 3-2: The Impact Pathway Approach for the Quantification of Marginal External Costs of Air Pollution



Source: Bickel et al. (2005)

In what follows, we briefly explain each of the above steps. In Step 1, we assess the emissions of all pollutants from vehicles. In particular, we compile the emissions of carbon dioxide, carbon monoxide, SO2, NOx and PM for each individual vehicle type. At this stage, the emission factors constitute an important part of our calculation. The emission factor shows a relationship between the amount of emissions that are released and the emission generating activity. The emission factors differ by fuel type (e.g. petrol, diesel), vehicle type (e.g. heavy diesel vehicles, diesel cars), emission standard (e.g. EURO2, EURO4) and driving pattern (i.e. speed, acceleration process) (UNITE, 2003b). Two main sources of emission factor database exist, namely U.K.' road vehicle emission factors 2009 (administered by U.K. Department of Transport) and Mobile Vehicle emission factor model (administered by the U.S. Environmental Protection Agency). For this project, the appropriate emission factors will be selected at a later stage. In addition, the information on the fuel consumed (represented by fuel sold) and the distance travelled by the vehicles are also important (Sansom et al., 2001).

Equation (3.3) is used to estimate amount of the CO, CO2, SO2, NOX, and PM10 released by the road vehicle if the fuel type (a) is used:

$$Emission_i = \sum_a [Fuel_a \cdot EF_a] \quad (3.3)$$

where:

$Emission_i$	=	the amount of emission (kg)
EF_a	=	emission factor (kg/TJ)
$Fuel_a$	=	fuel consumed (as represented by fuel sold)
a	=	fuel type a (e.g. diesel, gasoline, natural gas, LPG, etc.)
i	=	pollutant i (e.g. CO, CO_2, SO_2, NO_X, and PM_{10})

This approach can be used to estimate the emission of CO, CO2, SO2, NOX, and PM10 based on fuel sold because the total fuel consumption may be unknown. For this project, we can obtain fuel sold and fuel type data from the monthly report published by the Department of Energy Business, Ministry of Energy.

Equation (3.4) gives an alternative way of estimating the emission level:

$$Emission_i = \sum_{a,b,c,d} [Distance_{a,b,c,d} \cdot EF_{a,b,c,d}] + \sum_{a,b,c,d} C_{a,b,c,d} \quad (3.4)$$

where:

$Emission_i$	=	emission (kg)
$EF_{a,b,c,d}$	=	emission factor (kg/km.)
$Distance_{a,b,c,d}$	=	distance travelled (VKT)
$C_{a,b,c,d}$	=	emissions during warm-up phase (cold start).(km.)
a	=	fuel type a (e.g. diesel, gasoline, natural gas, LPG, etc.)
b	=	vehicle type
c	=	emission control technology (such as uncontrolled, catalytic converter, etc.)
d	=	operating conditions (e.g. urban or rural road type, climate or other environmental factor)
i	=	pollutant i (e.g. CO, CO_2, SO_2, NO_X, and PM_{10})

This approach can be used to estimate the emission of CO, CO2, SO2, NOX, and PM10 based on the distance travelled by vehicles and the emissions generated during the warm-up phase (cold start). We can obtain data on vehicle type from the annual report published by the Department of Land Transport, Ministry of Transport. But, currently we do not have data on emissions during the warm-up phase, the emission control technology data and the operating conditions data.

In Step 2, we assess the changes in the concentration and deposition of pollutants due to the additional emissions caused by the additional vehicle. Different range and type of pollutants considered require different models.

In Step 3, we assess the impacts of emissions from airborne pollutants by using the exposure-response functions which relate changes in human health to unit changes in ambient concentrations of pollutants. Exposure-response functions come in various functional forms, linear or non-linear (UNITE, 2003b). Table 3-9 reports the health impacts from some airborne pollutants, i.e. Carbon dioxide (CO2), Sulphur dioxide (SO2), Nitrogen dioxide (Nox), Carbon monoxide (CO) and Particulates (PM10).

Table 3-9 Health Impacts Caused by Airborne Pollutants

Pollutant	Source	Health Impacts
Carbon dioxide (CO_2)	- Burning of fossil fuels - Combustion in motor vehicles	- Headaches - Asphyxiation - Aggravation of cardiovascular disease
Sulphur dioxide (SO_2)	- Burning of fossil fuels (coal)	- Causes constriction of the airways in people with asthma - Repeated exposure causes a condition similar to bronchitis. - Increased risk of acute respiratory disease
Nitrogen dioxide (NO_x)	- Burning of fossil fuels especially motor vehicles	- Can irritate the lungs, aggravate the condition of people suffering from asthma or chronic bronchitis
Carbon monoxide (CO)	- Vehicle emissions	- Restricts oxygen uptake - Causes drowsiness - Headaches - Death
Particulates (PM_{10})	- Motor vehicles - Industry undergoes chemical reactions in the atmosphere.	- Aggravate bronchitis - Lung diseases - Reduce the body's ability to fight infections

Source: Gauteng SoER 1995 (http://www.ceroi.net/reports/johannesburg/csoe/html/nonjava/Pollution/Air/impact.htm)

In Step 4, we evaluate the emission costs associated with the 4 pollutants included in our analysis, namely CO, NOx, SO2 and SPM, we obtained this information from Massachusetts Department of Public Utilities. Table 3-10 shows these emission costs.

Table 3-10 Environmental costs from airborne pollutants

Emission	Emission Cost ($/ton)
CO	992
Nox	7,410
SO2	1,710
SPM	4,560

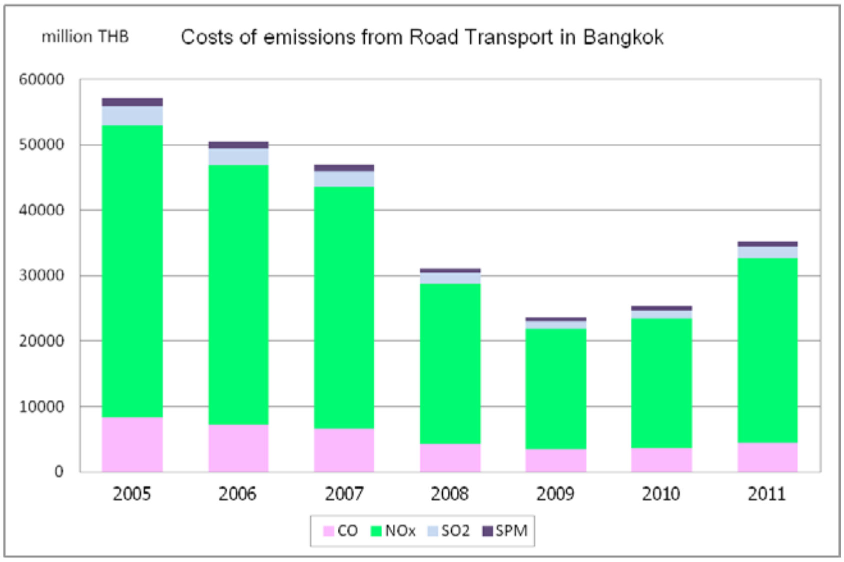
Source: Massachusetts Department of Public Utilities and Tamsunya (1998)

Given the costs of emissions, the next step is to calculate the emission values. We use the following formula in (3.5).

$$Emission\ values\ (\$) = Emission\ Loads\ (tons) \times Emission\ costs\ (\$/ton) \quad (3.5)$$

The results of our estimations of emission values in Thai baht resulted from road transport in Bangkok during 2005 – 2011 are shown in Figure 3-3. Figure 3-3 contains a summary on the emission costs classified by types of airborne pollutants.

Figure 3-3 Environmental costs of road transport during 2005 – 2011 (unit: million THB)



Source: Authors' own calculations

According to Table 3-3 in the earlier sections, we obtain the traffic volume in Bangkok during 2007 – 2011 (in vkm units) which includes vehicle registration data, traffic data, and energy consumption data. To derive the marginal environmental cost of road transport, we use an econometric approach, specifically an ordinary least square (OLS) regression. The following functional form in (3.6) is used to describe the relationship between total environmental costs of road transport and traffic volume during 2007 – 2011:

$$ln(TEC_{it}) = \beta_1 + \beta_2 \ln(Traffic\ Volume_{it}) + \varepsilon_{it} \quad (3.6)$$

where

TEC_{it}	=	total environmental cost associated with vehicle type i in year t
Traffic $volume_{it}$	=	traffic volume of vehicle type i in year t
ε_{it}	=	error term

The marginal cost of road transport (MEC) can be found by differentiating equation (3.7) with respect to the traffic volume, yields:

$$\frac{1}{TEC}\frac{d(TEC)}{d(Traffic\ Volume)} = \frac{1}{Traffic\ Volume}\beta_2$$

$$MEC = \frac{d(TEC)}{d(Traffic\ Volume)} = \beta_2\left(\frac{TEC}{Traffic\ Volume}\right) = \beta_2 AEC \quad (3.7)$$

where

AEC	=	average environmental cost of road transport

It is important to note that our OLS regression also contains the control variable, such as the vehicle dummy variable and the standard errors reported here are robust standard errors. The estimation results are contained in Table 3-11. Robust standard errors are shown in parentheses.

Table 3-11 Results of OLS estimation

Details	Equation (4)
ln (Traffic $Volume_{it}$)	0.5212629*** (0.0641542)
Number of Observation	25
R^2	0.9392

Note: *** denotes statistically significant at 99 percent

According to Table 3-11, it follows that β = 0.5212629. Using this result together with our calculation of average environmental cost of road transport (AEC), we can derive the marginal environmental cost (MEC) for 2007 – 2011 in Bangkok as shown in Table 3-12.

Table 3-12 Derivation of MEC of road transport in Bangkok during 2007 – 2011

Year	TEC (million THB)	Traffic Volume (million vkm)	AEC (million THB)	MEC (million THB)
2007	46,938.75917	119,858	0.391619743	0.204136843
2008	31,068.53044	123,936	0.250682049	0.130671252
2009	23,525.52978	129,093	0.182237068	0.094993422
2010	25,272.43909	135,352	0.186716407	0.097328336
2011	35,301.29672	145,854	0.242031735	0.126162164

Source: Authors' own calculations

3.2.4 Methodology for Revenue Analysis

To compare between costs and revenues of road transport, we have to calculate revenue from the price paid by users. The road users have to pay in fixed and variable amounts as described in Table 3-10.

Fixed revenue from road users are composed of excise duty on new vehicles and annual vehicle tax since these two types of revenue have to be paid annually by new owners of car, pick-up, and motorcycle. For the variable revenue, the road users have to pay for excise duty and VAT of the fuel consumption for their vehicles.

Table 3-10 All Revenues from Road Users

Fixed Revenue from Road Users	Variable Revenue from Road Users
Excise Duty on New Vehicles	Excise Duty on Fuel
Annual Vehicle Tax	VAT on Fuel

Source: Authors' own calculations from the Excise Department, the Department of Land Transport, and the Energy Policy and Planning Office.

Table 3-11 and 3-12 provide the data of fixed revenues for each type of vehicles and variable revenues, respectively, which we obtain from Department of Land Transport (DLT), Ministry of Energy, and Ministry of Finance.

Table 3-11 Fixed Revenues for Each Type of Vehicles in 2007-2011

Types of Vehicles	2007	2008	2009	2010	2011
Excise Duty on New Vehicles (Million Baht)					
Car	42,623	35,363	21,426	25,272	22,229
Pick-up	4,640	4,091	2,844	3,716	4,250
Motorcycle	501	409	323	327	305
Total	**47,764**	**39,862**	**24,593**	**29,315**	**26,783**
Annual Vehicle Tax (Million Baht)					
Car	7,030	7,338	7,714	8,335	9,054
Pick-up	1,257	1,265	1,283	1,322	1,371
Taxi	64	68	73	78	83
Motorcycle	451	466	475	495	520
Bus	244	248	251	267	273
Truck	1,425	1,472	1,476	1,459	1,534
Total	**10,470**	**10,857**	**11,272**	**11,956**	**12,835**

Source: Department of Land Transport (DLT)

Table 3-12 Variable Revenues in 2007-2011

Year	Excise Duty (Million Baht)	VAT (Million Baht)	Total (Million Baht)
2007	**24,044**	**11,674**	**35,718**
2008	13,323	13,197	26,519
2009	36,187	9,150	45,337
2010	46,579	10,825	57,404
2011	25,226	13,701	38,927

Source: Ministry of Energy and Ministry of Finance

CHAPTER 4 RESULTS AND CONCLUSIONS

4.1 Results

To answer the question whether the road users in Thailand pay more or less on what they impose to the society at large, the research team has to discuss about the magnitude of the external costs that road users impose for the society.

According to Samson et al (2001), society's economic welfare will be maximized when each transport user pays the marginal external cost of each trip. Hence, comparing between total costs incurred from road users and total revenue collected from them is the suitable way to measure for efficient pricing mechanism.

Table 4-1 provides the comparison between social costs occurred by road users comparing with earned revenue of society from them. To compare costs and revenue of the society, we apply total revenue-cost ratio and variable revenue-cost ratio.

The first ratio indicates that earned revenue is higher than total cost occurred from road users from 2007-2011 while the second ratio indicates that earned variable revenue is less than total cost occurred from road users in the same period. Since variable revenues are composed of excise duty and VAT on fuel, hence, price that road users pay for fuel consumption is less than total costs caused by road users, except in 2010, which means that price mechanism that government impose on fuel during 2007-2011 is less efficient than in 2010.

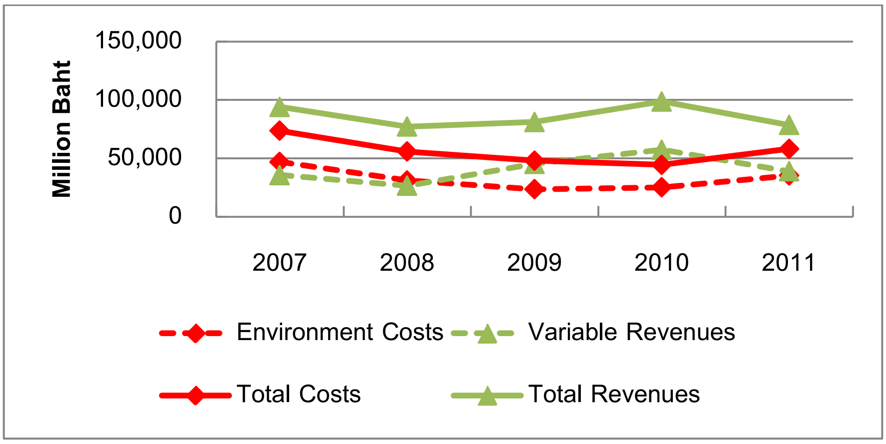
Table 4-1 Comparing between Costs Occurred by Road Users and the Price of Users Pay

Year	2007	2008	2009	2010	2011
Infrastructure Costs	12,899	11,883	13,043	9,757	14,484
Accident Costs	13,797	12,951	11,502	9,524	8,362
Environment Costs	46,939	31,069	23,526	25,272	35,301
Total Costs	**73,635**	**55,903**	**48,071**	**44,553**	**58,147**
Fixed Revenues	58,234	50,719	35,865	41,271	39,618
Variable Revenues	35,718	26,519	45,337	57,404	38,927
Total Revenues	**93,952**	**77,238**	**81,202**	**98,675**	**78,545**
Variable Revenue/ Cost Ratio	**0.485**	**0.474**	**0.943**	**1.288**	**0.669**
Total Revenue/ Cost Ratio	**1.276**	**1.382**	**1.689**	**2.215**	**1.351**

Source: Authors' own calculations

To consider types of cost, Table 4-1 shows that environment costs are the highest proportion of total costs occurred during 2007-2011. Since environment costs are involved with pollutants emission from fuel consumed by road users, comparing these costs with earned variable revenues from these users, shown in Figure 4-1, provides us that environment costs are decreasing when earned revenues from fuel consumption keep increasing during 2008-2010 and variable revenue is higher than environment cost during 2009-2011. Moreover, combining fixed revenues, collected from vehicle owners, with all variable ones, we can see that total revenues are higher than environment costs. Hence, price mechanism seems to work efficiently for social welfare on environment side during 2009-2011. In addition, total revenues collected from road users are higher than total costs occurred from them during 2007-2011, thus, price mechanism is still efficient to create social welfare. However, we should bear in mind that this calculation does not include the infrastructure investment cost, so that the total revenue/cost ration is not the full cost ration but rather the total revenue/marginal cost ratio.

Figure 4-1 Comparing Costs and Revenues



Source: Authors' own calculations

4.2 Conclusions

This research presents the concept of marginal social cost in road transport by calculating the marginal cost, then comparing the costs and revenues in Bangkok area. Since longitudinal and detailed data is a necessity for calculating the marginal cost and due to the lack of data, we are able to calculate only (roughly) marginal infrastructure cost and we only include consumption of ULG, HSD and LPG in the analysis of environment costs. However, we use the average accident cost as a proxy to the marginal cost and we exclude congestion cost in this study. The results show that price mechanism is still efficient to create social welfare, however, the policy of the excise duty on various fuel types may not consistent with the social cost occurred.

References

AEA Technology (1997). "Economic Evaluation of Air Quality Targets for CO and Benzene." Interim report prepared for the European Commission DG XI, Harvell, UK.

Button, K. (1990) Environment externalities and transport policy, Oxford Review of Economic Policy, 6, pp. 61-75.

Bickel, P., S. Schmid and R. Friedrich (2005). "Environmental Costs." Research in Transportation Economics, vol.14, pp.185-209.

Department of Highways (2007). "The Study of Traffic Accident Cost in Thailand". September 2007.

European Commision (1999a). "ExternE Externalities of Energy. Vol.7 - Methodology 1998 update." A Report produced for the EC – DG XII, Luxembourg, Office of Publications for the European Communities, Luxembourg.

European Commission (1999b). "ExternE Externalities of Energy. Vol.10 – National Implementation." A Report produced for the EC – DG XII, Luxembourg, Office of Publications for the European Communities, Luxembourg.

Friedrich, R. and P. Bickel (eds.) (2001). Environmental External Costs of Transport. Springer Verlag, Heidelberg.

INFRAS/IWW (2000). "External Costs of Transport." Study for the International Union of Railways, Paris.

McCubbin, D.R. and M.A. Delucchi (1996). "The Social Cost of the Health Effects of Motor Vehicle Air Pollution." Report No.11 in the Series: the Annualised Social Cost of Motor Vehicle Use in the United States, based on 1990-1991 data, UCD-IST-RR-96-3 (11), Davis, California, US.

Maibach, M., Schreyer, C., Sutter, D., van Essen, H.P., Boon, B.H., Smokers, R., Schroten, A., Doll, C., Pawlowska, B., Bak, M. (2007) Handbook on Estimation of External Cost in the Transport Sector, Internalisation Measures and Policies for All external Cost of Transport (IMPACT) Delft, CE, 2007.

Newbery, D. (1998) Fair Payment from Road Users: A Review of the Evidence on Social and Environmental Cost, AA Policy Paper, the Automobile Association, Basingstoke, UK.

Ruta, G. (2002) The Social Cost of Transport, Training module for the Environmental Economics and Development Policy Course, The World Bank, Washington DC July 15-26, 2002.

Samson, T., Nash, C.A., Mackie, P.J., Shires, J., and Watkiss, P. (2001) Surface Transport Costs and Charges: Great Britain 1998, Final Report for the Department of the Environment, Transport and the Regions, Institute for Transport Studies, University of Leeds, Leeds, UK.
Verhoef, E. (2001) The implementation of marginal external cost pricing in road transport, Paper in Regional Science, 79, pp. 307-332.

Sansom, T., C. Nash, P. Mackie, J. Shires and P. Wartkiss (2001). "Surface Transport Costs and Charges: Great Britain 1998." Final report for the Department of the Environment, Transport and the Regions. Institute for Transport Studies, University of Leeds, Leeds, July 2001.

UNITE (2002). Deliverable 10: Case Studies on Marginal Infrastructure Cost. Version 13, Competitive and Sustainable Growth (Growth) Programme.

UNITE (2003a). Deliverable 9: Marginal accident costs – case studies. Version 1.3, Competitive and Sustainable Growth (Growth) Programme.

UNITE (2003b). Deliverable 11: Environmental Marginal Cost Case Studies. Version 2.0, Competitive and Sustainable Growth (Growth) Programme.

Vassanadumrongdee, S. and S. Matsuoka (2005). "Risk Perceptions and Value of Statistical Life for Air Pollution and Traffic Accidents: Evidence from Bangkok, Thailand." The Journal of Risk and Uncertainty, vol.30(3), pp. 261-287.

World Health Organization (WHO) (1999). "Health Costs due to Road Traffic-related Air Pollution – An impact assessment project of Austria, France and Switzerland." Synthesis Report published by Federal Department of Environment, Transport, Energy and Communications – Bureau for Transport Studies, Bern, Switzerland.

Warapetcharayut, P. and I. Paw-armart (2004). "Emission Factor Development in Thailand." Automotive Air Pollution Section, Air Quality and Noise Management Bureau, Pollution Control Department.

Final Repor

Research Grant 20

ATRANS