# CHAPTER 1

# INTRODUCTION

In the UK, the use of road vehicles and the number of vehicles has increased dramatically over the last 20-50 years.[1] However and by comparison, the growth of roads measured by length has only increased slightly over the same period.[2] Similarly in Thailand, the growth in traffic and vehicles has been even greater and the development of the road network has only been slightly greater than in the UK.[3] In the UK, there is a concern that average speeds have dropped as the use of vehicles has increased more quickly than the road network. In particular, there has been concern over the reduction in urban traffic speeds.[4] Similarly, in Thailand, Bangkok traffic speeds have fallen in the last decade.[5]

[1] In the UK, Department for Transport Statistics (2012) shows that over the periods 1961-2011 and 1991-2011, the growth in ownership of vehicles was 278% (from 9 to 34 million licensed vehicle) and 36% (from 25 to 34 million vehicles). The use of road vehicles increased by 299% over the period 1961-2011 (from 123 to 489 billion vkm) and increased by 19% during the period 1991-2011 (from 212 to 489 billion vkm).

[2] The length of roads increased by 15% over the period 1961-2011 (from 314,000 to 395,000 kilometres) and by 10% over the period 1991-2011 (from 360,000 to 395,000 kilometres), see Department for Transport Statistics (2012).

[3] The number of Thai vehicles has increased by 265% over the period 1991-2011 (from 8 to 30 million licensed vehicles), see Department of Land Transport (2013). The length of the road network has increased by only 16% over the period 2004-2011 (from 190,000 to 223,000 kilometres), see Asian-Japan Transport Partnership (2011).

[4] For example, from 2007 to 2011, Transport for London (2012) shows that average speed in Central London decreased from 15.2 to 14.9 km/h and from 14.6 to 13.8 km/h during the morning peak and evening peak periods, respectively. It should be noted that the average speed during the weekday morning peak on locally London managed A roads has been increased from 39.60 to 40.73 km/h for the past five years (from 2007 to 2012).

[5] The Office of Transport and Traffic Policy and Planning (2012) reports that over the period 2008-2012 the average speed on Bangkok strategic roads has decreased from 19.4 to 17.9 km/h and from 23.4 to 21.6 km/h during morning and evening peaks, respectively.

Across the world, there is a concern about road congestion.[6789] Road transport connects people and goods and is crucial to the development of a growing economy. As a result, demand for road transport has expanded and congestion has reached critical levels. Congestion cost arises in terms of time delays and unreliable transport schedules. There are two possible policy responses to these problems. Firstly, the road network can be extended and improved. This is costly and is often opposed for environmental reasons. Environmental objections range from pollution degradation of the road route to use of materials for road construction. Additionally, the provision of more and better roads is likely to lead more traffic and climate change. The other policy is to increase the price of transport. This can be done in a variety of ways, e.g. increase the price of fuel through greater taxes, increase the price of vehicles and charge for the use of roads. It is this last policy that lies behind the motivation of the thesis. A good road pricing policy links the charge for use of roads to the external costs of road traffic and, in particular, congestion.

The external congestion time cost of road traffic is the subject of this thesis and the motivation for this subject is that estimates of these costs are essential for the construction of a theoretically coherent, effective and efficient road pricing policy

[6] The Confederation of British Industry suggests that the UK economy suffers to the extent of £8 billion a year from congestion on the gridlocked road network and that could increase to £22 billion a year by 2025. (Daily Mail Reporter, October 8th, 2012)

[7] The Department of Transport suggests that the estimated USA traffic congestion cost is $200 billion each year and more than one-quarter of total annual travel time in metropolitan areas occurs in congested conditions. (U.S. Government Accountability Office, January 12th, 2012)

[8] Chadchat Sittipunt, Minister of Transport Department states his view of solving the critical traffic congestion in Bangkok “It is possible that the government will start charging motorists for using roads in inner Bangkok.” (Travel Daily News, January 2nd, 2013)

[9] Siim Kallas, EU Vice President and commissioner for transport states that “congestion is a huge problem that already costs European businesses and citizens the equivalent of 1% of the EU’s GDP.” (Conference on Fair and Efficient Road Pricing at Brussels, December 5th, 2012)

that strives to be close as possible to the first best outcome. It is argued in this thesis that the standard theory of the economics of road congestion can be reworked and expressed in terms of density of road usage. This reworking provides a sound theoretical basis and exposes certain limitations in the standard theory when density and speed vary. The thesis shows how one can use observable speed-flow data to makes estimates of the marginal external congestion cost of road transport under different speed-flow circumstances. In periods of low congestion and nearly constant density and constant speed, there is only a slight difference in the estimated marginal external congestion time costs using the new and standard theory. It is shown in simulations that, during periods of higher congestion and hypercongestion, there are important differences in the empirical estimates following from the two approaches. The objective of the thesis is to develop and use a new theory of congestion and use it as the basis of empirical estimation of the external congestion costs. For this reason, we do not extensively discuss the policy of road pricing but it is the very important policy objective that lies behind the subject of this thesis. To this end, the literature reviews show how the theory of the economics of road congestion should lie behind practical road pricing policy.

The main contribution of this thesis is the development of a density based model of the marginal external congestion cost. This model is applied to the case of a single vehicle type during ordinary congestion and hypercongestion. The model is extended to consider multiple vehicle types during ordinary congestion; the extension to hypercongestion is simple. This model is used to examine a number of important and debates in the literature of the economics of road congestion. Importantly, we show how this model can be estimated on extensive and

previously unused data sets of the London Congestion Charging Scheme Area and the Chalerm Mahanakorn Expressway in Bangkok.

This thesis is organized in six chapters. Chapter 2 is a critical review of the literature on the external effects of road congestion. This Chapter starts with a brief history of the economic analysis of road congestion and follows with the standard view of the speed-flow-density model. A simple model of the aggregate of decisions of road users to use the road network is developed to examine the confused literature on the economics of ordinary congestion and hypercongestion. This model is helpful in explaining the debates between Else (1981 and 1982) and Nash (1982); Demza and Gould (1987) and Evans (1992a); Evans (1992a and 1992b) and Hills (1993); and Ohta (2001a and 2001b) and Verhoef (2001a). The critical review of these studies is used to show limitations in estimating the marginal external congestion cost that have occurred in many previous investigations. The literature on the importance of the value of time in determining marginal external cost is briefly reveiwed. A number of empirical studies investigating the marginal external cost of ordinary congestion are examined. The literature on the economics of hypercongestion is critically examined and again an attempt is made to resolve various debates. The literature on impacts of different vehicle types on road congestion is critically reviewed. The use of theoretical models of road congestion and empirical results in the formulation of road pricing policies is examined. Finally, various issues and problems found in the critical review of the economics of the road congestion are discussed.

Chapter 3 presents an analysis of the marginal external congestion cost based on a density model. The model is based on the density of road users and it is shown how the theory relates to the standard speed flow analysis. The model shows that

a full analysis of road congestion requires a multiperiod model and the marginal external costs depend on the elasticity of speed with respect to density and speeds in other periods. It is shown how this elasticity relates to the observable elasticity of speed with respect to flow. Importantly, possible differences in the standard speed flow approach and the conventional approach are examined though a simulation study. The second part of the Chapter shows how the theory can be applied to real world data taken from the measurement of speeds and flows in the Central London area. This data is used to estimate marginal external congestion time costs on different roads and shows the situations where there are and are not differences with the conventional approach. The differences are small for periods of low congestion, with nearly constant density and speed, and mainly of a theoretical nature. In periods of high and hypercongestion, these differences are larger. It should be pointed out that the external congestion costs associated with less desirable start and finish journey times cannot be easily determined and are absent from the marginal external congestion cost estimates presented here. The actual estimates of the marginal external time congestion costs for periods of low ordinary congestion are in the region of 0.2 minute per vkm.

Road traffic hypercongestion is defined as circumstances in which increased flow results in greater speed. By comparison, in the case of ordinary congestion, increased flow results in less speed. Hypercongestion is often associated with very low traffic speeds and is regarded as causing a severe economic externality in many urban areas[10]. In spite of the serious nature of this problem, conventional transport economics has limitations in past attempts to estimate the marginal

[10] Siim Kallas, EU Vice President and commissioner for transport emphasizes that “We know urbanisation and city traffic will continue to grow and our saturated roads cannot expand indefinitely.” (EU Commission Conference on Fair and Efficient Road Pricing Brussels, December 5th, 2012)

external hypercongestion cost using the speed flow model. The conventional estimation of the marginal external congestion cost makes use of the engineering concept of speed flow relationships or is derived from a theoretical approach as infinite. Implausibly, the conventional speed flow analysis suggests the unlikely outcome of hypercongestion being a positive externality. Thus, an alternative theory of hypercongestion is required that is capable of producing meaningful estimates of marginal external congestion costs.

In Chapter 4, we provide a density based model of hypercongestion that is capable of being estimated using speed flow data. Following on from Chapter 3, a model of hypercongestion is developed for a uniform road section and the case of uniform road users with perfect knowledge of traffic conditions. It is based on density of road users and it is shown how the theory relates to the standard speed flow analysis. Importantly, it is shown how real world data taken from the measurement of speeds and flows in the Central London area and the Chalerm Mahanakorn Expressway in Bangkok can be used to estimate the marginal external costs of hypercongestion. We show that for London urban roads, the hypercongested speed-flow relationship is essentially a vertical relationship with a high marginal external congestion cost and may be caused by bottleneck congestion. However, using data from the Chalerm Mahanakorn Expressway, we show that the speed-flow relationship for this express way has the standard form of a horizontal parabolic shape and the related marginal external hypercongestion time cost is very high.

The conclusion to be drawn from the critical review in Chapter 2 is that there are many different methods of investigating the different congestion effects of different types of vehicles in terms of the equivalent number of passenger car vehicles.

Unfortunately, there are problems with some of these methods. Many estimates of the relative congestion effect of different type of vehicles make use of simulation studies rather than direct estimation of such effects from empirical data. In project appraisal, it is common to find the simple assumption that large or heavy vehicles have an equivalent effect on congestion of two or more passenger cars. This lack of precision and evidence based estimates are an important omission in the literature on the economics of congestion.

Thus, in Chapter 5, we develop a theoretical model of the marginal external congestion costs of different vehicle types using a speed-density model that can be linked to observable speed flow relationships. The model is complex and shows the importance of interaction between the different vehicle-vehicle effects. A complete empirical analysis requires more data that is available here or in most data driven studies. The lack of sufficient data from the Chalerm Mahanakorn Expressway in Bangkok limits the generality of the implications of the empirical analysis but suggests that the marginal external congestion time costs of large and heavy vehicles exceeds the simple assumption that such vehicles cause twice as much congestion as two passenger cars.

Finally, Chapter 6 summarizes the contribution of this thesis. The conventional speed flow model is shown to be incomplete in capturing the important theoretical elements of the economics of road congestion. These omissions are important in periods of high or hypercongestion but of limited importance in periods of low congestion with constant speeds and density. More importantly, there are limitations in representing the external costs of congestion. A new model is developed that represents these external costs correctly but excludes the costs of journeys having to be made at less preferred start and finish times.

The new model is used to explain debates in the literature on the economics of road congestion and is compared to existing models. It is shown how the model can be used to estimate the external time costs of journeys but not the costs associated with their timing. These omissions and other issues in the empirical estimation of the new model are discussed. The Chapter concludes with suggestions for further applied research in the economics of road congestion.