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Road to Nowhere: An Assessment of Social Costs from the Use of Cars in Cypriot Cities

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Abstract

The paper offers an assessment of marginal external costs from car use in urban areas of Cyprus; these are the social costs generated by the use of cars other than those paid by car travellers themselves. On the basis of a European methodology and local traffic data, costs are computed for externalities such as congestion, accidents, noise, air pollution, greenhouse gas emissions and other social impacts. Results are in line with those for other similar European cities. Congestion represents the highest part of costs during most hours of the day, exceeding one Euro per kilometre during morning peak traffic. Accident costs prevail at night time. Impacts from noise, air pollution and climate change generate relatively low costs. External costs may be several times higher than private costs. Policy implications of these findings are discussed, with special emphasis on the importance of establishing an extensive public transportation infrastructure in Cypriot cities in order to tackle these externalities.

Keywords: accidents, congestion, emissions, externalities, noise, transportation.

1. Introduction

Mobility of passengers and goods is a major driver, and a major result, of economic development throughout the world. Although private transportation costs represent a very significant share of household expenditures, car ownership and car travel have been steadily growing during the last decades. This is a clear indication that private benefits of vehicle ownership are very high, and anyone who is willing to pay the private costs will enjoy these benefits. At the same time, however, transport activities, and particularly the use of private cars, have a number of unintended consequences such as increased congestion in urban areas, accidents and other environmental impacts. Unlike private costs such as ownership, maintenance and fuel costs, the additional costs to society from

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these consequences are generally not fully borne by car users: these are by definition external costs from the use of cars. Public policy interventions are required in order to 'internalise' these externalities, e.g. through the implementation of Pigouvian taxes, and thus to include external costs in the decision making process of transport users so as to achieve efficiency in the utilisation of transport infrastructure and environmental resources.

Despite some sizable progress in vehicle-related air pollution, transportation is still responsible for substantial social costs in Europe, notably because of congestion and accidents. Moreover, transport is the only sector in the European Union whose greenhouse gas emissions have been rising continuously (EEA, 2008). It is therefore no surprise that the assessment and internalisation of transport externalities has been an increasingly important topic in Europe. A large number of related research projects have been conducted since the early 1990s, which have considerably advanced knowledge in this field. Fair and efficient transport pricing has also been advocated in a number of policy documents of the European Commission, including the 2001 White Paper on European Transport Policy (EC, 2001) and the 2006 mid-term review of that White Paper (EC, 2006). Recently, in the framework of a study funded by the European Commission, a handbook was created with the aim to provide guidance across Europe on the most appropriate methods to calculate externalities of transport (CE Delft, 2007); it will be mentioned as 'the Handbook' in the rest of this article.

The issue of transport-related nuisance is increasingly gaining attention in Cyprus, primarily because of deteriorating traffic congestion and the absence of reliable public transport modes. Within this context, this paper summarises the first attempt to assess transport externalities in Cyprus, focusing on the costs of using private cars in urban areas of the country. It applies the methodology outlined in the above mentioned Handbook, and for this purpose it makes use of local data which come from studies that have been carried out by (or on behalf of) official authorities in Cyprus. Therefore, results presented here should be considered as an approximation of external costs of car transport on the basis of traffic conditions that are representative of Cypriot cities.

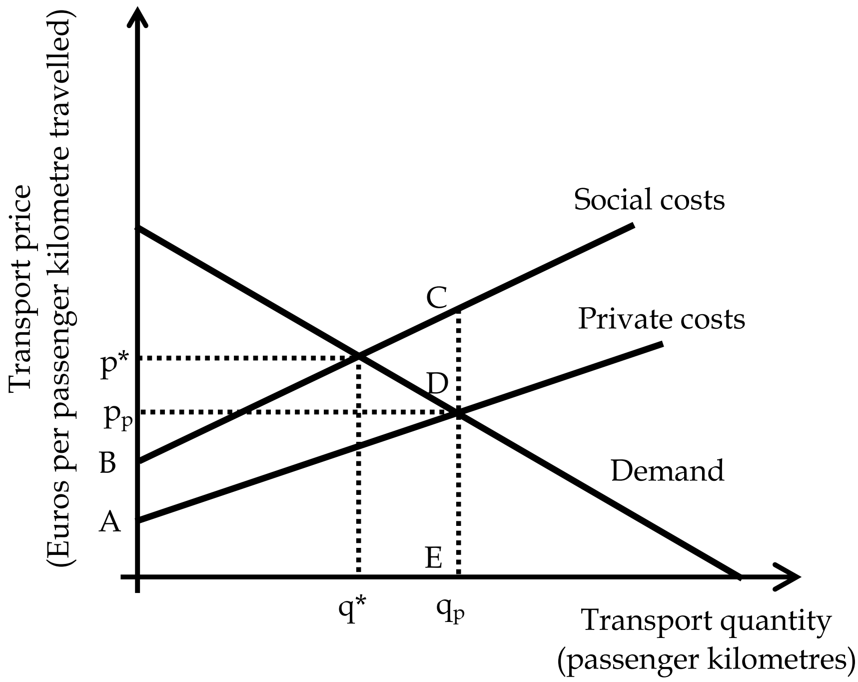
Our calculations, to be described in detail in section 2, show that congestion is responsible for the major part of externalities during most hours of the day, exceeding one Euro per kilometre during morning peak traffic. At night time accident costs prevail, while other cost items remain at comparatively low levels throughout the day. As shown in section 3, external costs turn out to be much higher than private transportation costs; this indicates clearly the need for corrective policy interventions so that car users bear the full social costs of their travel behaviour. Section 4 discusses several aspects that policymakers have to consider so that efficient and effective transport policies are implemented; most importantly, the paper stresses the urgent need for a well designed, modern and reliable public transportation system in Cypriot cities.

As the paper will focus on marginal external costs of private car travel, it is useful to clarify what this exactly means. *External* costs, as already mentioned, include all social costs from car use other than those paid (directly or indirectly) by car travellers themselves. *Marginal* costs are those caused by an additional vehicle (or an additional kilometre driven by a vehicle) that enters traffic in a given traffic situation. Therefore, these costs may differ greatly depending on the type of road, the time of the day and the current traffic patterns. Marginal costs should be clearly distinguished from average or total external costs of transport. The assessment of marginal costs cannot provide an estimate of total externalities; however, it can provide a valuable indication of the charges on road users that would be necessary now if externalities were to be tackled in an economically efficient manner.

The textbook example of externalities, as illustrated in Figure 1 for passenger transport, can explain the usefulness of assessing marginal external costs. When externalities are not internalised, car travellers face only private costs p_p, therefore demand meets supply at q_p, which is higher than the efficient level q^*. With transport quantity at the point q_p, total external costs equal the area ABCD, and marginal external costs correspond to CD. This paper attempts to calculate the magnitude of CD. Even if these marginal external costs are assessed, this does not mean that CE is the efficient price that would account for both private and external costs. The efficient price would be p^*, which would lead to the optimal level of transport demand q^*. As the demand curve is not known, particularly in the case of Cyprus where detailed travel data at micro level are largely not available, the efficient price level p^* can be approximated by calculating CD and assuming an elasticity of transport demand with respect to prices. A calculation of efficient car prices in Cypriot urban areas will be shown in section 4.

FIGURE 1

The textbook example of external costs in the case of passenger transport



A further clarification is in order. In the short run, externalities are associated with the costs of using the current infrastructure; hence fixed infrastructure costs are not relevant for efficient pricing. In the long run, however, externalities may also cause changes in infrastructure capacity, e.g. expansion of the road network due to increasing traffic, additional investments in roads for accident prevention, noise barriers etc. Whereas short-run marginal costs are relevant for efficient pricing of the existing road network, long-run marginal costs have to consider the financing of infrastructure expansion as well. This paper focuses on short-term marginal external costs, i.e. it attempts to assess externalities and suggest efficient charges given the current road infrastructure in Cypriot cities.

2. Assessment of costs by type of externality

Adverse impacts of road transportation, which give rise to social costs, are congestion, accidents, noise, air pollution, greenhouse gas emissions and other smaller effects. The methodology to assess externalities for each one of these effects is outlined in the following paragraphs. Most of these costs will be expressed in Euros (at 2007 prices) per vehicle-kilometre travelled in order to enable a uniform presentation; whether this is an appropriate unit in which all externalities should be expressed will be discussed in section 4.2.

2.1. Congestion

Congestion in road traffic, caused by excessive demand for road transport within a limited road capacity, gives rise to increases in travel time. Congestion costs consist of internal (i.e. private) and external components. Private congestion costs are the increasing time and operating costs experienced by a driver when approaching (or exceeding) the capacity of a road. External congestion costs are those costs experienced by all other travellers due to the entrance of this driver in the road. These costs are usually ignored by transport users and hence decrease social welfare.

Formally, congestion cost is the product of the inverse of travelling speed, which corresponds to congestion levels, and the Value of Time (VOT), or Value of Travel Time Savings (VTTS), which assigns a monetary value to the time lost by passengers in congestion.[1] Concerning VOT (or VTTS), there is a large literature with estimations of its value. VOT varies greatly depending on the purpose of a trip (business, commuting or leisure-time trip), the road type and the transport mode. Usually, VOT for business trips may be higher than the average hourly wage in a country, whereas VOT for other trip types is typically lower. As for the VOT of freight transport, this depends on transportation costs of firms and the importance of delays in their reliability and customer satisfaction. The Handbook offers a summary of European VOT assessments; on the basis of these, Table 1 shows the VOT values used for Cyprus, calculated on the basis of the EU average and an adjustment to the per capita GDP of Cyprus. Although our focus is on cars and urban areas, this table also offers VOT values for trucks and non-urban areas for comparative purposes.

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[1] More specifically, marginal external congestion costs, i.e. the derivative of average costs with respect to traffic volume, can be calculated with the following formula:

$$MEC_{congestion} = \left(Q_{pass} \cdot VOT_{pass} \cdot OCC + Q_{freight} \cdot VOT_{freight} \cdot LF\right) \cdot \frac{1}{v^2(Q)} \cdot \frac{\partial v}{\partial Q}$$

where Q_{pass} and $Q_{freight}$ is traffic volume of passenger cars and trucks respectively (in vehicles per hour), VOT_{pass} and $VOT_{freight}$ is the value of time when travelling by car and truck respectively (in Euros per passenger per hour and Euros per ton per hour), *OCC* is the occupancy rate of vehicles (number of passengers per vehicle), *LF* is the load factor of trucks (in tons transported per vehicle) and v is the travelling speed (in kilometres per hour).

TABLE 1

Values of time in road traffic in the case of Cyprus

Passenger traffic (Euros'2007 per passenger per hour)	
Urban roads	
Business trips	23.5
Commuting	8.9
Leisure	7.4
Rural roads	9.4
Motorways	
Business trips	23.5
Commuting	10.8
Leisure	9.0
Freight traffic (Euros'2007 per ton transported per hour)	
All road types	2.95

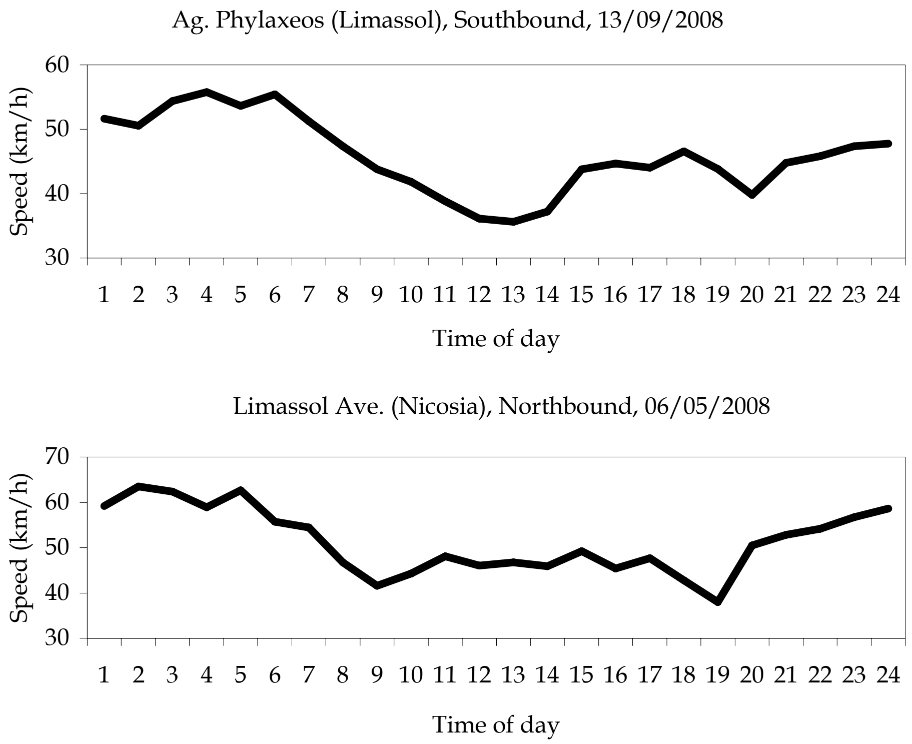
The other important factor for the calculation of congestion costs is the relationship between travelling speed and traffic load. Obviously, this relationship depends critically on the particular area under study, as well as on the type of road and the time of day. It is therefore crucial to use local traffic data in order to derive the speed-traffic flow relationship.

Measurements of traffic load, especially in urban areas, are regularly conducted by Cypriot governmental authorities such as the Public Works Department. However, there is very limited information on driving speed in cities – as opposed to speed measurements with automatic counters in motorways, which are now routinely carried out. Recently, however, such measurements in urban roads have been conducted in the framework of a study conducted for the Cypriot Department of Labour Inspection, which is the authority responsible for air pollution abatement (DLI, 2008). Since road transport is a major source of air pollution in cities, and air pollution critically depends on congestion, the study included speed measurements in several roads of Nicosia and Limassol with the aid of automatic devices installed on the road surface. Figure 2 displays two examples of such daily measurements, showing the evolution of instant speed (averaged in one-hour intervals) during typical workdays. What is more important in our case is the speed-traffic flow relationship, which is illustrated for two roads in Figure 3; it is evident that speed measurements reveal a non-linear inverse relationship between speed and traffic load, which can be approximated by a second degree polynomial function.

Based on several available measurements of this kind, speed-flow relationships were derived for three typical urban roads of Cyprus (major avenues, roads with medium traffic load and smaller streets). Assuming the share of vehicle-kilometres travelled in each one of these roads, the share of trips by purpose (business, commuting and leisure) and the share of trucks in daily traffic (on the basis of estimates from the above mentioned DLI study), it was possible to calculate marginal external congestion costs for each hour of a typical workday in Cypriot cities. These are shown in Table 2, which displays separately the cost (caused by an additional kilometre driven by a car) because of a marginal increase in congestion for cars and trucks. It is evident that during peak traffic hours (early in the morning and early in the afternoon) these costs may even exceed 1 Euro per kilometre, which is a pretty high (but not unusual for European standards) cost value, whereas at night time costs drop to almost zero. Although the urban traffic load is also high during late afternoon hours (17-18), costs are relatively lower during that time because a higher fraction of those trips are non-business trips, therefore a lower value of time has to be assigned to them.

FIGURE 2

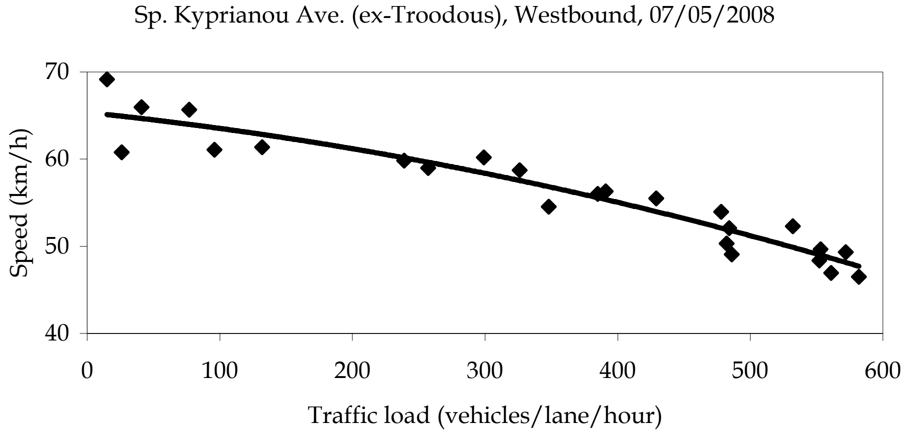
Evolution of driving speed over a typical workday in two urban roads

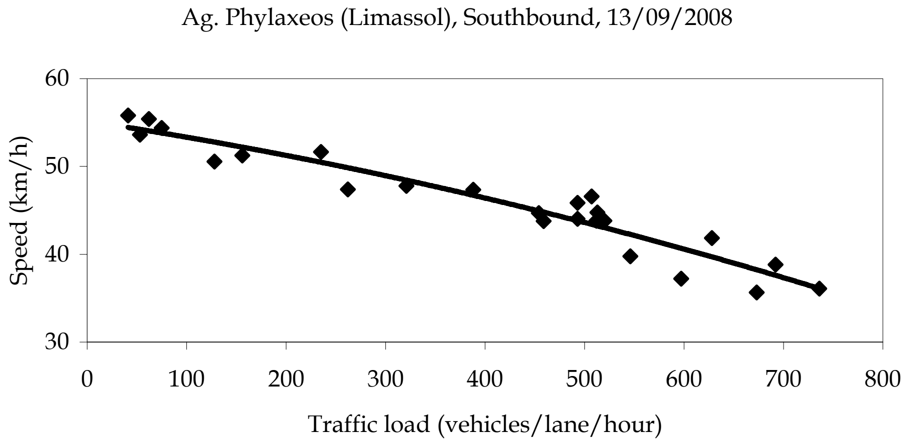


Source: DLI data

FIGURE 3

Relationship between speed and traffic load on a typical workday in two urban roads





Note: Points correspond to actual on-road measurements and curves correspond to quadratic trend lines.

Source: DLI data.

TABLE 2

Marginal external costs of congestion (Euros 2007 per vehicle-kilometre) due to car travel in urban roads of Cyprus

Time of day	Average-cars	Average-trucks	Weighted average (cars + trucks)
00 - 01	0.029	0.011	0.026
01 - 02	0.014	0.006	0.013
02 - 03	0.008	0.003	0.007
03 - 04	0.008	0.003	0.007
04 - 05	0.006	0.002	0.005
05 - 06	0.015	0.004	0.013
06 - 07	0.197	0.049	0.175
07 - 08	1.441	0.359	1.279
08 - 09	1.452	0.325	1.283
09 - 10	0.578	0.118	0.509
10 - 11	0.621	0.117	0.545
11 - 12	0.549	0.104	0.482
12 - 13	0.743	0.141	0.652
13 - 14	0.978	0.201	0.862
14 - 15	1.015	0.228	0.897
15 - 16	1.181	0.265	1.044
16 - 17	0.715	0.182	0.635
17 - 18	0.914	0.234	0.812
18 - 19	0.723	0.186	0.642
19 - 20	0.359	0.107	0.321
20 - 21	0.195	0.064	0.175
21 - 22	0.090	0.032	0.082
22 - 23	0.044	0.018	0.040
23 - 00	0.046	0.018	0.042

2.2. Accidents

External accident costs of traffic accidents are those social costs which are not covered by car insurance programmes. According to the Handbook, major accident cost categories are material damages, administrative costs, medical costs, production losses and the so called risk-value as a proxy to estimate pain, grief and suffering caused by traffic accidents in monetary values. It is mainly the latter category that is not covered properly by private insurance systems. The most important cost drivers in road transport are, besides vehicle kilometres, vehicle speed, type of road, drivers' characteristics (such as driving behaviour, experience, speeding), time of day and interaction with weather conditions. Road-specific characteristics such as the maintenance level or the level of segregation between road lanes play also an important rule, together with vehicle-specific safety characteristics.

In order to assign monetary values to accident fatalities and casualties, the value of casualties avoided or the value of a statistical life (VSL) has to be assessed. It has to be underlined that VSL is not the value of an individual life – neither in ethical nor in technical terms; it simply expresses the aggregate amount that a group of individuals is willing to pay in order to reduce their mortality risk by a specific small amount (Stavins, 2007). As regards VSL, diverse empirical estimates have been produced up to now depending on the country and the applied methodology – see e.g. the meta-analysis of de Blaeij (2003).

Although several studies have been conducted in Europe trying to assess accident externalities, it is difficult to transfer the results from one country or region to another because of different characteristics of road infrastructure and traffic patterns. Moreover, it is not straightforward to derive a simple relationship between, for instance, accident risk and traffic characteristics; for example, in congested roads the probability of an accident is higher, but the severity of the accident may be smaller because of low driving speeds, whereas in empty roads an accident is less likely to happen, but if it happens it may be much more severe. Therefore, and in view of very limited availability of appropriate accident data in Cyprus, the external costs provided for Cyprus in the Handbook were used for this study; these values are shown in Table 3. The costs for each vehicle type and each road type differ depending on the probability of having an accident and the severity of a possible accident; costs are highest in urban roads because, per kilometre driven, an accident is more likely to happen, while the costs are much higher for motorcycles than for cars because cyclists are faced with a higher probability of a serious injury once an accident happens. Note that only the externalities caused by passenger cars in urban roads are of interest for this study; figures for trucks and motorcycles and for non-urban roads are presented for comparative purposes only.

TABLE 3

Marginal external costs of accidents (Eurocents 2007 per vehicle kilometre)

Vehicle type	Urban roads	Motorways	Other roads
Passenger cars	5.84	0.41	2.22
Trucks	14.87	0.41	3.75
Motorcycles	42.95	0.28	7.65

2.3. Noise

Traffic noise can cause several adverse impacts on population exposed to it. All related costs can be regarded as external because drivers themselves take potential noise-related inconvenience into account before deciding whether to use their car or not. It is generally accepted that excessive noise can cause annoyance or discomfort, e.g. regarding sleep quality, but most importantly it can give rise to health effects such as hearing impairment, nervous stress and increased blood pressure. In order to reflect the physiological response of human ears, noise is measured in decibels (dB), whose scale is logarithmic. Therefore, the marginal effect of noise is much more pronounced at low traffic levels than during congested traffic: assuming a constant speed, the impact of an additional car driven in a road with a load of 100 vehicles per hour will be ten times larger than in a road with 1000 vehicles per hour. In fact, the marginal effect of noise may be less than the average effect in congested areas. This particularity may not be as significant as it seems, however, because normally there is a much larger population exposed to noise in congested areas than in locations with low traffic levels.

Marginal external costs of passenger cars due to noise will depend on the time of the day, the population exposed to that noise, the driving speed, the existing background noise levels and the condition of the vehicle (age and maintenance level). There are more than one methods for the monetary valuation of noise-related annoyance and health damage. Overall, the Handbook on transport externalities summarises previous work and provides recommended values for external costs for all EU countries. Table 4 presents these values for Cyprus (adjusted in order to be expressed at 2007 prices). There is an obvious distinction between day and night noise costs. Here again, values for vehicle types other than cars and for non-urban areas are shown for comparative purposes only.

TABLE 4

Marginal external costs of noise in Cyprus (Eurocents 2007 per vehicle-kilometre)

Vehicle type	Time of day	Urban	Suburban	Rural
Cars	Day	0.87	0.14	0.01
	Night	1.60	0.25	0.03
Motorcycles	Day	1.76	0.28	0.03
	Night	3.20	0.51	0.06
Buses	Day	4.38	0.68	0.08
	Night	7.99	1.26	0.15
Light duty trucks	Day	4.38	0.68	0.08
	Night	7.99	1.26	0.15
Heavy duty trucks	Day	8.06	1.26	0.15
	Night	14.70	2.30	0.26

Although the figures of Table 4 could not be directly derived from local traffic data, it was possible to cross-check this result with another method that can utilise some available noise measurements in Cypriot cities. In the framework of a study commissioned by the Cyprus Environment Service, measurements of noise levels were carried out in several locations of Nicosia and Limassol (MOA, 2007). These data enabled the creation of noise exposure maps, i.e. maps showing the number of people exposed to specific noise levels in each urban area, as required by EU legislation. Moreover, an earlier European study has assessed external noise costs per person exposed in each EU country, for each noise level above 50 dB(A)[2] (HEATCO, 2006). Combining the results of these two studies, an average external cost of about 1.5 Eurocents'2007 per vehicle-kilometre was found, which is in line with the cost figures of Table 4 for cars in urban areas. It is therefore reasonable to use the values of Table 4 in the calculations of this paper.

2.4. Air pollution

Air pollution is caused by the emission of pollutants such as sulphur dioxide (SO_2), nitrogen oxides (NOx), volatile organic compounds (VOC) and particulate matter (PM). In urban areas, road traffic is usually the largest source of such emissions. Adverse impacts comprise damages in

[2] dB(A) is the usual noise unit (decibels), adjusted in order to account relatively more for those frequencies that the human ear is more sensitive to. Moreover, noise levels during day, evening and night are weighted differently so as to account for the additional disturbance caused by evening and night-time noise.

buildings and materials, crop losses and degradation of ecosystems. The most important damages from air pollution, however, are those on human health due to the inhalation of polluted air; these include, among others, cancer, cardiopulmonary diseases, bronchitis and asthma. All pollution costs from road transport are external because road users are not charged for polluting while travelling.

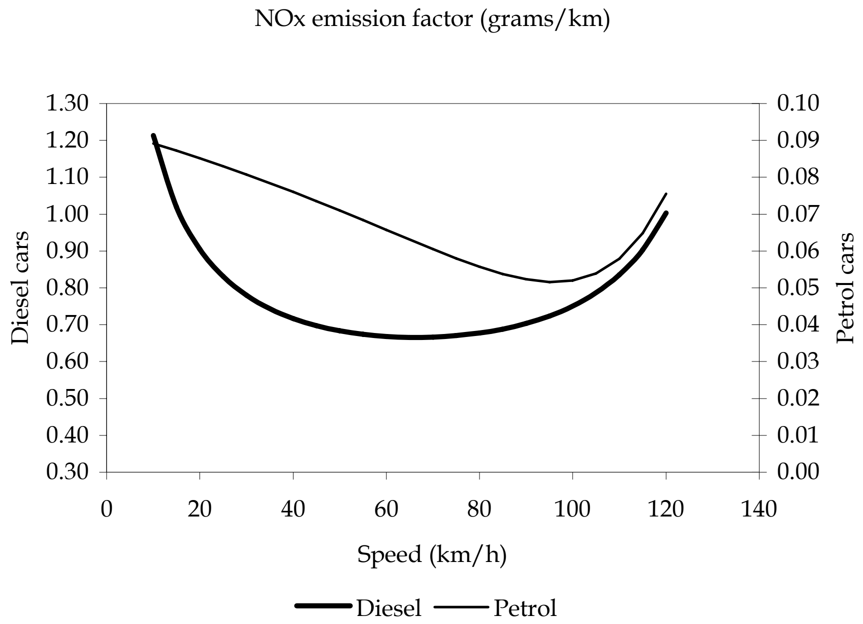
A sophisticated methodology, called ExternE, has been developed in order to assess externalities related to energy production and use (Bickel and Friedrich, 2005). As regards air pollution, the first step in this methodology is to determine pollutant emissions. Then air quality models are employed in order to calculate how these emissions are dispersed and chemically transformed in the atmosphere. The next step involves applying dose-response functions, which have been derived from epidemiological studies, in order to determine how much human health deteriorates as a function of increased concentrations of pollutants in ambient air. Finally, monetary valuation techniques are employed so as to translate physiological health impacts to monetary costs. The whole methodological approach is described in some detail in the Handbook on transport externalities.

In the case of Cyprus, we made use of data on the number, age and technological level of road vehicles as well as data on local traffic conditions in the large cities of Nicosia and Limassol in order to calculate pollutant emissions of passenger cars. Taking into account the mean driving speed for each hour of a typical workday (as described in section 2.1) and the share of cars by age and fuel type (as provided by the Cypriot Road transport Department), it is possible to assess the weighted average emissions of each pollutant per kilometre driven; for this purpose we applied the 'Copert 4' methodology, which is the state-of-the-art approach used for vehicle emissions calculation in Europe (Ntziachristos and Kouridis, 2007). Figure 4 illustrates an example of the sensitivity of emissions on driving speed and vehicle technology. This information was combined with external cost data available in the Handbook specifically for Cyprus, which are shown in Table 5. Since these data have been derived from numerous applications of the ExternE methodology around Europe, the cost figures provided for Cyprus have to be regarded as quite reliable – taking into account the uncertainties that are always associated with such approaches. The figures of Table 5 are quite low in comparison to those of other European countries; this should be attributed to the relatively small urban population (and low population density) in Cyprus, which means that relatively fewer people are exposed to urban air pollution.

Table 6 provides the resulting estimates of marginal air pollution costs of car use in Cypriot cities. Costs differ for each hour, reflecting different driving speeds, but this variation is quite small because particulate matter, which dominates the pollution costs, is less sensitive to average driving speed than other pollutants. In any case, costs do not exceed 0.5 Eurocents per vehicle-kilometre; this relatively low cost is a direct result of the low costs per ton of pollutant reported in Table 5.

FIGURE 4

Emissions of nitrogen oxides for petrol and diesel powered cars of engine size less than 2 litres and 'Euro III' technology (i.e. manufactured between years 2000 and 2005) as a function of driving speed



Source: Copert 4 methodology (Ntziachristos and Kouridis, 2007).

TABLE 5

Pollutant-specific costs of air pollution in Cyprus (Euros 2007 per ton of pollutant)

Pollutant	Costs
Nitrogen oxides (NOx)	575
Non-methane volatile organic compounds (NMVOC)	345
Sulphur dioxide (SO_2)	2300
Particulate matter (PM), urban areas	90504
Particulate matter (PM), non-urban areas	23690

TABLE 6

Marginal external costs of air pollution (Eurocents 2007 per vehicle kilometre), for each one of the four main pollutants

Time of day	NOx	NMVOC	SO_2	PM	Total
00 - 01	0.062	0.002	0.002	0.355	0.421
08 - 09	0.069	0.003	0.002	0.396	0.470
15 - 16	0.074	0.003	0.003	0.419	0.499
18 - 19	0.071	0.003	0.003	0.408	0.485
21 - 22	0.066	0.003	0.002	0.376	0.446

2.5. Emissions of greenhouse gases

Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are the major gases whose existence in the atmosphere causes climate change through the so called greenhouse effect. Climate change is a global externality with dynamic characteristics: the impact of greenhouse gases is the same regardless of where on earth they are emitted, and since these gases are chemically stable in the atmosphere they are accumulated over the years, hence their impact is getting worse over time. This means that, since emissions have been rising steadily in the past decades, their external costs have also been increasing. Transportation is currently responsible for 21% of greenhouse gas emissions in Europe, and this share is continuously rising; over 90% of these emissions come from cars and trucks (EEA, 2007).

To assess the externalities of car travel due to these emissions, an approach similar to that on air pollution is followed: first emissions per kilometre for each one of the three gases are calculated on the basis of the 'Copert 4' methodology, and then they are translated to monetary costs through multiplication with the marginal costs per ton of greenhouse gas emitted. To estimate the latter, one has to assess either the cost of the damages caused by an additional ton of greenhouse gas emitted now, or the cost of avoiding the emission of an additional ton of these gases. Damage costs of climate change (due to impacts such as sea level rise, water shortages, effects on human health, loss in agricultural production etc.) are particularly difficult to assess because of the large uncertainties associated with their magnitude. Avoidance costs may be a less comprehensive approach but may provide reasonable results in a region like Europe, where explicit emission reduction targets have been set out. For several reasons, outlined in detail in the Handbook[3], the latter approach is adopted for short-term cost estimates, and a marginal cost of 25 Euros per ton of CO_2 is used[4].

The resulting total costs are shown in Table 7. CO_2 is the main greenhouse gas emitted and is responsible for more than 95% of total emissions. As in the case of other externalities, costs are higher during congested periods of the day because fuel consumption is higher during these periods and CO_2 is proportional to fuel consumption.

TABLE 7

Marginal external costs from greenhouse gas emissions of cars (Eurocents 2007 per vehicle kilometre)

Time of day	All greenhouse gases
00 - 01	0.459
08 - 09	0.533
15 - 16	0.589
18 - 19	0.561
21 - 22	0.496

Although Table 7 provides cost figures per vehicle-kilometre, which is the same unit as that used for other externalities, in fact CO_2 emissions depend directly on the amount of fuel consumed: for each litre of petrol burnt in a vehicle, 2.37 kilograms of CO_2 are released to the atmosphere, and for each litre of diesel 2.66 kilograms are released. Taking also into account the greenhouse gases emitted during the production and the distribution of petrol and diesel, these figures become 2.76 and 3.12 respectively (EC, 2007). This leads to a marginal external cost of 6.9 Eurocents per litre of petrol and 7.8 Eurocents per litre of diesel respectively. The policy implications of charging for the climate externality per kilometre or per litre are discussed in section 4.

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[3] See pp. 73-87 and Annex F.

[4] In order to sum up the emissions of all greenhouse gases, these are expressed in 'tons of equivalent CO_2', taking into account the potential of each gas to contribute to global warming. For example, a ton of methane and a ton of nitrous oxide are equivalent to 25 and 298 tons of CO_2 respectively as regards their global warming potential over a period of 100 years (Forster et al., 2007). In accordance with this definition, marginal costs are expressed in Euros per ton of equivalent CO_2.

2.6. Other effects

Apart from the main externalities addressed in sections 2.1 to 2.5, there are additional adverse effects of transportation that have not been analysed at much detail up to now. Examples of such impacts are: pollution of soil and water due to the emissions of toxic substances; the additional emissions of air pollutants and greenhouse gases during the process of fuel production and distribution; increased dependency on imported energy; and other impacts in urban areas such as scarcity of space available to pedestrians and cyclists due to the development of road infrastructure. The Handbook on transport externalities summarises the scarce available data and provides cost estimates. Table 8 presents an assessment of these costs for the case of car use in urban areas of Cyprus.

TABLE 8

Marginal external costs due to other effects not addressed in sections 2.1-2.5 (Eurocents 2007 per vehicle kilometre)

Type of externality	Costs
Emissions of air pollutants & greenhouse gases during fuel production and distribution	0.80
Soil & water pollution	0.06
Increased energy dependency	0.40
Other impacts in urban areas	0.26
Total 'other costs'	1.52

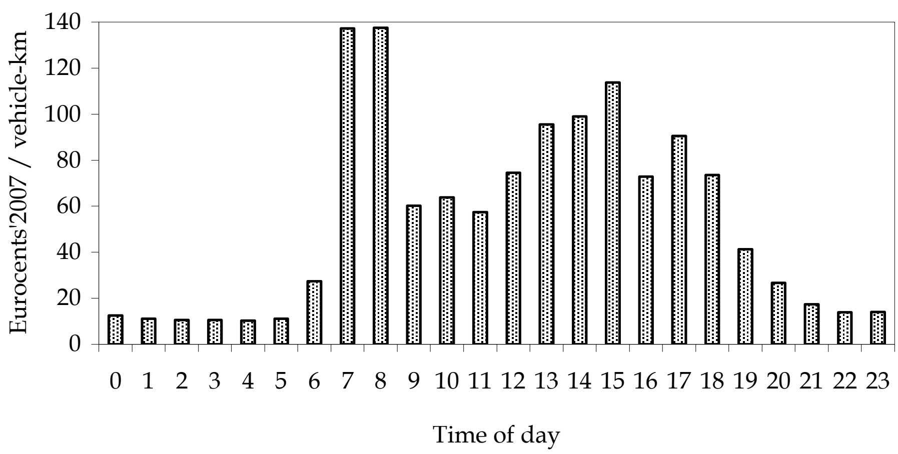
2.7. Total marginal external costs

Adding up the individual cost items calculated in sections 2.1 to 2.6, it is possible to compute the total marginal external costs due to the use of cars in urban areas. As a large part of these costs varies with traffic conditions, Figure 5 displays the evolution of these costs per hour throughout a typical workday. It turns out that estimated costs range between 10 cents per kilometre up to 1.37 Euros per kilometre. Evidently traffic patterns over the day play a dominant role in determining total externalities; this is further shown in Figure 6, which illustrates these costs in selected hours of a day for each type of externality. Congestion accounts for 70–90 percent of total costs during morning, afternoon and evening hours, and becomes negligible only late at night when accident costs become more important and noise costs increase modestly. Noise and 'other' impacts generate relatively low costs (less than two cents per kilometre), whereas costs associated with air pollution and climate change are almost equal and remain below one cent per kilometre throughout the day. Policy implications of these calculations will be discussed in section 4.

Cost estimates are generally in line with those from other European cities of similar size to Cypriot cities[5], which is expected because common methodologies are applied and Cyprus has a per capita GDP close to the EU average. For example, in UK cities marginal external congestion costs have been estimated at 1.44 Euros per kilometre in major streets in peak hours, and at 0.78 Euros per kilometre in off-peak hours; another UK study shows costs in individual cities ranging from 0.19 to 7.73 Euros per kilometre – all at prices of year 2005. Congestion costs have been calculated at 2.5 Euros per trip in Stockholm.[6] Central estimates for accident externalities of cars in urban roads in the EU vary from 1.14 Eurocents per kilometre in Romania to 6.69 Eurocents per kilometre in France – at 2000 prices. Costs from air pollution caused by particulate matter in urban (but not metropolitan) areas range from 13,800 Euros per ton of pollutant in Bulgaria to 216,200 Euros per ton in Luxembourg. It is evident that these cost values are similar with the corresponding ones used for Cyprus in this paper (see Tables 2, 3 and 5 respectively).

FIGURE 5

Marginal external costs due to the use of cars in urban areas of Cyprus and their hourly variation during a typical workday



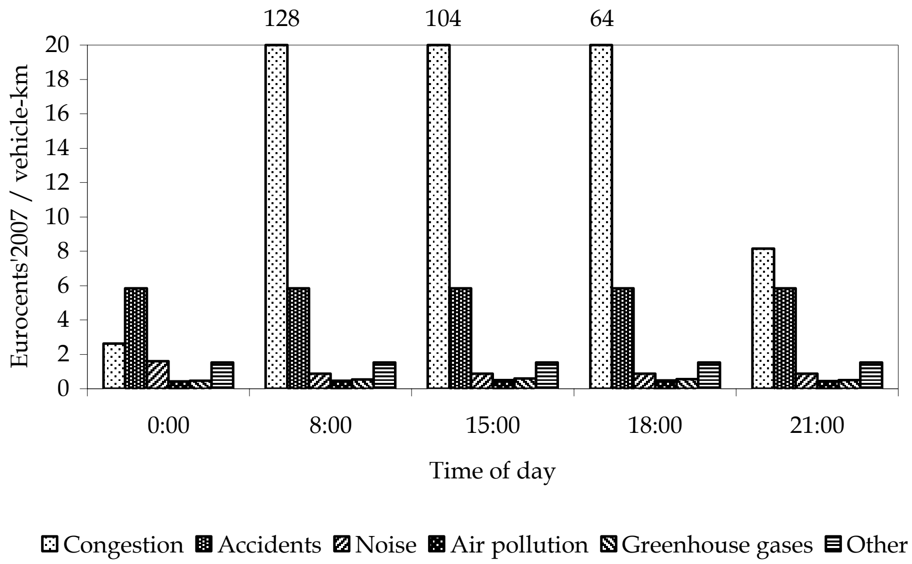
Source: Own Calculations.

[5] See Handbook (CE Delft 2007), particularly pp. 102–106 and Annex B.

[6] See Handbook (CE Delft 2007), pp. 152–153.

FIGURE 6

Marginal external costs due to the use of cars in urban areas of Cyprus during hours of peak and off-peak traffic, by type of externality



Source: Own Calculations.

3. Comparison with private transport costs

As explained in the beginning of this paper, external costs are those caused by car users but not borne by them. It is therefore useful to compare the externalities, as calculated in the previous section, with the marginal private costs that car users are faced with when deciding to use a car for their transport needs.

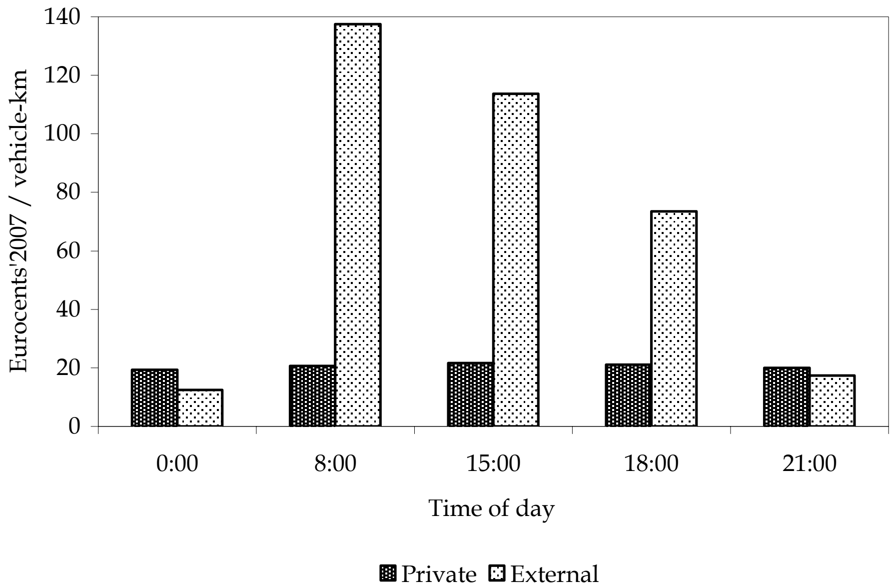
Private costs consist of the following:

- Fixed vehicle ownership and operation costs (purchase costs, registration and circulation taxes, value added tax, insurance fees)
- Variable operation and maintenance costs
- Fuel costs
- Time costs because of the time lost in congestion by the car traveller himself

The first cost category, although very significant, is not of interest here because these costs are fixed over a whole year and do not depend on kilometres driven; therefore they do not belong to marginal costs of car use. Estimates of variable operation and maintenance costs range from 5 to 15 cents per kilometre (see e.g. data from the European TREMOVE model – de Ceuster et al., 2007); the EU average for year 2005 is estimated at about 12 cents per kilometre, hence this is the value assumed for the case of Cyprus. Congestion costs are calculated as in the case of externalities (see section 2.1), but they only consist of the cost borne by the individuals using the car. Fuel costs are computed assuming a fuel price (for both petrol and diesel fuel) of 1 Euro per litre and applying the 'Copert 4' methodology to calculate fuel consumption. As a result, Figure 7 presents private marginal costs in different hours of the day and compares them with external costs: During peak traffic hours, external costs become six to seven times higher than private costs. This finding highlights again the importance of assessing and tackling externalities in urban car transport.

FIGURE 7

Comparison between private and external costs due to the use of cars in Cypriot urban areas



Source: Own Calculations.

4. Efficient pricing for urban car travellers in Cyprus and further policy considerations

4.1. An estimate of efficient car charges

As already mentioned in the introductory section, marginal external costs do not correspond to the 'optimal' price that car users have to pay in order to internalise all externalities, because transport demand will decrease in response to such a price until equilibrium is reached. In theory, the equilibrium solution will be the economically efficient one. In order to define the optimal solution one needs to know the transport demand curve as well as the curves for private and external costs. Although external and private cost functions have been approximated through the calculations shown in sections 2 and 3 respectively, there is hardly any information available in Cyprus to build a credible function of demand for urban car travel.

At the current situation in Cypriot cities, almost no alternatives to private car use are available; public transport is very limited due to the small number of buses and the infrequency of bus routes[7]. Therefore, it is clear that transport demand will be inelastic to price changes: the price elasticity cannot be expected to exceed 0.2 in absolute terms, particularly for short-term analyses, which means that the demand curve of Figure 1 will be steeply decreasing. It is therefore reasonable to assume that the 'optimal' price that internalises car externalities will be somewhat lower than the marginal external cost. Assuming a price at 80% of the calculated marginal externality, Table 9 provides the estimated 'efficient' price that car travellers in Cypriot cities have to be faced with if all externalities are charged per kilometre travelled. In other words, Table 9 provides an approximation of the level of a Pigouvian tax required to tackle all car externalities. These charges, which could be applied e.g. by installing road pricing schemes in urban areas, are evidently pretty high during peak traffic (in early morning and early afternoon). Assuming an average distance of 5 kilometres travelled in each urban trip, this price would amount to a charge of approximately 5 Euros per trip during peak hours and 50 cents per trip in off-peak hours. If this charge were applied on fuel prices, allowing for a different fuel price depending on traffic conditions,

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[7] According to official statistics, the total number of passengers has decreased by 50% since the early 1990s. A passenger mobility survey, carried out by the Statistical Service for the first time in year 2007, reports that only 1.8% of all trips and 2.7% of total passenger kilometers were travelled by public buses throughout Cyprus (CYSTAT, 2008).

and assuming an average fuel consumption of 1 litre per kilometre in urban areas, fuel prices would have to increase by 10 to 100 cents per litre depending on the time of the day. Section 4.2 below discusses the appropriateness of different types of charges.

When reading these cost estimates one has to keep in mind that they are associated with large uncertainties. Efficient transport prices can vary by at least a factor of two depending on the calculation method and the assumptions made. Instead of providing possible ranges for each number shown in Tables 1 to 8, it was preferred to show the central estimates only, thereby providing an estimate of the order of magnitude of different costs.

TABLE 9

Estimates of 'efficient' charges (in Eurocents 2007 per vehicle kilometre) for car travellers in Cypriot cities depending on the time of the day

Time of day	Price
00 - 01	10
08 - 09	110
15 - 16	91
18 - 19	59
21 - 22	14

4.2. Efficient prices per kilometre or per litre?

When considering alternative policy measures to internalise car externalities, one has to consider how each externality is generated in the first place. Congestion, accidents and noise are associated with the use of cars, i.e. with the number of kilometres travelled, and not with how much fuel they consume; hence it would not be appropriate to tackle these externalities by imposing an additional fuel tax – unless gas guzzlers are driven more than fuel efficient cars, but there is no evidence for that. The same holds for air pollution externalities: although one would expect that cars emit more pollutants for each litre of fuel consumed, this is not necessarily the case. Regulatory standards for vehicle emissions are expressed in grams of pollutant per kilometre driven; this forces auto manufacturers to adjust the emission performance of their vehicles in order to comply with these requirements. It is therefore appropriate to charge air pollution related externalities per kilometre. As regards climate change, however, the externality is associated directly with the amount of fuel burned when driving a car, and hence the appropriate approach would be a charge per litre of fuel in this case (which would be a little higher for diesel fuel than for petrol). The same can be said about 'other' externalities, which are dominated by the costs of energy dependence and the environmental impact of fuel production (see Table 8); both are associated with the quantities of fuel consumed.

4.3. Differentiating charges by car type

The external cost estimates of section 2 are meant to be weighted average figures for passenger cars circulating in Cypriot cities and have been derived by computing externalities for each main car category (different engine sizes, fuels and technologies). These averages, however, conceal important differences between individual categories. In the case of air pollution, for example, modern cars emit several times fewer pollutants than their 15-year-old counterparts (and cause much lower external costs) thanks to stringent emission regulations and technological breakthroughs. Differences are much less pronounced in the case of greenhouse gas emissions. Table 10 illustrates as an example marginal air pollution costs for vehicles of different technologies.

In view of these large differences, an efficient charging scheme to tackle air pollution externalities of cars would have to differentiate per kilometre charges according to a car's engine size and technological level. Since this might entail too high administrative costs, an alternative policy would be to apply a uniform per kilometre charge and differentiate annual vehicle circulation taxes depending on a car's pollution abatement technology. Although the latter approach would not account for the real external costs of each car category, it would still encourage the renewal of the vehicle stock.[8]

Evidently, the differences outlined here are not large enough to change the overall picture depicted in Figure 5: even for older cars, congestion and accident externalities still dominate. If, however, in addition to economic efficiency other policy priorities are at play – such as compliance with air quality regulations – then these differentiated charges might be justified.

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[8] As a side remark, Table 10 illustrates that a scheme offering car owners incentives to scrap their old cars (such as the one currently applied in Cyprus) can be very effective in reducing pollutant emissions and pollution externalities.

TABLE 10

Marginal external costs of air pollution for different vehicle types depending on fuel used and technological level (Eurocents 2007 per vehicle kilometre) [1]

Year of manufacture	Petrol cars	Diesel cars
Pre-1993	0.90	2.40
1993-1995 (Euro I)	0.75	1.00
1996-1999 (Euro II)	0.30	0.90
2000-2004 (Euro III)	0.10	0.75
2005-2008 (Euro IV)	0.05	0.40

Note: [1] Figures refer to cars with engine capacity between 1.4 and 2.0 litres. Labels 'Euro I' – 'Euro IV' refer to regulatory requirements for car emissions under EU legislation.

4.4. Multiple policy criteria

Although the focus of this paper is on economically efficient policies to reduce the externalities of car use, efficiency is not necessarily the only criterion for policy design. For example, policy makers have to consider other EU regulations concerning atmospheric pollution or noise reduction; even if these regulations impose too high costs from the point of view of economic efficiency, they nevertheless have to be respected unless a country is prepared to face penalties for non-compliance. This means that policy measures aimed at road traffic will have to be designed so as to fulfil multiple criteria, efficiency being just one of them.

Another significant aspect is the well-known possibility of trade-offs between efficiency and equity. Official Family Expenditure Surveys in Cyprus reveal that expenditures for automotive fuels (as a percentage of income) are roughly constant across all income groups. This implies that an additional fuel tax intended to address car externalities would disproportionately hurt low-income households. Although there are feasible measures to compensate parts of the population for these additional expenditures (e.g. through rebates or reductions in other taxes), this example shows that efficiency considerations cannot be the only guide for policy makers, and the policy process is much more complicated than economic textbook examples.[9]

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[9] A report of OECD's International Transport Forum includes a very useful discussion on different policy priorities in the transport sector (ITF, 2008, especially pp. 7–16).

4.5. Feasibility and appropriateness

Let us assume for a moment that economic efficiency is the sole criterion in designing transport policy and that car travel is charged according to the guidelines provided in sections 4.1 to 4.3. This would imply that a road pricing scheme is established to address congestion, accident, noise and air pollution costs, charging 5 Euros per trip during early morning traffic, 4 Euros per trip in early afternoon and lower amounts during other hours of the day; and another 6 cents are charged per litre of fuel sold in order to account for externalities related to greenhouse gas emissions and other environmental effects. Would this be an appropriate policy to control car externalities?

Based on the European experience of road pricing systems[10], administrative costs of such pricing schemes are usually lower than the benefits from the avoided external costs. However, this is not a sufficient evaluation criterion. A common feature of road pricing schemes is that they are implemented in cities with well-functioning public transport modes. Before enforcing such a charging scheme, national and local authorities want to make sure that passengers have a wide range of reliable alternatives addressing their transportation needs. This is currently not the case in Cyprus, with negligible public transport, and this is the reason why the price elasticity of transport demand is very low: in the absence of alternative options, city travellers adhere to cars regardless of the costs associated with car use. If a road pricing scheme is implemented in Cypriot cities, it will be equivalent to a new tax which car users cannot avoid. The appropriate approach would be to create as a first step a modern and reliable public transport system, which would offer real alternatives to passengers and thus would change the slope of the demand curve. After this step has been taken and public transportation is well established, policy makers may impose a road charging scheme that would boost the efficiency of the whole transport system.

Considering the long-term sustainability of urban transportation systems, promoting public transport is not only an effective but also an economically efficient approach: it can reduce external costs of car use in

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[10] See information on the website http://www.transport-pricing.net, and links contained therein. See also relevant information and links on the Wikipedia: http://en.wikipedia.org/wiki/Road_pricing

virtually all externality categories described in section 2[11] and in the future it may halt to some extent the ever increasing urban traffic levels. At the same time the public, after decades of being almost entirely dependent on private cars, will gradually get accustomed to using public transport modes. These will become an obvious transport option particularly for young generations, which can change the everyday transport behaviour of all citizens in the long term. Evidently public transport by itself cannot decrease external costs down to their 'optimal' level, but it can contribute significantly towards this objective. The alternative to promoting public transportation, i.e. letting things continue as they currently are and enforcing additional charges on fuels and car use, will certainly not be the environmentally and economically optimal policy option.

Even with a well functioning public transport system, transport demand may remain inelastic to some extent because of persistent travelling habits and the convenience offered to individuals by private car travel. Hence, apart from keeping costs of public transport at low levels for passengers, complementary measures have to be considered, which will tend to increase the costs borne by car users. Such measures could include, inter alia, higher parking fees in city centres and encouragement of car pooling and 'park and ride' schemes by applying extra fines to cars travelling with only one person in a city. By imposing relatively high costs on the individual use of private cars and allowing low costs for public transport users it may be possible to reduce urban transport externalities considerably, without the need of expensive road pricing schemes in the first place. After some first improvements have been attained and the public has familiarised themselves with both the image of a well functioning public transportation system and the high costs of car use, implementing a road pricing scheme might be a meaningful and effective instrument for further improvements in traffic related externalities: it would strengthen the incentives for using public transport and would be able to finance some of the additional public transport infrastructure investments required.

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[11] The externalities Handbook shows comparisons between passenger cars, buses and passenger trains, where external costs of trains and buses are several times lower than those of cars (CE Delft, 2007, pp. 112–113 & 209).

5. Conclusions

This paper has attempted to assess the marginal external costs from car use in urban areas of Cyprus; these are the social costs generated by the use of passenger cars other than those paid (directly or indirectly) by car travellers themselves. On the basis of a European methodology and very recent local traffic data, costs were computed for externalities such as congestion, accidents, noise, air pollution, emissions of greenhouse gases and other social impacts. Not surprisingly, the results are in line with cost calculations for other European cities of similar size with Cypriot cities. Congestion represents the highest part of these costs during most hours of the day, exceeding one Euro per kilometre during morning peak traffic. In night time accident costs prevail. Noise and 'other' impacts generate relatively low costs (less than two cents per kilometre), whereas costs associated with air pollution and climate change are almost equal and remain below one cent per kilometre throughout the day. The paper calculated also private marginal costs, i.e. those borne by car users themselves. It turned out that external costs may be six to seven times higher than private costs during peak traffic hours; only in late evening and at night are private and external costs almost equal.

As a result of the calculations of marginal external costs, the paper made a rough approximation of the optimal price that car users would have to pay in order to reach an economically efficient equilibrium between transport demand and supply. The estimated 'efficient' prices (equivalent to a Pigouvian tax on externalities) range from about one Euro per kilometre in peak traffic hours to ten cents per kilometre at night. At an average urban trip length of five kilometres, efficiency might be obtained if car travel in cities were charged with five Euros per trip in peak hours and much lower (down to fifty cents per trip) in off-peak traffic.

The existence of high marginal social costs that are not paid by anyone indicates the need for policy interventions in the transport sector. Section 4 of this paper has outlined some related policy aspects. First, efficiency would require that some externalities (congestion, accidents, noise, air pollution) are addressed by charging per kilometre driven while some others (greenhouse gas emissions and other miscellaneous environmental impacts) are tackled through an extra charge per litre of fuel. Second, such prices are only a weighted average of different impacts of individual car types; efficient pricing would involve differentiated charges to vehicle categories according to their technological level and the fuel they use. Third, efficiency is not necessarily the only criterion for policy design: other priorities such as equity or compliance with EU environmental standards are also at play, so that one should be cautious when recommending policy instruments directed at achieving economic efficiency alone.

Finally, even when considering efficiency only, the most appropriate first step would be the development of a modern and reliable public transportation system in Cypriot cities, along with complementary measures that would discourage the use of cars. This would provide alternatives to city travellers, thereby making transport demand more elastic, and would familiarise citizens with transportation options other than private cars. Such an approach would bring about most benefits, both from an economic and an environmental point of view, in the medium term. After this initial step has been taken and public transportation is established, policy makers should consider imposing a road charging scheme that would provide stronger incentives for using public transport and would finance some of the additional public transport infrastructure investments, thereby boosting the efficiency of the whole transport system over the longer term.

The assessment presented in this paper is far from complete because it does not include externalities from the use of other vehicle types (trucks, buses and motorcycles) and it only focuses on cities, while external costs in non-urban areas are not necessarily negligible. Moreover, the analysis would benefit from the availability of more local traffic data concerning traffic conditions and accidents, and the willingness of Cypriot travellers to pay for travel time savings or improvements in noise annoyance. Still, the paper can be a useful starting point for authorities involved in the design of economic and transportation policies.

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