Pricing for Sustainable Transport

Margaret M. O'Mahony,
Director
Transport Study and Research Group
Department of Civil, Structural & Environmental Engineering
Trinity College Dublin
Dublin 2
Ireland
Tel: 353 1 6082084
Fax: 353 1 6773072
Email: mmmahony@tcd.ie

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Note: The paper is a summary of the Final Report of the **E**nergy efficiency of **U**rban **RO**ad **PR**icing **I**nvestigation in **C**apitals of **E**urope (EUROPRICE) project. The other authors of that final report include Manos Vougioukas (Eurotrans, UK), Tasos Tillis (TRENDS, Athens), Fanis Katsanis (GeoTopos, Athens) and Janos Monigl (Transman, Budapest)

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Abstract

Road use pricing is one of the traffic demand management measures seen to have the most potential in delivering a framework for sustainable transport, by its leveling of the playing field in terms of the user pays principle. Although difficulties relating to implementation and acceptability exist, road use pricing continues to be a subject of particular interest in the field of transportation at EU, national and local authority level. Clearly the potential for revenue generation is of interest but more importantly the measure addresses very well the fair and efficiency principle, where road use pricing is seen as a means of internalising, as close as practically possible, the external costs of transport.

The reduction in private transport demand is the impact to which most reference is made in the literature but there exist other potential impacts that are not as well perceived but could be just as important in the medium to longer term. Saving energy is one of the secondary impacts and this was fundamental to the objectives of the EUROPRICE project, the primary aim of which is to evaluate the impact on energy savings of road use pricing. The more specific objectives of the project were to investigate the potential for user response, to evaluate the impacts on traffic levels and finally and most importantly to assess the resulting impact on fuel consumption.

Two pilot-actions, in Dublin and Athens, involving a sample of individuals in each city served as the basis for the user response evaluation. The road use pricing regimes applied in the two cities were quite different. In Dublin, the aim was to effect a reduction in private transport demand in the peak periods whereas in Athens the objective was more closely related to the encouragement of lower car usage and the potential for air pollution reduction. Both methods have positive implications for fuel consumption.

In addition to the trials in Dublin and Athens, the EUROPRICE project (funded under the SAVE II Programme) used transport modelling to further evaluate the impact of road use pricing. Four cities were modelled in the EUROPRICE project: Dublin, London, Athens and Budapest where once again the aim was to evaluate the impact of road use pricing on fuel consumption. The impacts realised in the pilot-actions are compared with the modelling results in the case of Dublin and Athens whereas in the case of London, vehicle fuel consumption was examined more closely.

The results of the project are interesting, useful and certainly add weight to the argument that private transport demand can be reduced and energy savings realised as a result of road use pricing. Although the samples involved in the pilot-actions are relatively small, primarily due to the difficulty in finding willing individuals, the indications from the results are worthy of note and further investigation. In the case of Dublin, there was a significant reduction in peak period trips, of the order of 22%, which appeared to result from trip suppression and transfer to other modes. Less evidence was available to suggest that individuals were transferring their trips from the peak to the off-peak period. In Athens, a 48% reduction in the total number of trips made each week was evident as a result of road use pricing. In this case, there appeared to be a significant transfer of trips from weekdays to weekends (no charges were applied at weekends).

Interesting results were also generated in the modelling tests where in Dublin the energy savings realised as a result of the application of a cordon around the CBD with a charge of 3.8 euro for passing the cordon produced a 35% reduction in energy consumption in the city. In the case of Athens, the reduction in energy usage as a result of increasing the cost per kilometre travelled by 120% was a saving of 300 million litres per year. The modelling test estimates made for a range of traffic demand levels in London suggested that reductions in traffic demand during the morning peak period of 10% and 15% were possible with corresponding reductions in fuel consumption levels of 19% and 32% respectively. When cordon tolling was applied around the inner city in Budapest, fuel savings in that area decrease by 50% although the level of fuel consumed in the whole city increased marginally.

Introduction

The paper addresses the impacts of road use pricing and the potential of the measure in terms of sustainable transport. The results presented in the paper are those obtained from the **E**nergy efficiency of **U**rban **RO**ad **PR**icing **I**nvestigation in **C**apitals of **E**urope (EUROPRICE) project (O'Mahony, Geraghty, Vougioukas, Tillis, Katsanis and Monigl, 1999). The objectives of that project were as follows:

a) To assess the fuel saving potential of urban road use pricing schemes in several European capital cities.

b) To extend and refine the findings of previous SAVE projects and other relevant urban road pricing initiatives by EU member states and the European Commission.

c) To test road use charging equipment in urban areas, in terms of user response (before and after a field trial), public acceptability, interoperability and energy efficiency implications.

d) To relate energy efficiency to integrated urban transport pricing and associated demand management measures.

e) To disseminate the findings of the project.

The potential impacts on energy saving as a result of road use pricing are not usually well perceived as immediate priorities by many city authorities due to the risk involved in terms of potential lack of public acceptability. Generally, when road use pricing is under consideration for a particular site, the impact on traffic levels and congestion tend to overshadow other impacts. A complementary objective of the proposed EUROPRICE project is therefore to help overcome these institutional and administrative obstacles, by highlighting the advantages of road use pricing as an energy efficiency measure to urban authorities in Europe.

The project centres on road use pricing field trials conducted in Dublin and Athens to estimate, using samples of individuals in each of the cities, the potential for energy savings through introduction of road use pricing. In addition, other issues are examined such as the potential for impact on traffic levels and the control of excessive pollution from traffic. The critical issue to be tested is whether the measure will influence car drivers to use other modes or change their travel patterns as a result of road use charging. If positive changes in behaviour occur, a corresponding reduction in fuel consumption will ensue, due to decreased use of the car.

To supplement the two field trials, modelling tests were conducted in Dublin, London, Athens and Budapest to establish the energy savings that would accrue if road pricing were to be introduced in the four cities. Other impacts examined are traffic demand reduction.

The paper includes firstly a summary of the road use and congestion pricing methods currently available followed by the pilot-action design used in Dublin and Athens in the EUROPRICE project, the instrumentation used in the trials, the user response and modelling results and finally conclusions and future work suggestions.

Types of Road Use Pricing

Road use pricing can be applied in a variety of forms:

- **Congestion pricing**: varying charge according to traffic conditions, area and time of day (in principle the higher the congestion the higher the charge).

- **Time-based pricing**: charge being proportional to the time spent travelling within a specified area.

- **Distance-based pricing**: charge is directly related to the distance travelled within a specified area.

- **Cordon pricing**: charges are applied at points crossing a cordon (usually around the city centre); charging could be one-way (e.g. for inbound traffic only) or two-way (with differential charge levels by direction).

- **Area pricing**: charging is applied to vehicles being in a specified area at specific periods of the day.

- **Combinations of the above**.

Pilot Action Design

The basic pilot-action design, to which all sites adhered in the EUROPRICE project, is similar, in that a sample of vehicles in each site was instrumented with In-vehicle Charging Units (ICUs). The pilot-action methodology allowed for the inclusion of site-specific differences. A more detailed outline for each site is included later in this section.

Before commencing the pilot-action, the participants were interviewed to investigate the factors influencing them in their choice of transport mode, their socio-economic characteristics, where they live in relation to their work place, extra-work activities which may influence the use of their car etc.

During the first phase of the field trial in each site, the in-vehicle unit (ICU) used in the field trials logged the start time and end time of each car trip, distance travelled, time taken to do the trip and the cost of the trip. The data collected in this Phase serves as a baseline against which to measure the reactions of the individuals to road use pricing.

During the second phase where road use pricing was applied, the ICU displayed the following to the car driver:

- Charge rate
- Budget (decrementing on a real-time basis as they travel)
- Cost on a real-time basis
- Distance covered
- Time
- Date

In Dublin, during this phase the ICU again logged the same information on the trips made as in Phase 1. The data from the ICU was downloaded after the second phase and the driver was interviewed to provide qualitative information to support any changes in behaviour. These data were then used in addition to the quantitative data uploaded from the ICU unit and analysed using statistical techniques similar to those used in the SAVE I project on car metering entitled The Influence of Mode Choice on Transport Energy Savings (O'Mahony et al, 1996).

The road use charge levels applied are an important factor in influencing changes in travel behaviour. From the TRENEN II STRAN project (Proost et al, 1998) the true economic cost of the marginal external costs of transport including congestion, pollution, noise and accidents can be calculated. The calibration of Dublin conducted in the TRENEN II STRAN project was used to select the charge levels to be applied in the pilot-action in Dublin. The charging method was set up like that of a taximeter to increase understanding and acceptability. It consisted of relatively high rates for travel in the peak period but nominal rates in the offpeak period. The rates were applied as cumulative distance and time based charges.

In Athens, the same types of data were recorded in the second phase and downloaded at the end. Travel diaries were kept by all household members for the duration of the experiment which served as a basis for investigating behavioural changes. The pricing regime applied related more specifically to the severe air pollution problems experienced in Athens. The principle behind the charging method was to reward a driver if he/she had used their car sparingly. The pricing method used involved applying a relatively large charge if the vehicle was used in the morning period. Another charge was applied per km travelled. If the individual used the car on the previous day this charge per km was increased by a predetermined increment. The levels of charges were set after considering the relative prices of existing modes (taxi, bus).

Equipment

The ICU is a programmable display and data logging instrument specifically for use in logging 'trip data' and displaying road use costs in this project. The ICU used in the EUROPRICE project was designed by Geraghty and Humphreys, Mechanical Engineering Department, TCD. It is an 'in-car' instrument and in most respects is a 'one-fits-all' solution in that it can be retrofitted to almost all models of car.

The ICU can record details of a driver's car usage, such as number of trips, distance and duration of the trip, speed data relating to each trip, over an extended period (up to 3 months). In addition, it can calculate a cost for each trip according to a predetermined formula. The cost may include components related to congestion pricing as well as the conventional cost elements, such as fuel, wear and tear and depreciation. The particular pricing mechanism may, with some restrictions, be chosen by the researcher. Feedback on cost was provided to the drivers by means of a display panel on the unit.

The recorded data was stored in non-volatile memory and was uploaded to a spreadsheet package via a serial interface at any time. Windows '95 based software is provided to configure the ICU and to retrieve the experimental data.

Modelling

Modelling runs were conducted to evaluate the energy impacts of road use pricing in Dublin, London and Budapest.

Dublin (O'Mahony, Geraghty, Vougioukas, Tillis, Katsanis and Monigl, 1999)

In Dublin, four road pricing schemes were considered. An elasticity of –0.2 was used for all three tests but an elasticity of –0.5 was also used for a second run of the first test. A standardised charge of £3 (3.81 ∈) per trip was applied to all tests. For the two-cordon test, this charge was applied at each cordon.

The tests are as follows:

Test 1

- Inner cordon only
- Cordon charge £3 (3.8 ∈)
- Elasticity –0.2

Test 2

- Inner cordon only
- Cordon charge £3 (3.8 ∈)
- Elasticity –0.5

Test 3

- Inner and M50 cordons
- Cordon charge £3 (3.8 ∈) at each cordon
- Total charge of £6 (7.6 ∈) for crossing both cordons
- Elasticity –0.2

Test 4

- M50 cordon only
- Charge related to time spent travelling within cordon
- Average charge £3 (3.8 ∈)
- Elasticity –0.2

Test 1 applies a charge at the inner (canal ring) cordon and thus intercepts only those trips entering or crossing the centre of Dublin. Those trips starting in the centre of Dublin incur no charge. Out of a total of 133,378 trips within the Greater Dublin area, only 33,134 (25%) would incur the charge (£3 - 3.8 ∈). With an elasticity of – 0.2, nearly 4,000 trips are suppressed with a further 1,600 diverting around the centre.

Despite the fact that there is a 3% reduction in the number of trips, the reduction in the number of vehicle-kilometres is only 1.7%. Firstly, applying a charge at a single point has a greater effect on suppressing short distance trips passing through the point. Secondly, those trips which divert around the centre increase the number of kilometres they travel.

Test 2 applies the same charges as Test 1 but assumes a greater user responsiveness (an elasticity of – 0.5) leading to a greater level of suppression and diversion around the centre. The additional suppression results in a similar proportional change in vehicle-kilometres, delays and vehicle hours.

Test 3 shows that congestion is not just a problem in the centre of Dublin but extends to a much wider area. This test intercepts a greater proportion of the total number of trips (nearly 40%) although clearly a significant proportion of the trips within the M50 which contribute to congestion are not subject to any charge. This policy lends to a reduction of 7.1% in the number of trips and 5.6% in the number of vehicle-kilometres. In common with Tests 1 and 2, there is still a disproportionate suppression of short distance trips, though not to quite such a great extent. The reduction in vehicle hours is more than twice as great as the reduction in vehicle-kilometres indicating a reduction in delay. The distribution of the benefit is far more widespread with savings outside the central area being as great as those within it.

London (O'Mahony, Geraghty, Vougioukas, Tillis, Katsanis and Monigl, 1999)

In London, the following specific road pricing scenarios were examined:

- **Cordon-based charging**, involving either a Central cordon or both Central and Inner cordons with entry charges of 5 Pounds (7.5 Euro) for the Central cordon and 2.5 Pounds (3.75 Euro) for the Inner cordon

- **Distance-based charging**, with 1.5 Pounds/km in Central London and 0.2 Pounds/km in Inner London

The results of the traffic and energy analyses are summarised in Table 1.

Traffic Demand and Fuel Consumption Reductions due to Road Pricing in London

Scenario	Traffic Reduction Central London	Traffic Reduction Inner London	Fuel Savings Central London	Fuel Savings Inner London
Cordon-based				
Central Cordon only	29.3	2.8	42.4	5.8
Central and Inner Cordons	26.3	8.2	38.9	15.2
Distance-based				
Central Area only	22.5	2.0	33.8	4.1
Central and Inner Areas	22.3	8.2	33.4	15.2

The above analyses indicate that the potential energy savings from road pricing in London are significant, ranging from 4% to 42% depending on the are considered.

Budapest (O'Mahony, Geraghty, Vougioukas, Tillis, Katsanis and Monigl, 1999)

The following theoretical cordon road pricing scenarios were investigated:

a) **Base/Reference scenario:**
This represents the "current" (1995) situation. All other case are evaluated by comparing them to this case.

b) **Road pricing scenario 1** - Danube Crossing Tolling:
The bridges inside the Big Ring (inner area) would be tolled meanwhile the bridges Margit and Pet□fi as part of the ring with 1 toll unit (HUF 50 = 2 PT single tickets) and the three other inner bridges with 2 units (HUF 100 = 4 PT single tickets).

c) **Road pricing scenario 2** - Inner City Tolling:
All entrance road sections in the Inner City Area inside the Big Ring would be tolled with 2 toll unit as well as the 2 ring bridges. The 3 inner bridges would be tolled with one unit only.

d) **Road pricing scenario 3** - Pest Side Tolling:
To protect more the Pest Side of the city the tolling should considered inside the outer Hungária ring too (interim area). In this case the entrance roads and the 5 Danube bridges serve as toll screenlines. The entrance roads of the outer Hungária ring would be tolled with unit. The access fee for the Inner City Area would be an additional 1 toll unit as well as the two Big Ring bridges. The inner bridges would be tolled with two units.

e) **Road pricing scenario 4** - Inner City Tolling:
The same scheme as Scenario 2 but with doubled tolls.

The Budapest modelling results were as follows:

- Trip reductions range from 1 - 6% in the inner area. The largest reduction is for Scenario 4. The network wide reductions are negligible.
- Trip diversions from the inner area are significant; some 20% at Scenario 1 and 40% at Scenario 2 and 3 and 50% at Scenario 4.
- The public transport modal share increased in the inner and interim area while decreased in outer area. There is only a slight general public transport patronage increase. (in case of simultaneous modal split it would be bigger)
- The running performance of cars decreased between 19-51% in the inner area.
- The total time consumption in the inner area has been reduced dramatically because of two reasons: the traffic volume performance decreased substantially and at the same time the speed at the car traffic increased from 18.4 km/h in the basic scenario to 21.0 km/h in Scenario 1, to 26.9 km/h in Scenario2, to 22.1 km/h in Scenario3 and 28.0 in Scenario 4.
- So at all scenarios the measures yielded fuel savings in the inner area but increased fuel consumption in interim and in outer area. In Scenario 1 the fuel saving in inner area is appr. 23%, at Scenario 2 and 3 is around 50% and at Scenario 4 is 57%. However considering the whole network the measures cause additional fuel consumption.
- The most effective scenario in terms of inner area protection is Scenario 4 and at the same time would yield the most toll revenue.

Conclusions

The EUROPRICE project covered many objectives: evaluating user response to road use pricing, estimating the impacts on energy consumption using network models and assessing innovative road use pricing methods not examined before. The results proved interesting and informative and are a useful addition to the research database on the subject of road use pricing. The energy efficient impacts of road use pricing had not been examined in detail before and it is in this context in particular that the EUROPRICE project is particularly helpful.

The conclusions from EUROPRICE are as follows:

1. Two road-use pricing methods were tested in the Dublin and Athens pilot actions. They include distance and time based pricing using in-vehicle meters, a reward and penalty scheme encouraging lower dependency on the car as a mode of transport, again using in-vehicle meters.

2. Significant evidence of user response to road use pricing was evident from the results of the Dublin and Athens pilot actions. Although the samples were relatively small, the trends in the results are useful indicators of likely response and deserve further investigation on larger samples and in other cities.

3. In terms of the responses in the pilot actions, a 4% decrease in total trips was evident in the Dublin results and a more significant reduction of 22% in peak period trips. The reduction in the latter case is due to a combination of trip suppression and use of cycling, walking and public transport. There was little evidence that the reduction was due to a significant transfer of trips from the peak to the off peak period. The sizeable reduction in trips of 48% in the case of the Athens pilot action is a result of a considerable shift of car trips from the charged weekdays to the uncharged weekend days.

4. In the modelling tests, the decrease in trip numbers in Dublin was in the range 3% -7%. In Athens the reduction was 12% and in the case of Budapest trip reductions were in the range 1% - 6%.

5. Energy consumption estimates were made for Dublin, London, Athens and Budapest. Energy savings of between 35% - 41% would be realised for Dublin if road use pricing were to be introduced. If the proposed Athens strategy were to be introduced, 20% - 40% fuel savings are predicted. In Budapest, energy savings within the city centre for charging for crossing the Danube would results in savings of 23% but for cordon schemes around the city centre, savings of 50% would accrue. In the case of London, 18%-24% energy savings are predicted within the proposed charging area with a 2%-3% reduction in the Greater London Area.

6. The in-vehicle meters proved useful to test the Dublin and Athens strategies. Roadside infrastructure and elaborate enforcement procedures were not required.

7. Increasingly, acceptability is an issue requiring closer attention in the subject area of road use pricing. Although user response, energy efficiency and traffic demand reduction received higher priority in terms of the objectives of the EUROPRICE project, acceptability is addressed in some of the proposed strategies.

Future Work

The findings of EUROPRICE would indicate that there is reason to evaluate further the use of in-vehicle meters for road use pricing strategies. Their ability to internalise more closely the external costs of transport than other methods is worthy of further consideration. It is proposed that the work of EUROPRICE be validated on larger samples. Furthermore, technical research to combine in-vehicle meters with other available technologies is necessary in order to offer to European cities and regions a wider range of options in devising strategies to meet the challenge of environmental degradation resulting from ever expanding car use.

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