EXTERNAL COSTS ASSOCIATED WITH INTERREGIONAL TRANSPORT

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ABSTRACT

QUANTIFICATION OF THE EXTERNAL COSTS ASSOCIATED WITH INTERREGIONAL TRANSPORT

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The environmental and social costs of transport are becoming an important issue in Europe as car ownership and usage levels continue to rise. A subject of current debate is the internalisation of these external costs by means of road use pricing in a fair and efficient way, particularly in urban areas. Similar theory could be applied in an interregional transport context but little research has been conducted in this area to date.

The TRENEN model has been developed under the European Union TRANSPORT Programme to quantify the marginal external costs of transport. Case studies have been completed for Brussels, Amsterdam, London and Dublin using the urban version of the model and for Belgium, Ireland and Italy using the interregional version. The calibration of the interregional model and the related case study results for Ireland are presented in this paper.

The conclusions of the case study suggest transport users of all modes currently pay less than the marginal external costs of their transport activities. Another finding is that traffic congestion is a major externality. The model allows comparison of different transport policy options with a full optimum scenario (the external costs are internalised precisely). Typically such a policy would be difficult to implement given the sophisticated pricing instrumentation required. However, it serves as a good baseline against which to test other policies. In the case of Ireland, when a congestion pricing policy (similar to that used in the motorways in

Note: 1ECU = $1.1

France) was compared with the full optimum case it achieved 60% of the maximum achievable welfare.

Key Words: External costs, interregional transport, environment, congestion pricing

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INTRODUCTION

A subject of current debate, particularly in Europe, is the internalisation of the external costs of transport. Most European countries have or are in the process of testing congestion or road use pricing by means of pilot trials or some, as in the case of Norway, have introduced road use pricing in Oslo, Trondheim and Bergen as part of urban transport policy. Less research has been done to date on the issue of internalisation of such costs on an interregional basis. This paper presents part of a project, funded under the European Union Directorate General VII TRANSPORT Programme, which concentrates on evaluating the external costs of transport at urban and interregional levels. One of the objectives of this project was to develop an economics model tool (the TRENEN model) (1) to quantify the marginal external costs i.e. congestion, air pollution and accidents. In addition, case studies have been completed for Brussels, Amsterdam, London and Dublin using the urban version of the TRENEN model and for Belgium, Ireland and Italy using the interregional version. The calibration of the interregional model for the year 2005 and the related case study results for Ireland are presented in this paper.

BACKGROUND

The TRENEN model aims to examine the performance of different transport policies in terms of ***tr***ansportation, ***en***ergy and the ***en***vironment. The directions of pricing reform are analysed in conjunction with the resultant change in external costs.

The structure of the TRENEN model (1) can be divided into three components a demand module, a supply module and an equilibrium price module.

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- The *demand module* represents the choices of the users of passenger and freight transport. Passenger choices are generated by assuming that a representative individual optimally allocates his spending between passenger transport and other goods.
- The *supply module* represents the activities and choices made by transport suppliers.
- A generalised price is calculated in the *equilibrium module*. This generalised price is made up of three elements: cost in vehicle kilometres provided by the supply module, transportation cost (time) and a tax (or subsidy).

The formulations of the TRENEN model are the subject of another paper (2) and given the lengthy nature of those formulations it is only possible to present a summary of the approach here. The purpose of the paper is to present a case study using the model as a tool.

The TRENEN model simulates a policy maker attempting to maximise the sum of consumer surplus of passenger and freight transport users, producer surplus of the suppliers of transport, and the tax revenue weighted by the marginal cost of public funds but with external costs subtracted. The government is assumed to select taxes for all transport goods and determines, through regulation, the types of transport technologies to be used to satisfy demand for each mode.

This is a traditional formulation for a regulatory problem with perfect information for the policy maker. The policy maker is assumed to know the demand functions and the marginal costs of the different supply options, and fixes the equilibrium by setting consumer prices and regulating supply. Tax revenues are returned to consumers in a lump sum way. Tax revenues receive, via the marginal cost of public funds parameter, a larger weight than consumer and

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producer welfare because it is costly to collect tax revenue.

This model uses a partial equilibrium approach in the sense that feedback on non-transport markets are neglected. More specifically prices on other markets including the price of inputs for transport are fixed and the valuation of externalities only depends on changes in the transport market.

Demand functions for each mode in each period are defined as a function of the generalised price of transport including a money cost and a time cost. Time costs may depend on the mode of transport (passenger or freight, car or public transport) and on the discomfort of the users (a minute lost in the morning peak has a higher subjective value than a minute lost during a shopping trip in the afternoon). The generalised price plays an important role in the model. Travel times are endogenous as they depend on the level of congestion of the transport mode used.

Passenger transport demand is represented using a nested Constant Elasticity of Substitution CES function (3). The CES function is easy to calibrate and requires a minimum of behavioural information: prices and quantities in a reference equilibrium together with substitution elasticities at each level. Nested logit functions are in theory a superior way to represent transport demand but they are more data intensive and cannot easily be used for the computation of optimal taxes (2).

The specific nested (CES) utility function used by the TRENEN model contains a set of nests (see Figure 1). The elasticities of substitution are determined:

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- assuming that the lower down the tree, the easier one can substitute between the alternatives,
- such that they yield price elasticities are consistent with the literature.

The model can be used to compute the welfare effects of a given policy proposal. An optimal policy package can also be calculated (called the Full Optimum) which is formulated by optimising a welfare function. This welfare function is calculated as a result of trade-offs between external costs, user valuation of transportation and tax revenue considerations. The optimal level of the taxes will be determined by the level of marginal external costs and by the demand elasticities for the different goods. The Full Optimum represents the taxes imposed if a first-best policy were to be implemented i.e. the marginal external costs are differentiated to time of day, type of car used, fuel type of vehicle and other similar factors. As implementation of the Full Optimum in real life conditions would require very sophisticated pricing instrumentation and is not considered a feasible option. However, it is useful as a benchmark against which second-best policies can be compared.

The costs of the externalities used by the model are summarised in Table 1 and the means by which they are calculated are described in (4). Emission factors and valuations for air pollution are based on ExternE data which is the best source of data for European vehicles (5). In the case study, the total air pollution costs can be reduced by choosing a cleaner car, a smaller car, a different, cleaner, transport mode or by reducing the volume of transport. More fuel-efficient cars were not introduced as a specific option.

For accident costs (4), one takes into account three types of costs: the willingness to pay of

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the victim to avoid an accident, the willingness to pay of the family of the victim and friends to avoid an accident and the direct economic costs of an accident (output loss for society, medical costs). The total social accident cost of adding an additional vehicle consists of two elements: the total accident costs for the occupants of the extra vehicle plus the increase in accident costs for all other road users due to the increased accident risk. The first category of social costs is internalised to a large extent by insurance premiums and because drivers take their own utility loss due to accident risk into account when deciding to make a trip. The only social costs of this category that are not internalised, are the costs to society which are not recovered from insurance companies (ambulance costs, some medical costs etc.). The second category, increased accident costs for other road users, is not internalised at all.

The external costs of congestion are calculated using a congestion function relating delay to volume of traffic. A congestion function is derived for the city and the computation. The external cost of congestion is the time loss suffered by the other road users if an additional passenger car unit (PCU) joins the traffic flow. Value of time estimates are used to express the time loss in monetary terms and those used for the Irish case study are presented in Table 1.

Ireland

Ireland is an island on the west of Europe. It covers an area of 70,283 square kilometres and has a population of 3.621 million. The country suffered economically in the 1980s and early 1990s but is currently enjoying a period of economic prosperity. The general increase in disposable income amongst the population has induced a large increase in car ownership, particularly in the last two years, resulting in a noticeable increase in traffic congestion on

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urban and interregional routes. Dublin is the capital city and largest sea port. It is located on the east coast of Ireland and currently has a population of 1.2 million. Other significant urban areas are Cork in the south, Galway and Limerick in the west and Waterford in the south-east. For the purposes of the project, an estimate of the population in the study year of 2005 was obtained by extrapolation of predictions made by the OECD (6).

Transport Characteristics

The transport modes investigated are passenger cars, scheduled bus services, passenger and freight rail and road freight. Although the model allows for the inclusion of transit freight traffic, this option was not included for Ireland as it is an island on the western periphery of Europe. Inland waterway transport was also excluded as the volume of waterway freight transport in Ireland is negligible compared with other countries such as Belgium.

The majority of freight in Ireland travels by road. The road haulage industry is characterised by a large number of small firms with 75% of licensed operators having only one or two vehicles. Rail accounts for only a small proportion of the freight market. Ireland is unusual in that all its mainline trains are diesel electric as opposed to electric. Irish state-owned companies run the passenger rail and bus services although competition now exists between the latter and interregional private bus operators.

Policy Packages

Several scenarios were examined in the project for the common analysis between Belgium and Ireland. The Reference (RF) situation is used as the base line scenario, i.e. what would be expected in the year 2005 using extrapolations from the present, assuming no internalisation of

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external costs. The Full Optimum (FO) is presented as the best possible gain achievable in social welfare. The Congestion Pricing (CO) is a scenario, which incorporates a toll differentiated according to the time of day. This type of toll is already used on some parts of the French motorway network.

REFERENCE SITUATION

The reference situation can be interpreted as reflecting initial market equilibrium consistent with observable information on prices and flows. Calibration of the TRENEN model for the RF involved data collection for demand levels, prices and traffic flows. These data are presented below and a comparison is made between the existing price levels and the marginal external cost imposed. It can be seen that for private car passenger transport, in particular, current price levels are less than the marginal external costs imposed.

Traffic Levels and Composition

Private Transport

The demand for travel on interregional roads in 1995 is documented in a report by the National Roads Authority (7). The data was collected from sixty-eight automatic traffic recorders installed throughout the main road network, which record the number of vehicles passing in each hour. Twelve of the stations are fitted with counters, which classify the vehicles by length. The National Roads Authority uses these data with a set of modified expansion factors to estimate the quantity of travel demanded by each vehicle type.

The private passenger transport demand levels required for the TRENEN model include the total private interregional traffic in Ireland. Available data is for 1995 where the private travel

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demand in urban and rural areas is 8202 and 1014 million vehicle kilometres per annum respectively. To predict the private car demand for interregional travel in 2005, historical data was examined. Data for total travel (all vehicle types) on national roads is available from 1991-96 and from these data an average growth rate was calculated. Assumptions were made for extrapolation of the growth rates to future years. One half of the average growth rate was used to estimate the value for 2000 and one quarter of the average growth rate was used to estimate the value for 2005. The extrapolations resulted in a value of 11769 million vehicle kilometres per annum for 2005.

Gasoline private cars accounted for 86.3% of all private cars in 1995. This included 898 vehicles using both gasoline and LPG. The remaining 13.7% of vehicles use diesel. The proportion of vehicles using other fuels was negligible. TRENEN requires the proportions of vehicle class per fuel type. Table 2 presents this information which has been calculated from the data presented above using simplifying assumptions.

To calculate the required demand in passenger kilometres, the value for vehicle kilometres is multiplied by the vehicle occupancy rate. The National Roads Authority supplied vehicle occupancy rates based on a 1989 traffic survey (most reliable data available). The average occupancy rate for cars is 1.85 person/vehicle. No Irish data are available for pooled vehicles so the same rate as for the Belgian case studies was used i.e. a rate of 2.5 persons per vehicle. The proportions of pooled and solo cars are calculated as:

Pooled Cars: 56.7%

Solo Cars: 43.3%

Note: 1ECU = $1.1

These proportions are then applied to the vehicle classification proportions presented above to give the input data presented in Table 3. Annual average vehicle travel distances used by the model are presented in Table 4.

Public Transport

A total of 907 million passenger kms were travelled on mainline rail services in Ireland in 1995 (8). An average occupancy of 157.64 passengers per train was determined from the available data. An extrapolation to 2005 is found using the same method as used for the private transport case to give 2.4904 million passenger kms per day in 2005. The same peak/off-peak period proportions were assumed as for private road travel resulting in demand levels of 0.9973 million passenger kms in the peak and 1.4959 million in the off-peak period.

The CSO (9) provided information on total vehicle kilometres, passenger journeys and receipts in its Statistical Bulletin on bus services (private and public). An average occupancy rate for interregional bus services was found to be 15 people per bus. A value of 2,650,560 passenger kms per day was found for 1995 and extrapolated to 2005 levels to give 3.1852 million passenger kms for that year. The same peak/off-peak proportions were assumed as for private road travel resulting in 1.2741 million passenger kms in the peak period and 1.9111 million passenger kms in the off-peak period.

Freight Transport

Information provided by the public rail company (8) was used to calculate a rail freight demand of 1.65 million tonne kms per day. This was extrapolated to 2005 resulting in a

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prediction of 1.66 million tonne kms per day for that year. The average yearly growth rate between 1991 and 1995 used in the extrapolation was 0.18%.

The Central Statistics Office (CSO) Road Freight Transport Survey in 1994 (10) provided an annual estimated transport activity for road freight. The demand was extrapolated to 2005 giving a predicted value of 5,459 million tonne kms per year for that year.

Prices and Taxes

Private Transport

The consumer price of private transport includes the annual acquisition cost per vehicle type and other operating costs (excluding fuel costs and including tax). These values are shown in Table 5. The price per litre of gasoline and diesel is 0.73 ECU/litre and 0.65 ECU/litre respectively. The private transport resource cost is defined as the marginal cost of providing one passenger km of travel and includes production and distribution costs of providing the necessary component inputs. It is equivalent to annual acquisition costs plus other operating costs excluding taxes. The resource costs of improved technologies in 2005 are assumed to be the same as those used in the other European case studies in the TRENEN project. Improved technologies (or 'clean' technologies) refer to fitting gasoline cars with burner-heated catalytic converters and diesel cars with particulate filters. The resource costs for each of the vehicle types are presented in Table 6.

Public Transport

The calibration program of the TRENEN model requires a money price for public transport, which corresponds to the average fare paid for public transport. The CSO Bulletin (9),

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published in 1997, provides data on total receipts from scheduled passenger bus services including interregional services. Average fare levels are as follows:

Train:	0.067 ECU /passenger km.
Bus:	0.086 ECU /passenger km.

The resource costs for rail services are based on the operating costs for mainline rail services (8). The capital costs of the rolling stock and the infrastructure costs are applied to the peak period only. The peak and off-peak period resource costs are as follows:

Peak Period:	0.2 ECU/passenger km
Off-peak Period:	0.096 ECU/passenger km

The resource costs for bus services are based on the operating costs for the public services (8). It was not possible to obtain data on the operating costs of private bus operators. For the purposes of the TRENEN application, it is assumed the resource cost for public bus services is representative of the resource cost of all bus services. The figures calculated are as follows:

Peak:	0.127 ECU/passenger km
Off-peak:	0.125 ECU/passenger km

Note: 1ECU = $1.1

Freight Transport

An Irish freight company called Globetrotter provided an average freight resource cost of 0.37 ECU/truck km for road haulage. Rail freight prices were calculated data provided from the public rail company (8). To translate the information into suitable units for the TRENEN model the total receipts were divided by the demand in tonne kms to give a value of 0.036 ECU/tonne-km. The resource cost for rail freight was calculated in a similar manner to that of passenger rail resulting in 0.159 ECU/tonne-km.

Traffic Flows

The nature of the interregional network means that congestion is very localised and is typically associated with towns on the main routes. The interregional roads in Ireland are modelled as one link in the TRENEN model. Information on speed/flow was inputted to the model in a function form derived in earlier work conducted at Trinity College Dublin (11)

A special program used for the TRENEN models (1) calculates the parameters of the speed-flow relationship. The inputs required for this program are the traffic speeds at certain demand levels on the network. The level of demand is measured in PCUs (Passenger Car Units) and the conversion factor between numbers of vehicles and PCUs for buses and HGVs is 2 (in common with the Belgian case study). The three demand levels chosen are at zero flow, during the peak period and during the off-peak period. The demand levels for each time period were found by summing the demand levels for private cars, passenger buses and HGVs. The free flow speed (speed at zero flow) is taken to be the speed limit on the National Primary roads, which is 96 km/hr. The speeds found for each of the other demand levels are 82.8

km/hr for the off-peak period (1.615 million PCU/hr) and 54.7 km/hr for the peak period (3.342 million PCU/hr).

The program calculates parameters for the following standard flow/delay function used by the TRENEN model:

$$S = 60/(a+(b * \exp(c*x))) \qquad (11)$$

where S is speed in km/hr,

x is demand in million PCU/hr and

a, b and c are region/country specific parameters.

The program (using best-fit curve fitting techniques) defines the parameters for the Irish situation as follows:

$$a = 0.582, b = 0.043, c = 0.744.$$

Prices, Taxes and Marginal External Costs in the Reference Situation

Table 7 shows a summary of the Reference Situation data along with the calculated marginal external costs. It is apparent, by comparing the tax paid with the marginal external cost, that almost all transport services are priced substantially below their corresponding marginal social costs. Peak private car users pay only one half to one third of their marginal external costs. The worst case is for the diesel small car user where only 0.09 ECU/pass.km is paid by the user compared with a marginal external cost of 0.32 ECU/pass.km.

Note: 1ECU = $1.1

The only exceptions are where the majority of the off-peak car users pay more than their marginal social costs. A large gasoline car user pays 0.16 ECU/pass.km in tax for travel in the off-peak period although the use of the car during that period imposes a marginal external cost of only 0.09 ECU/pass.km. The main reason for the difference can be attributed to congestion. The level of congestion during off-peak periods is quite low on Irish interregional roads. This means that the time cost imposed by an additional car on the network during the off-peak period is small compared with the effect during the peak period.

Road freight transport currently pays for only one tenth of its marginal social costs in the peak period and one-third in the off-peak period. Road freight is a major contributor to road damage and also imposes costs in terms of accidents, pollution and time delay. Rail freight is heavily subsidised although its marginal external cost is 0.004 ECU/tonne-km. It can also be noted that all public transport in Ireland is subsidised with peak train services receiving the largest subsidy. The marginal external cost of the passenger rail transport is very low at only 0.002 ECU/pass.km.

FULL OPTIMUM

The Full Optimum (FO) scenario considers the case where the government can use sophisticated pricing instruments. The policy instruments available include vehicle taxes, fuel taxes and tolls. A toll is used as an instrument which allows price differentiation between peak and off-peak periods.

The key results obtained in the FO are shown in Table 8. Passenger traffic levels decrease from 64.88 million pass.km/day in the RF to 63.36 million pass.km/day in the FO. The

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overall welfare gain compared with the reference is 0.47 million ECU per day which amounts to a 0.29% rise. The corresponding value for the case of Belgium was 0.8%. Average welfare is a simplified indicator in that it does not reflect the comparatively large taxes which should be imposed on some transport users to achieve fair and efficient pricing. The TRENEN model is one of the tools used to examine this issue by the EU as a means of addressing the polluter pays principle. A comparison of several urban case studies and a comparison between the Irish and Belgian case study is presented in (12).

When one examines the external costs of transport not currently paid by transport users on a journey by journey basis one can observe the considerable external costs not currently internalised. A journey from the capital of Ireland, Dublin, to the second largest city, Cork, was used to examine this issue. The length of the journey is 245 km. For a large diesel car in the reference situation the user pays 80 ECU including 26 ECU in tax but the marginal external cost is 79 ECU. In the optimum scenario the user pays 113 ECU and the tax paid is 48 ECU which covers the marginal external costs. Similarly in the case of a small gasoline car in the reference situation the user pays 64 ECU and 22 ECU in tax compared with a marginal external cost of 62 ECU. In the full optimum, the user pays 89 ECU and the tax paid is 47 ECU. The higher charges for diesel cars in the optimum reflect their more polluting nature.

A comparison of prices is shown in Table 9. Prices in the peak period in the case of the FO for both passenger and freight transport rise compared with the RF. This price rise is due to the increase in tax paid. The tax must increase so that each individual is paying for the marginal external costs of their travel. The price rise is proportionally larger for small cars,

Note: 1ECU = $1.1

because the tax paid in the RF was so much below the marginal external cost. Small gasoline cars have a price rise of 38.2% and small diesel cars 56.8%. Large gasoline cars have a price increase of only 15.5% and large diesel 43.5% resulting in a smaller price difference between small and large cars. This is driven by the congestion externalities as small and large cars are considered to contribute equally to congestion. In the RF it was noted that diesel car users paid considerably less of their marginal external costs compared with gasoline car users but this is redressed in the FO where diesel car prices rise substantially.

In the off-peak period, the small and large gasoline car prices decrease by 5.8% and 13.6% respectively compared with the RF. In the RF, the taxes paid were greater than the external costs imposed and so in the case of the FO the model strives to rectify this situation. Diesel car prices increase by a very small amount because the taxes paid in the RF did not quite cover the external costs imposed. The relative change in prices makes the diesel/gasoline and the large/small price differences smaller. Public transport prices increase substantially in the FO, since, in the RF public transport is heavily subsidised which in pure economic terms suggests inefficiency. The largest increase is in peak rail prices where there is an increase of 202.5% compared with RF.

The price of road freight increases in both the peak and off-peak periods (Table 9). The increase is much larger in the peak period (98.4% compared with 36.0% during the off-peak) and this creates a shift in demand from the peak to the off-peak. Rail freight was heavily subsidised in the reference situation and so the price rise is very large. This reduces the demand for rail freight where its share of the freight transport market decreases from 10% to 1.31%.

Note: 1ECU = $1.1

Other results from the model runs (although not shown in Table 9) include speed and revenue generated. The decrease in demand in the peak period increases the average speed for road traffic from 54.6 km/hr to 61.2 km/hr but in the off-peak period speed decreases by quite a small amount from 82.8 km/hr to 81.6 km/hr. Tax revenues for the FO condition indicate a large increase, notably so from freight transport. In this case the government would no longer subsidise freight transport but collect 0.70 million ECU/day if a Full Optimum pricing policy were to be implemented.

CONGESTION PRICING SCENARIO

Fuel prices are set at the reference level for the Congestion Pricing (CO) scenario but a toll is imposed on passenger cars and on road freight transport. This toll is different to that used in the FO as differentiation is according to time period only. Public transport prices are set to their resource costs and rail freight prices are constrained to the reference level. The CO scenario was modelled in two versions: one with standard vehicle technology (without clean technology for diesel vehicles) and one with improved technology for diesel vehicles. Similar tables of results can be produced for this scenario but for the purposes of the paper the results are summarised herewith.

The model, in optimising the tolls, aims to cover the total marginal external cost. As the tolling instrument in this case cannot differentiate according to vehicle type, the model chooses to reach an optimum where some prices will be above marginal external cost and others below. In the peak and off-peak periods the large gasoline car user pays a tax of 0.28 ECU/pass.km although its marginal external cost is 0.24 ECU/pass.km. The prices create a

Note: 1ECU = $1.1

shift in demand away from the peak period to the off-peak period, which helps relieve congestion. Public transport prices are increased to their resource costs and consequently the market share for public transport is reduced. The peak bus service shows a slight increase in market share from 2.0% to 2.3%. This can be attributed to the fact that its prices were very low initially and the price increases for other modes have made it more attractive.

Freight transport prices decrease in the peak period by 5.6% and even more considerably in the off-peak period by 37.1%. This causes a shift in demand from the peak period to the off-peak period. The taxes paid by road freight do not cover the external costs they impose. The welfare gain shown by this policy (including new technology) is 0.17% of the reference situation.

SENSITIVITY ANALYSIS

The following tests were run on an urban version (13) (same basis as interregional version) of the TRENEN model when applied ot the capital of Ireland, Dublin.

Test 1: Value of time is halved

Test 2: Value of time is doubled

Test 3: Substitution elasticity between peak to off-peak increased from 0.8 to 1.2

Test 4: Substitution elasticity between peak to off-peak decreased from 0.8 to 0.4

Test 5: Substitution elasticity between motorised and non-motorised modes increased from 0.3 to 0.8.

One would expect in the case of the reference situation that changes in the values of the above variables would have little effect on the results of the reference situation as this scenario represents the baseline condition. When the sensitivity analysis results were examined the

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maximum difference between the original reference case and the sensitivity tests was an increase of 0.14% in the market share for peak period public transport. All other differences were nominal. This shows the numerical precision of the model for replicating the reference situation.

When one examines the sensitivity tests on the full optimum scenario some interesting findings result giving a better insight into the workings of the TRENEN model. There was a sizeable reduction (21%) in demand for private transport in the peak period when the value of time for private and public was doubled. This is strongly influenced by the congestion costs imposed on the consumer. When the value of time is halved the consumer is less affected by congestion costs and the preference for private travel dominates.

The increase in ease of substitution between the peak and off-peak periods in Test 3 is reflected in the market shares where there are larger decreases in the peak share (6.81% compared with 4.96% - private and 21.6% compared with 18.5% - public) and larger increases in the off-peak share (17.2% compared with 15.9%) than those achieved in the original full optimum scenario. There was a slight increase in demand for slow modes in Test 5 and this results in lower tax revenue. There is a 505% increase in tax revenue from public transport compared with a 658% increase for the original optimum case. The results from Test 6 deviate by the least amount when compared with the original optimum which means that the level to which consumers will substitute between private and public transport in the peak period is limited. This is a true reflection of the current situation in Dublin.

Note: 1ECU = $1.1

COMPARISON OF SCENARIOS

A global summary of the key results of the different scenarios can be seen in Table 10. The Congestion Pricing Scenario (including improved technology) performs reasonably well compared with the Full Optimum in terms of welfare gain. It achieves 60.7% of the maximum obtainable welfare gain.

CONCLUSIONS

An evaluation of the main transport externalities was completed for Ireland as part of a European Union funded project and is presented in this paper. The externalities include traffic congestion, air pollution and accidents. Contrary to popular opinion, the externality with most impact was found not to be air pollution but traffic congestion. A full optimum condition was examined to observe the maximum possible gain in welfare. If a first-best policy such as the internalisation of external costs at this full optimum level were implemented, perfect pricing instruments would be required. In reality, this type of policy would be difficult to reproduce. However, the full optimum is a useful scenario with which to compare other more practical methods.

The change in welfare when comparing the optimum to the reference is relatively small. However, there is evidence that transport users do not pay for quite considerable external costs of transport in some cases. The issue of fair and efficient pricing is a key concern of the EU at the moment and the TRENEN model goes someway as a transferable tool to examine this issue. Further developments of the model to reflect network characteristics is currently underway.

Note: 1ECU = $1.1

The full optimum and the congestion pricing scenarios were compared with the baseline reference situation. The results indicate that in the reference situation taxation levels are generally lower than the marginal external costs associated with different transport modes. Congestion appears to have a dominant effect where in the full optimum the taxation levels of small and large cars are brought closer in line. Each is assumed to contribute equally to congestion. In the full optimum, the subsidies on public transport are removed and taxes are imposed. Subsidies are considered inefficient policies in true economic terms and so the TRENEN model strives to remove this inefficiency by taxing public transport users. However, subsidies may well be justified on economies of scale. Results from the TRENEN model should be used as a tool to examine externalities but the results need further refining before application.

The TRENEN model provides a useful tool to test, on a strong theoretical basis, possible scenarios, such as road use pricing, congestion pricing, cordon pricing, fuel taxation and implementation of new technologies, for internalisation of the external costs of transport. In the case of Ireland, the results suggest that the demand for travel in the peak period should be reduced and taxation on most transport modes increased.

Note: 1ECU = $1.1

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Note: 1ECU = $1.1

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Note: 1ECU = $1.1

Legends to Tables

Legend to Figure

Note: 1ECU = $1.1

	Welfare Level (million ECU/day)	Welfare Gain (%)	Passenger Traffic Level (million pass.km/day)	Freight Traffic Level (million tonne km/day)	External Cost (million ECU/day)
RF	162.33	0	64.88	16.62	2.998
FO	162.80	0.29	63.36	15.38	2.903

Table 3 Key results of Full Optimum (2005)

Note: 1ECU = $1.1

Prices and costs (ECU/pass-km); (ECU/tonne-km)				Tax	Marginal External Cost	Change compared with RF (%)
Passenger	Pea	Private	Small, gasoline	0.234	0.233	38.2
			Large, gasoline	0.235	0.234	15.5
			Small, diesel	0.240	0.239	56.8
			Large, diesel	0.245	0.244	43.5
		Train		0.002	0.002	202.5
		Bus		0.082	0.082	142.7
	Off-peak	Private	Small, gasoline	0.097	0.096	-5.8
			Large, gasoline	0.097	0.097	-13.6
			Small, diesel	0.103	0.102	6.0
			Large, diesel	0.106	0.105	0.9
		Train		0.002	0.002	47.5
		Bus		0.056	0.056	110.1
Freight		Peak road		0.085	0.085	98.4
		Off-peak road		0.039	0.039	36.0
		Railways		0.004	0.004	347.5

Table 4. Prices, taxes and marginal external costs in Full Optimum (2005)

Note: 1ECU = $1.1

	Welfare Gain (%)	Max Welfare Gain (%)	Traffic Level (m.pass.km /day)	Peak Private Demand (%)	Peak Public Demand (%)	Off-peak Private Demand (%)	Off-peak Public Demand	External Cost (mECU/day)
RF	0.0	0.00	64.88	36.5	3.5	54.8	5.25	3.00
CO	0.2	60.7	63.60	33.7	2.8	58.8	4.66	2.97
FO	0.3	100.0	63.36	34.0	2.4	59.3	4.33	2.90

Table 5. Key results of three scenarios (2005)

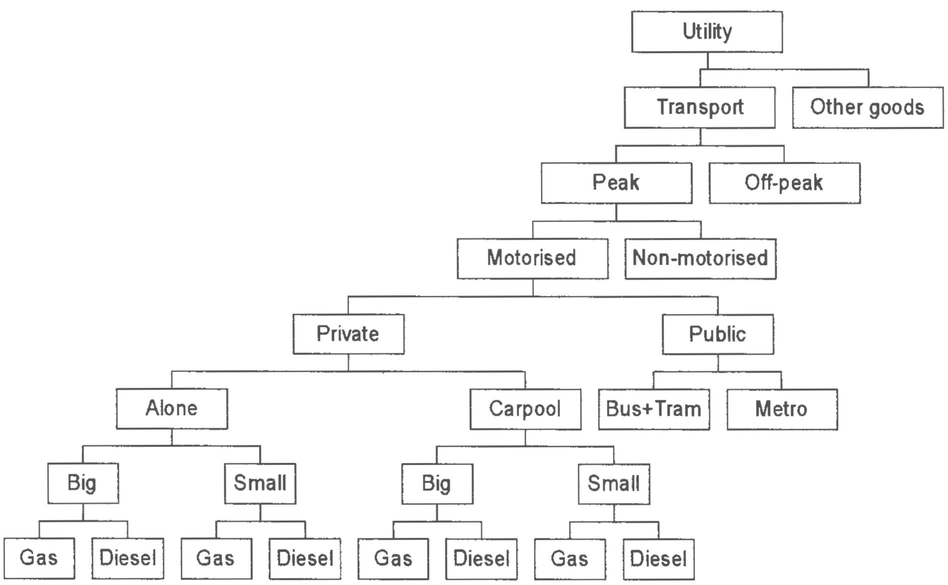

Figure 1. Nested structure of TRENEN model (2)

Note: 1ECU = $1.1