Transport and the environment: a multi- and interdisciplinary approach

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Abstract

This paper deals with a key problem facing transport policy makers committed to sustainable development. This is the problem of excessive car use and the need to reduce it, perhaps by making public transport a more attractive option. In particular, it provides suggestions for the evaluation framework to be used in a cost-benefit analysis of car to bus transfer. A central theme of the paper is the eclectic nature of this evaluation process, which involves inputs from many different subject disciplines. The focus of the paper is on the evaluation of exhaust emission costs, although other types of cost are considered.

1 Introduction

Considerable research has been undertaken on the economic, environmental and social effects of transport. While the progress made in these areas should not be underestimated, there are a number of gaps. First, the focus of much empirical work has tended towards the aggregate level. It is relatively easy to obtain estimates of total vehicle exhaust emissions from the transport sector, for example, but less easy to determine how these emissions change if car users start to travel by bus, or if companies start to send their freight by rail rather than road. Second, empirical work on the monetisation of exhaust emissions and other costs, if it exists, tends to offer a multiplicity of values based on different methodologies and local conditions. Third, there are problems over the status of some of the costs and benefits that comprise a typical evaluation. These problems create difficulties for transport planners and policy makers wanting to present a case for reducing car use, especially where they require a monetary value for the costs and benefits of this reduction. The aim of this paper is to identify a number of factors that should be included in a systematic evaluation of car to bus transfer, and the contribution that different subject disciplines can make to this evaluation process.
The remainder of this paper is structured as follows. Sections 2 and 3 discuss the nature of the evaluation process at the aggregate and disaggregate levels respectively. Section 4 makes the distinction between internal and external costs and emphasises its importance for policy making. Policy and behavioural issues are discussed in Section 5, and a brief description of the CarBus model given in Section 6. Concluding remarks are made in Section 7.

2 The aggregate analytical framework

The first stage of the evaluation process is to determine what costs should be included. Figure 1 shows the costs that the analyst might wish to consider:

![Diagram showing cost categories associated with car to bus transfer]

In general it will not be possible to include all the preferred costs. Changes in land use values, for example, tend to be particularly problematic. If a local authority is developing a sustainable city programme by reducing the number of out-of-town shopping centres to reduce car use and increase bus use, the associated changes in land values will occur slowly over time and be subject to considerable uncertainty. Other cost changes could include the reduction in community severance as a result of the reduction in car traffic. The next stage is to take each cost category in turn and consider the nature of the evaluation.
process within that category. In the case of exhaust emission costs, the evaluation process might involve the stages and subject disciplines shown in Figure 2. The list of subject disciplines is intended to be illustrative rather than exhaustive.

![Diagram](image)

Figure 2. The evaluation process for exhaust emission costs

Exhaust emissions modelling encompasses inputs from a number of disciplines, including chemistry, engineering and climatology. Assigning monetary values to these emissions necessitates inputs from disciplines such as economics, sociology and psychology. In the case of mortality caused by particulate emissions, for example, one might wish to consider not only the value of life of the victim, but also the pain, grief and suffering caused to relatives.

### 3 A disaggregate analytical framework

Figure 3 shows a more detailed framework for the analysis of exhaust emission cost changes. The evaluation begins with the identification of the exhaust emissions from car and bus engines that are most likely to have significant environmental and health effects. The quantity of these emissions over time, measured in terms of an appropriate unit of measurement such as grams emitted per kilometre travelled, will depend on a number of operating factors such as vehicle type and fleet structure.
Figure 3: A disaggregate framework for exhaust emissions costs
Vehicle type can be determined in terms of characteristics including the presence or absence of a three-way catalyst (TWC) and the size of vehicle. Changes in fleet structure, in terms of the proportion of new to old vehicles, are an important determinant of emissions over time. Older vehicles tend to be less fuel efficient, and more polluting than newer vehicles. Driving conditions such as hot or cold running, peak or off-peak, motorway or non-motorway will also affect the quantity of emissions. Finally, legal limits for emissions change both temporally and spatially and must be taken account of in the evaluation.

Car and bus load factors must also be considered a key parameter in the analysis of emissions changes. Low car and high bus load factors will favour bus relative to car travel, *ceteris paribus*. But load factors depend on both the time and place of travel, particularly for buses. Bus load factors can be very high in the urban peak but very low in the rural off-peak.

The next stage in the evaluation process is to estimate a monetary value for the various exhaust emissions. This process of monetisation is fraught with difficulty, not least because it involves placing a value on life where exhaust emissions have caused fatalities. Estimating a value of life can be done in a variety of ways, using factors such as the age of the victim concerned and the output or income that could have been attributed to him or her. There are effects on the relatives of the victim to be considered, such as pain, grief and suffering caused by untimely death. Air pollution also has adverse effects on crops, visibility, buildings, forests and water purity. The incidence of air pollution effects can differ, ranging from local to transboundary and tropospheric to stratospheric, and the pollutants themselves can interact to form further problems such as acid rain and tropospheric ozone.

Carbon dioxide emissions merit an individual mention, since they probably account for more than half the total man-made “greenhouse effect”. Global CO₂ emissions from transport are growing rapidly, and are likely to increase further as some developing countries achieve income levels that enable more widespread car ownership to occur. Although disputed by some, it appears that climate instability resulting from the greenhouse effect has become a major problem. There was unprecedented severe flooding in many parts of the UK in November 2000, and flooding has been severe in other parts of the world. Although a number of studies of the damage caused by global warming (and some of its benefits) have been made (e.g. Cline [1], Fankhauser and Tol [2]), their results are heavily dependent on parameters such as the choice of the discount rate, which links the monetary costs incurred by current and future generations. This is a prime area for climate modellers and economists to collaborate in and refine existing estimates. Climate change will also bring other costs that, to the author’s knowledge, have not yet been included in any existing studies. One such cost is that of the displacement and associated social and
economic instabilities arising as a result of the forced economic migration from those regions badly affected by climate change.

4 Internal and external costs

The evaluation process should try to distinguish between the internal and external monetary costs of exhaust emissions. External costs can be very large and, if omitted from the analysis, could result in poor policy decisions. Delucchi [3] argues that “... in practice, we may assume that all environmental damages from motor-vehicle use are externalities” (p. 137). An externality arises when the production or consumption decision of an individual (or firm) affects the production or consumption of other individuals (or firms) in ways that are not reflected in market prices. Classic forms of environmental externalities are global warming and transboundary air pollution such as acid rain, where the producer may be located in a different region from those affected. In the absence of a “market” for pollution, the producer can pollute without cost so that no “price” for pollution will emerge.

The starting point of this paper is the desire by policy makers to encourage a switch from car to bus use, and the evaluation of the costs and benefits of this modal transfer. For a transfer of 160 people from car to bus use in urban areas, Romilly [4] finds that the largest single annual external cost reduction from this transfer is that of congestion (−£91,040), followed by fuel savings (−£13,030), road accidents (−£4,480) and noise pollution (−£2,570). Although exhaust emission and road damage costs increase (£8,340 and £2,500 respectively), the overall cost change is negative (−£100,290) so that society benefits from car to bus transfer. The increase in exhaust emission costs occurs because diesel engine buses emit large amounts of particulate matter which have the highest health costs. These results are based on an average bus load factor of 45% and a car occupancy rate of 1.6 persons. These (and other) parameters are varied in order to conduct a sensitivity analysis, but in general the overall conclusions remain unchanged. These conclusions are that car to bus transfer brings net benefits to society, and that the engines and fuel used in buses should be designed to minimise particulate emissions without increasing other harmful emissions.

Although conceptually clear, the distinction between internal and external costs can be difficult to make in practice (Nash [5]). One reason for this is the uncertainty concerning the extent to which market forces have operated (or will operate) to determine a price for pollution and other “externalities”. In the case of man-made climate change, the economist would advocate a “carbon” tax on fossil fuels equal to the external costs of the damage caused by the climate change. Although the European Union is currently discussing the carbon tax
issue, it is not clear when, if ever, it will be implemented. Another complication is that the tax should be set at a level that includes the damage to future as well as current generations. In the UK a climate change “levy” is due to come into force. Since this will internalise the externality to some extent, a downward revision should in theory be made to the future external costs of UK carbon emissions, but the practical difficulty is determining how far this revision should go. Or to put the problem another way, to what extent will the climate change levy internalise the climate change externalities?

A related problem arises in the monetisation of fuel savings. It is not too difficult to estimate the changes in the physical quantity of petrol and diesel fuel use as a result of car to bus transfer, but it is much more difficult to assign a monetary value to these changes. Fossil fuel is ultimately a non-renewable resource, and current fuel savings will benefit future generations. These fuel savings can be substantial as bus load factors increase. To the extent that these benefits are not reflected in market prices, the fuel savings can be regarded as a form of intergenerational externality. In addition, there will also be annual reductions in carbon emissions compared to the no-fuel saving case. The approach taken in Romilly [4] is to use the current UK pre-tax retail price of fuel to measure the discounted benefits of fuel savings. The fuel tax is excluded because it is a revenue-raising tax rather than the climate change type of tax discussed in the previous paragraph. The arbitrariness of this monetary valuation is obvious, but given the current state of research it is unclear what values should be used in the evaluation process.

Even where the monetary values of the externality are relatively uncontroversial, there may still be a problem over the status of the externality. The total external costs of traffic congestion in the UK, updated to 1993 prices, have been estimated at £19.1bn (Newbery [6]), and this value is comparable to those of other studies. But the Royal Commission on Environmental Pollution (RCEP) [7] argued that “congestion costs ... are not external to road users as a group”, implying that they should not be included in the type of evaluation process conducted above. If this were the case, then the cost reductions from car to bus transfer estimated by Romilly [4] would be dramatically reduced (by £91,040) and the case for policies aimed at encouraging such a transfer would be correspondingly weakened.

Fortunately for public transport advocates, the RCEP argument is erroneous. A car user joining a congested flow of traffic will incur a delay to him or her (internal cost), but will also create delays for other road users (external costs). The argument that these external costs can be ignored because they originate and take effect within the group of road users is irrelevant and misleading. The externalities clearly affect each individual road user and must be included in the evaluation process. This example serves to highlight the importance, from both a
theoretical and transport policy perspective, of making the distinction between internal and external costs.

5 Policy changes and behavioural parameters

The preceding discussion has dealt with the policy outcome rather than the nature of the policy itself. In general, policy makers have two ways of reducing car use. Firstly, the price of car use can be raised through appropriate taxes (first best pricing) or, if this method cannot be implemented because of political or other difficulties, the price of bus use can be lowered through subsidies (second best pricing). Secondly, policy makers can use non-price or quantity controls to reduce car use. These can include the creation of bus lanes and the removal of car parking spaces. These policies have different impacts in terms of their efficiency in allocating scarce resources. In general, quantity controls are less efficient (i.e. produce a lower social welfare) than price changes, and second best pricing is less efficient than first best pricing. The implication is that the evaluation process should be able to take into account the type of policy change as well as its outcome.

To estimate the social welfare changes from different policies it is necessary to estimate the demand and supply functions for car and bus travel, as well as the relationship between the two markets. For example, a policy of deregulating bus services will reduce the price of bus travel if the deregulated market is more competitive than the regulated one, and will increase bus travel and reduce car travel to greater or lesser degrees, depending on the strength of the response to the price change. The estimation of the numerical values of these responses is the subject matter of econometrics, a discipline that fuses together the efforts of economists, statisticians and mathematicians. If econometric analysis is not feasible, perhaps because of data limitations, then sociologists or psychologists may be able to provide a measure of the behavioural responses. Once again, it is important to recognise the extent to which different subject disciplines can inform transport policy making.

6 The CarBus model

Romilly [4] estimates a number of costs from car to bus transfer in urban areas (see Section 4) using a spreadsheet model called CarBus. The model has six types of passenger road vehicle (petrol car without catalyst, petrol car with catalyst, diesel car, small bus, midibus and large bus), six types of exhaust emission (carbon monoxide, volatile organic compounds, nitrogen oxides, sulphur dioxide, small particulate matter and carbon dioxide) and around seventy
other parameters to determine the overall cost saving from car to bus transfer. These other parameters include the monetary costs of exhaust emissions, emission factors, average distance travelled in each vehicle category, vehicle distributions, average fuel consumption, fuel prices, load factors, congestion weightings, noise costs, accident costs and road damage costs.

The model is by no means comprehensive and, ideally, should include other parameters. An obvious extension (see Figure 3) is to take into account car to bus transfer in rural areas, where load factors and behavioural parameters may differ significantly from urban areas, and alternative fuels such as LPG and CNG. The model should also be sensitive to the type of policy used, as suggested in Section 5. The evaluation framework discussed in previous sections could also be used to determine the costs and benefits of transferring people from car to rail use, or freight traffic from road to rail. It is probably advisable to develop a general model so that interaction effects between transport sectors can be identified more precisely. These interaction effects can be seen in the case of a policy such as road pricing, where higher charges for peak-period road use may not only persuade some people to travel by bus or train rather than car, but also shift some freight from road to rail.

7 Conclusion remarks

This paper has discussed ways in which a systematic evaluation of car to bus transfer can be conducted. Although it has focused on the link between emissions modelling and monetisation, many of the remarks apply to the other costs shown in Figure 1. In particular, it has stressed the wide range of subject disciplines that are encompassed in such an evaluation, and the links that exist (or should exist) between them.

A key task for the short to medium term is to pull together these different strands of research work into a single model that can be used by transport analysts to quantify, in monetary terms, the effects of a policy that causes people to transfer from car to bus travel. The policy could be the installation of bus lanes or some form of road pricing. The model should be designed to allow for a wide range of factors so that it can be used at a relatively disaggregate level; the transport analyst should be able to determine the net benefits of car to bus transfer in places as diverse as New York or Lemnos. Since there are overall net benefits from car to bus transfer, quantification of these benefits also has the advantage of allowing transport policy makers to present a stronger case for policies that discourage car use. It would also be of interest to compare the results of different researchers in this area in order to establish a range of values that can be used with reasonable confidence in such models.
In the longer term, the model could be extended to encompass other transport sectors, such as rail and air travel. As more research is done in these areas to determine the environmental effects of rail and air travel, so the feasibility of such a general model increases.

References


