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February 1998

**Towards The Sustainable City:**  
**The Impact Of Transport-Land Use Interactions,**  
**Deliverable 6. The Final Report**

**A D May**  
**A L Bristow**

## TABLE OF CONTENTS

Abstract .....	1
1. Introduction and Objectives .....	2
2. Project Management.....	2
3. Outline of the Research .....	3
4. Results .....	4
5. Conclusions and Further Research.....	6
6. Exploitation .....	6
7. Publications .....	7

## **Abstract**

Very few transport studies have been able to demonstrate that transport policy measures alone can improve sustainability by reducing fuel consumption and emissions below existing levels. There is therefore an increasing interest in the use of coordinated transport-land use policies, but a lack of understanding of relevant relationships. This research sought to obtain greater insight into these relationships. The main objectives were: (i) to increase our understanding of the impact of accessibility and environmental quality on individuals' and firms' location decisions; (ii) to use the findings of (i) to enhance a newly developed strategic transport and land use interaction model; (iii) to use the enhanced model to assess the implications for urban sustainability of the impact of transport policy on location choice; and (iv) to use the enhanced model to assess the relative performance of different combinations of transport and land use strategy.

There were two main strands to the work. The first involved the use of a newly developed strategic transport-land use model DELTA/START to test the effects of a range of values for environmental and accessibility coefficients. The tests were based on Edinburgh, and included several combinations of road pricing, fares reductions and light rail, and an alternative land use strategy. The second strand involved a literature review and survey work undertaken in Edinburgh using a stated preference approach to identify values for environmental indicators and accessibility to feed into the model.

The survey work of households and businesses was successful in producing values for environmental quality and accessibility. We found that changes in air quality were valued more highly than corresponding changes in noise levels. The survey also revealed some interesting issues that merit further investigation: deteriorations in environmental quality were valued more highly than improvements, there was a greater resistance to increases in council tax beyond current levels than up to current levels and valuations were higher where conditions were worse.

The transport strategies were predicted to induce considerable shifts in activity, with city centre populations increasing by up to 20%. However, these substantial changes in activity had relatively small impacts on the transport indicators. The results for the alternative land use scenario showed similar effects. Generally it appears, from the tests involving the strategic transport model that the effects on transport indicators of land use changes, whether induced through transport strategies or imposed through land use planning, are an order of magnitude lower than those of the transport strategies themselves. This is an important policy result since it calls into question how much can be achieved by pursuing coordinated land use and transport strategies.

## **1. Introduction and Objectives**

The proposal for this research was submitted to EPSRC in March 1995, under the Sustainable Cities initiative. It was based on our extensive experience in research on integrated transport strategies; the conclusion that very few transport studies have been able to demonstrate that transport policy measures alone will achieve a more sustainable outcome (with fuel consumption and emissions below today's levels) (May and Roberts, 1995); and the growing interest in the use of co-ordinated land use and transport policies (DoE and DoT, 1994, 1996). Subsequently literature reviews and interviews in a parallel EPSRC CASE studentship demonstrated that the impact of transport on land use is perceived by planners as a serious gap in policy understanding. Interviews also revealed that land use-transport models are treated with some scepticism, because there is insufficient understanding of the relationships within them and because the existing models are perceived as unduly complex (Still, 1996).

As a result of this lack of understanding, there is a danger that impacts of transport on land use might have counter-productive effects on the land use-transport strategy. For example, road pricing, which may be a key element in a sustainable transport strategy, may reduce accessibility by private car and hence lead to outmigration of business, thus producing a less sustainable land use pattern. Conversely it could enhance the city centre environment, and hence encourage certain firms to relocate to the centre. These twin impacts of transport policy on accessibility and environmental quality are the key elements in predicting the resulting location decisions of individuals and firms, and need to be better understood if sustainable land use-transport strategies are to be developed. This project was designed to address these issues, with the following main objectives:

- i. to increase our understanding of the impact of accessibility and environmental quality on individuals' and firms' location decisions;
- ii. to use the findings of (i) to enhance a newly developed strategic transport and land use interaction model;
- iii. to use the enhanced model to assess the implications for urban sustainability of the impact of transport policy on location choice;
- iv. to use the enhanced model to assess the relative performance of different combinations of transport and land use strategy.

## **2. Project Management**

The project commenced on 1/9/95, with the appointment of Ms Frances Hodgson to undertake the initial literature review and work on survey design and implementation. Dr Simon Shepherd joined the project early in 1996 to undertake the strategic transport-land use modeling. Dr Mark Wardman contributed the design and analysis of the stated preference experiment. Mr Roy Clarke undertook the programming of the computer based interview tool. The project was undertaken with the collaboration of three bodies, The MVA Consultancy, the David Simmonds Consultancy and Lothian Regional Council (later Edinburgh City Council); regular meetings were held with collaborative partners at approximately 6 monthly intervals, with more frequent consultation at certain phases of the project.

Work on the project commenced as anticipated. Although a variety of problems were encountered during the development of the strategic land use-transport model and the incorporation of the results of the survey, these were only to be expected in such developmental work and did not disrupt progress unduly. The project was completed in November 1997.

### **3. Outline of the Research**

The research was divided into two main strands and six tasks; the work relating to the strategic transport-land use model (Tasks 2, 5, 6) and the literature review and survey work designed to produce coefficients to describe the responses of land use to changes in the accessibility and the environment in the model (Tasks 1, 3, 4).

Task 1 was the literature review, the results of which fed into the initial specification of coefficients on accessibility and the environment, specifically noise and air pollution, in the DELTA-START model. The modeling approach involved the integration of two models:- The MVA Consultancy's START strategic transport model (Roberts and Simmonds, 1995) and the David Simmonds Consultancy's newly developed strategic land use response model, DELTA (Simmonds, 1997). The consultancies were primarily responsible for the integration of the two models, while research under the grant provided enhanced coefficients. DELTA is a dynamic land use model incorporating sub-models of development, employment, location, household transitions and area quality. The location response has been enhanced to include responses to changes in the transport system via changes in accessibility and transport-related environmental output calculated by START. The models are run sequentially (in this study in ten periods of two years each) effectively creating a varying land use scenario in which land use location responds to the transport strategy through reaction to changes in accessibility and transport-related environmental conditions. Task 2 of the project involved runs of the strategic transport-land use model incorporating the best estimates of these coefficients that could be made from the literature review and a range of values around them, in order to examine the range of possible impacts of location choices and the sensitivity of those impacts to the assumptions made regarding the coefficients. Six transport strategies involving combinations of light rail provision, fares reduction and road pricing were compared, together with a do-minimum, and three levels of location response to accessibility and environmental indicators were tested in five combinations.

The second strand of the project was underway at the same time, involving the development and implementation of the surveys of the effects of accessibility and environmental factors on the location choices of households and businesses, (Tasks 3 and 4). Households' and firms' preferences amongst different levels of environmental quality, accessibility and monetary outlay (using Council Tax Levels as a proxy) were established using a Stated Preference (SP) exercise. Comparable analysis of actual decision making would have required the collection of a very large data set and would face the problem of isolating the effects of attributes which are of particular interest to this study from attributes specific to particular houses or offices. The advantage of the SP approach is that it can control what is evaluated by individuals and the SP exercises used here exploit this feature by specifying that the alternatives differ solely in terms of their accessibility, environmental and cost characteristics. A willingness to pay question was used as a supplement and comparison with the SP experiment. The survey was administered as

a home or office interview using portable computers and the ESPS (Edinburgh Stated Preference Survey) instrument developed for this project. The design of the SP experiment and the questionnaire was a complex exercise given the requirements of DELTA for input and the difficulty in expressing realistic trade-offs in the survey. The survey covered 403 households and 26 businesses with the business survey being a more exploratory exercise. These sample sizes were as envisaged in the original proposal. Measurements of noise levels and nitrogen dioxide (as a proxy measure for total local air pollutants) were undertaken at a number of sites, which allowed us to match an actual to a perceived measure of these impacts for just under half the sample of households.

Once the survey results from Tasks 3 and 4 had been analysed, the relationships identified were converted into coefficients for the DELTA model, the first part of Task 5. These revised coefficients were incorporated into DELTA and transport strategies were again tested to establish any differences in the land use response. At this stage we also tested an alternative land use scenario, which concentrated development in the light rail corridors.

The final task of the project involved reporting and dissemination of the results. We have held two open seminars on the project at ITS. We have presented two papers at the PTRC European Transport Forum in 1997, containing initial results. We have had two papers (and one associated one) accepted for the 1998 World Conference on Transport Research in Antwerp this summer, which have now been written and submitted. We have a series of ITS Working Papers relating to the project. A further paper has been offered for the 1998 European Transport Forum. Journal articles are in preparation and we are considering the viability of a book on land use-transport modeling which would draw heavily on this project.

We have thus achieved all the objectives and measurable sub objectives set out in the Case for Support, and satisfied the criteria for success listed there.

## **4. Results**

The initial results from Task 2 are reported more fully in Bristow, May and Shepherd (1997). The conclusions reached were that:-

- i. at the response levels tested, the impacts of land use response are small in terms of trips, car trips and hence fuel consumption ;
- ii. however, the impacts on location are significant, particularly for strategies involving light rail;
- iii. the impacts on choice of public transport mode with response to accessibility included are substantial, with marked differences between those with and without light rail as an element;
- iv. at the levels tested the accessibility impacts on trip patterns are greater than the environmental ones, but the latter are also important, and for light rail strategies act in the opposite direction;
- v. in terms of response to the environment, only road pricing can improve the city centre environment significantly and so cause in-migration; however, when the responses are combined this is outweighed by the decentralising effect of the response to reduced accessibility;



- vi. the effects on land use are not additive across strategies but are additive across responses to accessibility and environment; the effects on trip rates are broadly additive across strategies but not always across responses;
- vii. the effects are frequently non-linear, particularly when involving light rail.

The results of Tasks 3 & 4 are reported more fully in Wardman, Bristow and Hodgson (1997 and 1998). Changes in air quality were valued more highly than corresponding changes in noise levels and deteriorations in environmental quality were valued more highly than improvements. There was also a greater resistance to increases in council tax beyond current levels than to increases up to current levels. The study generated new coefficients of response to changes in accessibility and environmental quality, which were used to enhance the strategic model (Task 5). While the average levels of the coefficients were similar to those used in Task 2, they differed more between income groups.

The results from Task 5 are reported more fully in Bristow, May and Shepherd (1998). Although there were some differences in the coefficients used, the impact of the changes was primarily to moderate the predicted population shift. Even so, the transport strategies were predicted to induce considerable shifts in activity, with a 20% increase in city centre population and a 16% increase in resident workers in the centre as a result of the combined strategy; most of this impact was generated by the light rail provision. Both changes in accessibility and changes in the environment are important in this process, and can, e.g. for light rail, operate in opposing directions. However, these substantial changes in activity have relatively small impacts on the transport indicators. The combined strategy resulted in a 5% increase in trips, a 2% increase in car trips and a 3% increase in fuel consumption, but most of these changes were present for all strategies; the net effect of the land use response to the combined strategy was an order of magnitude less than the effect of the combined strategy itself on car trips and fuel consumption. The changes in bus and light rail trips were slightly more sensitive to land use responses; this appears primarily to be due to changes between these two modes.

The results for the alternative land use scenario showed similar effects. Concentrating development in the city centre and on light rail corridors increased population and residential employment in the city centre by around 12%, but the changes in trips, car use and fuel consumption were all around 1% to 2%.

## **5. Conclusions and Further Research**

The SP work raised a number of methodological issues. One element of the research was a comparison of two means of presenting air quality based on proportionate changes and on reference to levels of air quality in different locations with which the respondent would be familiar. Our preference is for the latter approach, which yields lower and, we would argue, more plausible values. The values obtained from the households' willingness to pay questions were lower than those derived from the stated preference analysis. We believe that the incentive to bias is greater in the willingness to pay questions. There was quite strong evidence to suggest that the valuations of noise and air quality were dependent upon existing environmental conditions. The valuations were higher where conditions were worse and in future research this could be built into an appropriate functional form of the model. While our results are based on hypothetical questioning, it may be possible to develop models based on actual residential location choices; such an approach should be pursued in further research.

Generally it appears from the results of the tests using the strategic transport land use model that the effects on transport indicators of land use changes, whether induced through transport strategies or imposed through land use planning, are an order of magnitude lower than those of the transport strategies themselves. This result appears to have been generated also by a parallel Sustainable Cities project based on Swindon (Steadman et al, 1998). It is an important policy result, since it calls into question how much can be achieved by the coordinated land use and transport strategies advocated by the previous Government (DoE, DoT, 1996).

However, it must be stressed that these results are preliminary. They are based, as intended, on the analysis of the system-wide performance indicators from the DELTA-START model. They are drawn from tests of a subset of transport policies, and only one alternative land use strategy. In addition they are drawn from a strategic (rather than detailed) model of one conurbation. It is intended to conduct further research in which the results from these initial policy tests will be analysed at a far more disaggregate level, further transport and land use strategies tested to identify the potential for improved performance and, if possible, the programme of model tests replicated for a more detailed model of a small conurbation.

## **6. Exploitation**

The results have been widely disseminated, as described above, and we envisage further policy discussions with central and local government. The DELTA-START model is being exploited commercially and our Collaboration Agreement specifies the arrangements for treatment of foreground IPR in this process. We expect, as a result, to obtain experience in the use of the model, and hence to identify further research issues.

## **7. Publications**

### **Conference Papers**

Wardman M., Bristow A.L. & Hodgson F.C. (1997) Valuations of Noise, Air Quality and Accessibility: Evidence from Households and Businesses. Paper to PTRC European Transport Forum, Annual Meeting, Brunel.

Bristow A.L., May A.D. & Shepherd S.P. (1997) Towards the Sustainable City: The Impact of Land Use Transport Interactions, Paper to PTRC, European Transport Forum, Annual Meeting, Brunel.

### **Forthcoming**

Bristow A.L., May A.D. & Shepherd S.P. (1998) Land Use - Transport Interaction Models: The Role of Environment and Accessibility in Location Choice. Paper to the 8<sup>th</sup> World Conference on Transport Research, Area D3 Integrated Supply/Demand Modeling

Wardman M., Bristow A.L. & Hodgson F.C. (1998) Noise and Air Quality Valuations: Evidence from Stated Preference Residential and Business Choice Models. Paper to the 8<sup>th</sup> World Conference on Transport Research, Area E3 Valuation of Internal and External Benefits/Costs.

Still B.G. & Simmonds D.C. (1998) DELTA/START: Adding Land Use Analysis to Integrated Transport Models. Paper to the 8<sup>th</sup> World Conference on Transport Research.

### **ITS Working Papers**

Still B.G. & Simmonds D.C. (1997) The Implementation of the DELTA/START Model. Working Paper 494, Institute for Transport Studies, University of Leeds.

Shepherd S.P. (1997) Towards the Sustainable City: The Impact of Transport - Land Use Interactions Deliverable 1. The Impact of Accessibility and Environment Coefficients in Location Choice on Transport Strategy Performance. WP 512.

Hodgson F.C. (1997) Towards the Sustainable City: The Impact of Transport - Land Use Interactions Deliverable 2. Development of a Survey Methodology. WP513

Wardman M. (1997) Towards the Sustainable City: The Impact of Transport - Land Use Interaction Deliverable 3 Valuations of Noise, Air Quality and Accessibility: Evidence from Stated Preference Residential and Business Choice Models. WP 514.

Shepherd S.P. (1997) Towards the Sustainable City: The Impact of Transport - Land Use Interactions Deliverable 4 The Development of Revised Location Coefficients. WP 515.

Shepherd S.P. (1997) Towards the Sustainable City: The Impact of Transport - Land Use Interactions Deliverable 5. A Comparison of the Impact of the Initial and Final Coefficients on Location Choice on Transport Strategies and Land Use Scenarios. WP 516.

May A.D. & Bristow A.L. (1998) Towards the Sustainable City: The Impact of Transport - Land Use Interactions Deliverable 6. The Final Report. WP 517. (This report).

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