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# LAND USE - TRANSPORT INTERACTION MODELS: THE ROLE OF ENVIRONMENT AND ACCESSIBILITY IN LOCATION CHOICE

ABIGAIL L BRISTOW
ANTHONY D MAY
SIMON P SHEPHERD
Institute for Transport Studies
University of Leeds
Leeds LS2 9JT, UK

## Abstract

The paper reports results of a study which aimed to increase understanding of the impact of accessibility and environmental quality on individuals' and firms' location decisions through the use of the newly developed strategic land use - transport interaction model DELTA/START in which the location of activities is sensitive to changes in accessibility and environmental quality induced by transport strategies. The model was used to test a series of transport strategies for Edinburgh and the interaction between these and a revised land use scenario in which development was focused on the city centre and on light rail corridors.

## INTRODUCTION

Over the last decade the concept of integrated transport strategies has been developed and widely accepted into practice, based on the identification of synergy between transport policy instruments (May and Roberts, 1995). However, very few studies have been able to demonstrate that transport policy measures alone will achieve a situation in which fuel consumption and emissions are maintained at or below current levels. In most cases, land use changes will need to be co-ordinated with transport measures if sustainability is to be achieved, and recommendations for appropriate land use measures are beginning to emerge, (DoE, 1994; DoE & DoT, 1996). Literature reviews and interviews have demonstrated that the impact of transport on land use is perceived 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 two impacts of transport policy on accessibility and on 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 paper reports the results of a study of these issues, funded by the UK Engineering and Physical Sciences Research Council. The principal objectives of the project 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, DELTA/START;
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.

The research has involved a literature review, to identify information on the impacts of accessibility and land use; the use of DELTA/START with coefficients based on the literature review, to carry out an initial set of policy tests based on Edinburgh (Bristow *et al* 1997); surveys of householders and businesses in Edinburgh to improve our understanding of these relationships (Wardman *et al* 1997, Wardman *et al* 1998); a second set of policy tests using these improved coefficients; and a subsequent set of tests of the impact of alternative land use policies. This paper focuses on the test results. It contains a brief description of the DELTA/START model and outlines the coefficients adopted. Results of the main set of policy tests, and the land use policy tests are reported and conclusions drawn.

## OVERVIEW OF THE DELTA/START STRATEGIC TRANSPORT LAND USE MODEL

Figure 1 shows the links between the land use (DELTA) and transport (START) elements of the model. The model moves forward over time in successive periods (2 years for the Lothian application). For each period, DELTA provides the land use inputs to START. In turn, START supplies accessibility and environmental information to DELTA. Thus each model treats the other as a black box.

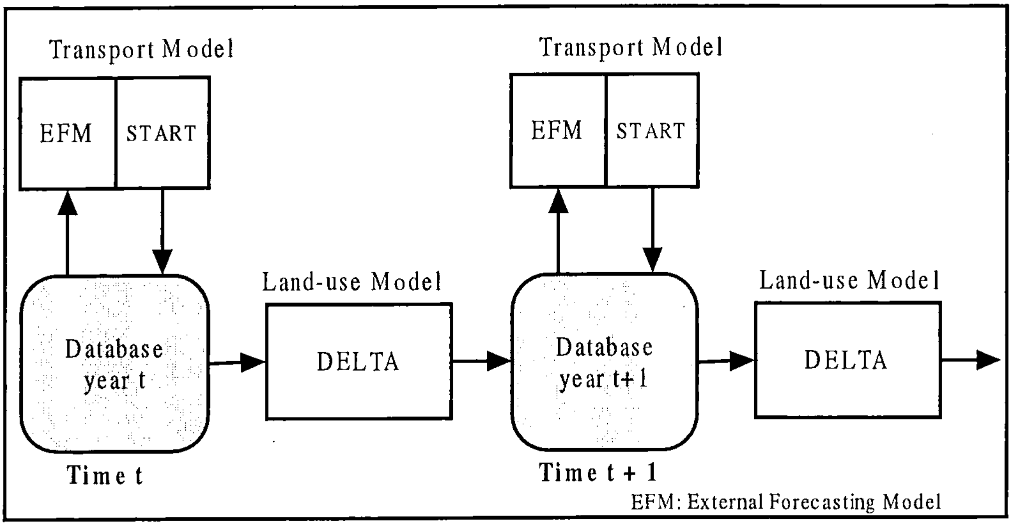


**Figure 1: Operation of the DELTA / START model over time**

The START strategic transport model was developed by The MVA Consultancy to facilitate transport planning using the 'top-down' approach, appropriate when an overall transport strategy for an area needs to be formulated (Coombe and Copley, 1993). As such it is designed to be able to test a large number of strategies in as short a time as possible. The model is designed to encompass all the major elements of a transport strategy and the expected effects of these policies on the transport system. It has been applied in many urban areas both in the UK and abroad, including Edinburgh, Bristol, Merseyside and Sao Paulo.

There are two parts to the START model; (1) the external forecasting model (EFM), which calculates growth in trips from the base year to the future year, and (2) the transport model proper, which determines what will happen to the transport system. The EFM functions as a trip generation and distribution model. It assumes that if there was no change in transport conditions, then demand for travel would be a function of: changes in the households and persons living in each zone; changes in the employment in each zone; changes in car ownership (influenced by household income and structure).

The transport model works on the basic premise that all travel responses to changes in the transport system can be represented by changes in components of generalised cost. It consists of two basic elements, a demand model and a supply model. The demand model responds to changes in generalised cost, and reassigns trip makers by route, mode, time of travel and trip frequency (the latter only for certain purposes: e.g. shopping and retail). This is then fed into a supply model, which contains the transport supply conditions from the 2010 transport policy. The supply component calculates the changes in congestion on the roads and on public transport, and in turn modifies the generalised costs. It includes treatment of congestion, parking delays, public transport overcrowding and the response of private operators. The model iterates until the components of generalised cost have reached convergence criteria.

The DELTA land use model contains five major submodels which reflect, as far as possible, familiar urban processes. These are, development, area quality, location, transition and employment matching. There is relatively little interaction between the submodels in any one time period; what does occur is related to competition or constraint, for example, the effect of available space in constraining activities' location choice. Instead, most interactions take place over time, with activities responding to changing conditions in past periods. This follows a characteristic of many urban models,. which comprise a set of relatively simple submodels, but with a complex set of linkages between them.

DELTA requires land use data not only for the base year, but for successive years before the base year, in order that the location choice in the early years is responding to a previous situation. The model does not therefore begin from a static equilibrium point (as compared to START, which begins from a converged 1991 base). DELTA operates by reading a 'database' of land use, activity, transport and environmental data for the end of the last period. It then calculates the changes in land use, and outputs this data to the 'database' for the new 'end' year. These successive databases provide the data points for the changes with which the model works. The DELTA model and submodels are described more fully in Still and Simmonds (1997).

## COEFFICIENTS OF ACCESSIBILITY AND TRANSPORT RELATED ENVIRONMENTAL QUALITY

### The Underlying Model

The land use model DELTA contains a location sub-model which locates and relocates households by maximising their utility of location. The model responds to changes in utility of location and to the amount of space available. The change in utility of location is defined as follows :-

$$\Delta V_{ti}^{h} = \theta^{hU}(U_{ti}^{h} - U_{(t-l)i}^{h}) + \theta^{hA}(A_{ti}^{h} - A_{(t-l)i}^{h}) + \theta^{hQ}(Q_{ti}^{h} - Q_{(t-l)i}^{h}) + \theta^{hR}(R_{ti}^{h} - R_{(t-l)i}^{h}) \quad ($$

where

$V_{ti}^{h}$ = utility of location for households of type h locating in zone i at time t

$U_{ti}^{h}$ = utility of consumption for households of type h locating in zone i at time t

$A_{ti}^{h}$ = accessibility of zone i for households of type h at time t

$Q_{ti}^{h}$ = quality of housing areas for households of type h in zone i at time t

$R_{ti}^{h}$ = transport-related environmental quality perceived by households of type h in zone i at time t

*t-l* = time period *t-l* for lagged variables, *l* may vary by household type and by variable as needed

$\theta^{hU}$ = coefficient of response to change in utility of consumption for households of type h

$\theta^{hA}$ = coefficient of response to change in accessibility for households of type h

$\theta^{hQ}$ = coefficient of response to change in area quality for households of type h

$\theta^{hR}$ = coefficient of response to change in transport-related environmental quality for households of type h

### Estimation of the Initial and Final Coefficients

The initial coefficients on the utility of consumption and accessibility were derived from a cross-sectional calibration carried out using data for Bristol as part of a model implementation process. The initial area quality coefficient was defined in relation to rent levels such that an increase of 1 unit in the area quality variable for a zone should generate a 1% increase in rents, on average. However, if quality were to improve by the same amount in all zones, there would be no change in rent, as no zone would have changed its level of attraction relative to other zones.

The environmental quality coefficient includes the following elements, noise, carbon monoxide, (CO) oxides of nitrogen ($NO_x$) and volatile organic compounds (VOC), the levels of which are provided as output by the START model. This variable was assumed to have an equal but opposite effect to the area quality variable, such that an increase of 1 unit will on average lead to a rent reduction of 1%. Evidence (Tinch, 1995) suggested that a 1 dBA change in noise levels would produce a change in rents of approximately 0.8%. The three air pollutants were then weighted against each other based on toxicity (0.548 $NO_x$, 0.449 VOC and 0.003 CO) again using evidence from Tinch, to give the initial environmental quality coefficient.

These initial coefficients were then modified, based on the results of the stated preference surveys. The process, which was complex, is described in Shepherd (1998a). Detailed checks were made to ensure that the resulting changes in the coefficients were justifiable.

## THE EFFECTS OF THE COEFFICIENTS

### The Tests Conducted

The location sub-model was outlined earlier in eqn (1); here we are concerned with the coefficients on accessibility $\theta^{hA}$ and of transport-related environmental quality $\theta^{hR}$. In our tests these coefficients varied as follows:-

**Base Response:** both accessibility and transport related environment coefficients set to zero giving no transport related response in the land use location model i.e. $\theta^{hR} = \theta^{hA} = 0$.
**Initial Response:** best estimates of all the coefficients from the literature review.
**Final Response:** both coefficients derived from the stated preference survey analysis.

Seven basic transport strategies for Edinburgh were:-

- do-minimum (described below);
- do-minimum plus Light Rapid Transit (LRT), involving two lines North-South and East-West with a high frequency of 12 trains per hour;
- do-minimum plus two way road pricing cordon around the city centre with a charge of £1.50 per crossing in either direction;
- do-minimum plus a reduction in bus fares of 50%;
- do-minimum plus LRT and road pricing as above;
- do-minimum plus bus fare reduction and road pricing;
- do-minimum plus LRT, bus fare reduction and road pricing.

The do-minimum strategy has the following features: SCOOT traffic control, M8 extension, increases in city centre parking charges, switch from private to more public parking spaces, greenways on major radials (corridors with significant bus priority and traffic calming), fare inflation of 1.29 over 20 years, and earnings index 1.8 over 20 years.

We also carried out a number of tests to investigate the sensitivity of the results to a doubling of the initial coefficients and the omission of one or the other, (Bristow *et al*, 1997); these are summarised below. In the reporting of results we focus on the comparison between the base model, the model with the initial estimates and that with our final estimates.

## Issues arising from tests of the initial response

The main results from the tests of the initial response were :-

(i) The impacts on location are significant, particularly for strategies involving LRT. The impact is less on jobs than on population, with large increases in the city centre.

(ii) At the response levels tested, the impacts of land use response are small in terms of car trips and hence fuel consumption (and an order of magnitude lower than those produced by the integrated strategy with no land use response).

(iii) The impacts on choice of public transport mode with response to accessibility included are substantial, with marked differences between those with and without LRT 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 LRT 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 when the response is doubled.

The most striking result in terms of strategies is the response to LRT strategies. The very high frequency LRT system as modelled here provides better alternatives to bus and some car routes for a majority of origin-destination pairings within the Edinburgh area; it also provides limited park and ride facilities for some of the outer zones. The response to this increased accessibility is to centralise the population within the centre of Edinburgh where the changes in accessibility are greatest. This results in higher city centre rents and as a result of this the larger households, who are more sensitive to changes in accessibility, tend to dominate the city centre. This results in total trips increasing with LRT strategies.

## Comparison of the base, initial, and final responses

The tables that follow present the results using the three different sets of coefficients and seven transport strategies including the do-minimum. The top left hand cell in each table gives the absolute value of the indicator for the do-minimum strategy with the base response (that is no transport related response in the land use location model, in other words the coefficients on the accessibility and transport related environmental impacts are set to zero).

The transport strategy results are then presented in column one as percentage changes from the do-minimum for the base response. The second column shows results for the initial coefficients minus the base results for the same strategy again as a percentage of the do-minimum for the base response. Column three shows results for the final response minus the base response for the same strategy, again expressed as a percentage of the do-minimum for the base response. Column four shows the percentage change for the initial response for each strategy relative to a do-minimum for the initial response, while column five shows the change for the final response for each strategy with respect to the do-minimum for the final response.

Thus a comparison of changes due to a change in response coefficients is possible for each strategy using columns 2 and 3 whilst a comparison of responses due to strategy implementation (for each response ) is possible comparing the changes between strategies in each of the last two columns.
Tables 1 to 8 show the results for a subset of indicators: total trips, car trips, bus trips, LRT trips, fuel consumption, housing rents in the city centre, population in the city centre and resident workers in the city centre. The full set of results are provided in Shepherd (1998b).

**Table 1: Total trips (thousands) in 2011 and percentage changes**

| Land Use Response | Base (zero) | Initial | Final | Initial | Final |
|---|---|---|---|---|---|
| % change from | Do Min | Base | Base | Do Min | Do Min |
| Strategy | | | | | |
| Do-min | 1060 | -1.9 | 3.0 | 0.0 | 0.0 |
| LRT | 0.7 | 2.4 | 4.6 | 5.0 | 2.2 |
| Road Pricing | -1.4 | -1.5 | 3.3 | -1.1 | -1.1 |
| Fare Reduction | 0.8 | -1.7 | 3.0 | 1.0 | 0.7 |
| LRT+RP | -0.8 | 2.5 | 5.1 | 3.7 | 1.2 |
| Fare +RP | -0.7 | -1.2 | 3.4 | 0.0 | -0.3 |
| LRT+fare+RP | -0.2 | 1.6 | 4.6 | 3.4 | 1.4 |

In the base the different transport strategies have very little impact on trip making; the greatest change is a 1.4% reduction with road pricing. (The sensitivity tests showed that the inclusion of the accessibility response alone led to a reduction of around 1% with those strategies that exclude LRT, and an increase of 2-3% with those which include LRT. The inclusion of the environmental response alone led to reductions of up to 0.6% for all strategies). The initial response tends to reduce trip making slightly, with the exception of strategies involving light rail. The final response increased trips by between 3% for the do minimum and around 5% for those involving light rail. The impacts of the strategies (columns 4 and 5) are similar to those in the base (column 1) except for those strategies which involve light rail, which increase trip making through the land use response.

**Table 2: Car trips (thousands) in 2011**

| Land Use Response | Base (zero) | Initial | Final | Initial | Final |
|---|---|---|---|---|---|
| % change from | Do Min | Base | Base | Do Min | Do Min |
| Strategy | | | | | |
| Do-min | 672.3 | -1.5 | 3.0 | 0.0 | 0.0 |
| LRT | -2.1 | 0.2 | 2.8 | -0.4 | -2.3 |
| Road Pricing | -10.5 | -1.4 | 3.0 | -10.6 | -10.2 |
| Fare Reduction | -3.2 | -1.4 | 2.9 | -3.1 | -3.2 |
| LRT+RP | -12.8 | 0.0 | 2.5 | -11.4 | -12.9 |
| Fare +RP | -13.9 | -1.0 | 2.7 | -13.6 | -13.8 |
| LRT+fare+RP | -15.4 | -0.1 | 2.4 | -14.3 | -15.6 |

While the strategies have little effect on overall trips they do, as expected, change modal shares with the base response. Table 2 shows that road pricing achieves a 10.5% reduction in car trips, fare reduction 3.2% and light rail 2.1%, and these effects are broadly cumulative in combined strategies. The effects of tests including the accessibility and environmental coefficients in isolation had small impacts on the number of car trips. The effects of the land use response on car trips are similar to those for all trips for both the initial and final responses (columns 2 and 3). The effects of the strategies on car trips are very similar for the initial and final responses (columns 4 and 5) and for the base response (column 1). Thus the land use response is not influencing the impact of the strategies on car trips.

**Table 3 : Bus Trips (thousands) 2011**

| Land Use Response | Base (zero) | Initial | Final | Initial | Final |
|---|---|---|---|---|---|
| % change from | Do Min | Base | Base | Do Min | Do Min |
| Strategy | | | | | |
| Do-min | 332.4 | -3.3 | 3.9 | 0.0 | 0.0 |
| LRT | -23.2 | 2.6 | 5.3 | -18.0 | -21.0 |
| Road Pricing | 15.7 | -2.2 | 5.0 | 17.3 | 16.1 |
| Fare Reduction | 11.2 | -3.0 | 4.2 | 11.9 | 11.1 |
| LRT+RP | -7.6 | 3.1 | 6.2 | -1.3 | -5.2 |
| Fare +RP | 27.4 | -2.3 | 5.8 | 29.3 | 28.2 |
| LRT+fare+RP | 7.9 | 1.6 | 6.7 | 13.2 | 10.2 |

The strategies also have large effects on bus trips (from base response), with road pricing achieving a 15.7% increase, fare reduction an 11.2% increase, and light rail a 23.2% reduction (see Table 3). As with the impact on car trips, these effects are broadly cumulative in combined strategies; with the exception of the total combined strategy which has a greater than expected increase. (In the sensitivity tests, the effects of adding the accessibility response alone are to work against the direction of the transport strategy change, e.g. reducing the number of bus trips by 1.4% for road pricing, 2.2% for fare reduction and increasing them by 3% for LRT. The environment response alone leads to small decreases (<1%) in bus trips for all strategies, with the exception of road pricing where there is a very small (0.2%) increase). The initial land use response reduces bus trips, with the exception of strategies including light rail. The final land use response increases bus trips for all strategies, by between 4% for the do minimum and almost 7% for the combined strategy. These effects are higher than for all trips. The differences in the effects of strategies between columns 1, 4 and 5 are again relatively small, with at most a 6% difference for the initial response, and at most a 2% difference for the final response. Thus the impacts of land use response on bus trips are typically considerably less than the impacts of the transport strategies themselves.

**Table 4 : LRT Trips (thousands) in 2011**

| Land Use Response | Base (zero) | Initial | Final | Initial | Final |
|---|---|---|---|---|---|
| % change from | LRT strategy | Base LRT strategy | Base LRT strategy | LRT strategy | LRT strategy |
| Strategy | | | | | |
| LRT | 102.4 | 9.6 | 12.0 | 0.0 | 0.0 |
| LRT+RP | 1.5 | 10.0 | 13.9 | 1.7 | 3.0 |
| LRT+fare+RP | -19.4 | 6.8 | 10.0 | -20.2 | -19.2 |

Table 4 shows the effects on LRT trips. Since there are by definition none in the do minimum, the comparison is with the LRT strategy. It shows the effects of the strategies on LRT trips are as expected; their numbers are higher with road pricing and lower when bus fares are reduced. In all cases the effect of including responses to accessibility is to increase light rail trips by 10% or more. This suggests that activities are relocating to benefit from the high level of accessibility provided by LRT. In contrast the effects of adding the environmental response are small (<1%). Both the initial and final land use responses generate substantial changes in light rail trips for all light rail strategies, with a 14% increase for the light rail and road pricing strategy with the final response. Even so, the changes in light rail trips resulting from the combined strategies (columns 1, 4 and 5) are similar with no response and with both initial and final responses.

**Table 5: Fuel consumption (cars - millions litres)**

| Land Use Response | Base (zero) | Initial | Final | Initial | Final |
|---|---|---|---|---|---|
| % change from | Do Min | Base | Base | Do Min | Do Min |
| Strategy | | | | | |
| Do-min | 353.5 | -1.2 | 2.7 | 0.0 | 0.0 |
| LRT | -0.8 | 1.2 | 3.4 | 1.5 | -0.1 |
| Road Pricing | -7.4 | -0.8 | 2.9 | -7.2 | -7.1 |
| Fare Reduction | -3.5 | -0.9 | 2.5 | -3.3 | -3.6 |
| LRT+RP | -8.1 | 0.5 | 2.5 | -6.5 | -8.0 |
| Fare +RP | -10.8 | -0.5 | 2.5 | -10.3 | -10.8 |
| LRT+fare+RP | -10.9 | 0.5 | 2.7 | -9.4 | -10.7 |

The effect of the strategies is to reduce fuel consumption by cars, with road pricing being most effective single strategy, producing a 7.4% decrease as shown in Table 5. The effects are broadly additive when strategies are combined. The effect of introducing the accessibility response alone is to further decrease fuel consumption slightly for strategies excluding LRT; where LRT is included consumption increases slightly, reflecting the impact of LRT on car trips. Introducing the environmental response has a similar scale of response, reducing fuel consumption in all cases. The effect of the initial response is to reduce fuel consumption by around 1% for all strategies without LRT, and to increase it by around 1% for those which include LRT. The final response generates a more consistent 3% increase for all strategies. Once again, the impacts of the strategies are very similar with no response and with the initial and final responses (columns 1, 4 and 5); the only exceptions are the light rail-based strategies with the initial response. Tables 6 - 8 cover land use responses for which the percentage changes in column 1 are zero, since there is no mechanism for land use to change. Table 6 shows the results for housing rents in the city centre. Introducing the accessibility response causes rents to fall slightly in the do-minimum and for all strategies which exclude LRT. The inclusion of LRT leads to rent increases exceeding 10%. While the inclusion of the environmental response increases rents slightly in all cases.

**Table 6 : Housing Rents in City Centre (£ per m sq per week)**

| Land Use Response | Base (zero) | Initial | Final | Initial | Final |
|---|---|---|---|---|---|
| % change from | Do Min | Base | Base | Do Min | Do Min |
| Strategy | | | | | |
| Do-min | 0.947 | -2.0 | -17.1 | 0.0 | 0.0 |
| LRT | 0.0 | 12.7 | -14.8 | 15.0 | 2.8 |
| Road Pricing | 0.0 | -1.8 | -14.5 | 0.2 | 3.2 |
| Fare Reduction | 0.0 | -1.2 | -16.7 | 0.9 | 0.5 |
| LRT+RP | 0.0 | 16.8 | -11.0 | 19.2 | 7.4 |
| Fare +RP | 0.0 | -0.6 | -14.0 | 1.4 | 3.7 |
| LRT+fare+RP | 0.0 | 16.5 | -10.9 | 18.9 | 7.5 |

The initial response produces small reductions in rents for strategies which exclude LRT, and increases of 13% to 17% for those which include it. The final response produces much more consistent results across all strategies, with reductions of around 11% to 17%. Not surprisingly the strategies are predicted to have different impacts with the initial and final responses. With the initial response, light rail-based strategies increase rents, by comparison with the do minimum, by 15% to 19%. With the final response the impact is in the range 3% to 8% with road pricing also increasing rents by around 3% to 4%.

**Table 7 : Population in City Centre**

| Land Use Response | Base (zero) | Initial | Final | Initial | Final |
|---|---|---|---|---|---|
| % change from | Do Min | Base | Base | Do Min | Do Min |
| Strategy | | | | | |
| Do-min | 41016 | -3.7 | -17.7 | 0.0 | 0.0 |
| LRT | 0.0 | 20.9 | -7.2 | 25.6 | 12.8 |
| Road Pricing | 0.0 | -5.5 | -15.9 | -1.8 | 2.2 |
| Fare Reduction | 0.0 | -2.6 | -17.0 | 1.2 | 0.8 |
| LRT+RP | 0.0 | 27.2 | -0.6 | 32.1 | 20.8 |
| Fare +RP | 0.0 | -3.9 | -14.9 | -0.2 | 3.4 |
| LRT+fare+RP | 0.0 | 26.0 | -0.6 | 30.9 | 20.8 |

Table 7 shows the results for population in the city centre. Introducing the accessibility response alone, causes the population in the city centre to fall for all strategies excluding LRT. However, strategies including LRT increase population levels in the centre by more than 20%. The effect of the environmental response is very small except for strategies involving road pricing which lead to increases of around 2.5%, implying that only road pricing, of the strategies tested, improves the environment sufficiently to attract new residents. The initial response once again produces different impacts for strategies without light rail, where population falls by 3% to 6% and with light rail, where population rises by 21% to 27%. With the final response the distinction remains but is less marked. Here population falls by 18% in the do minimum and by between 15% and 17% for non-light rail strategies; with light rail the reduction is limited to 1% to 7%. Both responses therefore show a net increase of population with light rail: of 26% to 32% with the initial response, and 13% to 21% with the final response. Other strategies have much smaller impacts of up to 3% on population.

Table 8 shows the results for resident workers in the city centre. The patterns are very similar to those for population, with the exception that the effects of light rail-based strategies are smaller than for population, at 10% to 16% with the final response.

**Table 8 : Resident workers in City Centre**

| Land Use Response | Base (zero) | Initial | Final | Initial | Final |
|---|---|---|---|---|---|
| % change from | Do Min | Base | Base | Do Min | Do Min` |
| Strategy | | | | | |
| Do-min | 20145 | -3.7 | -12.4 | 0.0 | 0.0 |
| LRT | 0.0 | 20.5 | -3.9 | 25.1 | 9.7 |
| Road Pricing | 0.0 | -5.1 | -11.4 | -1.5 | 1.1 |
| Fare Reduction | 0.0 | -2.3 | -11.6 | 1.4 | 0.9 |
| LRT+RP | 0.0 | 27.2 | 1.5 | 32.1 | 15.9 |
| Fare +RP | 0.0 | -3.4 | -10.4 | 0.3 | 2.3 |
| LRT+fare+RP | 0.0 | 26.4 | 1.8 | 31.3 | 16.2 |

## RESULTS FOR THE ALTERNATIVE LAND USE SCENARIO

### Introduction

The land use scenario used as a basis for the results reported above was developed in line with data given in the Edinburgh structure plan and is termed land use scenario 1 (LU1). A second theoretical land use scenario has been developed to test the effect of concentrating exogenous development within the Edinburgh area; the broad aim of the second scenario (LU2) being to develop land around the LRT corridors rather than in the outer areas. The second land use scenario has been simulated for the four main strategies i.e. do-minimum, LRT, road pricing and fare reduction alone, plus the total combined strategy with the final response coefficients.

The percentage change columns between land use scenarios are the most important measures as they indicate the shift in each indicator due to a change in land use scenario for each set of responses. If we assume that the difference between the do-minimum scenario for each indicator is the expected shift due to this change in land use assumptions, then the other results are dependent upon or affected by the strategy if the change is significantly different to this first value.

### Comparison Of Transport Indicators

**Table 9 :Total trips (thousands) in 2011 and percentage change from LU1 to LU2**

| Strategy | LU1 | LU2 | %LU2-LU1 |
|---|---|---|---|
| Do-min | 1092 | 1103 | 1.0 |
| LRT | 1116 | 1128 | 1.1 |
| Road Pricing | 1080 | 1091 | 1.0 |
| Fare Reduction | 1100 | 1111 | 1.0 |
| LRT+fare+RP | 1107 | 1118 | 1.0 |

In all cases the revised land use scenario increases trips by around 1% (Table 9).

**Table 10 : Fuel consumption (cars - millions litres)**

| Strategy | LU1 | LU2 | %LU2-LU1 |
|---|---|---|---|
| Do-min | 363.1 | 362.9 | -0.1 |
| LRT | 362.7 | 362.1 | -0.2 |
| Road Pricing | 337.5 | 335.4 | -0.6 |
| Fare Reduction | 350 | 349.4 | -0.2 |
| LRT+fare+RP | 324.3 | 322.1 | -0.7 |

The changes in fuel consumption arising from the alternative land use scenario are very small in magnitude. However, as Table 10 shows there is some variation between transport strategies, as road pricing and the combined strategy produce reductions of 0.6% and 0.7% respectively compared with a reduction of 0.1% in the do-minimum.

The other transport indicators reflects a similar pattern with the difference between the land use scenarios in the do-minimum being broadly repeated in the strategies. The impact of the land use scenarios on transport indicators is fairly small overall.

## Comparison of Land Use Indicators

Again the analysis concentrates on the shift due to the change in land use scenarios and any exceptions to the expected shift. The impacts of the different land use scenarios on the land use indicators are an order of magnitude larger; as might be expected.

**Table 11 : Housing Rents in City Centre (£ per m sq per week)**

| Strategy | LU1 | LU2 | %LU2-LU1 |
|---|---|---|---|
| Do-min | 0.785 | 0.721 | -8.2 |
| LRT | 0.807 | 0.739 | -8.4 |
| Road Pricing | 0.81 | 0.747 | -7.8 |
| Fare Reduction | 0.789 | 0.725 | -8.1 |
| LRT+fare+RP | 0.844 | 0.772 | -8.5 |

City centre rents decrease by 8.2% in the do-minimum as shown in Table 11. All strategies give similar shifts with the exception of LRT and combined strategies, which give slightly greater decreases in rents.

**Table 12 : Population in City Centre**

| Strategy | LU1 | LU2 | %LU2-LU1 |
|---|---|---|---|
| Do-min | 33754 | 38134 | 13.0 |
| LRT | 38070 | 42763 | 12.3 |
| Road Pricing | 34505 | 39231 | 13.7 |
| Fare Reduction | 34039 | 38457 | 13.0 |
| LRT+fare+RP | 40782 | 45943 | 12.7 |

Table 12 shows that city centre population increases by 13.0% in the do-minimum. LRT strategies give a slightly lower increase. Road pricing alone gives a greater increase, while the combined strategy result shows a slightly lower increase in population.

**Table 13 : Resident workers in City Centre**

| Strategy | LU1 | LU2 | % LU2-LU1 |
|---|---|---|---|
| Do-min | 17649 | 20066 | 13.7 |
| LRT | 19357 | 21813 | 12.7 |
| Road Pricing | 17851 | 20390 | 14.2 |
| Fare Reduction | 17807 | 20226 | 13.6 |
| LRT+fare+RP | 20515 | 23063 | 12.4 |

Table 13 shows that the increase in city centre resident workers is 13.7% for the do-minimum. The LRT strategy gives a lower increase in resident workers. Road pricing alone gives a greater increase in resident workers in the city centre whereas the combined strategy gives a lower increase in workers.

## CONCLUSIONS

A strategic land use - transport interaction model, DELTA/START, has been developed, in which location of activities is sensitive to the changes in accessibility and environmental quality induced by transport strategies. Coefficients in the model for response to accessibility and environment were initially estimated from the literature, and subsequently generated from additional stated preference surveys. Both sets of coefficients gave broadly similar results.

The new model was used to test a series of transport strategies for Edinburgh, involving combinations of light rail provision, road pricing and fares reductions. It was also used to test the interaction between these and a revised land use scenario in which development was focused in the city centre and on the light rail corridors.

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 response; 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%. Generally it appears 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, and one which it is intended to investigate in more detail in subsequent research.

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