Published paper
Simon Shepherd (1998) *Towards the Sustainable City: The Impact of Land Use - Transport Interactions. The development of revised location coefficients.* Institute of Transport Studies, University of Leeds, Working Paper 515

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1. Development of DELTA location coefficients for Response 5

This paper gives an outline of the steps undertaken to convert from the willingness to pay for travel time savings, air quality and noise derived in tasks 3 and 4 to the location coefficients for use with the DELTA/START model.

2. Basis of the previous Task 2 Response 1 coefficients

(See David's note 24/11/96)

Before describing the process for developing the new estimates it is useful to review the coefficients and the development of those used in task 2 i.e. response 1.

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 :-

$$\Delta V_{ti}^{h} = \theta^{hU}(U_{ti}^{h} - U_{(t-l)i}^{h}) + \theta^{hA}(A_{ti}^{h} - A_{(t-l)i}^{h}) + \theta^{hQ}(Q_{ti}^{h} - Q_{(t-l)i}^{h}) + \theta^{hR}(R_{ti}^{h} - R_{(t-l)i}^{h}) \quad (2)$$

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 as 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 required

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

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

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

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

The utility of consumption coefficients were initially developed from Family Expenditure survey information. The function in use is the simplest possible Cobb-Douglas function with just two goods - housing and other.

2.1 Utility of Consumption and Accessibility coefficients (response 1 task 2)

The four coefficients described above have been estimated from two different sources of data. The coefficients on utility of consumption and on accessibility were derived from a cross-sectional calibration carried out on data for Bristol, as part of DELTA implementation. The values were estimated using the ALOGIT program for just four income groups. In order to apply them in DELTA, a relationship between the coefficients and the household incomes was hypothesised (**which was?),** and coefficients were accordingly interpolated or extrapolated. The absolute values of the coefficients were taken, not just their relative values, so these determine the overall sensitivity of the model.

Note that the two coefficients derived from the Bristol work deal with the effect of variables which must change for the model to work at all, i.e. accessibility and utility of consumption (housing rent). The coefficient on utility of consumption is particularly important as it is possible to derive the coefficient for any other variable that will produce an exogenously researched willingness-to-pay.

2.2 Coefficient of Area Quality (response 1 task 2)

The “area quality” variable was defined in terms of a premium on rent. An increase of 1 unit in the quality variable for a zone should produce, on average, a 1% increase in rent. This is only true for localised changes as increasing the quality in all zones will have zero effect (as no zone will be relatively better than any other). The average coefficient on area quality was found empirically by running DELTA and then scaled to adjust for each income level.

2.3 Composition of the Environment variable (response 1 task 2)

This was complicated by the need to combine START outputs - noise, carbon monoxide, oxides of nitrogen and volatile organic compounds. A compound variable was produced which was assumed to have an equal but opposite effect to the area quality variable - i.e. an increase of 1 unit will typically produce a rent decrease of 1%. The coefficient for each household type is therefore the negative of that on area quality.

Within this compound environment variable the elements are weighted as follows :-

noise : 0.8 as a 1dBA increase in noise will on average produce a 0.8% decrease in rent (**should this be negative?)**

The weights on different components of air quality have been calculated using two pieces of information

- the relative toxicity of different emissions, as a means of estimating their relative importance;

- and an overall willingness-to-pay for a reduction in atmospheric pollution.

Again it has been assumed that willingness-to-pay varies with income. The required information was taken from tables in Tinch (1995).

In general, all the coefficients then vary with household type directly except accessibility which has four repeating values (-.001, -.002, -.004, -.006) which is related to SEG and therefore household income, with the assumption that the highest income group of a particular household type is least responsive to changes in accessibility.

3. Calculation of response 5 coefficients from the stated preference survey.

The process for converting the results of the SP survey into the four coefficients used above in DELTA is described in this section in outline only, for further information see appendix A. The results from the SP survey are for specific units and for 1996 prices. The variables produced were not initially related to income, though other variables were produced which reflected the income effect, see Wardman et al (1997). Thus the process for converting from the SP results into the DELTA coefficients involves many steps to take account of changes in units, income effects, difference between time and accessibility, and change of base year between SP survey and START base year. The final steps include a scaling to account for a change in the base utility of consumption coefficient. The outline procedure is as follows :-

Notation used in flow chart :

Willingness to pay values are generally given by the letter w with various subscripts and superscripts. Location model coefficients are denoted by θ with relevant subscripts as in equation 2 above. Note that for simplicity the household subscript h has been dropped.

Thus we have :-

w_t willingness to pay for time savings
w_n willingness to pay for changes in noise
w_a willingness to pay for changes in air quality
w_t^i willingness to pay for time savings by household income i in 1991
w_n^i willingness to pay for changes in noise by household income i in 1991
w_a^i willingness to pay for changes in air quality by household income i in 1991
w_A^{iS} willingness to pay for **accessibility** savings by household income i in 1991 related to START units S
w_n^{iS} willingness to pay for changes in noise by household income i in 1991 related to START units S
w_a^{iS} willingness to pay for changes in air quality by household income i in 1991 related to START units S

w_U^{iD} willingness to pay for changes in utility of consumption U by household income i in 1991 related to DELTA units D

θ^U = coefficient of response to change in utility of consumption

θ^A = coefficient of response to change in accessibility

θ^Q = coefficient of response to change in area quality

θ^R = coefficient of response to change in transport-related environmental quality

F is the income related scaling factor which ensures θ^A is in the same range for response 5 as for response 1.

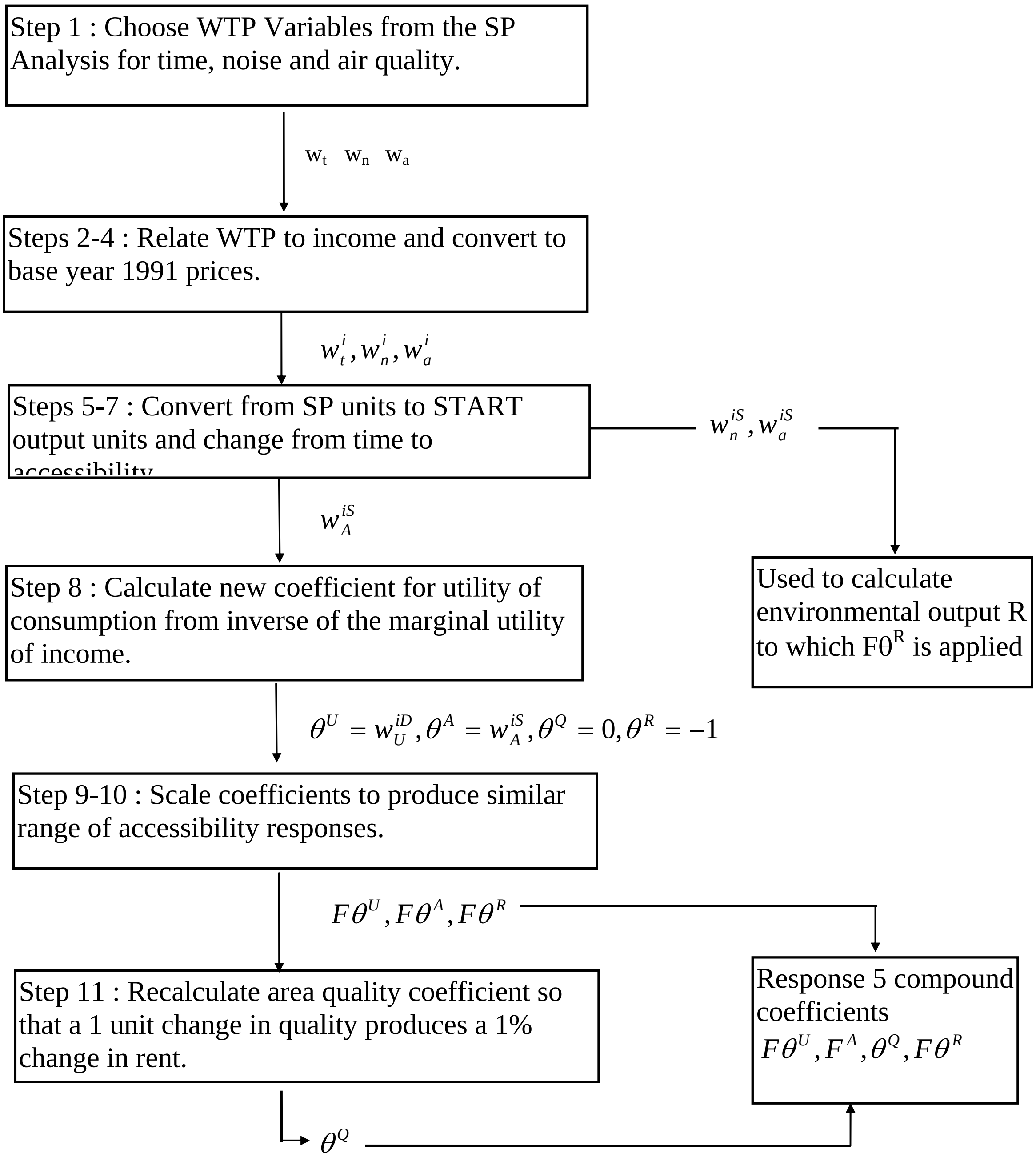

Figure 1 : Flow chart of calculation of response 5 coefficients

1. **Step 1 : Choose variables from SP results for time (accessibility), noise and air quality.**
   Values of time, noise and air quality were chosen from the preferred model resulting from the SP analysis. The variables chosen were Car Save for time (accessibility), noise4 for noise and AirLM2 for air quality, taken from Wardman et al (1997). These are w_t, w_n, and w_a in figure 1.

2. **Step 2 : Produce relationship to income (1996) for 3 WTP variables.**
   Linear regression produced for 3 variables (see Appendix A)

3. **Step 3 : Scale to 1996 weekly incomes by household type.**

Incomes in base year per household were in location model input files which were then factored to yearly incomes in 1996 to make use of the regression models from step 2.

4. **Step 4 : Convert to WTP for base year 1991.**
The conversion factor used is based upon START earnings index of 1.8 over 20 years i.e. for converting from 1996 back to 1991 use $\left(\frac{1}{1.0298}\right)^5$ = 0.863.

5. **Step 5 : Calculate relationship between accessibility as defined in START output and changes in in-vehicle-time as used in the SP questionnaire.**
Derived from START runs (see Appendix A).

6. **Change Noise units**
Change from percentage changes to perceived dBA changes - factor by 7 (see Appendix A)

7. **Change air quality units for CO only (see Appendix A)**

8. **Calculate new utility of consumption coefficient using program UCML11**
Setting inputs as follows θ^{hU}=0, θ^{hQ}=0, θ^{hR}=-1, and $\theta^{hA} = w_A^{iS}$ i.e. the accessibility values from the SP model scaled by income for each household and the IVT/accessibility ratio as in steps 1-5. The program then calculates the new coefficient on utility of consumption $\theta^{hU} = w_U^{iD}$. This is done by calculating the change in utility of consumption for a 1 unit rise in income and hence the inverse of the marginal utility of income which is equal to the willingness to pay for a 1 unit change in utility of consumption w_U^{iD}.

9. **Step 9 : Produce a scaling factor.**
The accessibility coefficients derived in steps 1-6 were scaled so that the values were within the previous range i.e. -0.001 to -0.006. This was achieved by forming a linear relationship with household income so that the highest household income had an accessibility coefficient of -0.001 and the lowest household income had an accessibility coefficient of -0.006. This produced household specific scaling factors which were then used in step 10.

10. **Step 10 : Scale coefficients** The coefficients input in step 8 plus the calculated θ^{hU} are then scaled by the specific factors produced from step 9.

11. **Step 11 : Recalculate the area quality coefficient.**
This process is the same as for the previous set of coefficients in that it is derived from DELTA runs so that a 1 unit change in quality produces a 1% change in rent.

Having followed this procedure a new set of coefficients termed response 5 are produced for use with DELTA/START strategy tests as applied in task 2.

4. A comparison of response 1 and response 5 coefficients

This section shows how the coefficients from response 5 are related to household income and how they compare to response 1 coefficients.

Figure 2 shows the willingness to pay relationships w_t^i, w_n^i , and w_a^i derived from the SP analysis for values of time, air quality and noise versus household income. The coefficients are plotted against household income. Figure 2 shows that from the SP analysis the higher household incomes are willing to pay more than lower household incomes for improvements in noise, time and air quality.

Figure 3 shows the income related scaling factor derived from the accessibility relationships between R1 and R5 discussed in appendix A and applied to utility of consumption, noise and pollution. This scaling factor is represented by F in the flowchart although it is actually a set of factors related to each households' income. The area quality coefficient is not scaled by F as it is calculated post-scaling to give a 1% change in rent for a change of 1 unit in area quality. This process results in the set of response 5 coefficients $F\theta^{hU}$, $F\theta^{hA}$, θ^{hQ} and $F\theta^{hR}$. (Here it could be argued that the area quality coefficient is equivalent to a scaled coefficient $F\theta^{hQ}$ as it was calculated with all others scaled.)

Ideally we would base a comparison on the willingness to pay values for each attribute for response 1 and response 5. However this is not practicable as the two responses were derived using different methods and the willingness to pay for response 1 are not available for noise and accessibility as the analysis resulted in direct θ values rather than willingness to pay. However for air quality we can compare the values for response 1, taken from Tinch (1995) from a Norwegian study; which had a range of £282 - £561 per annum for a 50% reduction in air pollution with those used in response 5 which had a range of £211 - £400 plus calculated from tables 5 and 6 Wardman et al (1997). The willingness to pay appears to be lower in the UK than in Norway (although the income range was different ?).

A further valid comparison is to look at the ratios of the coefficients with the coefficient on utility of consumption i.e. we look at the relative utilities of accessibility, noise, pollution and area quality with respect to willingness to forgo utility of consumption across the responses. This analysis is necessary as the scaling of utility of consumption coefficients has had the effect of changing the relative importance of the responses in terms of overall utility of consumption and therefore of location. Dividing the coefficients through by the coefficient on utility of consumption is a means of expressing the response to changes in accessibility, noise and pollution in terms of ability to influence changes in rent for example $\frac{F\theta^A}{F\theta^U}$ has the units change in utils per minute and the scaling factor cancels out. We are effectively comparing the pre-scaled ratios of the coefficients for both responses.

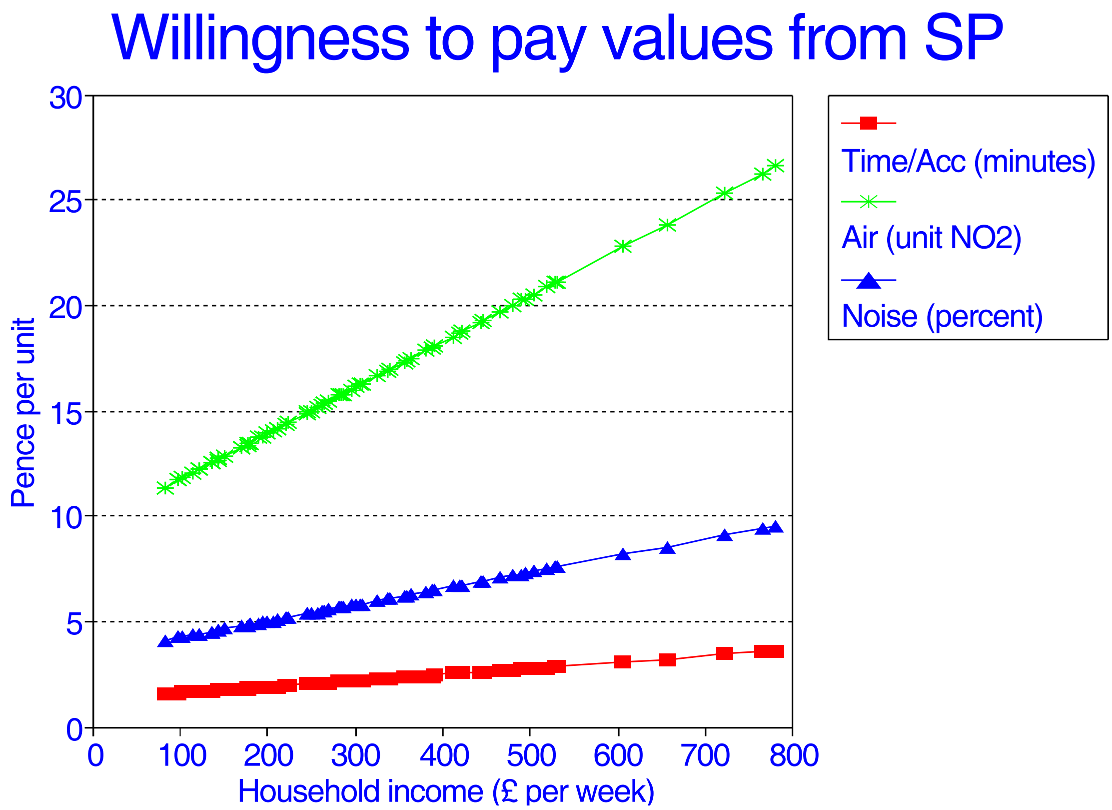

Figure 2 : Willingness To Pay variables from SP

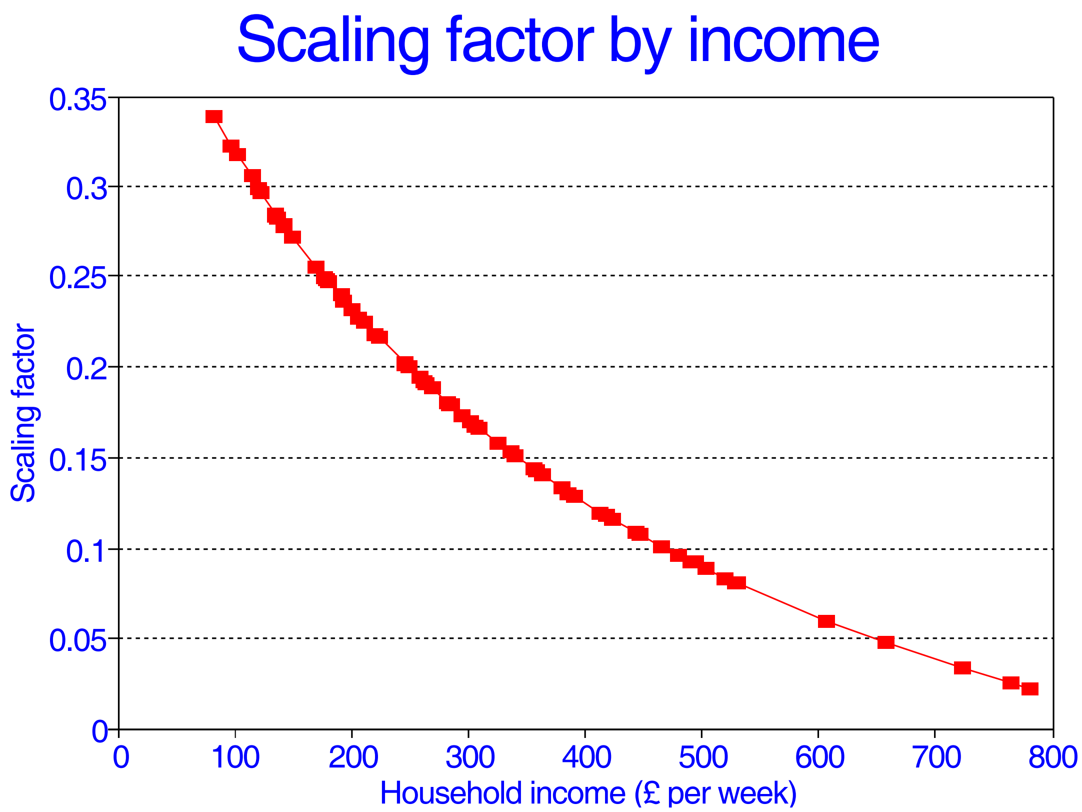

Figure 3 : Scaling factor

Figures 4-7 show the ratios of coefficients to the coefficient on utility of consumption. Figure 4 shows that the noise[1] response relative to rent (or Utility of consumption) for the R5 response is a lot lower than for R1 as income increases.

Figure 5 shows that the pollution[2] response for R5 has a lower response relative to rent than R1 does. However this pollution response also has the additional complication that for R5 the response is based solely on CO output whereas the R1 response is based upon CO, NO_x and VOC's which may have implications when comparing the coefficients.

Figure 6 shows the area quality coefficients have the same general curve, as R5 was not factored by the scaling factor, again R5 response relative to rent is actually lower than R1 relative to rent.

Figure 7 shows the accessibility response. High incomes are more responsive relative to rent for both R1 and R5. Again R5 response is lower than R1 which has four curves separated by SEG.

For all four variables the sensitivity to change increases with higher incomes as reflected in the willingness to pay relationships shown in figure 2.

[1] Note that for noise the compound response is plotted i.e. $F\theta^R w_n^{iS}$ for response 5 and $\theta^R w_n^{iS}$ for response 1.

[2] Note that for pollution the compound response is plotted i.e. $F\theta^R w_a^{iS}$ for response 5 and $\theta^R w_a^{iS}$ for response 1.

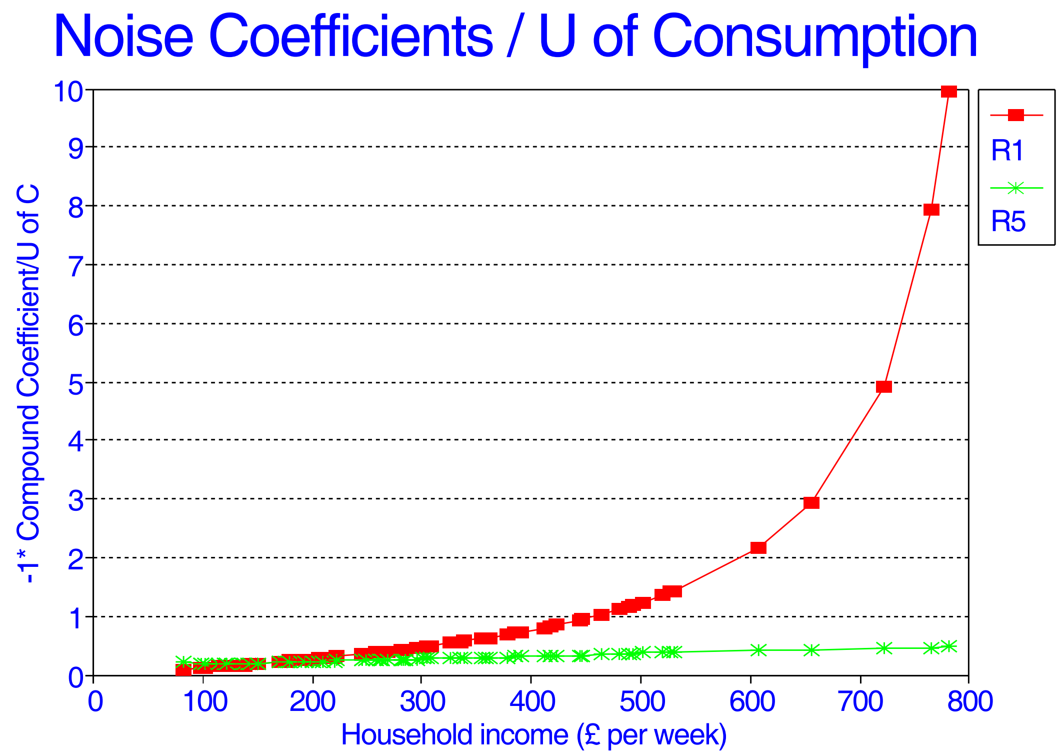

Figure 4 : Noise / Utility of consumption

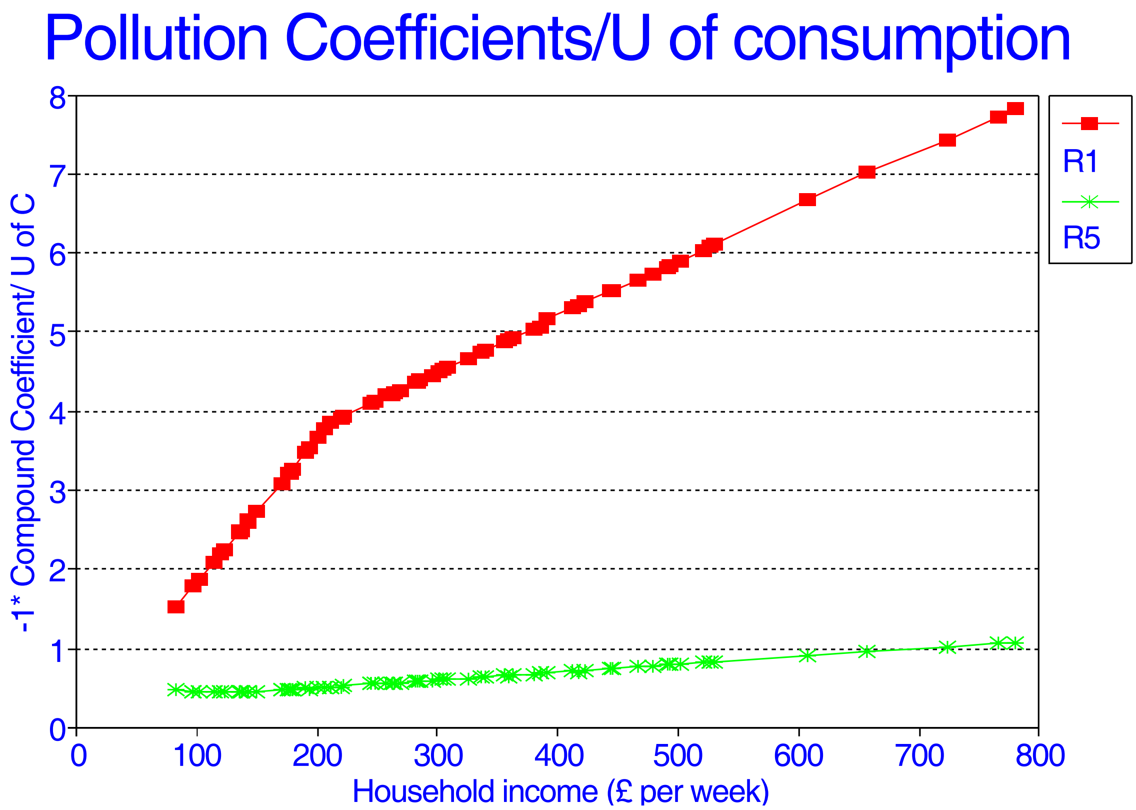

Figure 5 : Pollution / Utility of consumption

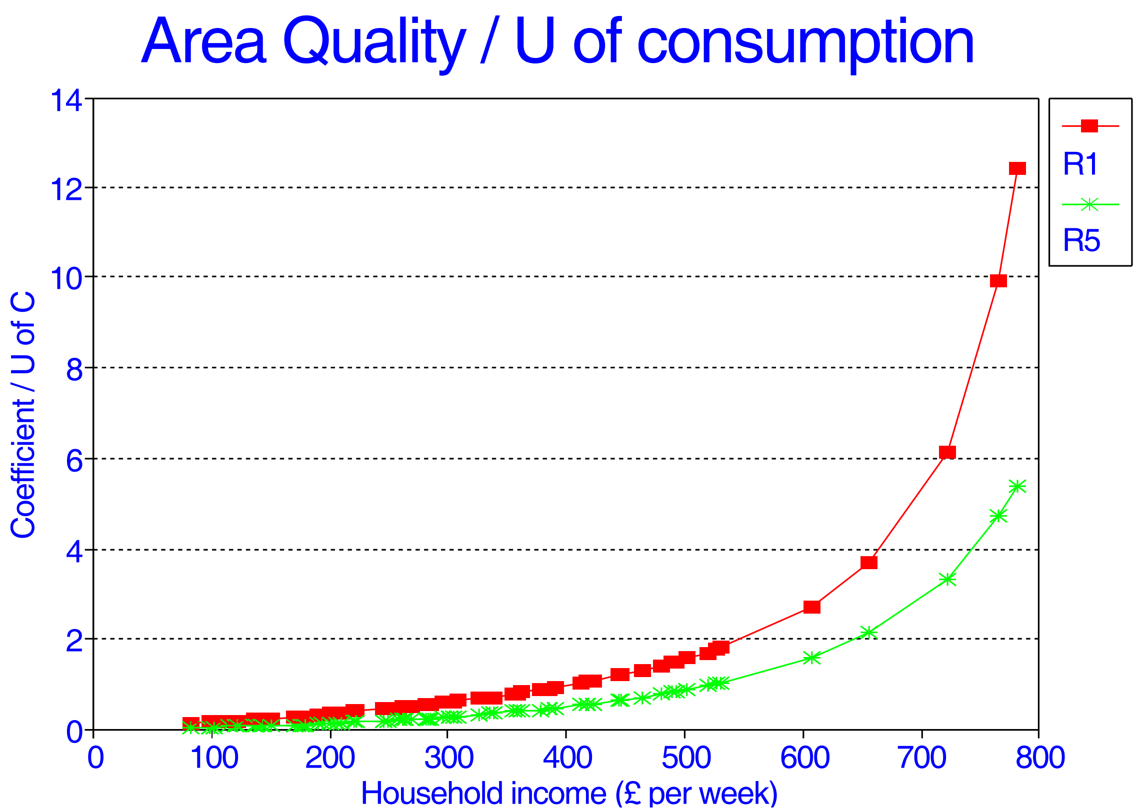

Figure 6 : Area Quality / Utility of consumption

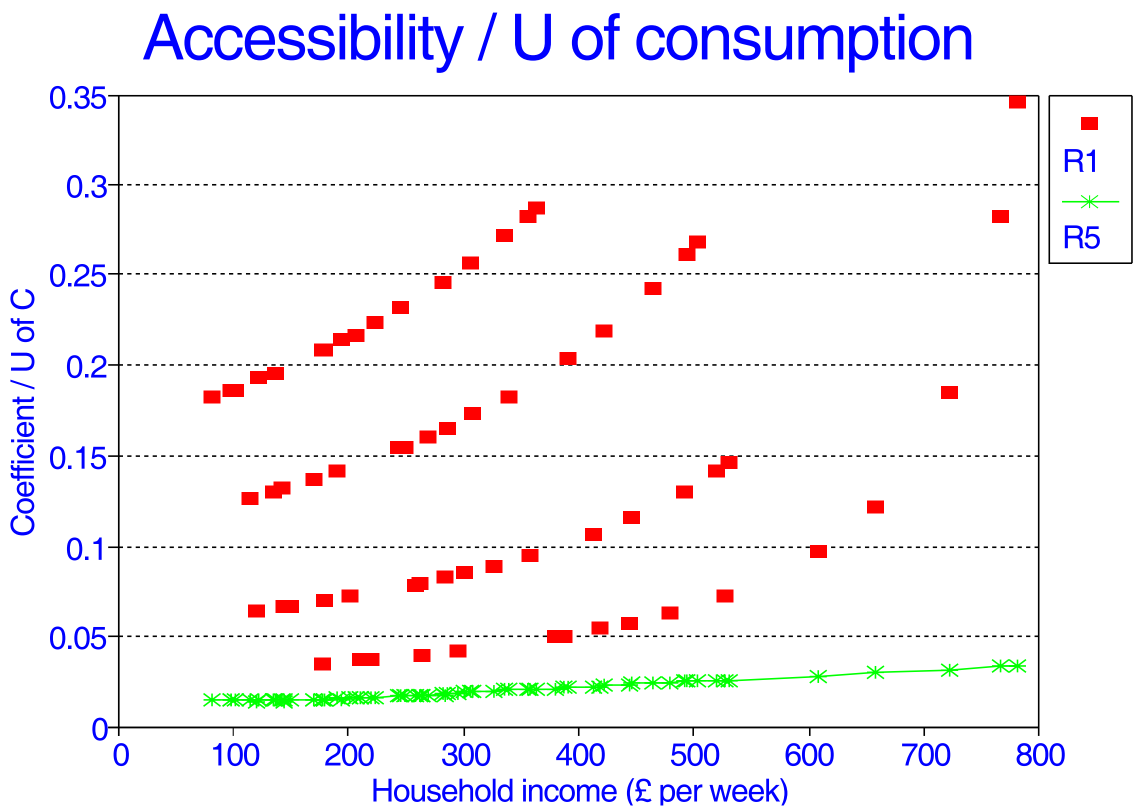

Figure 7: Accessibility / Utility of consumption

Figures 8-12 show the compound coefficients, after scaling, on utility of consumption, accessibility, area quality, noise and pollution against household income (though for the accessibility coefficient it is easy to spot the SEG groupings from R1) for both response 1 and response 5.

4.1 Utility of consumption

Figure 8 implies that lower income households are more sensitive to changes in rent. Response 5 is greater than response 1 for all incomes and the shape of the curve is characterised by the scaling factor curve in figure 3 above.

4.2 Accessibility

From Figure 9 it can be seen that the assumed linear relationship for R5 used to set the accessibility ranges to those used in R1 gives a completely different set of coefficients compared to R1. This assumption that high income households have a lower response to changes in accessibility forms the basis of the scaling factor curve in figure 3 which is then applied to utility of consumption, noise and pollution coefficients.

The arguments for the assumption are :-

- high income households generally live further from their work place / city centre and so generally accept living in zones with lower accessibility (for reasons such as better quality etc.)
- lower income households cannot afford outer areas and value savings made on transport costs.

This appears at first sight to be contrary to the willingness to pay curve for time savings. However, as figure 7 shows the higher income households are willing to pay more for savings in accessibility relative to changes in utility of consumption.

4.3 Area Quality

Figure 10. Area quality was derived from the R1 estimates and is simply factored by 4.5, this value being obtained from running DELTA so that a 1 unit change in quality causes a 1% change in rent. Higher income households are more responsive to changes in area quality.

4.4 Noise

Figure 11. The scaling factor has been applied to noise and has the effect of inverting the relationship with respect to income compared to both the R1 coefficients and the WTP in figure 2. Thus lower income households are now apparently more responsive to changes in noise. Again from figure 4 it can be seen that the ratio to utility of consumption relationships increase with income, though the ratio is lower for higher incomes for response 5.

4.5 Pollution

Figure 12. Again the scaling factor has been applied to the pollution coefficients for R5 and has inverted the WTP relationship in figure 2. The initial R1 curve was a quadratic and so is similar to R5 for high income households but has lower sensitivity for low income households. Again the ratio with utility of consumption shown in figure 5 shows that the response increases with higher incomes though response 5 is far lower than response 1.

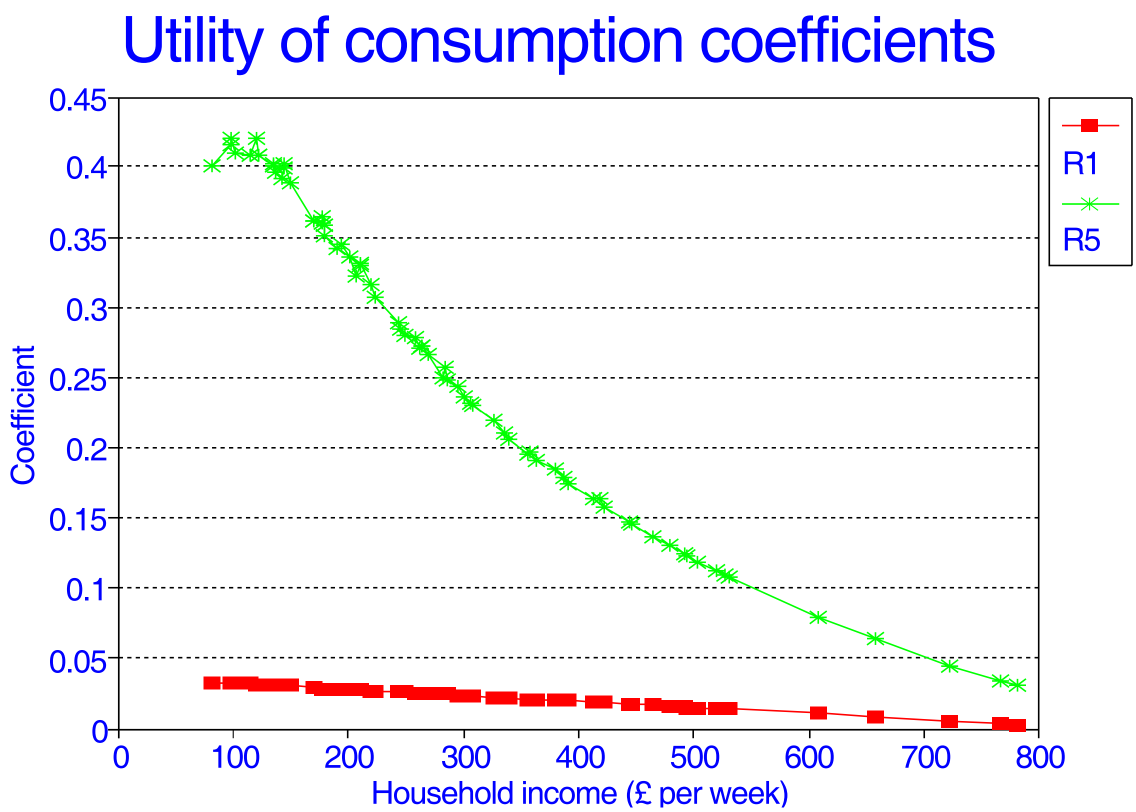

Figure 8 : Utility of consumption coefficients

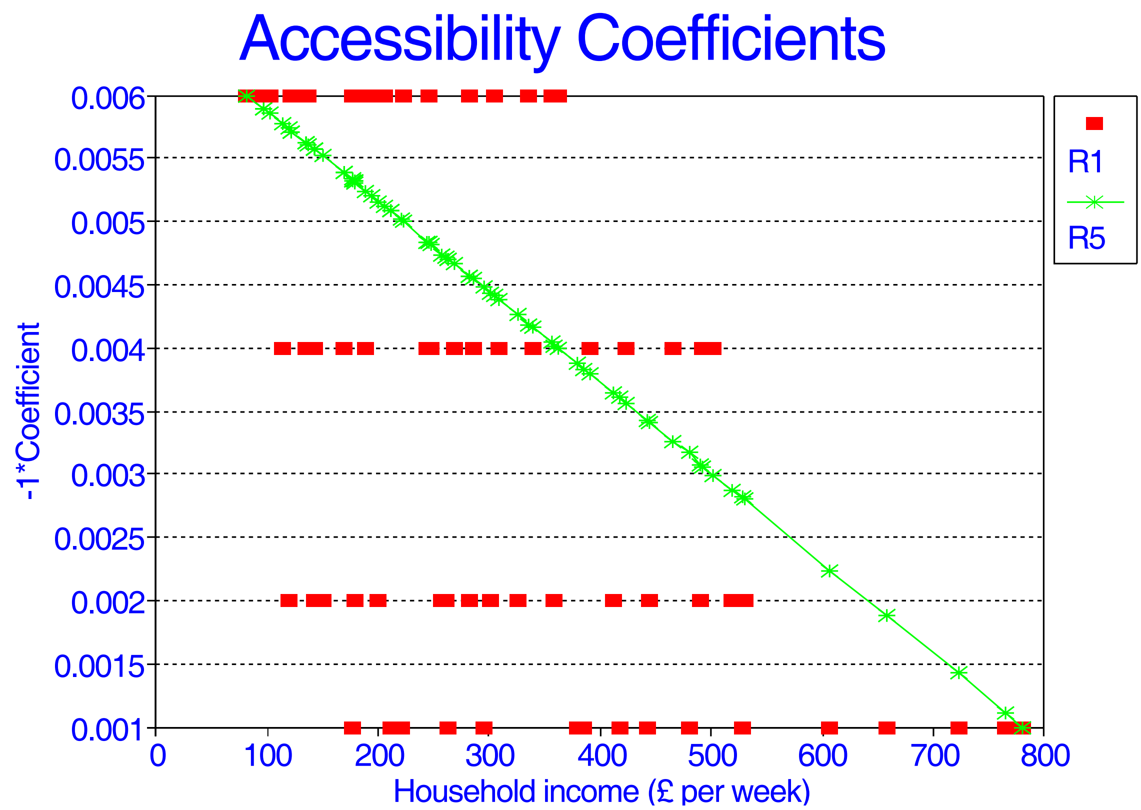

Figure 9: Accessibility coefficients

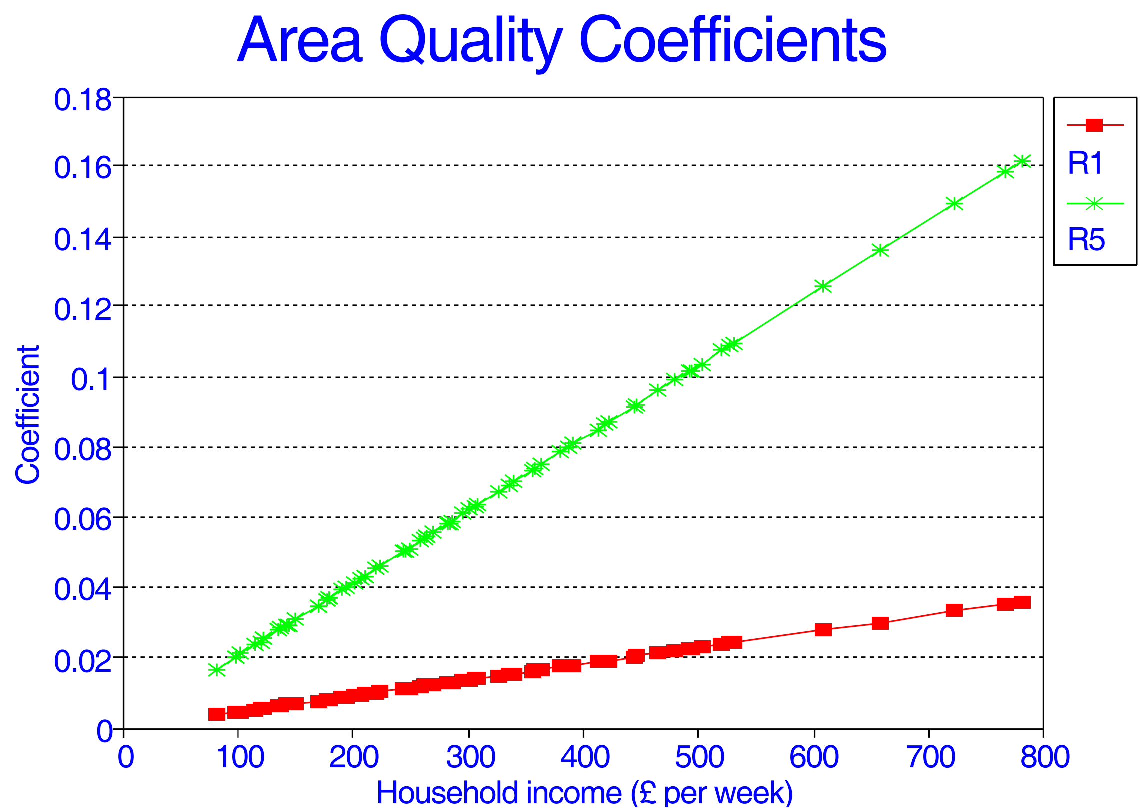

Figure 10 : Area Quality coefficients

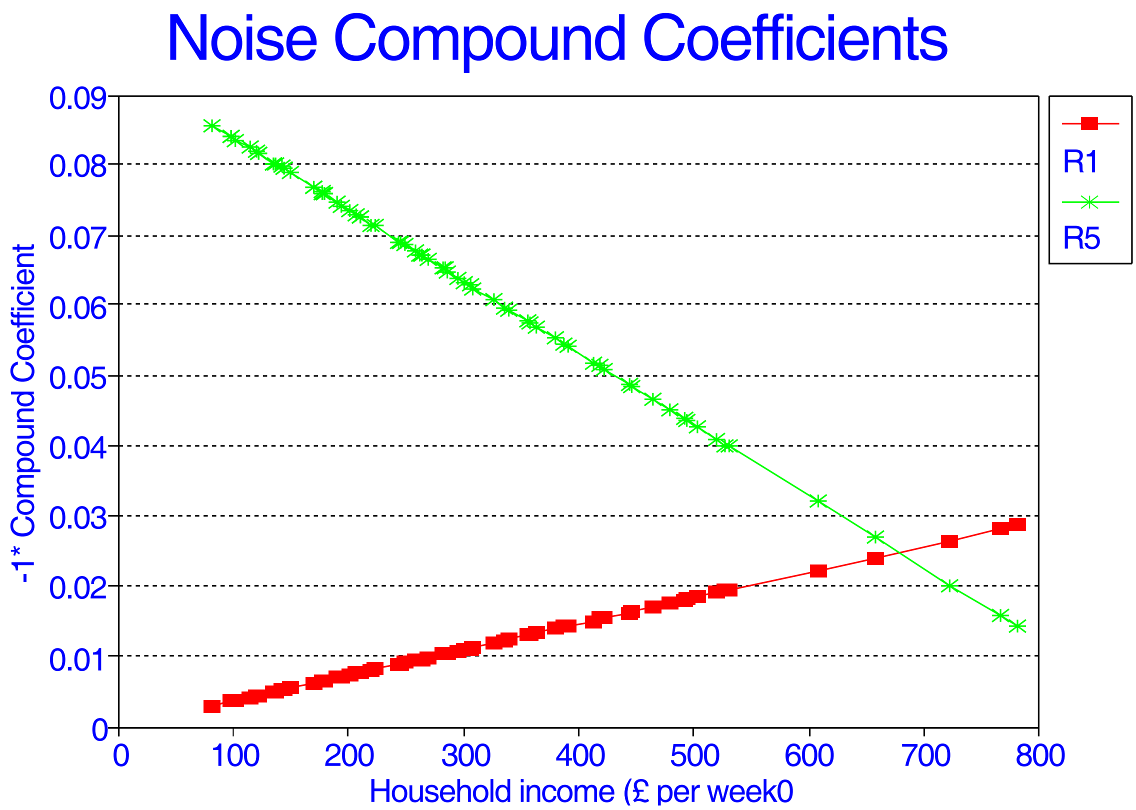

Figure 11 : Noise compound coefficients

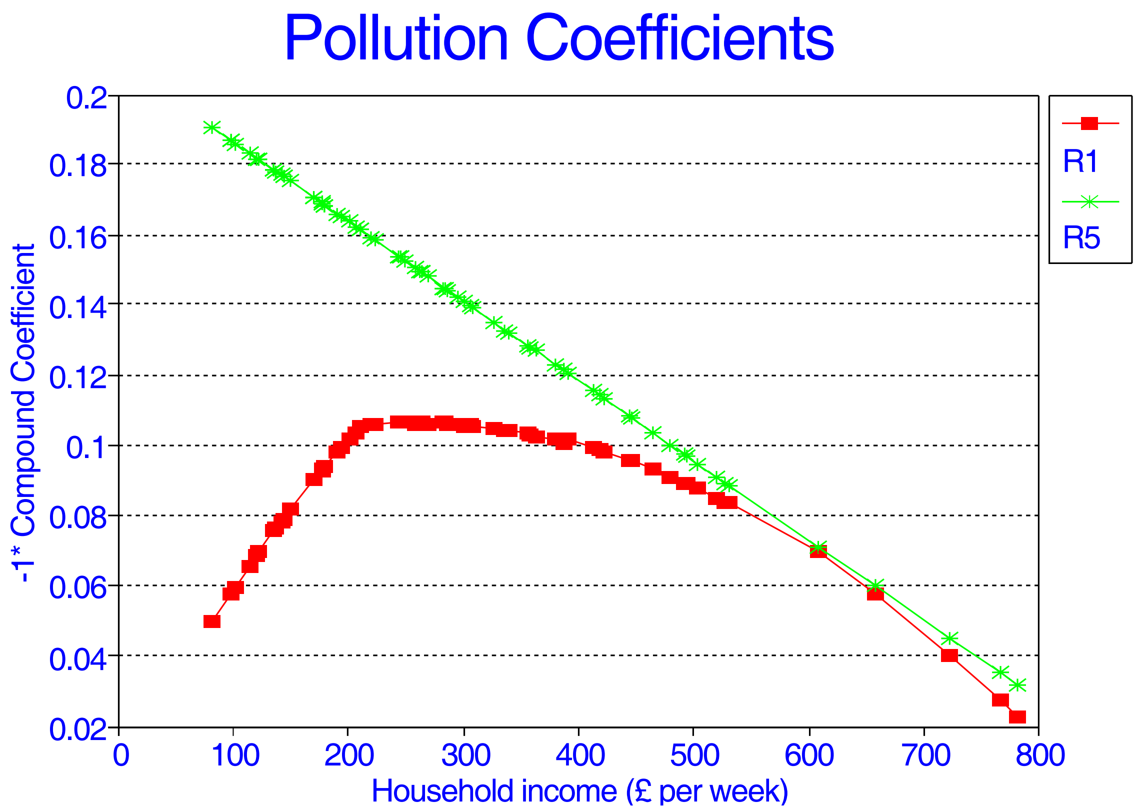

Figure 12 : Pollution compound coefficients

The assumption behind the scaling curve on the accessibility response feeds through to apparently invert noise and pollution WTP and scales the coefficient on utility of consumption. In an attempt to understand these curves it is necessary to view the response coefficients in the context of the location model described by equation 2. Thus for each household type a utility of location is derived for each zone in money terms. If we consider each household type separately then V for each zone is made up from a response to utility of consumption, accessibility, area quality and environment related variables. The magnitude of V for a particular zone will differ significantly for each household type, however the relative response to the components can be analysed by basing the responses on the response to rent i.e. utility of consumption. This results in the comparison made for figures 4-7 and shows that the responses are similar in direction but that the response 5 coefficients are less responsive to changes in the transport system and more responsive to changes in utility of consumption or rent.

Appendix A : Detail of steps used to produce response 5 coefficients

Step 2 : Produce relationship to income in 1996 for 3 chosen variables from step 1.

The regression was calculated using the mid-points of the first five income bands in the SP analysis as the independent variable and dividing the coefficients by the five tax1 variables to produce the dependent Y values. The final income band was ignored in the analysis. Each regression had an R^2 value of 0.967.
The following table gives the linear regression results for the three variables :-

Variable	Constant	X-coeff
Time-Car-Save	0.012972	5.67E-07
Air-LM2	0.095595	4.18E-06
Noise4	0.034403	1.5E-06

The units are as expected so for example for time-car-save an income of £30,000 p.a. gives a value of 0.03 or 3 pence per minute. The units for AirLM2 are pence per unit change in NO_2, for noise pence per percentage change.

Step 5 : Calculation of relationship between accessibility and in-vehicle-time

In order to use the coefficients derived from the SP survey for changes in in-vehicle-time it was necessary to derive the relationship between the modelled in-vehicle-time and the modelled accessibility for changes in certain supply conditions.

It was possible to produce changes in car and bus in-vehicle times together (via speed flow data) with a range of percentage changes between -7% and -35% for zone to zone movements with associated changes in bus in-vehicle times of between -7% and +8% which produces changes in the overall accessibility measure in the range -4 to -7%.

It was possible to change bus in-vehicle time by 3 to 14% with only slight changes in car times which produce less than a 1% change in overall accessibility measures.

The revised method was as follows :-

1. to use 6 START input scenarios for car and bus speed changes (plus an LRT strategy).
2. to produce a zone based average in-vehicle time and hence a change in average in-vehicle time for car, bus and for a composite based on a split of 65% car 35% bus.
3. to produce the ratio by zone:

$$Ratio = \frac{Abs.Change\_IVT * Household\_Trip\_rate}{Abs.Change\_Accessibility}$$

i.e. change in IVT divided by {absolute change in accessibility for a particular household (from ASRV file) divided by the average household trip rate for that household} for car, bus and composite modes. This is done for household types 10 and 62 which are young single employed SEG 2 and young couple with children (2 employed) SEG 2.

4. to repeat steps 2 and 3 for the set of START scenarios.
5. to average this ratio over the 14 inner zones and by the 25 zones, weighted by population in those zones, for car, bus and composite modes.
6. choose a representative ratio for use in the overall process

Note that in step 2 the averaging process will be a straight average over the time periods and zones of what is currently available. This is a simplification but it allows us to produce a set of coefficients within the time available.

Car and bus coefficients are being developed separately as there are different value of time coefficients and also different changes in the overall accessibility measure when bus changes are implemented alone (see above).

RESULTS Over 14 Zones

The following tables show the ratios (for each household in turn) for car, bus and composite modes for each household over the range of scenarios. The scenarios are described by the expected change in the input in-vehicle time for the car and bus mode, noting that where car is changed the bus speeds also change! The last row of each table is for a run which implemented LRT only, it may not be useful here as the composite times do not include LRT times.

Results for HH10 : Young Single Employed SEG 2

Start Input in terms of % change in I.V.T		(IVT change * HH trip rate) ÷ Accessibility change		
CAR	BUS	CAR	BUS	COMPOSITE
-20	0	0.79	0.64	0.74
30	0	0.87	0.72	0.81
-20	20	0.87	0.38	0.70
0	20	0.14	3.11	1.18
0	-20	0.14	3.09	1.17
0	-40	0.14	3.05	1.16
LRT	LRT	0.05	0.12	0.08

Results for HH62 : Young Couple + children 2 Employed SEG 2

Start Input in terms of % change in I.V.T		(IVT change * HH trip rate) ÷ Accessibility change		
CAR	BUS	CAR	BUS	COMPOSITE
-20	0	0.81	0.65	0.75
30	0	0.89	0.73	0.83
-20	20	0.89	0.38	0.71
0	20	0.14	3.13	1.18
0	-20	0.14	3.10	1.18
0	-40	0.14	3.05	1.16
LRT	LRT	0.06	0.15	0.09

First of all the ratios do not change between households. However the ratios are generally below 1.0 for car strategies which implies we reduce the value of time coefficient. This was not the expected result as in-vehicle time is only part of the generalised cost and so it was expected that the changes in in-vehicle time would be larger than the associated changes in accessibility. This can be explained by the fact that the changes in accessibility are for the full 25 zones compared to the changes in in-vehicle-time which are for the inner 14 zones only.

The ratios vary according to the strategy implemented, car only strategies giving significantly different results to bus only strategies even at the composite level. Although the LRT ratios are probably not valid the changes in accessibility caused by implementing LRT were a factor of 10 greater than those for car only strategies.

Results over 25 zones

The same method was applied for the young single employed SEG 2 household for all 25 zones. The results are shown in the following table.

Results for HH10 : Young Single Employed SEG 2 over 25 zones

Start Input in terms of % change in I.V.T		(IVT change * HH trip rate) ÷ Accessibility change		
CAR	BUS	CAR	BUS	COMPOSITE
-20	0	1.48	1.4	1.45
30	0	1.48	1.4	1.45
-20	20	1.54	0.56	1.2
0	20	1.18	163.8	58.1
0	-20	0.25	5.41	2.05
0	-40	-0.02	-19.36	-6.79

The first 3 results look promising in that the ratios are greater than 1.0 as expected for car and composite modes. The accessibility change has been calculated for all 25 zones which explains the low ratios in the results over 14 zones (as the accessibility change is actually for 25 zones hence larger than it should have been). However, as bus times are increased compared to car the ratio for bus drops below 1.0.

Further problems arise for bus only strategies in that the car ratio can fall below 1.0, the bus ratio can be dominated by outer zones which have only a small change in accessibility (hence high ratio) and for some outer zones the change in accessibility was small and of the wrong sign giving a negative ratio! These effects can also feed through to the composite ratio.

The choice of ratio was determined by the fact that the DELTA model responds to composite changes in accessibility and could not be broken down by mode. It was decided that a value between the bus strategy value over 14 zones (1.18) and the car strategy value over 25 zones (1.45) should be used. The value chosen was 1.3.

Step 6 : Change Noise units from percentage change to change in dBA.

The willingness to pay for percentage changes in noise must be factored to take account of the START output which is given as changes in dBA for each zone. The factor for a percentage change was considered as follows :-

We have two assumptions to consider in respect to what a halving or doubling of noise actually meant to respondents. The first is to assume the change to be actual change in energy, the second is to assume a perceived change. The first assumption implies a change of 3 dBA to double or halve energy or noise intensity. The second assumption on perceived change is to say that a 10 dBA change is equivalent to a halving or doubling of the noise level.

Method 1

Energy : Consider a noise level L_{100} for noise intensity I. Then to find the value of a 1 dBA increase we form the following equations :-

$$L_{100} = 10 \, Log_{10}(I)$$

$$L_{100+x} = 10 \, Log_{10}[(I)*(100+x)/100]$$

$$L_{100+x} = L_{100} + 10 \, Log_{10}[(100+x)/100]$$

thus for a 1 dBA change we need to solve $1 = 10 \, Log_{10}[(100+x)/100]$ which gives x=26 i.e. a 26% increase in noise level is equivalent to a 1 dBA increase or L_{126}. For a 1 dBA decrease then x = -21% or L_{79}

Similarly we have 3 dBA increase is equivalent to a 100% increase and 3 dBA decrease is equivalent to a 50% decrease in noise level i.e. L_{200} and L_{50} respectively.

From the SP survey we have a value per percentage change in noise level £N per percent change for increases and decreases. In order to convert the START output in dBA to £ we have to multiply the change in dBA by :-

$\frac{26*(100*N)}{100}$ where N is for a 1% change. This equals a factor of 26 for increases in noise and similarly 21 for a decrease in noise.

Perception : Method 2

This method uses the same equations as the previous method but actually solves the problem for any value of change in dBA say G.

For energy assumption we simply solve :-

$$x = 100ALog_{10}\left(\frac{G}{10}\right) - 100 \qquad (1)$$

For the perception model we require a change of +10 dBA to give a 100% increase in perceived level of noise or

$$100 = 100ALog_{10}(10*f) - 100 \qquad (2)$$

which gives a value for f of 0.03. We then have a similar equation for perception as for energy :-

$$x_p = 100ALog_{10}(G*0.03) - 100 \qquad (3)$$

where x_p is the percentage change in perceived noise level.

Solving equation 1 and 3 for various changes in dBA G we form the following table of results :-

G =Change in dBA of noise level	x = percentage change in intensity	x_p = perceived percentage change
-10	-90	-50
-5	-68	-29
-3	-50	-19
-2	-37	-13
-1	-21	-7
+1	26	7
+2	58	15
+3	100	23
+5	216	41
+10	900	100

This method gives the same perceived percentage change for a 1 dBA increase as for decrease, i.e. 7% implying a factor of 7 to be applied to the noise4 value which is then applied to the noise output from START.

Obviously the best method would be to use either equation 1 or 3 in the conversion of output from START to avoid linear approximations.

Step 7 : Change air quality units to account for START outputs CO, NOX and VOC.

The air quality willingness to pay coefficient (based on NO_2 measurements) was to be split between the START pollutants by the same weights as used in the initial analysis i.e. derived from relative toxicity and Tinch's tables. However the START output for NOX did not lie within the range implied by the NO_2 measurements and so an alternative was to associate the willingness to pay from NO_2 to the START output CO measured in ppm.

This section sets out calculations which confirm the ranges of measured NO_2 (micro-grammes /m3) to be in line with the ranges of CO output by START in ppm. The assumptions are taken from the Design Manual for Roads and Bridges Volume 11 unless otherwise stated.

Starting with the NO_2 values measured as weekly averages in micro-grammes per m^3.

We collected the range 11 - 56 micro-grammes/m^3.

Divide through by 1.913 to convert to ppb giving 5.75 - 29.27 ppb weekly average

Multiply by 2.4 to give 98th percentile 1 hour NO_2 13.8 - 70.25 ppb (98th percentile 1 hour NO_2)

Graph page 6/24 DMRB to factor by 4 to give NOX from NO_2 50 - 300 ppb NOX average during traffic peak hour.

Assuming average speed of 45 km/h from START output and using the relative emission graph from old TRRL (REF?) model to factor NOX to CO emissions divide by 0.075 giving 666 - 4000 ppb CO peak hour average.

Convert to maximum 8 hourly average using 1.19+1.85*hourly value gives 2.3 - 8.59 ppm CO 8 hour maximums.
The START outputs a range of 2 to 10 ppm CO 8 hour maximums with 8.3 and 8.9 in the centre. Zones 15 and 16 are higher for some reason.

Producing a common factor.

If we take the above calculations then to get from 11 to 2.3 would imply a factor of 0.209, whereas to get from 56 to 8.59 would imply a factor of 0.15 i.e. no common factor due to the very last step with the intercept of 1.19.

However if we take the START CO range and compare it with the measured range then we have 2/11=0.18 and 10/56=0.18.
Hence to value air quality we can take the coefficient for AIR from the SP results £M per unit NO_2 and apply it to the change in CO output factored by 5.6 (the inverse of 0.18). The model is set up to factor the outputs for pollution rather than factor the

coefficient. The other pollutants will be factored by zero to eliminate them from the response.

Step 8 : Calculate new utility of consumption coefficient using program UCML11.

Setting inputs as follows $\theta^{hU}=0$, $\theta^{hQ}=0$, $\theta^{hR}=-1$, and $\theta^{hA} = w_A^{iS}$ i.e. the accessibility values from the SP model scaled by income for each household and the IVT/accessibility ratio as in steps 1-5. The program then calculates the new coefficient on utility of consumption $\theta^{hU} = w_U^{iD}$. This is done by calculating the change in utility of consumption for a 1 unit rise in income and hence the inverse of the marginal utility of income which is equal to the willingness to pay for a 1 unit change in utility of consumption w_U^{iD}.

The UCML11 program also calculated

$$V_i^h = \theta^{Uh} U_i^h + \theta^{Ah} A_i^h + \theta^{Rh} R_i^h$$

in the form

$$V_i^h = \theta^{Uh} U_i^h + \theta^{Ah} A_i^h + \phi^{Nh} N_i + \sum_p \phi^{ph} P_i^p$$

where

V_i^h	is the utility of location in zone i for household type h
U_i^h	is the utility of consumption for households h in zone I
A_i^h	is the accessibility of zone i for households h
R_i^h	is the transport related environmental output for zone i households h
P_i^p	is the components p of air pollution at I (from START)
N_i	is the noise level at i (from START)
ϕ^{Nh}	WTP of households h for reduction in N_i
ϕ^{Ph}	WTP of households h for reduction in P_i^p
θ^{Uh}	is the (marginal utility of income)$^{-1}$ for household type h
θ^{Ah} ,θ^{Rh}	are WTP for accessibility and environment respectively

The inputs for the program were derived in steps 1-7. The outputs are household type h, zone i, number of households choosing to locate in zone i of type h, residential floorspace in zone i and utility of location V_i^h.

The cross-sectional analysis of this data set will produce a set of coefficients for V_i^h perhaps grouped by income bands or household types (check with David). This set of coefficients was to be used in step 10 to re-scale the coefficients on accessibility and transport related environment and the calculated coefficient on utility of consumption.

Step 11 : Recalculate the area quality coefficient.

The base DELTA model is run with the new coefficients for all except area quality (previous values are first used for area quality). The quality of a typical zone is then increased by 1 unit and the model is run again. The area quality coefficients are adjusted in an iterative manner until an adjustment of 1 unit causes approximately a 1% change in rent for the zone considered. The process is applied to three or four zones to give a better overall result. The resulting factor of 4.5 was applied to all the previous area quality coefficients.

Reference

Tinch, R (1995). The valuation of environmental externalities. Report prepared for the Department of Transport