Forecasting mode and destination choice responses to income change

Abstract: When average income is forecast to change, it is reasonable to expect that mode and destination choices will also change, in particular that more expensive modes and more distant destinations may be chosen more extensively when incomes increase. The paper investigates two specific ways in which mode and destination choices are affected by income changes. First, travellers' willingness to pay for travel options depends on their income. Second, additional income-related variables influence choice, particularly mode choice. Reviewing the literature on willingness to pay, we find that the relationship with income is much stronger in longitudinal than in cross-sectional analyses. It seems that this difference is related to the correlation of 'taste' variables with income. For forecasting, we propose a procedure that incorporates socio-economic shifts, particularly in employment, as well as allowing a general increase in income related to overall welfare.

The approach for forecasting appears to be novel.

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1. Introduction

Decision-makers seeking to accommodate and to influence traveller behaviour are particularly concerned with travellers' choices of mode and destination, as it is these choices, along with journey frequency, that set the main dimensions of travel flows and that are most subject to influence by the policy levers that are available. The development of models of mode and destination choice is then a useful means of understanding and predicting the way in which travel flows might change in response to transport policy or to developments exogenous to the transport system.

1.1 Objectives of the paper

In developing models of mode and destination choice the cost of each alternative to the user is naturally found to be an important influence on choice (ref. our report, WebTAG, others?). In those models where it is possible to enter the traveller's income into the model, income is usually found to have a significant effect, higher incomes mitigating the effect of cost. Usually, this effect is represented in the models by dividing the cost by an income-dependent 'value of time' (VOT) which allows the cost to be represented on the same linear scale as time.

Additionally, however, we often find that choice, particularly mode choices, are influenced by income in ways that are not directly related to cost, e.g. through 'dummy' variables indicating an increased probability of choice for specific income groups.

The paper starts by reviewing the literature on the relationship between VOT and income, and this review highlights that the relationship is much stronger over time than in cross-section. Building on the review of the VOT literature, the paper aims to identify the theoretical expectations for VOT income elasticities.

A key objective of the paper is to set out the 'welfare factor' approach for representing the impact of income growth over time. This approach is the key contribution of this paper, and draws on empirical experience from a number of large-scale model applications.

The paper concludes with a section that aims to provide advice to practitioners on the ways in which models of mode and destination choice for private travel should be adjusted for forecast situations in which travellers' incomes are expected to change.

1.2 Cost and income in travel demand models

Among the variables influencing mode and destination choice is of course the cost of each alternative. Travellers' incomes determine their ability and willingness to pay and therefore income differences, whether between groups at a fixed time or with changing general incomes over time, are crucial to forecasting choice and understanding the impact of policy on the various population groups. For this reason it is important to understand how the sensitivity of travellers to cost changes varies with their income. Understanding income sensitivity is important to predicting how behaviour will change over time, as incomes change, but also to understand how travellers might respond to a policy change or a new travel alternative. For example, will average trip lengths continue to increase, if ability to pay continues to increase? Would it be largely the better-off who would use a premium-priced high-speed rail service?

An important issue in this area of modelling is that income is correlated with a number of other variables that are relevant to choice but not necessarily included in the large-scale data sources from which travel demand models are constructed; indeed, some of these variables are intrinsically difficult to measure. Variables such as social class, social standing or status would be among these. If incomes increase, travellers' ability to pay increases, but changes in status are less clear. For example, over time there has been a shift in developed countries from manufacturing to office-based service employment, but it is not clear how this affects workers' attitudes to commuting distances and to the use of travel modes (e.g. bus and cycle are seen as having low status in some countries). It is therefore important first to isolate the effect of income from that of other variables by including as many of these other variables as possible in the model, but also to study the separate impact of cross-sectional and longitudinal income differences to try to separate the impact of ability to pay and proxy effects of income.

An important segmentation of traffic flows is between those in the business sector and those in the private sector. The costs of business travel, whether to transport freight or to transport people to do their work (ranging from plumbers to 'briefcase travellers') are typically met by a business or government and do not relate directly to the individual traveller's income, though no doubt the business will be concerned with lost productivity, which might correlate with the traveller's income. In this paper, however, we focus on travel in the private sector, which usually includes commuting and almost always includes travel for education, shopping, recreation, social and other such purposes; here the costs are borne by the traveller (though there may be tax or subsidy by the government or an employer) and are compared with the traveller's willingness or ability to pay.

The value of travel time (VOT), i.e. the trade-off ratio between money and time, is central to the effect of income on willingness to pay in mode and destination choice. McIntosh and Quarmby (1970) introduced the concept of generalised cost for modelling travel choices and the use of VOT to convert between a money scale and a time scale. In a key sentence, they stated: "*It can be argued that time has much the same value in terms of personal utility to people of different incomes, and to people living now and at some future date.*" On this basis, they recommended that behavioural modelling should be conducted on a time scale, with travel costs converted to time-equivalent units by dividing by the VOT.

In more modern work, also, it seems that for relatively simple behavioural modelling it is much more correct to work with a *numéraire* that gives a fixed time scale (i.e. the same time coefficient for all travellers), with the assumptions for inter-personal variation that this implies, than to make assumptions relating to a money scale. An important part (but not all) of the variation in the money scale relates to income. Thus, if income changes, VOT changes accordingly and this is an important mechanism by which behaviour is altered. Additionally, however, we need to take account of the proxy effects of income, as we have noted above.

In the practical modelling of travellers' choices, particularly mode choices, we commonly find an impact of income additional to the impact through the cost of the alternatives. That is, as well as converting the cost to a time equivalent, though the use of VOTs that vary with income, we need to add further variables to the model to reflect observed but not otherwise explained effects, for example that travellers from wealthy households are more likely to make long-distance journeys by air or rail (Rohr *et al*., 2010). To a large extent, these income-related variables may be proxies for income-correlated variables, such as tastes, but they may also incorporate 'real' income effects, such as the choice for travel to particular destinations which are more attractive to higher-income travellers, e.g. expensive recreational destinations.

1.3 The structure of this paper

An important focus of this paper is on the impact of cross-sectional and longitudinal income differences on the sensitivity of mode and destination choice to travel cost. Often, the evidence on cost sensitivity takes the form of VOT, converting cost differences to a time scale as discussed above. Section 2 summarises the literature on income elasticities of VOT, drawing on three principal sources:

- cross-sectional income elasticities derived from revealed preference mode-destination choice models;
- cross-sectional income elasticities derived from stated choice models, including cases where cross-sectional income elasticities have been obtained from stated choice exercises repeated at two points in time in the same study area; and
- longitudinal income elasticities obtained from meta-analysis of numerous studies.

The review highlights differences between the different measures, and in particular between cross-sectional and time series estimates.

Section 3 then reviews the theoretical considerations that apply to the treatment of income elasticities, both cross-sectional and over time. In particular, the treatment of cost and income needs to be set in the framework of models that are feasible to apply in a practical planning context. For example, if cost sensitivity is segmented by income band, for forecasting this introduces a requirement to forecast how the number of people in each income band changes over time.

Section 4 presents an approach that has been developed to treat income growth over time as a combination of an overall 'welfare increase', applied as a uniform increase to all incomes, and some re-distribution from lower to higher income bands. The application of the welfare and re-distribution approach to data from the UK is demonstrated. The main contribution of this paper is to present this approach, having set it in context.

Finally, Section 5 presents conclusions from the research, and presents recommendations for further work.

2. Existing Evidence

In reviewing the evidence on income elasticities, we distinguish between cross-sectional elasticities of VOT to income, of which there is evidence from both revealed preference and stated preference models, and the longitudinal elasticity of VOT to real-terms income changes over time.

2.1 Elasticities from Revealed Preference Models

The revealed preference evidence is drawn from individual-level models of mode choice, joint mode and destination choice, and models where the VOT has been estimated as the trade-off between wage and commuting time. Model estimation yields information about cost sensitivity which may vary by income within the cross-section or models may be estimated at different points in time. These models typically comprise:

- a cost term, possibly segmented by income band, typically (but not always) uniform across modes;
- in-vehicle time terms, which may vary by mode, e.g. between car and public transport;

- socio-economic terms, reflecting differences in mode preference by segment, potentially including an income segmentation;
- for mode-destination models, attraction terms, such as population or employment, representing the attractiveness of each destination zone.

If the cost terms in the models are segmented by income band, or have some other relationship with income, then it is possible to obtain evidence on the cross-sectional elasticities of the models. In our own unpublished work for Sydney (New South Wales), the mode-destination models for commuting travel indicate a cross-sectional VOT elasticity with respect to personal income of 0.38.

In two published cases, revealed preference models have been estimated at two points at time in the same study area, and these studies give insight into changes in cost sensitivity over time.

- Fowkes *et al.* (1986) obtained a cross-sectional elasticity of VOT to personal income of 1.05 from mode choice models estimated using data collected from commuters in North Kent. The income measure used was personal income, and the elasticity was obtained by comparing the VOT in the bottom and top income bands, which had mean incomes of £5259 and £19844 respectively.
- Swardh (1998) used Swedish panel data to investigate the time series elasticity of value of time for travel to work, which he estimated as the trade-off between wage and commuting time. He used Swedish administrative longitudinal matched employee establishment data sampled in 1998. This data included employee status observations in 1986, 1990 and 1993 as well as 1998. Commuting times were determined for a matrix of possible combinations of small market area statistics (SAMS), with Sweden divided into 9230 SAMS, with around 1000 persons per SAMS area. Swardh obtained a value for the personal income elasticity of 0.93 (p value = 0.23), which was not significantly different from one, and therefore Swardh concluded his data provided no evidence for a temporal income elasticity of less than one.

2.2 Elasticities from Stated Choice Models

As Wardman (1998) notes, a large number of Stated Choice (SC) studies have been undertaken since the 1980s. The use of computer based survey techniques facilitated their wider use, with in the UK a shift in emphasis from road building to (for example) evaluating possible demand for new public transport services, and in particular for alternatives that do not exist at the time of the survey, such as new metro services.

In reviewing SC studies we start by summarising evidence on cross-sectional income elasticities, then go on to examine a sub-set of SC studies where the same SC exercise has been undertaken in the same location at different points at time, thus providing evidence for changes in income elasticities over time.

Wardman (2001) assembled evidence on cross-sectional income elasticities from a number of key SC studies in the UK, the Netherlands and Scandinavia, largely from national VOT studies. Table 1 summarises the values from Wardman's paper, and in addition quotes more recent results from Tapley *et al.* (2007), Börjesson *et al.* (2009), Axhausen *et al*. (2008) and Ramjerdi *et al.* (2010).

In most cases, Wardman presented results showing how value of time varied with income in the various models. Income elasticities have been derived from these results by making assumptions about the income in the bottom and top income bands.

Table 1: Cross Sectional Stated Choice Income Elasticities of VOT

Area	Year of Survey	Reference	Income Measure[a]	Elasticity[b]
UK	1987	MVA *et al.* (1987)	Household	0.10 - 0.16
Netherlands	1988	Gunn and Rohr (1986)	Household	0.17 - 0.20
UK	1994	AHCG (1999)	Household	0.35 - 0.65
Sweden	1994	Algers *et al.* (1996)	Personal Household	0.23 - 0.42 0.07 - 0.24
Finland	1996	Pursula and Kurri (1996)	not clear	0.2
Norway	1997	Ramjerdi (1997)	Personal	0.20 - 0.23
Netherlands	1997	Gunn *et al.* (1998)	Household	0.29 - 0.34
Denmark	2004	Fosgerau *et al*. (2007)	Personal	0.3 – 0.7
UK	1994, 2006	Tapley *et al.* (2007)	Personal	0.3
Sweden	1994, 2007	Börjesson *et al.* (2009)	Personal	0.6 - 0.7
Switzerland	2005?	Axhausen *et al*. (2008)	Household	0.17 (commuting)
Norway	2009	Ramjerdi *et al.* (2010)	Personal	0.25 - 0.62

[a] In the case of the Swedish studies it appears that net (after tax) income is used; in other cases it is likely that gross income is used, though not all the studies are clear on this point.

[b] These ranges generally refer to travel by different modes or for different journey lengths; all of the studies except the Finnish one include car drivers, some include other modes such as bus, train, ferry and air; in some cases business travel may be included.

If simple averages are taken of the figures given by Wardman (2001), using midpoints when a range is given, then for personal income we obtain an average cross-sectional income elasticity of 0.40 and for household income measures the average elasticity is about 0.24. Overall, the studies suggest an average cross-sectional income elasticity that is significantly less than one. Wardman concluded there was some evidence that the income elasticity varied with the type of income measure used, with personal income elasticities tending to be higher.

The UK government view of the cross-sectional income elasticity of VOT is also that it is much less than 1 (see the Appendix for the published guidance, where we see the 'official' value for all non-work travel is 0.22). However, an effective elasticity would be a little higher, if account is taken of the longer distances travelled by higher income people and the positive effect on VOT of distance.

Tapley *et al.* (2007) summarised cases where repeated SC exercises have been undertaken at the same location at different points in time. These comparisons give insight into changes in value of time over time.

Table 2: Repeated Stated Choice Studies

Area	Years of Data	Reference	Findings
UK	1985, 1994	AHCG (1996)	After allowing for income, socio-economic and other characteristics, overall trend decline in VOT uncovered.
Netherlands	1988, 1997	Gunn *et al.* (1999)	After allowing for income, socio-economic and other characteristics, overall trend decline in VOT uncovered. Trend decline offset the VOT increase due to income growth, so that real VOT remained broadly constant over the 9 years.
UK	1994, 2006	Tapley *et al.* (2007)	1994 data is trunk roads incl. motorways, 2006 data is motorway users only. Using a model taking account of cross-sectional income variation, with an average cross-sectional income elasticity of 0.3, VOT decreased by 5% (commute) or increased by 11% (other).

In these three studies, there is evidence that value of time has increased in real terms only at the rate indicated by cross-sectional elasticity over periods of 9 to 12 years. These results are at odds with the results from the time series analysis of aggregate models presented in the next section.

2.3 Longitudinal Elasticities from Meta-Analysis

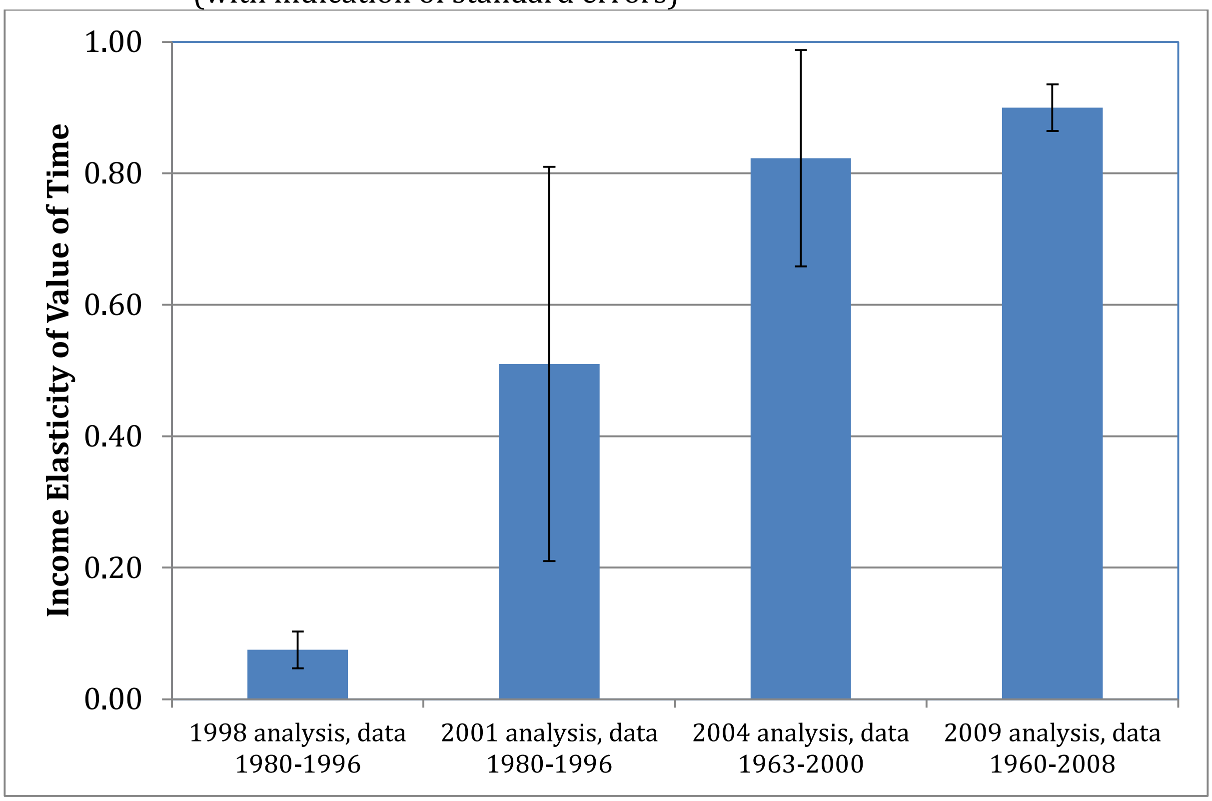
Wardman (1998, 2001, 2004), and Abrantes and Wardman (2009) have run meta-analyses of UK VOT studies. Data from SC, Stated Preference rating and Revealed Preference studies was included in their analysis. The studies give value of time observations at different points in time, and in their meta-analysis they develop a model that allows changes in the value of time values over time to be related to changes in GDP per capita.

The first study (Wardman, 1998) focussed solely on the value of in-vehicle time, and included 444 observations from 105 studies conducted over the period 1980 to 1996. The GDP per capita elasticity was very low, 0.075 ± 0.028, a result that was attributed to limited range in the GDP over the period due to the UK recession of the early 1990s; however, we note that the confidence limits exclude elasticity values greater than 0.13.

The second study (Wardman, 2001) extended the scope of the analysis beyond in-vehicle time. Walk time, access time, wait time, service headway, parking search time, car congested time, car free flow time, departure time shift, late arrival time and having to interchange on public transport were included as factors. The same time period was used, 1980 to 1996, but an additional 27 studies were added. In this

analysis, an income elasticity of 0.510 ± 0.300 was identified (note the relatively high standard error).
The third study (Wardman, 2004) aimed to give more insight into how VOT varied over time, and therefore the time period of the studies included was extended significantly to cover 1960 to 2000. A higher elasticity was obtained, with a reduction in the standard error, namely 0.823 ± 0.165.
The final study (Abrantes and Wardman, 2009) added more recent data so that the studies included covered 1960 to 2008. The resulting elasticity was 0.900 ± 0.035. The evolution of the GDP per capita elasticity between the studies is illustrated in Figure 1.

Figure 1: Wardman Meta-Analysis Estimates of Income Elasticity
(with indication of standard errors)



The graph demonstrates how adding additional data to the analysis, in particular data that yields greater spread in value of time, has improved the precision of the income elasticity estimate. The best estimate of the time series income elasticity is 0.900 ± 0.035, a value that is not far from unity.
Other European meta-analysis studies have been undertaken. Swardh (2008) notes that: "*An EU-financed project aiming to harmonize CBA input values in Europe, HEATCO (2006), suggests that, when no country-specific results are obtainable, value of time should be adjusted over time with an inter-temporal income elasticity of 0.7 based on the results of different meta-studies (Wardman, 2001; Shires and De Jong, 2006).*"
Finally, we note the official UK government view that the longitudinal elasticity of VOT with respect to income should be taken to be 0.8, based on Wardman's 2004 analysis (see the Appendix).

2.4 Discussion

The evidence from revealed preference studies is limited. Cross-sectional models from 1984 UK data give a personal income elasticity of VOT close to one (1.05, Fowkes, 1986). Panel analysis of Swedish data from 1986, 1990, 1993 and 1998 gave a longitudinal personal income elasticity of 0.93, again close to a value of unity. However, unpublished analysis of models we have developed for commuting travel in Sydney give a much lower cross-sectional personal income elasticity of 0.38.

More evidence is available from stated choice studies. On average, cross-sectional elasticities of VOT are significantly less than one, with a mean value of around 0.3. Studies that have reported elasticities separately for models with personal and household income observe higher elasticities if personal income is used. The UK government recommends a cross-sectional household income elasticity of 0.22, perhaps a little higher in practice.

The Fowkes study (1986) is at variance with the consensus but this is a single data set and we have little concern in neglecting this finding in favour of the bulk of other evidence.

Meta analysis of a large number of UK value-of-time studies has suggested longitudinal VOT elasticity of 0.900 ± 0.035. The 2006 Heatco European Commission study advises longitudinal elasticity of 0.7, based on Wardman's 2004 analysis (which suggested longitudinal elasticity of 0.823) and a separate European meta-analysis. The UK government WebTAG recommends a value of 0.8, based on Wardman's 2004 analysis. This value seems to be consistent with the wider evidence.

The three studies reported in Table 2 differ from this consensus in suggesting no increase in VOT with income. This is of concern, because the three studies were specifically designed to look at the issue of the stability of VOT with income changes. However, the bulk of the evidence and in particular the very large meta-analyses (in which those studies are included) is clear that longitudinal income elasticity of VOT is high and close to 1.

In summary, it seems that there is substantial evidence that cross-sectional income elasticity of VOT is significantly less than 1, with values around 0.3 being more consistent with the empirical evidence. However, longitudinal elasticity is much higher and close to 1. Early UK results, however, are at variance with the generality of other results.

The dependence of VOT on income forms an important part of the demand response to income changes. Additionally, however, we must take account of other alternative-specific effects which, as noted above, may well be proxy effects where income is representing taste variation.

3. Theoretical Considerations

Given the findings from empirical work outlined in the previous section, it is worth asking what the theoretical expectations might be for VOT income elasticities. In particular, we may ask whether the proxy effect of income might be relevant.

Mackie *et al.* (2001) contains a useful discussion, in particular Section 6, which concludes "*Thus a reasonable expectation is for the value of savings in non-working time to increase less than proportionately to increases in wage rates, say proportionately to per capita income growth. Of course, this argument cannot be conclusive but the proposition that the value of non-working time savings grows significantly slower than GDP per capita – say at only half the rate – does seem to lie at one end of the range of possibilities. Consideration of the trends in the values of work, leisure and travel time is a subject which warrants a wide range of theoretical and empirical study*".

Tapley *et al.* (2007) state: "*On balance, given the continual improvement in vehicle quality and available facilities, we feel that changes in the disutility of travel will operate to reduce the value of time over time*." Their arguments were as follows.

- Income will grow over time, leading to a decrease in the marginal utility of money, and increase in VOT.
- The attribute used to measure travel costs (e.g. toll or petrol cost) may be perceived differently across time periods, in particular people in the 2007 study may have been more accustomed now to paying toll costs; this might imply an increase in VOT.
- There are trends in the disutility of travel, often ignored in official recommendations of VOT, e.g.:
  - quality, comfort and facilities improve in all transport modes, thus reducing the disutility of time and VOT;
  - in the UK, both highway congestion and crowding on rail routes into large conurbations have increased, increasing the disutility of time and VOT.
- However, on balance, they judged that the disutility of travel had declined over time, sufficiently to reduce VOT, despite the other effects.

However, the argument of this study, in particular, appears to relate to the specific period of the late 20th century when changes in technology were such as to make travel by all modes less onerous relative to other activities. This trend cannot be assumed to apply to all periods of study. Moreover, Tapley *et al.* (2007) studied primarily long-distance travel, where these effects would be expected to be most important.

A point made some time ago (e.g. Viton, 1985) is that part of what we measure by income in choice models may be taste variation correlated with income. Indeed, Viton shows that if we have income variables not interacted with the alternative prices, e.g. as income-group specific variables attached to mode alternatives, then to be consistent with budget-constrained utility maximisation these *must* be interpreted as taste variation, not as 'pure' income, i.e. they cannot relate directly to ability to pay.

In the practical situations of estimating models on limited data, in particular where income data may be reported partially, with error, or not at all, it is difficult to make hard-and-fast attributions of income effects relating to prices or to alternative-specific effects, each possibly interacted with socio-economic variables. It seems therefore that it is not possible to indicate theoretically what the link between income and VOT should be, either within the cross-section or longitudinally. When the empirical evidence suggests so strongly that longitudinal elasticity is much higher than cross-sectional elasticity (e.g. around 0.9 against 0.3), then it seems that the theoretical background is sufficiently flexible to accept such values.

There is also an important theoretical argument that the longitudinal income elasticity of VOT should be at least 1. If incomes rise, the proportion of new income that is spent on time-saving measures, such as using faster modes, will surely be expected to rise. This appears to be what has happened in the past, taking a long-term view. This view of time saving as a 'luxury good', taking an increasing share of increasing income, implies an elasticity not less than 1. Empirical observation of lower values of elasticity in recent years could be consistent with improvements in comfort and increasing use of technology *en route*, but these would be essentially transient.

In forecasting, it is clear that VOT values should be changed in line with the expected income changes, applying an estimate of the longitudinal elasticity. However, what is to be done with other income-related variables is less clear and depends on the approach taken to forecasting.

4. The Welfare Factor Approach

In many transport studies, it is necessary to make forecasts over an extended period. In particular, when considering major infrastructure, the period of decision-making, planning and construction may mean that there are several years between making the forecast and the opening of the infrastructure, while the infrastructure will be expected to be beneficial over a period of many years after that. A forecasting horizon of 20 years would be common.

Over such a period, it may be expected that incomes may change significantly, as long-term real income growth has generally been about 2% per annum and often much higher in developing countries. Of course, recessions like the recent one may cause large divergences from the long-term growth, so that there is a range of uncertainty. For this reason it is desirable to consider a range of possible income growth values in sensitivity testing, to allow for the possibility that income forecasts may be incorrect. Income forecasting is itself a major contributor to forecast error and is strongly correlated with other important inputs to the forecasting process such as car ownership (de Jong *et al.*, 2005, 2007). Income forecasts and sensitivity tests based on variation in income forecasts therefore need to incorporate a consistent set of forecast variables, e.g. including employment and car ownership forecasts consistent with income forecasts.

In principle, it would be preferable to make forecasts concerning the distribution of income as well as the overall level. It could be desirable for some applications to consider the impact of such changes, e.g. by postulating changes in the equality of incomes around the overall average, but we are not aware that such investigations have been carried out in the context of travel demand forecasting. When forecasts of income distributions are made, they typically carry forward the existing distribution into the future.

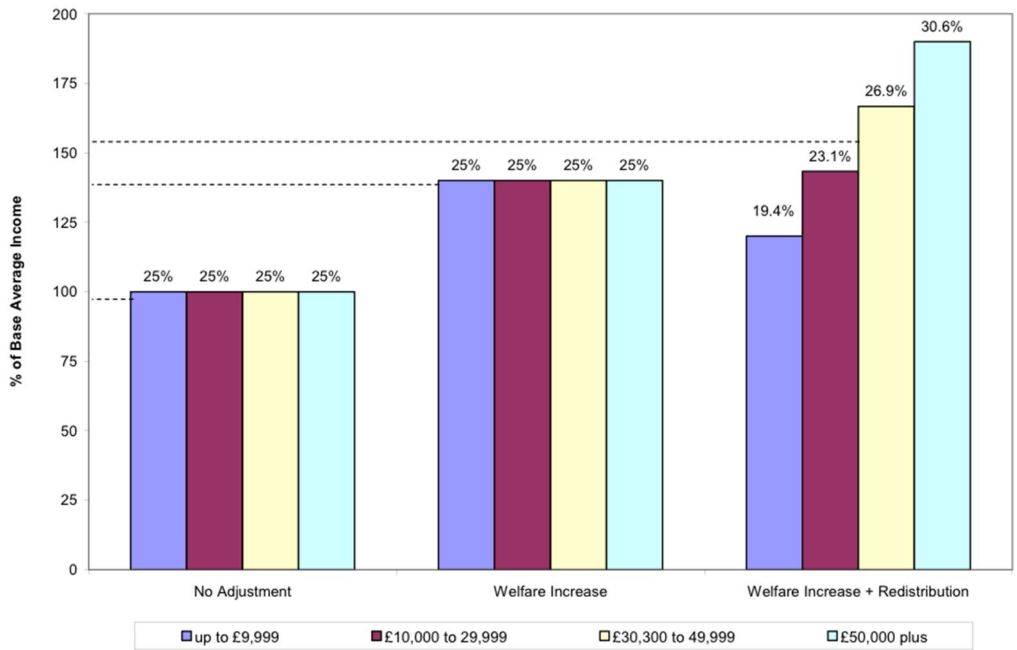
The key feature of consistent forecasts is to retain plausible correlations in the variables. Most importantly in the present context, the relationship between income and employment needs to be maintained in a reasonable way, for example that households with more workers typically have higher incomes than households without workers. The welfare factor approach is designed to work within the context of 'prototypical sampling' which allows these correlations to be maintained. Prototypical sampling (e.g. Daly, 1998) requires, for each zone for which the model is applied, consistent 'target' forecasts of both income and employment, as well as other socio-demographic indicators such as age-sex distributions and household size. Expansion factors are then determined for each zone to match these indicators as well as possible, without departing too far from the original distribution of the population over household types that are defined for this expansion. However, within this procedure the only possibility for incomes to increase is for the types of households that have high incomes to become more numerous, i.e. households with multiple workers become more numerous and households without workers become less numerous. In scenarios where household sizes are expected to decline and increasing numbers of older people to be offset by higher retirement ages, this does not always give a plausible description of the population.
Practical experience from work developing a model for the West Midlands region of England (PRISM) indicated that if income was specified as a target, the increases in incomes relative to the base year could only be achieved by giving higher weights to multi-worker households in the future. This resulted in an over-prediction of the number of workers relative to the zonal targets. The solution that was developed for the PRISM model was to de-compose income growth into two components:

- a 'welfare increase', a uniform increase in all incomes;
- redistribution, where the relative frequency of income bands changes, opening the possibility that higher income groups become more frequent.

Thus the key contribution of this approach is to separate income growth into two separate components, a welfare increase representing a uniform increase in all incomes, and redistribution where individuals move between different income bands. The approach allows income growth forecasts to be reconciled with changes in the numbers of workers, and it believed to be novel for application of models of mode and destination choice.
The household types were specified from the number of adults, the number of workers, the age of the head of the household, and the presence of children. A total of 46 different categories are defined.
The notion of a welfare increase relates to a general increase in productivity, which would mean that the same number of workers would generate more income. Similarly, one would expect that social benefit payments would increase. In practice, the appropriate balance between the welfare increase and the re-distribution effect is identified using a trial-and-error procedure where the process is run with different assumptions, and the fits to the income and workers target are assessed. This process is illustrated in the following figure. In this example, a welfare increase of 35% is applied to all incomes, and then further growth in incomes to 55% is achieved through re-distribution from lower to higher income bands. In the Figure

the percentages above each bar indicate the proportion of the population falling in each income group.

Figure 2: Decomposition of Income Growth



The approach can be expressed mathematically as follows:

$$I^f = GI^b$$
$$I^b = \sum_s p_s^f I_s$$

where: I^b and I^f are the base and future income respectively
I_s is the mean income in income segment s
P_b is the proportion of the base sample in income segment s
G is the total income growth

G is then decomposed into growth due to the welfare factor and growth due to redistribution:

$$I^f = W \sum_s p_s^f I_s$$

where: W is the welfare increase

If there is no re-distribution, i.e. $p_s^f = p_s^b \in s$, then $W = G$.

In practice, the balance between the two effects depends on the way in which the workforce is expected to change in the future. In the second half of the 20th century, for example, many western countries saw an increase in the number of women working, so that incomes increased separately from productivity per worker (welfare effect). However, now it seems that the size of the workforce is relatively stable and income increases rely on increases in productivity, e.g. a move from less skilled to more skilled occupations. For example, the table below shows a typical scenario for the UK, in which the bulk of the increase is explained by the welfare factor; indeed for the period up to 2016 it explains *all* of the increase.

Period	Total Income Growth	Welfare Factor	Proportion of Income Growth Due to Welfare Increase	Proportion of Income Growth Due to Re-distribution
2008–2016	1.104	1.104	100%	0%
2008–2031	1.503	1.450	89%	11%

An issue that needs to be resolved in current circumstances is to reflect the impact of the recent recession on these developments. An important consideration here is the impact of changes in full-time and part-time employment rates. For longer-term forecasting, for which these methods are generally intended, these detailed short-term issues could be ignored, except insofar as they impact on overall income growth in the relevant period.

Relating this discussion to the difference between cross-sectional and longitudinal elasticities, it might be tempting to relate welfare effects to longitudinal elasticity and category shift to cross-sectional elasticity. In the table above, we see that the income increases over time are almost entirely due to the welfare changes and that redistribution over household classes contributes very little to income growth. However, as we have noted, in earlier periods there were significant shifts between household classes, so that there is no guarantee that the close relationship between welfare increase and longitudinal change will hold in the future. Similarly, while cross-sectional income differences are of course due to household type differences, it is not plausible to model all of these differences through household segmentation.

In summary, the welfare factor approach gives a plausible and reasonable method for forecasting changes in income by zone and the distribution of income over income groups, given area-wide income forecasts. These changes can be applied directly to VOT for forecasting. However, for the other income-related variables, there are two possible approaches:

- it may be assumed that they relate to taste variables that are proxied by income and therefore, when income changes, these variables do not change as they most likely represent a relative position in the population, or
- it may be assumed that they represent a 'true' income effect and need to be changed in value when income changes, possibly applying an elasticity.

The present situation is that there does not appear to be any decisive theoretical or practical advice concerning the treatment of these variables. The obvious solution at this stage would be to undertake scenario tests incorporating both assumptions.

5. Summary and Recommendations

The paper discusses the ways in which models of mode and destination choice for private travel should be adjusted for forecast situations in which travellers' incomes are expected to change. The mechanisms by which responses are modelled operate through (a) the dependence of VOT on income, affecting the way in which cost impacts on travellers' behaviour, and (b) additional income-related variables, separate from cost, that also significantly affect choices.

Reviewing the literature, it is clear that the longitudinal sensitivity of VOT is considerably higher than the variation in the cross-section. Elasticities appear to lie in the vicinity of 1 and 0.3 respectively. UK government advice, giving values 0.8 and 0.22 for these elasticities, is reasonably consistent with the international evidence. Some repeated stated-choice studies suggest a lower longitudinal elasticity but they may include specific groups of travellers (long distances) that have benefited more from comfort improvements and the weight of the evidence in any case supports high longitudinal elasticity.

We have hypothesised that the difference between longitudinal and cross-sectional elasticities is related to the existence of proxy effects, in which variables correlated with income operate to influence choices. Cross-sectional elasticity estimates should therefore not be used for forecasting the impact of income changes. There is evidence that longitudinal elasticities should be close to 1, possibly adjusted for transient effects that change comfort or productivity *en route*.

In general, theory seems to suggest that VOT elasticity to income should be at least 1. However, it is quite possible that different values, lower or even higher, could be observed in the short term and this may be what is happening in recent decades. A further point is that income variables appearing in the model that are not related to prices need to be interpreted as 'proxy' variables indicating taste variation, for consistency with utility maximisation (Viton, 1985). But the practicalities of model estimation with limited data mean that precise attributions of effects cannot be made.

We present a 'welfare factor' method that we have applied for forecasting income change in a number of contexts. This method separates income growth due to socio-economic change, particularly employment changes, from more general income growth (i.e. productivity changes). Both of these changes can be applied to adjust VOT for forecast contexts, given income forecasts. The welfare factor approach offers a consistent method for forecasting income and related variables, particularly employment.

Further work is required to understand better how the variables related to income but not price should be treated in forecasting circumstances.

We are not aware of other work addressing the problems discussed in this paper and we offer these ideas as an initial basis for development of methods in a quite important area. Travel demand forecasts are highly dependent on income forecasts and it is therefore important to improve income forecasting methods.

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APPENDIX: WebTAG formulations of income elasticity of values of time

(from: http://www.dft.gov.uk/webtag/documents/index.php, accessed 2 July 2012)

WebTAG 3.5.6

Annual Rates of Growth in Values of Time [i.e. longitudinal]

1.2.21 The value of non-working time is assumed to increase with income, with an elasticity of 0.8. Working values of time are assumed to grow in line with income, with an elasticity of 1. The measure of income used is GDP per head.

WebTAG 3.12.2

Local Values of Time for Non-Work Trips [cross-sectional]

11.4.1 If information is available on the distribution by income and distance of trips in the study area, then local values of time can be estimated using the model below. This is taken from *Values of Travel Time Savings in the UK,* a research study commissioned by the Department for Transport and undertaken by the Institute of Transport Studies, University of Leeds in association with John Bates Services.

11.4.2 Data on household income and mileage travelled is required. This data should be collected in the segments that are to be adopted ... . An average household income and an average mileage must be calculated for each of the chosen income segments as well as for the overall sample. (Note that it is important to calculate the average mileage for each segment, as well as the average income. Average mileage is likely to increase with income, so assuming the same average mileage for all segments will result in a biased result. The values derived using national studies and presented above take account of the national distribution of average mileage with income.)

$$VoT = K\left[\frac{\beta_t}{\beta_c}\right]\left(\frac{Inc}{Inc_0}\right)^{\eta_{Inc}}\left(\frac{D}{D_0}\right)^{\eta_c}$$

11.4.3 The term K is a correction for inflation between the year 1994 and the year in which local data is collected. ....

11.4.4 The parameter values for each non-work purpose are presented in Table A6 below. *Inc* represents the average household income in £'000 p.a. based on local data. *Inc0* is set equal to K multiplied by 35. *D* is the average distance travelled *in miles* from the local data and *D0* is 7.58 miles.

Table A6: Value of Time Parameters

Parameter	Commuting	Other	Total Non-Work
β_t (time coefficient)	-0.10098	-0.082918	-0.086344
β_c (cost (distance) coefficient)	-0.024729	-0.022275	-0.021143
Inc_0	35 x K	35 x K	35 x K
D_0	7.58	7.58	7.58
η_{Inc} (income elasticity)	0.358773	0.156806	0.222585
η_c (cost (distance) elasticity)	0.421305	0.314727	0.307487

11.4.5 The model and the parameters given in the table above will calculate the values of time for non-work purposes in the year you specify. The values will be expressed as market prices and in pence per minute.