Development of a Welfare Index for use in Transport Analysis and Evaluation

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ABSTRACT

Travel demand estimation, and the evaluation of transport policy, often relies on personal or household income as one of the explanatory or evaluative variables. Unfortunately, the financial significance of a unit of income varies from person to person and from household to household. At the same household income level, for example, a small household can buy more for its individual members than a larger household. Income alone is therefore not sufficient for determining one's welfare status or financial capacity. Consequently, it is by itself not an adequate economic explanatory variable for travel behaviour or evaluation.

This paper summarises the development of a measure of a households' welfare status. This measure, called a Welfare Index, is the result of a practical application of the welfare economics concept of "equivalence scales", used in classifying households based on the relative cumulative needs or living cost of the members of the household. Applied in combination with household income, it rates households on a relative and uniform standard of financial or welfare capacity. The result is therefore a better explanatory variable for travel behaviour than personal or household income.

This work is based on data from the Victorian Activity and Travel Survey (VATS), an on-going continuous household survey that gathers socio-demographic as well as travel and activity information. Of particular importance to the development of the welfare index is the data on personal income, household structure and the demographic profile of household members.

The paper illustrates the use of the Welfare Index in examining the relationship between mobility and income and in evaluating the equity implications of usage of the various modes of public transport available in Melbourne.

1.   INTRODUCTION

The estimation of travel demand or the evaluation of transport policies often relies on information about household or personal income as one of the explanatory or evaluative variables. One of the primary uses of income information in transport planning has been to examine the equity implications of a range of transport policies and practices. In particular, several studies (Amos and Starrs, 1984; Travers Morgan, 1992; Duldig and Gaudry, 1993; Radbone, 1994) have examined the equity or "social justice" implications of the pricing of public transport services.

Each of the above studies have reached conclusions about the equity of public transport subsidies. Generally, they have concluded that "the work of a number of scholars would lead us to conclude that existing public transport is socially unjust - that public transport results in a net transfer of wealth from the worse-off to the better-off" (Radbone, 1994). However, Radbone (1994) also concludes that "these arguments can be criticised as flawed in terms of their conceptual underpinnings and the methodology used to measure social justice outcomes".

In particular, Radbone (1994) questions the techniques used to measure "income". He states that "the use of individual income is difficult because of the distorting effects of children". He also criticises the use of household income on several grounds. Firstly, he observes that "to divide households into quartiles is not necessarily to divide the population into quartiles". Secondly, he observes that "total household income may not be a good indicator of financial well-being", primarily because of the size and composition of households having the highest household incomes. As a result of these limitations, he concludes that "such factors point to the wisdom of not relying on individual income as a measure of transport advantage, but they also suggest we cannot rely on household income either. Studies which rely on such data need to be carefully qualified".

The current paper seeks to make a contribution to the development of a more rigorous measurement of "income" which can be used in important transport policy studies such as those noted above. It does not seek to make monumental policy pronouncements, but merely to report on some underlying research and development which will enable others to make more informed decisions about the equity implications of transport policies.

2.   THE BASIC CONCEPT

The basic concept underlying the techniques developed in this paper is that the welfare significance of a unit of household income varies from household to household. At the same level of household income, for example, a small household can buy more for its individual members than a larger household because it has fewer members with which to share the income. In the case of using personal income, the economic capacity of people who have dependants are over-rated relative to

those who do not have to share their income with anyone else. On the other hand, non-income-earning members of the population would be under-rated because they may well have access to someone else's income. Knowing income alone, whether household or personal income, is therefore not sufficient for determining an individual's capacity for undertaking economic activities. Consequently, income by itself is not an adequate economic explanatory variable for travel behaviour or evaluation.

A better measure of a person's economic capacity is one that is standardised across the whole population being considered. In other words, a unit of this income measure should represent the same economic capacity irrespective of the characteristics of the person or household. This paper summarises the development of such a measure which has been named a *Welfare Index*. It is the result of a practical application of the welfare economics concept of *equivalence scales*, used in classifying households based on the relative cumulative needs or living cost of their members. Applied in combination with after-tax household income, it rates households on a relative and uniform standard of financial or welfare capacity. The result is therefore a better explanatory variable for travel behaviour than personal or household income.

This work is based on data from the Victorian Activity and Travel Survey (VATS), an on-going continuous household survey that gathers socio-demographic as well as travel and activity information. Of particular importance to the development of the welfare index is the data on personal income, household structure and the demographic profile of household members.

3.   THE EQUIVALENCE SCALE

The simplest logical approach to obtaining a relative measure of welfare that is independent of the household characteristics is to use "per-capita household income" obtained by dividing household income by the number of people in the household. This approach, however, has the fallacy of inferring that, for the same level of well-being, the household income required is directly and linearly proportional to the size of the household. It also suggests that all members of the household draw equally from the household resources (income), regardless of their individual characteristics. The actual situation, however, is not as simple. First of all, there are economies of scale in household expenditures. This can be exemplified by housing cost. Generally, the cost of housing two people in one household is not as high as the cost of comparable housing for two people living in separate households. Secondly, different members of the household have different needs and therefore draw disproportionately from household resources. The higher cost of providing for an adult, as opposed to that of a child, is a good example of this. For further discussions on these issues, see, among others, Whiteford (1985) and Bradbury (1989).

A better approach, therefore, is to use an *equivalence scale*. An equivalence scale is basically a series of factors that correlate the income level of a standard household (generally either "a couple without

children" or "a couple with two children") to the equivalent income level required by other household types to attain the same level of well-being. The standard household is conventionally assigned the value of 1.00, and the other household types are scaled accordingly. For example, a value of 1.20 on the equivalence scale means that it requires 20% more income for that particular household type to attain the same level of well-being as that of the standard household. In general, larger households have larger values on the equivalence scale, and vice versa, but not proportionally larger.

The minimum household characteristic that is used to classify the different household types in an equivalence scale is the size (number of people) of the household. However, using this approach would have the same result as using per-capita household income. As explained earlier, this has many significant weaknesses. In more developed equivalence scales, the determining attributes may include some or all of the following:

- the breakdown of adults and children in the household,
- the gender and/or age of individual household members,
- the employment status of individual household members, and
- the income level (total or per capita) of the household.

There are three common approaches used for determining equivalence scales: the political (also referred to as the administrative approach), the budgetary and the expenditure approaches (Bradbury 1989). The first approach, as the name implies, produces the equivalence scales through the political process. The resulting scales are used, inter alia, for determining tax structures. In the budgetary approach, the equivalence scales are based on experts' estimation of the financial requirements needed to provide for the necessities of the different household types. This is the most widely used of the three approaches, and its use is particularly prevalent in the setting of poverty lines. With the expenditure approach, the equivalence scales are based on observed (surveyed) expenditures of the different household types.

A more recently developed approach is the evaluative or attitudinal approach, in which the equivalence scales are based on individuals' subjective evaluation of a household's well-being in relation to its income level (Bradbury 1989).

4.   CHOICE OF EQUIVALENCE SCALE

A comparative study by Whiteford (1985) on sixty different equivalence scales, including some based on the attitudinal approach, concluded that "... no single method for deriving [an] equivalence scale can be regarded as entirely satisfactory, nor can any of the estimated scales be regarded as indubitably correct". Given that, no preference can therefore be given to any approach or to any particular equivalence scale over another. However, Whiteford (1985) also stated that equivalence scales based

on the budgetary approach "show somewhat a greater consistency than those derived from other approaches". It is therefore sensible that an equivalence scale of that type be adopted for this work.

The set of equivalence scales chosen for this work were originally developed by Henderson (1975) for his pioneering work on poverty in Australia. These scales have been chosen for several reasons, namely:

- they are based on the budgetary approach,

- they have been applied in Australia, and

- a comprehensive documentation of their construction is available.

What may be perceived as a flaw in using the Henderson set of equivalence scales is the fact that they were developed based on data from a study in New York City in 1954. However, Manning (1982, as reported in Johnson 1987) pointed out that their "divergences with other scales are not large and that similar scales have been derived in different ways from different base data". It was also a conclusion of the Whiteford (1985) comparative study that, overall, the Henderson equivalence scale performed no worse than the rest.

5. HENDERSON'S EQUIVALENCE SCALE

In his approach, Henderson (1975) considers the household as consisting of one or more income units, where an income unit is basically a single adult, a couple or a nuclear family supported by earnings or pension of its members. By Henderson's definition, it consists of an adult man (or woman, if there are no adult men in the household) defined as the income unit head, his wife (if the income unit head is a married male and living with his wife) and dependent children, if any, for whom the unit adult(s) is/are responsible. In his definition, Henderson assumes that the male adult is always the head of the income unit if both a male and female adult exist. This is a particularly important assumption because, in the calculation of standard costs (see below), Henderson assigns different values to male and female members of the income unit. A dependent child is one who is unmarried and aged 15 or less, or one who is unmarried, aged 20 or less and still in secondary school. A tertiary student, a person aged 15 or more and not attending school, a married person aged 15 or more, and anyone aged 21 or more, are all categorised as not being dependent children, but belonging to a separate income unit to their parents even if they live under the same roof.

For each income unit, Henderson assigns a standard cost which is the sum of the standard costs of each of the individual members of the unit, the standard cost of housing and the standard cost of ancillary requirements (for such things as power and fuel). It is this standard cost that is used for determining the equivalence scale value of the income unit by dividing it by the standard cost of the standard household. The standard cost of the income unit can be written as:

$$C = c^h(a^a, s, e, t) + c^w(a^a, e) + \sum_i c_i^c(a^c, s) + \tfrac{n'}{n} c^{hs}(n) + \tfrac{n'}{n} c^a(n) \tag{1}$$

where

C is the income unit standard cost,

$c^h(a^a,s,e,t)$ is the standard cost of the income unit head of age range a^a, sex s, employment status e and household type t,

$c^w(a^a,e)$ is the standard cost of a "wife" of age range a^a and employment status e,

$c^c_i(a^c,s)$ is the standard cost of the ith child of age range a^c and sex s,

$c^{hs}(n)$ is the standard cost of housing for household size n,

$c^a(n)$ is the standard cost of ancillary requirements for household size n,

n is the size of the household, and

n' is the size of the income unit.

The household type t has only 2 possible values, namely single-person household and multiple person household. The adult age range a^a has the possible values of *under 40*, *40-65* and *65 and above*, while the values of the child age range a^c are *6*, *6-15* and *15 and over*.

The equivalence scale for a particular income unit is then:

$$ES = \frac{C}{C'} \tag{2}$$

where ES is the equivalent scale value, and C' is the standard cost of the standard household.

Given that there are virtually unlimited numbers of possible income unit compositions, such that it would be impractical to consider all of them in the construction of an equivalence scale, some simplifications are usually applied. Another important reason for simplifying equivalence scales is the limitation in the level of detail in data to be used in conjunction with them. For example, such variables as "age" and "sex" may not be readily available for the description of household members. To employ those variables in the construction of the equivalence scales is therefore pointless as they would not be available in the application stage. In such situations, the standard costs are usually generalised, that is, some variables are assumed to have no effects on the standard cost. Examples of simplified Henderson-based sets of equivalence scales can be found in Whiteford (1985) and Johnson (1987).

In this particular work, instead of using an established (simplified) equivalence scale, the standard cost of each individual income unit is calculated using the household and personal characteristics supplied by the VATS data, and the equivalence scale values are obtained from them. The resulting equivalence scale value is then used for dividing income into a measure of economic capacity or welfare that is standardised against a standard household. Since this standardised measure has no direct monetary significance (except for the standard household whose equivalence scale value is 1), it can be further factored by any arbitrary number without losing any significance. It was therefore decided to divide it by the mean of the standardised welfare measure so that the value of 1.00

represents an income unit of average welfare capacity. The resulting factored measure of welfare capacity is called the *Welfare Index*.

6.   APPLICABILITY OF THE HENDERSON APPROACH

Henderson's division of the household into income units requires that each income unit be clearly defined. However, when there are more than one income unit in the household, the VATS data can usually positively identify only one. As for the other income units, an informed estimate would have to be made about their composition. The VATS survey questionnaire was designed such that the oldest person in the surveyed household is designated as *Person 1*. The status of every other person in the household is then related to this Person 1. A problem arises when Person 1 is not an income unit parent. In such cases, it may not be readily possible to determine the composition of any income unit in the household. Other information (such as the age and sex of household members) can sometimes be used to make an informed estimate, but when this is not possible each person is treated as a separate income unit. This is particularly the case for groups of unrelated persons living in a common household.

Henderson's classification of people and his definition of income unit used in determining the standard costs also prove to be unpractical and unsuitable with present social conditions. Problematic issues in this regard are:

- There is no standard cost applicable to a non-head male adult, which implies that a male adult is always treated as an income unit head.

- The above also implies that if both male and female adults are present, then the female is, by default, never an income unit head.

- The personal standard costs are gender specific, but the differences are marginal (0.7- 5% for employed adults, 6-19% for unemployed adults with the larger difference occurring in single person households, and 0-18% for children with the larger difference occurring in children aged 15 or more).

- The personal standard costs are also age group specific. Among adults, this difference can be as low as 3-4%, for employed people, but can go as high as 18%, for unemployed people. The difference between the lowest and highest child age group can be as much as 156%, but because of the relatively smaller contribution of children into the total standard cost of an income unit, this represents only a maximum of 18% for a household (for an income unit consisting of a single parent and a child).

- An income unit is narrowly defined to the extent of a nuclear family only. In fact, even family members who are no longer dependents (by Henderson's definition) are not

included in the same income unit. In a real situation, however, some extended households operate as a single income unit, in the sense that resources (specifically income) are shared among all members.

The first three issues deal with gender inequality in the cost of living and in status within an income unit (head or not head). Although this may well be relevant to the social environment of the time of Henderson's study (mid 1970's), it is felt that it does not reflect the present day situation. For that reason, a common standard cost was used for both sexes. This decision is also justified by the fact that the differences in cost are marginal. As for the issue of income unit head, it has now become arbitrary which of the two parents (or any other adult for that matter) in the income unit is so designated since both would have the same standard cost. However, the practice of assigning only one adult as head of an income unit is retained.

The age issue is dealt with similarly. For the sake of practicality, and considering that the differences are marginal, age group standard cost variances in adults are overlooked. A common value is instead adopted. As for children, despite the relatively large standard cost variance between age groups, the fact that the effective difference it makes on the total standard cost is marginal, it was deemed justifiable to adopt a common value of personal standard cost for all children.

As for the definition of income unit, it was decided to expand it to include all related people, regardless of whether they are, by some definition, considered dependents or not. Any people living under the same roof identified as being related (including relation by marriage/in-laws and de-facto relationships) are therefore placed in the same income unit, while everyone else is considered to be in separate income units. The personal standard cost assigned to these additional income unit members (those beyond the nuclear family) is equivalent to that of the non-head adult parent for an adult or that of a child for a child-age person.

Following these modifications, the equation of the income unit standard cost becomes:

$$C = c^h(e,t) + \sum_i c^o_i(e) + \sum_j c^c_j + \frac{n'}{n} c^{hs}(n) + \frac{n'}{n} c^a(n) \tag{3}$$

where

C is the income unit standard cost,

$c^h(e,t)$ is the standard cost of the income unit head of employment status e and household type t,

$c^o_i(e)$ is the standard cost of the ith non-head adult of employment status e,

c^c_j is the standard cost of the jth child of age range a^c and sex s,

$c^{hs}(n)$ is the standard cost of housing for household size n,

$c^a(n)$ is the standard cost of ancillary requirements for household size n,

n is the size of the household, and

n' is the size of the income unit.

The standard cost values to be used with this equation, a modified (simplified) version of Henderson's original values, are shown later in Tables 2 and 3.

7.   THE EFFECTS OF INCOME LEVEL

Several existing equivalence scales suggest that the actual income level of a household has an effect on (and is therefore a variable in the determination of) the equivalence scales. In other words, different income brackets follow a different set of equivalence scales (see, for example, Muellbauer 1977:471 and Kakwani 1980:363). However, Kakwani (1980) showed that the variation of equivalence scales is negligible over the wide range of income. It was therefore decided that this variation can be overlooked.

8.   THE VATS WELFARE INDEX

The Welfare Index constructed within the VATS project is developed in a number of stages:

1.   Personal incomes are collected in the VATS survey using the same question as used by the Australian Bureau of Statistics in the 1991 Census of Population and Housing. This question has 15 income categories ranging from "less than $3001 per year" up to "more than $80,000 per year".

2.   Because the ABS income question (in 1991) does not have a specific "zero income" category, this category is created in the VATS data by assigning anyone in the lowest income category, and anyone not reporting an income, a value of zero if they state that they are unemployed and a student. Both conditions must be satisfied, since employed students can earn an income while unemployed non-students may be in receipt of welfare benefits (which are counted as income).

3.   Those remaining respondents who have not reported a personal income (about 7% of respondents) now have an income imputed for them using a stochastic multiple regression technique, as described in Richardson and Loeis (1997). At the end of this step, all respondents have a reported or estimated personal income.

4.   The respondents in each household must now be grouped into "income units", as described in Section 5 above. Generally, most households consist of a single income unit (e.g. parents and children living together). However, in some households there may be more than one income unit where, for example, unrelated adults live at the same address.

5.   The after-tax personal income is calculated for each respondent using the Australian income tax scales in force at the time of the survey, as shown in Table 1.

Table 1   Australian Income Tax Scales for 1994 and 1995

1994

Income Range	Base Tax	Marginal Rate
less than $5,400	$0	0.0%
$5,400 - $20,700	$0	20.0%
$20,701 - $36,000	$3,060	35.5%
$36,001 - $38,000	$8,492	38.5%
$38,001 - $50,000	$9,262	44.1%
more than $50,000	$14,557	47.0%

1995

Income Range	Base Tax	Marginal Rate
less than $5,400	$0	0.0%
$5,400 - $20,700	$0	20.0%
$20,701 - $38,000	$3,060	34.0%
$38,001 - $50,000	$8,942	43.0%
more than $50,000	$14,102	47.0%

It is realised that the calculation of real after-tax income is not quite as straight-forward as simply applying the above tax rates to the total personal income of each respondent. In reality, consideration must be given to the number of dependents for each respondent and a range of other tax deductions that each respondent might have. However, for the purposes of this analysis, it is assumed that such a calculation will give a reasonable approximation of the non-linear effects of tax-rates on after-tax incomes.

6.   For each income unit, the total "income unit" pre-tax and after-tax incomes are obtained by summing the personal incomes of the members of the income unit. These quantities are similar to the "household income" often quoted in other studies, except that they apply to "income units" within households, and one of the measures applies to after-tax income. For simplicity of expression, these "income unit" incomes are referred to as household incomes in the remainder of this paper.

7.   The standardised costs of each "income unit" are now calculated using equation (3) above. This standardised cost consists of two major components; the Personal Standard Costs corresponding to each member of the "income unit", plus the overhead costs applying to the income unit itself in the form of Housing and Ancillary Requirements costs, which depend on the size of the income unit. The Personal Standard Costs used in the VATS project are shown in Table 2 while the Housing and Ancillary Requirements Standard Costs are shown in Table 3.

Table 2   Personal Standard Cost

Person Type	Employment Status	
	Employed	Unemployed
Unit Head (c^h)	20.00	13.00
Other (c^o)	18.50	9.50
Children (c^o)	7.50	

Table 3   Housing (c^{hs}) and Ancillary Requirements (c^a)

Number of people	Housing	Fuel/power etc.
1	12.1	4.9
2	13.3	6.7
3	14.5	8.0
4	15.7	9.3
5	16.9	10.6
6	18.2	11.8
7	19.4	12.6
8	20.0	14.0
9	21.2	14.8
10	21.8	16.2
11	22.4	17.6
12+	24.2	19.8

8.   A relative measure of household income is now obtained by dividing the after-tax household income by the total standardised cost for that "income unit". The average of these relative incomes is then obtained across all "income units".

9.   The Welfare Index is finally calculated by dividing the relative measure of income obtained in step 8 for each "income unit" by the average of these relative incomes.

The Welfare Index has been calculated for the VATS data from the 1994 and 1995 calendar years, and the results are shown below for the 1995 calendar year. For each of the cumulative distributions shown in Figures 1, 2 and 3, the distributions have been constructed on a "per person" basis. While this is obvious for the distribution of personal incomes, it should be noted that a household of N people with a household income of $X will mean that N observations of $X are recorded in the distribution of household incomes. The same logic applies to the distribution of the Welfare Index.
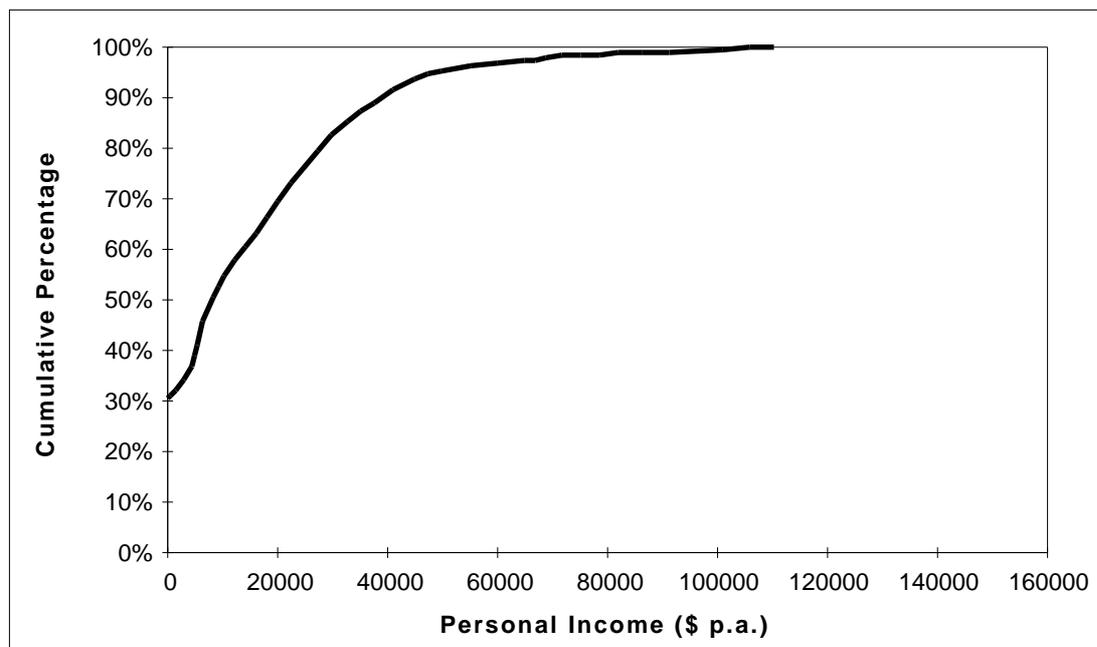

Figure 1   The Distribution of Personal Incomes
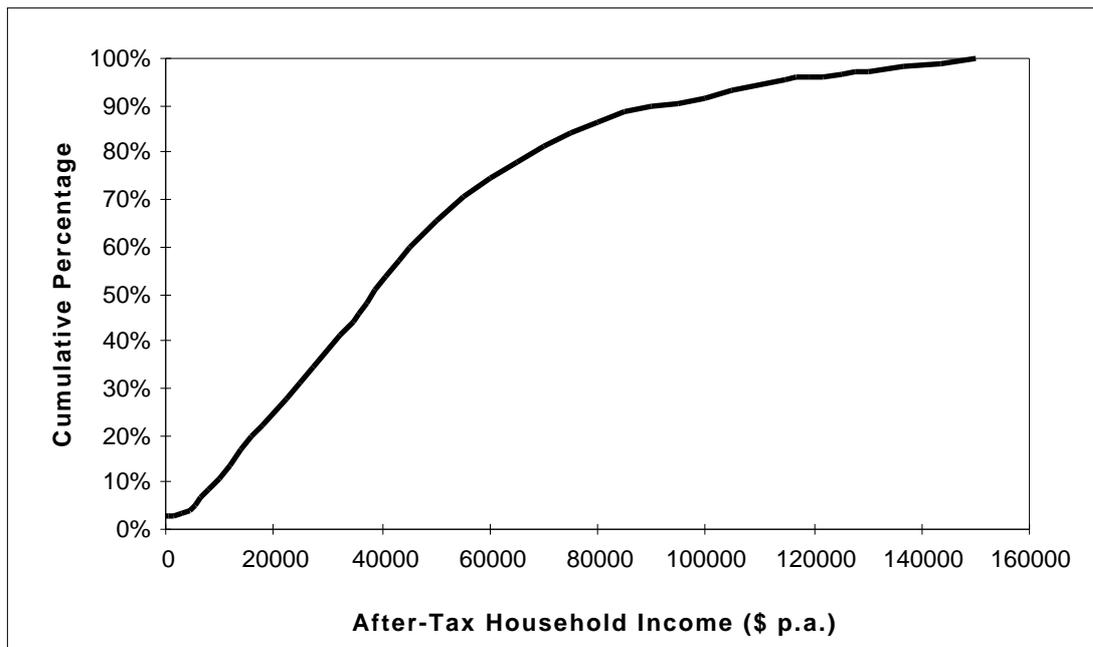
Figure 2   The Person Distribution of After-Tax Household Incomes

The first observation from Figures 1, 2 and 3 is that each distribution has a distinctly different intercept on the vertical axis. While 30% of the population (of all ages) has no personal income, only 3% of the population report that their household has no household income (which is possible if they are living entirely from their accumulated wealth), while 5% of the population are in the lowest Welfare Index group (less than 10% of the average Welfare Index). Secondly, the shape of the distributions are different, with personal income being most skewed and the Welfare Index being the most normally distributed. This illustrates the balancing effects of household size, household composition and the tax scales in evening out the after-tax income available to meet household expenditures. The median personal income is about $8,000 p.a. (including those earning no income), the median after-tax household income is about $38,000, while the median value of the Welfare Index is 0.85 (indicating a slight skew to the right).
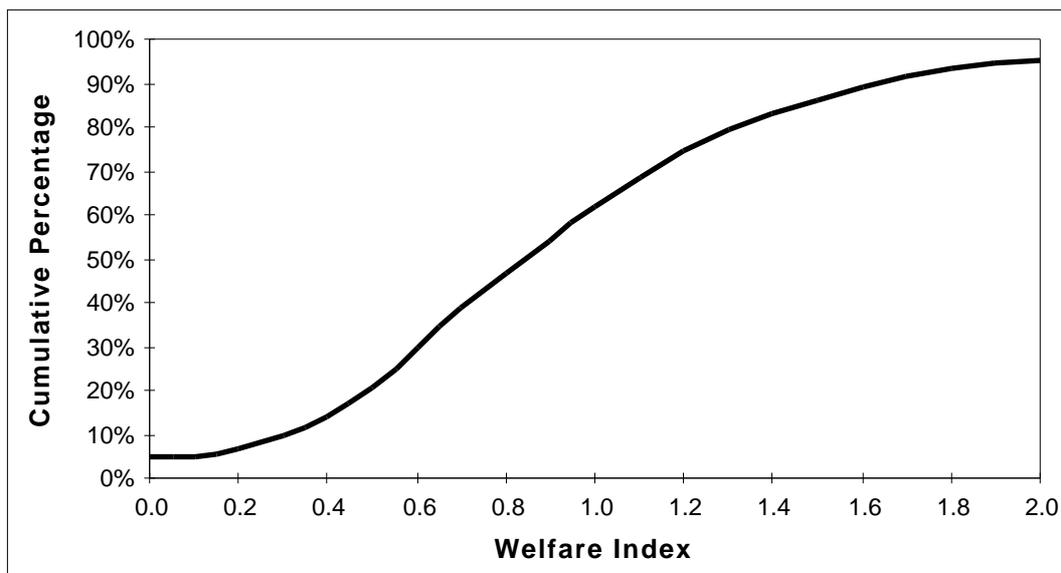
Figure 3   The Person Distribution of the Welfare Index

While there are differences in the three measures of income, as shown above, it might be argued that it would not make any difference which measure of income was used if there are linear, or at least monotonic, relationships between all three measures. Therefore, it is important to investigate the relationships between the three measures of income. Figure 4 shows the relationship between personal income and after-tax household income. It can be seen that the relationship is not even monotonic. Those people with the lowest personal incomes do not belong to households with the lowest after-tax household incomes. Bearing in mind that the median after-tax household income is about $38,000, it can be seen that those people in the lowest two personal income groups in fact belong to households with above-median after-tax household incomes. These people are primarily children with either no income or with pocket-money income derived from paper rounds, odd jobs etc. The lowest after-tax household incomes belong to people with personal incomes between $5,000 and $10,000 p.a. These people are primarily those on pensions and welfare benefits of some type. For personal incomes above about $15,000, it can be seen that the after-tax household income of a person is approximately $25,000 more than their personal income.
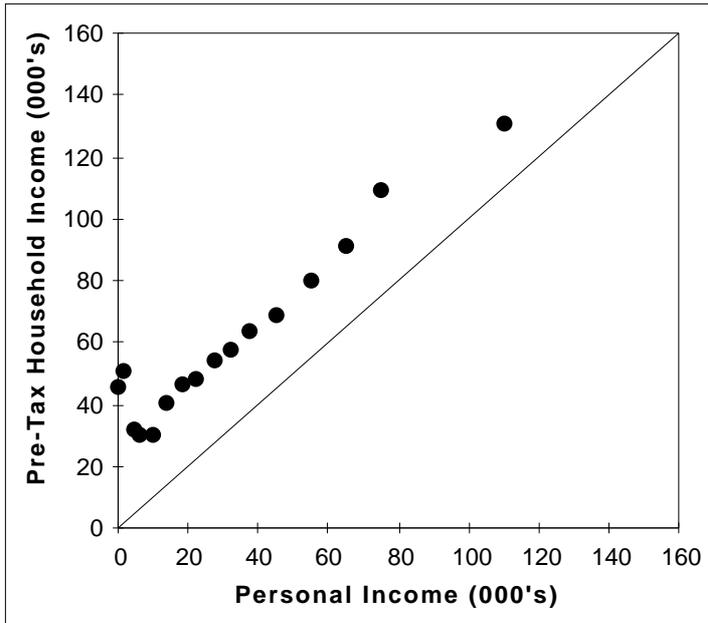
Figure 4   Personal Income vs After-Tax Household Income

The relationship between after-tax household income and the Welfare Index is shown in Figure 5. It can be seen that, unlike Figure 4, the relationship is at least monotonic, even if it is not linear. The Welfare Index initially rises quickly as the after-tax household income increases. However, beyond an after-tax household income of about $10,000, the Welfare Index increases at a slower rate until an after-tax income of about $30,000, beyond which it increases at a relatively constant rate. The reason for this transition is primarily concerned with an increase in the number of people sharing the household income, thus reducing the rate of increase in Welfare Index as the household income increases. At the top end of the after-tax household income scale (i.e above $100,000), the Welfare Index increases at a much lower rate. Interpretation of this change should be guarded, however, because of the relatively small number of people in these categories.
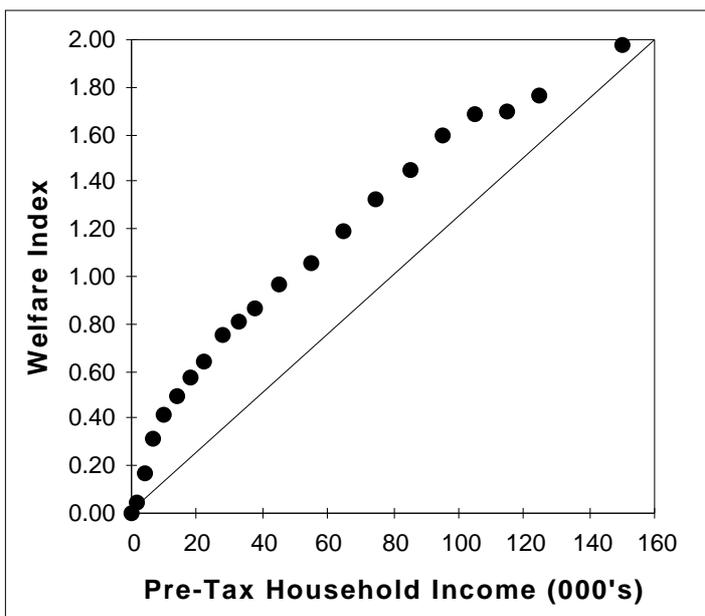

Figure 5   Welfare Index vs After-Tax Household Income

The major points to emerge from the above discussion are that:

• after-tax household income is not monotonically related to personal income

• the Welfare Index is not linearly related to after-tax household income

• by extension, the Welfare Index is neither monotonically nor linearly related to personal income

The selection of an appropriate measure of income must be related to the purpose of the analysis and the interpretations which are to be drawn from the analysis.

9. SOME APPLICATIONS OF THE WELFARE INDEX

The above sections have outlined the development of several measures of income, and have shown that the relationships between them may be non-monotonic and non-linear. This section will show how such measures of income may be used to examine relationship between mobility and income and the income characteristics of public transport users in Melbourne.

The data for this analysis is drawn from the Victorian Activity & Travel Survey (VATS) being conducted by the Transport Research Centre. VATS is an ongoing survey using a mail-out/mail-back self-completion questionnaire technique which has been developed and used over many years in Australia and overseas by members of the Transport Research Centre (Richardson and Ampt, 1995). The survey records all travel by all modes by all people in the responding households in the survey sample. Each household is asked to provide this information for a specified travel day. The survey is continuous, covering all 365 days of the year, thereby enabling temporal variations in activity patterns to be observed. It is intended to continue the VATS survey for at least five years, generating an expected total response of about 25,000 households in the first five years. The VATS survey began in December 1993 and has collected information from about 5000 responding households in each of the financial years from 1993-94 through 1996-97. The information being used in this paper is from the period January 1995 through December 1995.

A basic requirement for developing a new measure of income for use in transport planning and evaluation is that there is some relationship between income and mobility. Data from the 1995 VATS survey has therefore been used to verify this hypothesis. For each person in the sample, their personal income, their household's total after-tax income, and their household's Welfare Index has been calculated. These measures of income have been standardised by constructing the cumulative distribution of each income measure, and then locating each person within these cumulative distributions. A standardised measure of personal mobility has also been calculated as the ratio of the number of trip stages undertaken by that person to the average number of trip stages undertaken by the total population (including those who did not travel on their nominated Travel Day). Other measures of mobility (such as using linked trips rather than unlinked trip stages) could equally well be used, with similar results.

The relationships between each of these measures of income and the Standardised Personal Mobility Index are shown in Figure 6. It can be seen that there is indeed a relationship between mobility and income, irrespective of which measure of income is used. People at the median point of each income scale (i.e. the 50% point) have approximately an average level of mobility (i.e. a value of 1.00). Those with lower incomes have below average mobility and those with higher incomes have above average mobility. The extent of this difference is that those in the top 10% of incomes make approximately 20% more trips, while those in the lowest 10% of incomes make approximately 20% less trips than average.

Figure 6   Personal Mobility as a Function of Relative Income

The above results seem to indicate that it does not make a great deal of difference which measure of income is used. However, such a conclusion should be treated with caution. The degree to which the different measures of income make a difference will depend on the application to which the data is applied. The following example, dealing with the income characteristics of public transport users, will demonstrate this point.

As noted earlier, questions have been raised about the measure of income which should be used when examining the equity implications of public transport usage (Radbone, 1994). For that reason, an analysis of mode usage is reported below which uses the three different measures of income derived above: personal income, after-tax household income, and the Welfare Index.

The incomes associated with all trip stages (i.e. each trip stage contributes one value of income to the total distribution) for all types of mode are shown in Table 4, while incomes associated with public transport trips using various types of fare are shown in Table 5.

Table 4   Income Measures for Various Modes

	Personal Income	After-tax Household Income	Welfare Index
Non-Motorised	$16,380	$48,943	1.02
Car Driver	$27,310	$55,383	1.11
Car Passenger	$7,302	$52,849	0.98
Public Transport	$15,757	$48,591	1.00
Other Modes	$17,093	$53,894	1.07
ALL MODES	$18,672	$52,647	1.05

Table 5   Income Measures for Public Transport Trips by Various Fares

	Personal Income	After-tax Household Income	Welfare Index
Full adult fare	$28,000	$53,346	1.16
Secondary Student Concession	$787	$65,206	1.04
Tertiary Student Concession	$5,087	$48,145	0.90
Over 60's / Age Concession	$11,784	$23,195	0.75
Other Welfare Concession	$8,527	$26,932	0.67
All Other Fares	$8,324	$42,759	0.88
TOTAL Public Transport	$15,303	$48,584	1.00
ALL MODES	$18,672	$52,647	1.05

Several features of Tables 4 and 5 are worth noting. Firstly, the income values for all public transport modes in Tables 4 and 5 are slightly different due to missing values for fare types in Table 5. Secondly, the average value of the Welfare Index across all modes is 1.05, despite the fact that the average value across all people is, by definition, 1.00. This is because, as shown in Figure 6, the trip rates are higher for higher income people and thus there are more high income values in the income distribution based on trip stages than there are in the income distribution based on people. Thirdly, it can be seen (on close examination) that there are significant variations in the income values across modes and types of fare. In addition, there are relative variations across the various income measures within each mode or type of fare.

This latter observation can be seen more closely if the measures of income are standardised, such that the value of each income measure for all modes is set equal to 1.00. The standardised income values are shown in Figure 7 for various types of mode, and in Figure 8 for public transport trips by various types of fare. It can be seen that significant various in income ratio exist across the different measures of income. For example, in Figure 7, it can be seen that the personal income of car drivers is much higher than the average, while the personal income of car passengers is much lower than the average. However, when either the household income or the Welfare Index are used to measure income, car

driver and car passenger have much closer values of income. That is, while car passengers do not have high personal incomes, they do not necessarily come from poor households.
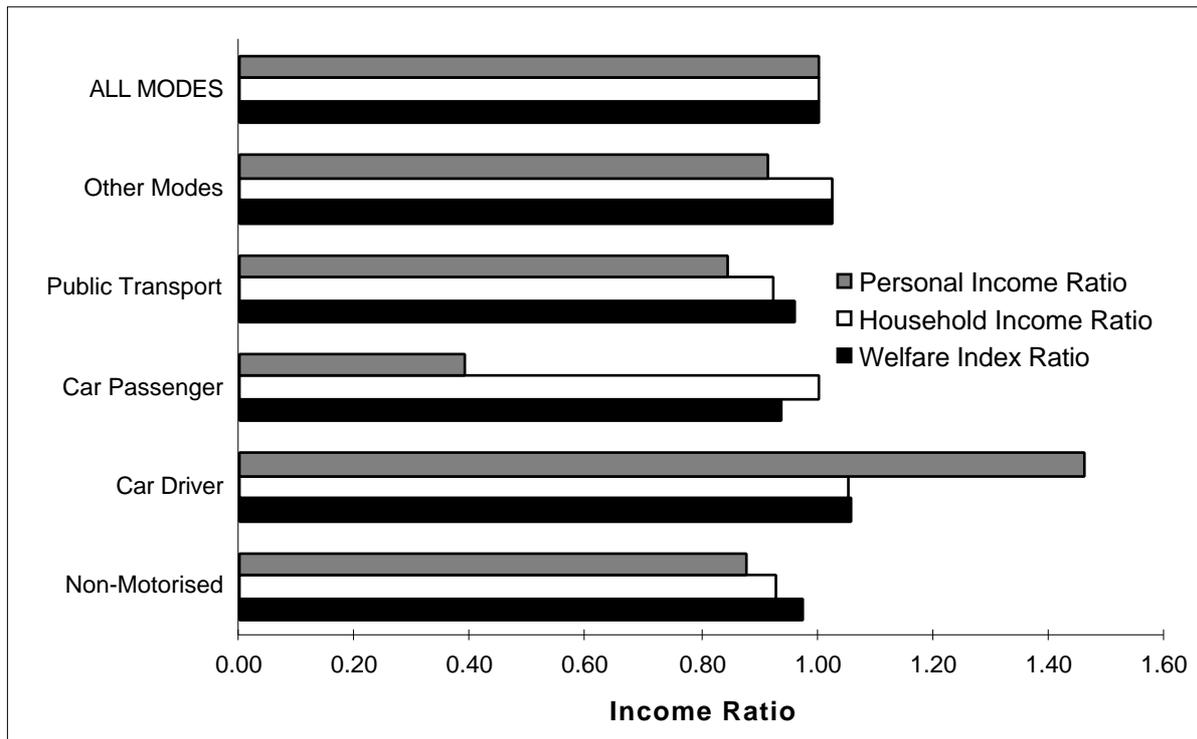

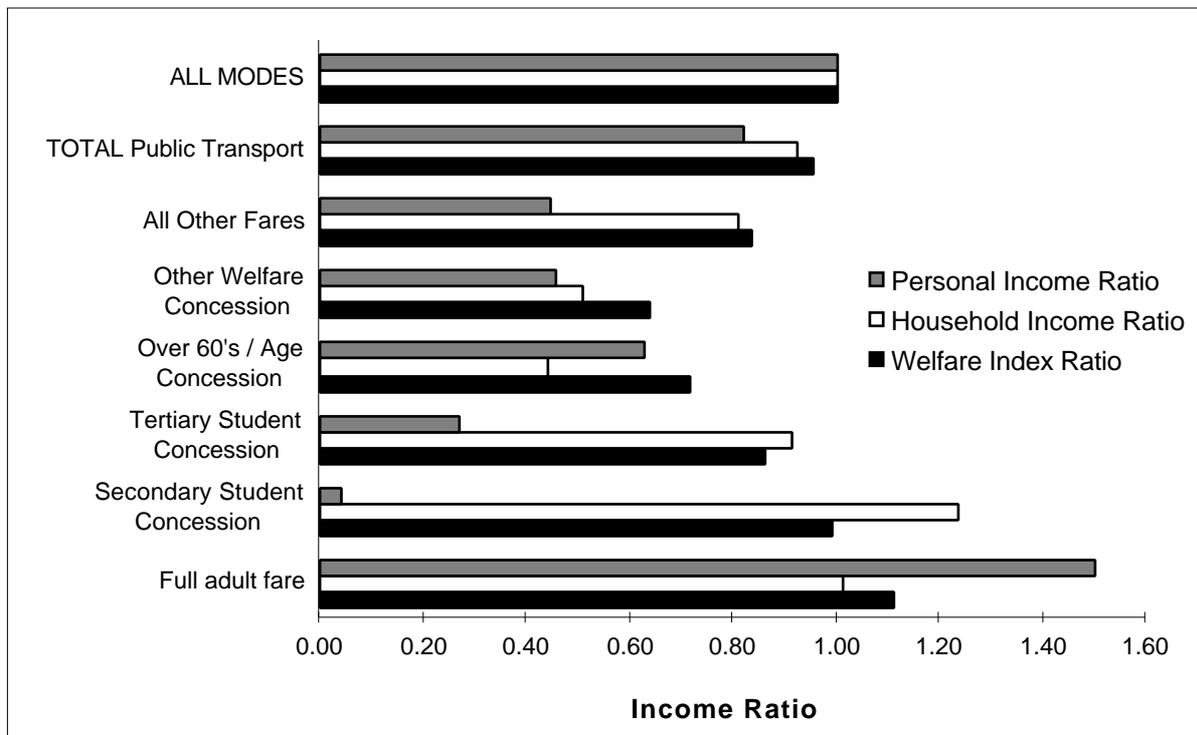**Figure 7   Income Ratios for Various Modes of Transport**

Figure 8   Income Ratios for Public Transport Trips by Various Fares

Even more considerable variations in income ratio are seen in Figure 8 for different types of public transport fares. For example, secondary and tertiary students have very low personal incomes, but

their household incomes and Welfare Indices are much higher. Indeed, the household income for secondary student concession trips is the highest of all types of trips (mainly because secondary school students tend to come from larger households). For trips made on age and welfare concession fares, the personal incomes are fairly low, but slightly higher when the Welfare Index is used. On average, public transport trips are made by people on lower than average incomes, although this difference is less pronounced when household income or Welfare Index is used as the measure of income. Most of these low income users, however, are on concession fares. In fact, public transport users paying full fare have higher than average incomes. Indeed, the Welfare Index for full fare public transport tripmakers is the highest of all modes, with a Welfare Index ratio of 1.11 compared to a ratio of 1.06 for car drivers.

This income profile for public transport users, however, is not uniform across the different modes of public transport. As shown in Table 6, the Welfare Index is higher for train and tram users, and lower for bus users, for both full fare and concession fare trips. In addition, the proportion of bus trips being made on concession fares is much higher than on train or tram, with the result that while the average Welfare Index for all trips on train or tram is about the average of all modes (remembering that the average for all modes is 1.05), the average Welfare Index for all bus trips is considerably lower.

Table 6   Welfare Index for Different Modes of Public Transport

	Full Fare		Concession		All Fares	
Mode	% of Trips	Welfare Index	% of Trips	Welfare Index	% of Trips	Welfare Index
Train	53%	1.20	47%	0.90	100%	1.06
Tram	49%	1.17	51%	0.94	100%	1.05
Bus	27%	1.05	73%	0.82	100%	0.89
TOTAL	44%	1.16	56%	0.88	100%	1.01

10.   CONCLUSION

This paper has described the development of a new measure of income, namely the Welfare Index, which can be used in travel behaviour analysis and in transport evaluation. The Welfare Index accounts for both the total after-tax income available to a household and the demands placed on the use of that income (as a function of household size and composition) to determine a relative measure of spending power across different household types. It has been shown that the three measures of income (personal income, after-tax household income, and the Welfare Index) are not monotonically or linearly related to each other. While all have been shown to be related to personal mobility, they provide very different insights when used to describe the income characteristics of public transport users. Differences in interpretation are shown to exist across all modes, across modes of public transport and across types of public transport fares.

The use of the Welfare Index is seen to account for many of the methodological difficulties identified by Radbone (1994), and is seen to provide a useful technique for the rigorous evaluation of the equity implications of a range of transport policies.

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