TIME AND INCOME IN TRAVEL DEMAND
Towards a microeconomic activity framework.

Sergio R. Jara-Díaz
Universidad de Chile, Casilla 228-3, Santiago, Chile
Fax (56-2) 6712799 e-mail: jaradiaz@tamarugo.cec.uchile.cl

Abstract

In the first part of this chapter, the microeconomic theory behind discrete mode choice models is summarized, and presently used specifications of modal utility are analyzed with particular emphasis on the role of time and income. Recent theoretical developments are illustrated with empirical results. The framework is then expanded to account for all dimensions of urban travel; to do this, the evolution of time related theories of consumer behavior is synthesized and the need to understand travel as part of a general activity framework is highlighted.

TIME AND INCOME IN TRAVEL DEMAND
Towards a microeconomic activity framework.

Sergio R. Jara-Díaz
Universidad de Chile

1.- INTRODUCTION.

Understanding urban travel demand is nearly like understanding life itself. The day has twenty four hours, and travel time usually consumes a substantial proportion of the truly uncommitted time. In general, individuals would rather be doing something else than riding a bus or driving a car, either at home, at work, or somewhere else. Accordingly, travelers would like to diminish the number of trips, to travel to closer destinations and to reduce travel time for a given trip. But such behavior seems more a consequence than an isolated phenomenon.

On the other hand, most of the relevant characteristics of travelers are obtained through the estimation of discrete choice models within the random utility paradigm. The main objective of this paper is to summarize the microeconomic foundations of discrete (mode) choice models, with emphasis on the role of time and income. The central idea is to highlight both the genesis and properties of such models, which means to accept the interpretation of results in terms of economically meaningful constructs as the marginal utility of income or the subjective value of time. This will be shown to have important consequences in the correct specification of such models.

The second objective of the paper is to expand the framework in order to encompass all travel decisions. To achieve this, the evolution of time related theories of consumer behavior is synthesized; the need to understand travel as part of a general activity framework is highlighted.

2.- DISCRETE CHOICES IN TRAVEL DEMAND.

Disaggregate choice models are the most popular type of travel demand models. The most important element is the (alternative-specific) utility level, usually represented through a linear combination of cost and characteristics of each alternative, and socio-economic variables for each group of individuals. Under this approach the analyst is assumed to know, for each individual type, which variables determine the level of non-random utility associated to each discrete alternative. This poses many questions regarding model specification: the structure of decisions, the distribution of the unknown portion of utility, functional form of the observable part, type and form of variables that should be used, and criteria to decide which group of individuals will be regarded as "alike".

The choice of the word utility to describe the equation that represents the level of satisfaction associated to each alternative, is not casual. It is borrowed from the terminology in microeconomics, a discipline that provides a theoretical framework to understand and specify choice models. The objective in this section is to expose the foundations of this approach in order to understand the role of income, time, characteristics, preferences, etc. Two caveats should be made. First, the primary sources of utility will not be examined (i.e. the psychological mechanisms that make consumption or actions pleasurable). Secondly, and in order to avoid confusion, it is important to stress that what is called utility to describe an alternative in discrete choice models, is in fact a conditional indirect utility function that already includes the role of the constraints faced by the individual as well as a first level of decisions. Thus, although the genesis of direct preferences are not analyzed, the formation of alternative specific utility levels (e.g. modal) is in the center of the following synthesis.

2.1 Quality and income in discrete choice.

The traditional microeconomic framework for consumer's behaviour is stated in terms of a bundle of continuous goods X which are chosen by the individual in an attempt to obtain the maximum level of satisfaction, within all possible bundles allowed by his/her purchasing power. After the formalization of Lancaster (1966), who introduced the notion of goods characteristics as the primary source of utility, the level of satisfaction could be stated in terms of those characteristics (flavor, nutrient, warmth, beauty); accordingly, the problem of choice can be understood properly accounting for the fact that characteristics can be obtained through the purchase of market goods, which in turn require money.

There is a relevant type of consumer's decision which can be faced with a slight modification of the preceding framework: discrete choices. Such a problem arises when the decision to acquire one unit of a certain generic good (e.g. a car, fruit, a trip) is followed by the choice of a specific type (e.g. a car model, a fruit type, a mode). Then the consumer can be viewed as choosing both the amount of continuous goods and one of the discrete alternatives (mode), each one described by a vector Q_j containing its qualitative characteristics. Formally (adapting from Mc Fadden, 1981), an individual is assumed to behave as if

$$\underset{x,j}{\mathrm{Max}}\, U(X,Q_j) \tag{1}$$

subject to

$$\sum P_i X_i + c_j \le I \qquad j \in M \tag{2}$$

where P_i and X_i are the price and quantity of good i respectively , c_j is the cost of using mode j , I is money income and M is the set of alternatives.

Such a problem can be solved on X conditional on the discrete choice j, obtaining conditional demands $X_i(P,I - c_j, Q_j)$. Once these are replaced in U, the resulting conditional indirect utility function $V(P,I - c_j, Q_j) \equiv V_j$ represents the maximum utility the individual can get if alternative (mode) j is chosen. Then the preferred alternative will be that which fulfills $V_j > V_i \, \forall i \neq j$. This means that not necessarily all arguments in V will actually influence mode choice. The portion of V_j that decides the result of the discrete comparison, is a truncated utility $\overline{U}_j$. From the derivation of the conditional indirect utility function V_j, it is clear that

a) Marginal utility of income = $\dfrac{\partial V}{\partial I} = -\dfrac{\partial V}{\partial c_j}$ $\quad$ *(MUI)* $\quad$ (3)

b) Subjective value of characteristic $j = \dfrac{\partial V / \partial q_j}{\partial V / \partial c_j}$ $\quad$ (SV_j) $\quad$ (4)

c) Modal utility is in fact a truncated conditional indirect utility function.

To illustrate this, let us represent V_j with a linear function, i.e.

$$V_j = \boldsymbol{a} + \sum_i \boldsymbol{b}_i P_i + \sum_k g_k q_{kj} + l(I - c_j) \tag{5}$$

Which one is the largest value for V_j among all $j \in M$, will depend only on the characteristics in Q_j and the cost c_j (all other terms cancel out when comparing V_i and V_j). Thus, the relevant part of V_j for discrete choice modelling is

$$\overline{U}_j = -l\, c_j + \sum_k g_k q_{kj} \,. \tag{6}$$

Eq. (6) justifies the usual linear in cost and time (and other variables) specification of modal utility, so frequent in applications. According to eq. (3), the MUI is minus the coefficient of modal cost, and the SV_j is simply the ratio of the corresponding quality coefficient over the MUI. The simplicity of the model, though, has a cost: income plays no role in the discrete choice, which might not be the case for many groups in urban areas. In fact, Mc Fadden's (1981) AIRUM model structure (additive income random utility maximizing) yields choice probabilities that are independent of current income.

A very simple extension of the usual linear utility model permits a much better understanding of the role of income (Jara-Díaz and Videla, 1989). For simplicity only, assume that the utility function U in (1) is separable in X and Q_j. This implies that the level of satisfaction attained from consuming a bundle X is independent of modal characteristics, i.e.

$$\frac{\partial^2 U}{\partial x_i \partial q_{jk}} = O, \forall i, \forall j, k. \tag{7}$$

Under the separability assumption, we can write the utility function as

$$U\{X, Q_j\} = U_1(X) + U_2(Q_j) \tag{8}$$

The optimization problem on X has a solution that is conditional on c_j alone, yielding a set of functions $X^*(P, I - c_j)$; once they are replaced in $U_1(X)$, a partial indirect utility function is obtained, i.e.

$$\underset{X \in x}{\mathrm{Max}} [U_1(X) / PX^T \leq I - c_j] \equiv V_1(P, I - c_j). \tag{9}$$

Thus the conditional indirect utility function is in fact

$$V(P, I - c_j, Q_j) = V_1(P, I - c_j) + U_2(Q_j) \tag{10}$$

The role of income involves V_1 only. Assuming that prices of continuous goods are constant, V_1 can be approximated by a Taylor expansion around (P, I), i.e.

$$V_1(P, I - c_j) = V_1(P, I) + \sum_{i=1}^{n} \frac{1}{i!} V_1^i(P, I)(-c_j)^i + R_{n+1} \tag{11}$$

where V_1^i denotes the i th derivative of V_1 with respect to $I - c_j$ evaluated at I, and R_{n+1} represents terms of order $n+1$ and higher. If a Taylor expansion to the order n is assumed to be sufficiently accurate, then R_{n+1} is close to zero; therefore, V_1^n is a function of P only.

Therefore, V_j is given by

$$V_j = V_1(P,I) + \sum_{i=1}^{n-1} \frac{1}{i!} V_1^i(P,I)(-c_j)^i + \frac{1}{n!} V_1^n(P)(-c_j)^n + U_2(Q_j) \qquad (12)$$

This shows that mode choice does depend on the level of individual income for $n \geq 2$, since at least one term of the form $V_1^i(P,I)$ will appear. This means that comparing $V(c_i, Q_i)$ against $V(c_j, Q_j)$ may yield a different result for different levels of income. In other words, if the best specification for V_j involves terms in c_j of order two or higher, then income influences mode choice.

This framework has been applied to a middle-low income corridor in Santiago, Chile. Modal utility was specified using linear and squared terms in cost for the whole sample; as the squared term came out significant, the sample was divided into four homogeneous income groups and mode choice models were estimated using the second order specification. Within each sub sample, the squared cost term come significant only for the three poorest groups, and its level diminished with income, which meant that the influence of income on choice was reduced as purchasing power increased.

In general, the MUI can be calculated at an individual level as

$$l = \frac{\partial V^*}{\partial I} = V_1^1(P,I) + \sum_{i=1}^{n-1} \frac{1}{i!} V_1^{i+1}(P,I)(-c_d)^i \qquad (13)$$

where d stands for the chosen mode. Applying this to the described data, the MUI was found to diminish with income, which is an expected result.

It is worth mentioning that, although weakly justified, specifications including modal cost and income can be found in the literature. The discrete choice framework unambiguously show that they should be linked, but usually the treatment of units makes this a fuzzy point (for a discussion of related matters, see Viton, 1985).

2.2 The goods/leisure framework

The preceding approach to model discrete choices is fairly general, i.e. it applies to most type of purchasing decisions when the choice has to be made among a family of goods with qualitative internal differences. The transport - specific dimensions enter the picture when variables like the components of travel time (in - vehicle, waiting and access times) are included in Q_j. An obvious alternative for the modelling of an activity like travel, in which the assignment of time is the basic dimension, is to include time in the framework from the beginning.

The analysis of travel choices within the framework of consumer behaviour explicitly including time, was a fairly natural extension of the early theoretical attempts to account for time as a "requisite" for goods consumption (reviewed in the next section). By 1970, Gronau adapted Becker's (1965) theory to model mode choice including both time and money constraints, showing that the (discrete) decision depended on something that now we would call modal utility, which was a weighted sum of cost and travel time (see Gronau, 1986).

One of the most popular microeconomic approaches specifically aimed at understanding mode choice, some years later introduced modal travel time t_i and cost c_i as variables that influence utility through the impact on goods consumption G and leisure time L. This goods/leisure trade-off approach (Train and Mc Fadden, 1978) can be summarized as follows, for the case of a single trip in a given O-D pair

$$\text{Max}\, U(G,L) \tag{14}$$

subject to

$$G + c_i = wW + E \tag{15}$$

$$L + W + t_i = \boldsymbol{t} \tag{16}$$

$$i \in M,$$

where W is working time, w is wage rate, E is income from other sources and $\boldsymbol{t}$ is total available time. By virtue of equation (15), working more (increasing W) means consuming more (G) reducing leisure (L), and vice versa. Thus, the trade-off between goods and leisure is synthesized by W. As in the previous problem, represented by equations (1) and (2), this can be solved in two steps, using W as a "pivot", replacing G and L as functions of W from (15) and (16) in (14). Then the optimal value for W can be found conditional on mode choice (i.e. on c_i and t_i), which yields a conditional demand for working time W^* as a function of $w, E - c_i$ and $\boldsymbol{t} - t_i$. If this is replaced back in the utility function, a conditional indirect utility V_i is obtained. Giving U the Cobb-Douglas form $K\, G^{1-b} L^b$, the result is

$$V_i = K(1 - \boldsymbol{b})^{1-b}\, \boldsymbol{b}^b\, [w^{1-b}(\boldsymbol{t} - t_i) + w^{-b}(E - c_i)]. \tag{17}$$

Again, mode choice is decided by comparison among $V_i, \forall i \in M$. For a given individual, this approach yields choices commanded by the maximum value of $-c_i / w - t_i$ or $-c_i - wt_i$.

It should be noted that what we have called the truncated conditional indirect utility function $\overline{U}_i$, in the case of equation (17) corresponds to an expression of the form

$$\overline{U}_i = K' w^{1-b} t_i - K' w^{-b} c_i \tag{18}$$

which is again linear in cost and time. Note that when $b \rightarrow 0$, then $K' = K$ and choice is determined by $-c_i - wt_i$; when $b \rightarrow 1$, then $K' = K$ and choice follows the maximum of $-t_i - c_i / w$. This is the origin of the popular cost over income specification of modal utility, in which income is in fact a proxy for the wage rate.

The preceding model includes a rather strong assumption, i.e. that the individual can choose working time freely at a prespecified wage rate. Nothing essential changes if a fixed working schedule and a fixed income is introduced in this framework, provided the individual works extra time at a marginal wage rate w. However, if no additional work is produced, then a model with exogenous income I is obtained. Under this setting, the trade-off between goods and leisure no longer depends on assigning more or less time to work, but on choosing faster (and more expensive) modes or slower and cheaper ones. In this model, the conditional indirect utility function is directly obtained replacing G and L from the constraints into U. If utility with a Cobb-Douglas form is approximated to a second order Taylor expansion around $(I, T - W)$, replacement of G and L plus a convenient rearrangement of terms, yields a truncated conditional indirect utility function given by (Jara-Díaz, 1990)

$$\overline{U}_i = -q(1-b)\frac{c_i}{g} - qb\, t_i + \frac{1}{2} qb(1-b)(S_T - S_I)\left(\frac{c_i}{g} - t_i\right), \tag{19}$$

where g is an expenditure rate $I / (T - w)$, S_I and S_T are the share of income $\left(\frac{c_i}{I}\right)$ and free time $\left(\frac{t_i}{T - W}\right)$ spent in transport respectively, and q is $K g^{1-b}$ (note that $S_I \neq S_T$ always).

The expression for the modal utility represented by equation (19) involves a number of novelties. First of all, if either S_I or S_T were significantly different from zero, then second order terms in travel cost, travel time or both, should be included in the specification. This is consistent with a previous observation regarding the role of income in mode choice captured by second order terms in cost, because (as should be recalled from the standard theory of consumer behaviour) a high share of income in the consumption of a particular good, is indicative of the presence of income effect. Secondly, if both S_I and S_T were negligible, a linear specification would be appropriate, keeping some resemblance with the previous version of $\overline{U}_i$ in equation (18) which involves the modal cost over the wage rate; in this fixed income case, though, cost is divided by an expenditure rate which represents the amount of money to be spent in a $T - W$ period (Jara-Díaz and Farah, 1987). We have named these specifications the wage rate and expenditure rate models respectively. Such specifications were empirically explored by Jara-Díaz and Ortúzar (1989). Note that a constant working schedule across the population in a sample of fixed income travelers would provide a clear case for the cost over income specification.

The generalized expenditure rate model represented by equation (19) helps clarifying an important point regarding the stratification of travelers for model estimation. Imagine that a traditional mode choice model with linear utility is specified with the usual cost over income and time variables; assume as well that individuals in the sample have similar preferences (i.e. same K and b) but trips involve a variety of travel distances (or travel time). This means that individuals in the sample would have different values for S_T and , therefore, different coefficients for cost and time according to eq. (19). Therefore, different linear models should be estimated for individuals traveling short and long distances. In other words, the sample should be stratified according to distance.

The goods/leisure approach can be used to explore the presumptive relation between income and "pure" or unrestricted preferences, represented by the parameter b in direct utility. If second order effects are assumed negligible in equation (19) and the first order terms are conveniently manipulated, one obtains

$$\overline{U}_i = -A\, g^{-b}\, c_i - B\, g^{1-b}\, t_i\,. \qquad (20)$$

Mode choice models can be estimated to obtain A, B and b for populations with different income, in order to examine possible monotonicity between the income level and the estimated b values. This approach was used by Jara-Díaz (1991) in a study involving two income groups within each of two corridors, clearly rejecting the correlation between income and the parameter representing unrestricted preferences.

Finally, the appeal of the goods/leisure approach goes beyond its simplicity. It can be adapted to cases like interurban travel or vacation trips to a resort area. Imagine an individual that is self-employed and whose vacations are planned as a long run decision, including destination, length of stay, and travel mode. In this case the existence of earnings per unit time, and the endogenous decision on the length of time out of work play a key role in the specification of utility ; the resulting model will be similar to a wage rate model. On the other hand, if the individual has a pre-specified vacation period, the expenditure rate approach (properly adapted) could be used, making the vacation budget play the role of fixed income.

2.3 Extensions and discussion

One might be tempted to include here a discussion on the value of time but, although related, the emphasis is intended on the formation of the truncated conditional indirect utility function. Nevertheless, one can observe that the goods/leisure framework yields a value of time equal to the (marginal) wage rate under its endogenous income version, but the result is different (and more interesting) if income is regarded as exogenous. In fact, for the Cobb-Douglas form of direct utility, the subjective value of time *(SVT)* is given by

$$SVT = \frac{\boldsymbol{b}}{1-\boldsymbol{b}} \frac{I - c_i}{T - W - t_i} \tag{21}$$

which is nearly proportional to the expenditure rate when c_i and t_i are negligible compared to income and leisure time respectively; in fact, to a first order approximation, SVT is equal to $g\boldsymbol{b}/(1-\boldsymbol{b})$ from the first part of equation (19). Note that, for a given income level, a person that works less has a lower value of time. This explains empirical results like those obtained by Bates and Roberts (1986) regarding the low SVT for retired individuals. Also, note that SVT increases with t_i, which means that the (marginal) subjective valuation of travel time increases with trip length. This is an important point as some claim that one more minute in a short trip should be perceived as more valuable than one more minute in a long one; this fallacy ignores the fact that what is valuable to an individual is leisure time, which is the complement of t_i. Thus, what matters is the perception of one minute relative to leisure, which diminishes as leisure increases, or **increases** with t_i.

In applied work, any version of the alternative-specific utility functions introduced here, includes c_i divided by some form of income (e.g. wage rate, income itself or expenditure rate), all components of travel time, other (modal) characteristics, socio-economic indexes, etc. Each variable has a parameter such that the MUI and SV_j are easily calculated using equations (3) and (4) respectively. As discussed, the SVT under the original version of the goods/leisure trade-off framework is equal to the wage rate, but this is rarely the result in empirical work, in which the ratio of the travel time coefficient over the cost/wage coefficient is usually less than one (a result theoretically supported by Gronau, 1986). This is related with the formulation of the trade-off model, in wich the absolute perception of time is captured by the multiplier of the corresponding constraint, which is the same for all activities included in L, for work and for travel. Thus, the price of time is equal for all activities and equal to the wage rate. The case would be different if restrictions regarding time were identified beyond equation (16). One possibility is that of minimum time requirements, like those identified by Truong and Hensher (1985). On the other hand, a ratio significantly greater than one has also been obtained (Jara-Díaz and Ortúzar, 1989). In this latter case, an expenditure rate approach would accept such values as a possibility, as shown in equation (21), where $\boldsymbol{b}/(1-\boldsymbol{b})$ can take any positive value within the interval $0 \leq \boldsymbol{b} \leq 1$. Note that $\boldsymbol{b}$ represents the importance of time in direct utility, which means that individuals with a large absolute perception of time could reveal a high SVT if the fixed income, fixed working schedule, is the relevant one.

So far, it seems as if the main issue for the correct specification of (modal) utility is the role of income, its endogeneity or exogeneity, depending on whether paid working hours are decided or not by the individual. In fact, time plays a key role which will be exposed in the next section.

3.- FROM CONSUMPTION TO ACTIVITIES: THE HISTORY OF TIME RELATED MICROECONOMIC THEORY.

From a microeconomic viewpoint, modeling urban travel demand means introducing time and space in consumer theory. For a given location pattern, an individual has to choose what goods to buy and what activities to perform, potentially including leisure, work and transportation. The role of time began to be discussed with special emphasis from 1965 to 1972 in the economic literature. The traditional framework to model consumer behaviour sees individuals as trying to achieve the highest level of satisfaction given the constraints that each one faces. As the level of satisfaction was assumed to be dependent on the amount of goods consumed only, the natural constraint was that of a limited purchasing power. The need to understand the labor market made it mandatory to introduce time as an important element in that framework, as the consumer was assumed to face a choice between work and non-work time. The emphasis, of course, was on the relation between wage and the willingness to work (labor supply). In this context, an activity which is essentially time consuming as travel was also of interest. In this section, the consumer theories involving the assignment of time are reviewed and discussed, in order to facilitate the integration between the theory of urban travel with the general theory of time allocation.

3.1 The allocation of time

Becker (1965) brought attention to the fact that market goods X are not consumed as they are bought, but they have to be transformed into "basic commodities" Z, which require time to be prepared. Thus, as satisfaction comes from Z, and each Z_i depends upon goods consumption X_i and preparation time T_i, then utility should be seen as $U(X,T)$. In Becker's model, income is essentially an endogenously determined variable, as the individual decides how many hours W to work at a pre-specified wage rate w. Thus, two constraints appear originally in his formulation: the traditional budget constraint which relates expenses in market goods with income wW, and a new time constraint which states that working hours plus $\sum_i T_i$ should be equal to total available time. However, Becker turns the two constraints into one by noting that "time can be converted into goods by using less time at consumption and more at work" (pp. 496-497). The resulting constraint is stated in money terms where a full price for each generalized good Z_i appears; this full price encompasses the expenses on the necessary market goods, plus a time cost given by wT_i which represents the value of forgone income, i.e. the amount of money the individual would earn if he/she assigned T_i to work more (see Table 1). Both Johnson (1966) and Oort (1969) used the new time constraint in order to model and understand trip generation and the role of travel time respectively; both, however, included work time in utility.

A few years later, DeSerpa (1971) developed a model that resembles Becker's, as both goods and time are included as arguments in utility; however, the approach features important differences. The first one deals with the inclusion of all time components in the utility function in addition to goods, particularly working time which was explicitly excluded from the previous framework. The second difference is the addition of a series of constraints reflecting minimum time requirements for the consumption of each good. DeSerpa's notation is not the most appropriate, as reflected by the need to introduce a number of observations to explain potential limitations of the model (e.g. the concept of pure time commodities, a work commodity, and negative prices). Although he makes no reference to the concept of "basic commodities", consumption time is introduced in utility together with goods; later on, the consumption of each good is called an "activity". The income and time constraints are presented as independent equations, and the role of the minimum required consumption time is highlighted as the source of the positive valuation of a reduction in T_i only if the corresponding constraint is active, which means that the individual would have liked to spend less time on it.

The first microeconomic model dealing with activities as a central issue was formulated by Evans (1972). Here, the primary source of satisfaction is the type of activity performed, and its measure is the amount of time T_i assigned to that particular activity within a period. Thus, in essence, Evans introduced $U(T)$ as an apparently simple departure from the classical goods consumption model; however, activities are costly because they require goods to be actually performed. Thus, market goods are inputs which are necessary to develop activities and, in turn, goods are the source of the activity cost. What DeSerpa had called pure time activities are allowed to exist in Evans framework simply as a particular case; their cost can be either positive (the individual pays) or negative (the individual is paid). If Q is a matrix containing the input of goods at a certain rate per unit time which are required for each activity, then QT is the vector of goods that has to be bought in order to be able to do the activities contained in T. Thus, the budget constraint is in fact related to QT. On the other hand, activities will be interdependent in general. This is taken into account by Evans introducing a matrix J that represents links among activity times.

The relation $X = QT$ is the first explicit introduction of a transformation function that turns activities into goods and viceversa, which was implicitly expressed both in Becker's model (the b_{ij} coefficients in Table 1) and in DeSerpa's (the a_i coefficients). For Evans, the amount of time to be assigned to each activity is the basic variable, the source of direct utility and the original source of both expenses and income. Accordingly, his model is stated in terms of the vector T only, as shown in Table 1. For completeness, it should be mentioned that Michael and Becker (1973) further elaborated on the role of the "household production function" $Z(X,T)$, along different lines.

3.2 Discussion

As seen, time evolved in consumption theory from a secondary role to a central one in a short period. However, today the basic approach to model consumer behaviour still rests on the idea of goods consumption as the primary source of direct utility. From our brief account, though, it seems that the fundamental role assigned by Evans to activity time allocation generates a more general and meaningful framework. If one looks at Table 1 trying to make a synthesis, there are three key issues to discuss. The first one is the relation between goods and time. Such a relation is fairly general in both Becker's and Evans' models through a matrix of fixed coefficients (b_{ij} in the first one and Q in the second). The second issue is the presence (or absence) of working time W in the direct utility function. Unlike Becker, who explicitly leave them out, both DeSerpa and Evans include working hours as a direct source of utility. This is an important matter, as including working hours in utility would make Becker's synthesis of income and time constraints into one, a mistake, because W could not be used as a pivot variable since the utility level would be affected. This is specifically pointed out by Evans, and it has previously been highlighted by Johnson (1966) and Oort (1969) in their independent departures from Becker's approach. In fact, Evans criticizes both Johnson and Oort for not introducing other time related restrictions as, for example, minimum time required to perform an activity (DeSerpa's model is not mentioned by Evans). If no time restrictions are accounted for, the value of time would be equal for all activities because time is adjusted accordingly. And this leads to the third issue, which is more ample than specific minimum time requirements: the interrelation among activities. This is explicit in Evans' model only, although De Serpa introduces a related idea which, as explained here, is somewhat related to the idea of a transformation function representing the relation between goods and time. This interrelation is the source of the relative importance of different activities from an analytical viewpoint; as this differential perception of activities is in fact observed, omitting such a constraint would yield erroneous models.

Thus, starting with time as an addition to commodity consumption in the microeconomic theory of consumer behaviour, we find an approach like Evans', which encompasses all dimensions of the problem. The striking fact is that his model can be stated in terms of activity times **only**, as shown in Table 1. Can this model be converted into a goods consumption model? It appeared as possible, according to the conversion of times T into goods X, i.e. $T = Q^{-1} X$. But even if this is done, the two other constraints still remain: the total time constraint, and a set of linked-activity type constraints. The resulting commodity consumption model is, therefore, a different one.

On the other hand, and with a different purpose, time played a very important role in what today is called home economics. In Gronau's (1986) review, the original formulation of Becker's (1965) time allocation model was generalized to include a "work activity" Z_n that enters utility directly; furthermore, the conditions for time to be converted into money are unambiguously established (including an endogenous labor supply and no effect of Z_n on U). This analysis is particularly interesting, as the Z_i's are clearly associated with activities, which becomes evident not only in the treatment of work but in an example where a trip is a necessary ingredient in the production of a "visit". As two modes are assumed available for the trip, that example is illuminating in two respects: first, a discrete mode choice model is the outcome and, second, Becker's final goods Z are directly defined as **activities**. It seems like all roads lead to Rome.

An appropriate view of individual behaviour from a microeconomic perspective should rest on activities as the primary source of utility, a view that has received some support in the economic behaviour literature within the last decade (e.g. Juster, 1990 ; Winston, 1987). This implies looking at goods as means that are necessary to actually realize a set of activities. Doing this requires the introduction of a conversion or transformation function that turns activity times into goods and vice versa. A relation among activity times themselves seems to be necessary as well. This means that introducing time in a microeconomic framework goes beyond the addition of a time constraint. Moreover, time should not be seen as the number of minutes necessary to either prepare a final good or consume a market commodity; it is the direct source of utility by means of its assignment to activities. Note that this apparently innocent change of perspective moves things in a different direction. First, the primary result of a consumer model would be activity "demand" functions (as opposed to market demands for goods) and, second, if a $U(X,T)$ type of utility was taken as a correct formulation, an explanation should be given for the presence of X (as opposed to that of T). Note that one possible explanation would be the qualitative content of a certain type of activity, i.e. the marginal utility of activity i could be dependent on the type and amount of goods used, making $\partial^2 U / \partial T_i \partial X_j$ different from zero; note also that this would depend solely on the degree of detail used to describe an activity (e.g. dinning versus dinning elegantly).

4.- TOWARDS A SYNTHESIS: A MICROECONOMIC TRAVEL-ACTIVITIES MODEL

So far, the microeconomic basis for discrete choice models has been summarized, and the time-related theories of consumer behavior have been explored and analyzed. Here follows an attempt at a constructive synthesis.

4.1 Travel choice and time allocation theory

In their original form, both the goods/leisure approach (Train and McFadden, 1978) and Becker's time allocation model yield the same value of time: the wage rate. This should be no surprise, as in both cases three conditions concur : income is endogenously determined by freely choosing working hours, these do not affect direct utility, and no constraints besides income and time budgets are included. Although they look different and their utilities have different foundations, both models are in fact conceptually the same; it should be recalled, however, that X and T in Becker's model are the inputs to obtain the basic commodities Z, and both are **vectors**, as opposed to G and L in Train and McFadden's, which are aggregates.

The preceding argument makes Gronau's (1986) extension a relevant one, as he includes a work commodity in the direct utility, as well as a potentially given labor supply, making Becker's model a particular case. By association, a generalized version of the goods/leisure model can be constructed, simply replacing W in equation (16) by $W_F + W_v$ representing fixed and variable (endogenously decided) working hours respectively, and putting $W = W_v$ and $E = I$ (fixed income) in equation (15). Such a model still would be lacking work in direct utility. However, both the wage rate and expenditure rate specifications could be obtained as particular cases, using W_v as pivot; if W_v results with a positive value, the wage rate approach holds, and a zero value (corner solution) implies an expenditure rate model. Note that the endogeneity of marginal working hours is something that can be observed.

The literature shows some attempts to formulate and interpret mode choice models according to the general frameworks previously developed to approach time allocation. One example of this is the work by Truong and Hensher (1985), later improved by Bates (1987). They try to translate both Becker's and DeSerpa's general frameworks into (discrete) mode choice formulations. Due to the presence of DeSerpa's technical constraints regarding minimum time requirements, they show that the conditional indirect (modal) utility should have a mode-specific time coefficient; this coefficient should be generic if mode choice was derived from Becker's framework. This difference is also influenced by the fact that travel time does not enter direct utility in the so-called Becker type model, while it does appear explicitly in DeSerpa's counterpart. In both cases the THB formulation follows the goods-leisure approach which, as we have seen, is in fact Becker's. However, as goods and "activities" in DeSerpa's are also vectors explicitly written as such, as working time is not adjustable, and as additional time constraints appear, interpreting DeSerpa's utility arguments X and T as goods and leisure seems a misuse.

In the preceding paragraphs, the possibility of both building a more general framework for travel decisions and linking this with the theories of time allocation, has been highlighted. But there is a basic issue to be solved: the arguments in direct utility. Here, the so-called "final commodities" Z seems more an excuse to plug X and T in utility than anything else. In fact, Z is never defined with enough precision with the exception of Gronau (1986), who eventually calls them "activities". On the other hand, Evans (1972) argues in favour of **time devoted to activities** as the basic quantifiable source of utility.

For Becker, T is time to prepare the final commodities (which is the reason why W is left out of utility); for DeSerpa, T is consumption time; for Train and McFadden, the aggregate source of utility is leisure; Truong and Hensher include travel time in direct utility in the so-called DeSerpa model. As particularly emphasized by Evans (1972), Bates (1987) and Gronau (1986), including or not an activity time in direct utility plays a key role in the interpretation of a model. In analytical terms, the behavior represented by the corresponding first order conditions for optimality, might include or not include a marginal utility of time assigned to the particular activity in question. The basic point is whether the individual level of satisfaction can change only because of transfers among leisure, work and travel, through the time constraint with an impact on purchasing power, or also due to direct pleasure or displeasure.

It seems that there has been an emphasis on keeping as arguments in utility only those elements which are believed to increase satisfaction (e.g. leisure, goods). Somehow the idea of non-leisure activities as direct arguments has been postponed, in spite of the previous examples and discussions. To test whether a variable should enter U, the problem can be restated as follows: if

everything else is kept constant, would a change in that variable induce a change in satisfaction? Under this question, all variables that act **through other** variables in U should not belong to U (as, for instance, income). Thus, work and travel time should indeed be included; generically, goods should not, as they require the assignment of time to their use. Even if some goods are bought for the pleasure of acquiring, satisfaction is realized in the act of buying; if it is a piece of art, satisfaction is experienced by the act of admiring or by enhancing an action (either at work or at ease). Thus, all particularly identifiable activities should enter U, as separate entities. The only justification for X in U would be a generic description of the activities (e.g. having a more comfortable bed increases the satisfaction of sleeping as a grossly described activity).

In short, what to use as an argument in direct utility, what constraints should be considered, and what is fixed or what is variable, are key decisions to propose a framework aimed at the modelling and understanding of travel decisions. The elements of the problem have been explored, and they seem to be enough to make a concrete proposal.

4.2 A unified model for travel and activities[1]

After looking at the microeconomics of mode choice models and the time allocation literature, a unified model can be proposed. There are three basic elements. First, the source of utility is the time devoted to each activity, including **all** activities (sleep, eat, talk, travel, work, and so on); second, market goods and services are needed to participate in the different activities, and they are the source of expenses; finally, besides time and income budget constraints, there are objetive relations among T and X (feasible T for given X, necessary X for given T), and among the T_i's themselves (e.g. activities which require other activities).

From the preceding discussion, a model of travel choices can be looked at as a time allocation problem, recognizing that utility is directly derived from what the individual does (activities) which requires goods that are costly. Formally,

$$\underset{T,W_v,\{m\},B}{\text{Max}} \quad U(T,W_F,W_v,t) \tag{22}$$

subject to

$$\sum_i T_i + W_v + W_F + \sum_{j=1}^{B} \sum_{i \in M_j} d_{ij}\, t_{ij} = t \tag{23}$$

$$F(X,T,W_F,W_r,t) \geq 0 \tag{24}$$

---

[1] This section reproduces the essence of the model in Jara-Díaz (1994).

$$\sum_i \sum_d P_{id} X_{id} + \sum_{j=1}^{B} \sum_{i \in M_j} \delta_{ij} c_{ij} \qquad = I_F + wW_v \tag{25}$$

$$B = B(X) \quad , \tag{26}$$

where

T	:	vector of activity times T_i in period τ
t	:	vector of travel times t_{ij} in period τ
B	:	number of trips in period τ
δ_{ij}	:	1 if mode i is used in trip j; 0 otherwise.
F	:	technical transformation function that converts activities into goods and vice versa; it includes the interrelations among activities.
X_{id}	:	amount of good i bought in zone d in period τ
P_{id}	:	price of good i in zone d .
M_j	:	set of modes available for trip j .

In this model, goods can be bought in different locations, at potentially different prices. As residence and work places are given, the number of trips is only sensitive to the choice of X , a relation which appears as eq. (26). This can be viewed as the result of a network related sub-problem (e.g. optimal number of trips given X). Note that the transformation function (24) is not Becker's $Z(X,T)$, but Evans' implicit functions $X - QT = O$ and $J'T \leq O$.

The given variables are $W_F, I_F, t_{ij}, c_{ij}, \tau, P_{id}$ and w, while the decision variables are $\{T_i\},\{\delta_{ij}\},\{X_{id}\},W_v$ and B. The solution for B is the generation model, the solution for X is the distribution model, and the solution for δ is the mode choice model. Note that this formulation is not compatible with the goods-leisure framework. As discussed earlier, $\sum T_i = L$ and $\sum P_{id} X_{id} = G$. Because of the technical relation between goods and activities, there is an implicit relation between G and L which has a straightforward interpretation : goods consumption require L and vice versa, which is a missing assumption in both Becker and Train - McFadden models.

Let us see how the model develops when analyzing mode choice in the case of one trip k, which is the prevailing modelling approach in the field. All other trip decisions will be assumed as given, i.e. number of trips B, destinations (which are one of the dimensions in X), and all other mode choices. The new problem is

$$\underset{X,T,W_v,i\in M_k}{\mathrm{Max}}\; U(T, W_F, W_v, t_1, \ldots t_{ik}, \ldots t_B) \tag{27}$$

subject to

$$\sum_i T_i + W_v + W_F + \sum_{j\neq k} t_j + t_{ik} = \boldsymbol{t} \tag{28}$$

$$F(X, T, W_F, V_r, t) \geq 0 \tag{29}$$

$$\sum P_i X_i + \sum_{j\neq k} c_j + c_{ik} = I_F + W_v \quad , \tag{30}$$

plus the non-negativity constraints. For simplicity only, relation (26) between B and X has been dropped, which means that **the amount** of goods does not affect the number of trips. As usual in the discrete choice approach, problem (27) - (30) can be solved conditional on mode choice, which yields conditional solutions for T, X and W. Formally,

$$T_i^* = T_i^*[\, \boldsymbol{t} - W_F - \bar{t} - t_{ik}, W_F, \vec{t}, t_{ik}, \frac{1}{w}(I_F - \bar{c} - c_{ik})] \quad \geq 0 \tag{31}$$

$$X_i^* = X_i^*[\%] \quad \geq 0 \tag{32}$$

$$W_v^* = W_v^*[\%] \quad \geq 0 \quad , \tag{33}$$

where $\bar{t}$ and $\bar{c}$ are obviously defined, and $\vec{t}$ is the vector of travel times except t_{ik}. Then the conditional indirect utility function corresponds to (**if** $W_v > O$)

$$U(T^*, W_F, W_v^*, t_{ik}, \vec{t}) \equiv V[\, \boldsymbol{t} - W_F - \bar{t} - t_{ik}, W_F, t_{ik}, \vec{t}, \frac{1}{w}(I_F - \bar{c} - c_{ik})]. \tag{34}$$

This expression is very helpful to disclose explicitly some key aspects in the specification of modal utility. First, unlike modal cost, travel time plays a dual role in the indirect utility : it provides direct dissatisfaction, as a survivor from U in (27), and it affects available time to do other activities, as a consequence of constraint (28). This latter role of travel time deals with the trade-off with pleasurable activities. The second key aspect is that both roles cannot be distinguished if V in (34) is approximated linearly. If this is accepted as a reasonable representation of (indirect) utility, the conditional comparisons would be based upon an expression like

$$V_i = k + \alpha(\tau - W_F - \bar{t} - t_{ik}) + \beta W_F + \gamma t_{ik} + \sum \theta_h t_h + \delta \frac{1}{w}(I_F - \bar{c} - c_{ik}) \tag{35}$$

and the only terms that would influence mode choice would be

$$\overline{U}_i = (\gamma - \alpha) t_{ik} - \delta \frac{c_{ik}}{w} \quad , \tag{36}$$

from which one can only estimate (γ - α) and δ, but neither γ nor α can be calculated. Note also that a first order approximation like (35) would make all other variables but travel time and cost, irrelevant (e.g. income). As explained earlier, this would not happen if a second order expansion was believed to be a better model than this.

The third key aspect is the role of the wage rate w. In this framework, the relevant value of w is the hourly payment the individual is offered to do extra work. It is true that this might have a relation to I_F / W_F, but w represents the real opportunity cost of activities performed outside the (fixed) working schedule. According to this, individuals in a sample should be asked about their work arrangement; if the individual has a fixed salary and fixed working time, he/she should be asked the value of the wage rate for additional work, as this is the value that should enter modal utility, provided $W_v > 0$.

The conditional indirect modal utility in equation (34) can be interpreted in terms of "goods and leisure". The first argument is in fact total time available to perform T (which can be associated with L) or to keep on working, and the last argument is the time equivalent to buy X. i.e. G / w, minus the actual extra time worked. Formally,

$$V_i = V(L + W_v, W_F, t_{ik}.\vec{t}, \frac{G}{w} - W_v) \tag{37}$$

which explicitly highlights the difference to the goods-leisure approach.

4.3 Comments

The proposed framework to understand travel behavior rests on Evans' view as a gross construct, and also on the goods/leisure version of the discrete choice approach. Accordingly, it should be no surprise that a wage rate type specification for modal utility is recovered when a mode choice decision is derived under the appropriate assumptions, provided that variable working hours exist. At this point, it seems fairly clear that the role of labor supply is highly relevant: if it is fixed (exogenous income, at least in the short run), what matters is the time available to spend the money, while if it is variable (endogenous income), marginal adjustments make the wage rate a key variable. Some additional properties of the travel model are

(a) travel and activities time allocation are decisions that pertain to the same class;
(b) the interrelations among activities, and those between activities and goods, make it difficult to accept continuous analytical solutions because of minimum required durations and the presence of durable goods ;
(c) the subjective value of each activity can be different;
(d) if income is relatively small, choices in the time space can be very limited because of the relations between goods and activities, which can make the time constraint irrelevant ;
(e) if income is relatively large, a number of activities are open for consideration because the necessary goods and services could be acquired. This could make the income constraint irrelevant.

An approach like the one presented here puts the emphasis on time allocation and, therefore, on the perception of time. The decisions on what to do within a time frame become the relevant phenomenon to investigate. Part of this deals with the analysis of labour supply (how much to work), but understanding individual time allocation as a whole requires a very deep look at human activities. Maybe analyzing travel decisions does not require understanding the profound motives behind the search for richness, fame or power, but the influence of dominant social values is indeed relevant when studying the structure of daily activities. This should redirect research towards the identification of socially induced activities, telecommunication, or the relations between prices and uses of goods (e.g. in addition to the "do I have money" question, add the "do I have extra time to use it", or "what will I stop doing in order to use this"). Thus, acquiring cable TV, having a compact disc player in the car or playing soccer with the neighbors, become something relevant to understand and model. On the other hand, there is a need to understand activity choice when income is small enough to rule out the acquisition of leisure goods (e.g. toys, gadgets) or the admission to leisure activities (e.g. movies, sports). It might well be that we are facing the emergence of two social “classes” : those that still have money when the day ends, and those that still have day when they run out of money.

Needless to say, the aggregate trends on social behaviour, the role of technology and social values, or social idiosyncracy, seem essential to understand travel. Along these lines, the high subjective valuation of time in Santiago (Chile) previously mentioned, has been examined from the viewpoint of the absolute perception of time. A detailed survey on chilean students showed perceptions which are closer to individuals in the U.S.A. than in Brazil, regarding punctuality, coordination of activities, synchronization, and so on. The conclusion was that the high valuation of time relative to income revealed by the travel demand models could well be the result of time perceptions which are highly influenced by the life style in the developed world (Jara-Díaz and Romero, 1992).

The activity-travel framework presented here has also been used to provide a microeconomic basis to understand residential location (Jara-Díaz, Martínez and Zurita, 1994). One of the nicest results was the analytical deduction of a term that represents accessibility, associated to each location, which combines the utility obtained from performing activities in different locations with the generalized cost to reach those places.

5.- CONCLUSIONS.

Consumer theory essentially provides a framework to describe economic behaviour. Within this framework, the concept of utility function has been instrumental to model demand for goods and services and to model labour supply. Here, the individual is looked at as if such a function is maximized. Although travel demand has also benefited from this framework, it seemed necessary to make a revision of the specific manner in which the general framework has been adapted to understand and model urban transport users' behaviour. In this article, travel choices have been examined from the perspective of consumer theory, in an attempt to unveil the specific role of the different elements which are part of users' decisions.

Discrete choices, the goods/leisure framework and time related theories of behaviour have been exposed and examined. From this analysis of the microeconomic foundations of models related to trip decisions, some issues have been clearly established. First is the question about the sources of direct utility; starting from goods consumed and going through the concept of basic commodities, consumption time appeared as a **necessary** item to realize utility. After this modest beginning, time devoted to activities emerged as **the** basic source of satisfaction, and it is goods that should be looked at as means to an end. Once this is accepted, every single minute in a period should be considered. This means, among other things, that both working and travel times are variables that should enter utility just as all other activities. Thus, time cannot be converted into money (through more work) without altering utility, which makes the fusion of income and time constraints a mistake.

On the other hand, the traditional time and income budget constraints are not enough to complete the picture of individual behavior, as market goods and activity times are interrelated (as well as activities themselves). The addition of a set of technical constraints is necessary to strengthen the fact that certain activities which would be omitted otherwise, are performed. This is a point raised originally by DeSerpa (1971) and Evans (1972), introduced later in the discrete choice literature by Troung and Hensher (1985). It is a fact, though, that no explicit reference to a transformation function has been made so far within the context of mode choice. This needs revision and discussions, and Evans' contribution seems to be the best departure point.

It is somewhat surprising to realize that little discussion has taken place regarding the variables in direct utility. In fact, goods and services seemed a reasonable choice until the recognition of a time constraint. The introduction of such a constraint implies a relation between goods and activities that cannot be overlooked. Furthermore, once this has been firmly established, identifying the assignment of time to activities as the basic source of satisfaction seems evident. However, this gives urban travel a different status.

According to Gronau (1986) and Jara-Díaz and Romero (1992), activities related to personal care (eating, sleeping and other biological needs) consumes in average a little more than eleven hours daily. A normal working schedule would leave something like four hours for discretionary activities on a working day. Time assigned to mandatory urban travel can consume a relevant part of this potentially uncommitted time. Thus, understanding travel demand means understanding activities.

This suggests the convenience of combining the urban travel demand framework with the elements and analysis of the home economics literature. In fact, in this literature the role of travel has been highlighted already. "The shadow price of time affects customer's choice of the optimum combination of time and market inputs and the decision whether to participate in market work or not. The imputation of this shadow price is therefore based on the observation of choices where time is traded for goods, and the choice concerning labor force participation. Unfortunately, most often in situations where goods are traded for time, the amount of time saved is unrecorded"... "One of the few exceptions is the field of transportation " (Gronau, 1986, pp. 292). In this quote, emphasis reveal a goods-leisure point of view; the explanation lies in the type of problems addressed in the home economics literature, particularly those pertaining to (domestic) daily life. The individual can make a choice among buying frozen food (which requires a microwave oven), cooking, hiring somebody to cook, or dining out; in essence, this is a choice involving quality, money and... time. And it is true that the trade-offs are difficult to establish because of lack of recorded information. It would be desirable indeed to collect and analyze such information in order to be able to model and understand travel choice as well as goods consumption and activity patterns.

Although a framework does not necessarily translates immediately into an operational model, implementation should be kept in mind. For example, an activity-travel model as the one proposed here, yields conditional demands for goods, work and activities as intermediate results when modelling mode choice (see eqs. 31 to 33), which turn into unconditional ones if choice is observed. All variables are potentially known, and a system of equations could be estimated. Undoubtedly, there has been a historical emphasis on market demand for goods, which has blurred the activity oriented approaches (maybe the present universal trend towards the "I have no time" syndrome, will reverse the situation).

For synthesis, understanding travel behaviour requires understanding the conditions which shape individuals' decisions to engage in different patterns of activities. The (relatively new) theory of home production should be looked at as belonging to the same family of urban travel theory. It should be remembered, though, that economics does not explore the motives behind perceptions; this belongs to the field of psychology.

ACKNOWLEDGEMENTS

This research was partially funded by FONDECYT, Chile. The first version of the activity-travel model was presented at the 7th. IATBR Conference in Valle Nevado, Chile (Jara-Díaz, 1994); comments and feedback by the participants are gratefully acknowledged.

REFERENCES

Bates, J.(1987) Measuring travel time values with a discrete choice model : a note. **The Economic Journal**. 97, 493 - 498.

Bates, J.and M. Roberts (1986) Value of time research : summary of methodology and findings. **PTRC Summer Annual Meeting**.

Becker, G. (1965) A theory of the allocation of time. **The Economic Journal** 75, 493 - 517.

DeSerpa, A. (1971) A theory of the economics of time. **The Economic Journal** 81, 828 - 846.

Evans, A. (1972) On the theory of the valuation and allocation of time. Scottish **Journal of Political Economy**, February, 1-17.

Gronau, R. (1986) Home production - a survey. In **Handbook of Labor Economics,** Vol. 1, O. Ashenfelter and R. Layard, eds. North Holland, 273 - 304.

Jara-Díaz, S. R, (1990) Valor subjetivo del tiempo y utilidad marginal del ingreso en modelos de partición modal. **Apuntes de Ingeniería** 39, 41 - 50.

Jara-Díaz, S. R, (1991) Income and taste in mode choice models: are they surrogates? **Transportation Research** 25B, 341 - 350.

Jara-Díaz, S. R, (1994) A general micro-model of users' behavior: the basic issues. **7th. International Conference on Travel Behavior,** Preprints Vol. 1, 91 - 103. Valle Nevado, Chile.

Jara-Díaz, S.R. and M. Farah (1987) Transport demand and user's benefits with fixed income : the goods / leisure trade - off revisited. **Transportation Research** 21B, 165 - 170.

Jara-Díaz, S. R, F. Martínez and I. Zurita (1994) A microeconomic framework to understand residential location. **Proceedings Seminar H, 22nd. European Transport Forum,** U. of Warwick, 115 - 128.

Jara-Díaz, S. R, and J. de D. Ortúzar (1989) Introducing the expenditure rate in the estimation of mode choice models. **Jornal of Transport Economics and Policy** 23, September, 293 - 308.

Jara-Díaz, S.R. and C. Romero (1992) Valoración subjetiva del tiempo: transporte, trabajo y ocio en Santiago. En **Tecnología y Modernidad en Latinoamérica,** E. Sabrovsky, comp. Hachette, Santiago.

Jara-Díaz, S. R. and J. Videla (1989) Detection of income effect in mode choice : theory and application. **Transportation Research** 23B, 393 - 400.

Johnson, B. (1966) Travel time and the price of leisure. **Western Economic Journal,** Spring, 135 - 145.

Juster, F.T. (1990) Rethinking utility theory. **The Journal of Behavioral Economics,** 19, 155-179.

Lancaster, K. (1966) A new approach to consumer theory. **Journal of Political Economy.** 74, 132 - 157.

McFadden, D. (1981) Econometric models of probabilistic choice. In **Structural Analysis of Discrete Data with Econometric Applications**, C. Manski and D. McFadden, eds. MIT Press, Cambridge, MA.

Michael, R, and G. Becker (1973) On the new theory of consumer behavior. **Swedish Journal of Economics** 75, 378 - 396.

Oort, C. (1969) The evaluation of travelling time. **Journal of Transport Economics and Policy,** September, 279 - 286.

Train, K. and D. McFadden (1978) The goods / leisure trade-off and disaggregate work trip mode choice models. **Transportation Research** 12, 349 - 353.

Truong, P. and D. Hensher (1985) Measurement of travel time values and opportunity cost from a discrete - choice model. **The Economic Journal** 95, 438 - 451.

Viton, P. (1985) On the interpretation of income variables in discrete choice models. **Economic Letters** 17, 203 - 206.

Winston, G.C. (1987) Activity Choice : a new approach to economic behavior. **Journal of Economic Behavior and Organization** 8, 567 - 585.

Table 1. Time related theories of consumer behavior

Framework / Element	Traditional	Becker '65	Johnson '66	Oort '69	De Serpa '71	Evans '72
Utility	$U(X)$	$U[Z(X,\overline{T}\,)\,]$ (1)	$U(B,G,W,L)$	$U(W,L,tt,I)$	$U(X,T\,)$ (2)	$U(T)$
Income constraint	$P'X \leq I$	$\sum_{i,j}\left(P_j b_{ij} + T_i w\right) = \boldsymbol{t}w$	$G + cB = wW$	$I = wW$	$P'X \leq I$	$P'QT = O$
Time constraint	—	included in income	$W + L + tB = \boldsymbol{t}$	$W + L + tt = \boldsymbol{t}$	$\sum T_i = \boldsymbol{t}$	$\sum T_i = \boldsymbol{t}$
Technical constraint	—	implicit in income	—	—	$T_i \geq a_i X_i$	$JT \leq O$ $(X = QT)$

(1) $\overline{T}$ does not include working time
(2) X can include “pure time” comodities