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TOPIC 15
TRAVEL CHOICE AND
DEMAND MODELLING

MODELLING ACTIVITY PATTERNS WITH RESPECT TO LIMITED TIME AND MONEY BUDGETS

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Abstract

The paper presents a model to determine the total activity patterns, based on micro-economics, where people are believed to maximise total utility of the activity pattern. This utility is given by the utility of each activity separately, the disutility of travel and the utility of goods purchased. Total utility is maximised under time and money budget constraints and the output is given by duration, frequency and distances of the activities.

INTRODUCTION

The continuous growth in personal travel in most industrialised countries in the last decades, caused by economic growth and individualisation, raises the question whether in the short or long run there will be limits to this growth due to certain bounds on time and money expenditures on travel. In the Netherlands personal travel demand has increased for the last decades both in travel distance, number of trips *and* total travel time (see Gommers and Krikken, 1992). Given the limitedness of the amount of time and money available (hereafter denoted as budgets) the question is when and at what level total travel time reaches its limit. To investigate the hypothesis of the existence of limits to personal travel a theoretical framework is developed for the allocation of time and money on activities under constraints of limited time and money budgets.

The theory is based on economic theory in which people try to maximise the satisfaction (denoted as utility) they obtain by undertaking activities. An important feature in the theory is the interaction or trade-off between time and money expenditures and the interaction between travel and other activities. The former can be interpreted as the amount of time allocated to labour. The more hours one works, the more money one has available to spend on goods, but the less time one has available to spend on other activities. The latter is interpreted as the possible allocation of time (or money) saved on travel to other activities (or goods).

Research on travel budgets has been carried out by, among others, Goodwin (1981), Golob *et al* (1981), Zahavi and McLynn (1983), van der Hoorn *et al* (1983), Downes and Emmerson (1983, 1985), but in all these approaches travel is considered separately, independent of the total activity pattern. The time spent on other activities is not considered, just like the purchase of consumption goods. There exist two approaches in travel budget research, namely of fixed and flexible budgets. In the fixed travel budget approach total travel time and travel cost consumed are considered more or less constant: time (or money) saved on travel (by using a faster (or cheaper) mode or travelling over a shorter distance) will be allocated to other travel. In the flexible travel budget approach time or money saved on travel can be allocated to other activities or goods as well.

Research on the allocation of time has been carried out by, among others, Becker (1965), de Donnea (1972), Winston (1982, 1987) where the utility function is defined as a function of 'commodities' or production functions. According to this approach people do not get satisfaction from the purchase of consumption goods or services as such, but from something more fundamental by the *use* of these goods and services. In the analysis the time spent on activities is essential and so it is possible to analyse the interaction between the time spent on activities and the goods purchased.

The theory presented in this paper is based on the theory of allocation of time combined with aspects of the theory of flexible budgets. Time as well as money will be allocated to various activities and goods, including travel. The allocation is based on utility maximisation, where the utility depends on characteristics of outdoor activities, like priority, duration, location and frequency, the effort of travel, the amount of time spent at home and money spent on consumption goods.

The outline of the paper is as follows: the next section presents the theoretical framework on the allocation of time and money, divided into a general model structure, the functional form of the model and a theoretical analysis. The following section gives some reflections for implementing and estimating the model, describes the data used for estimation and the first estimation results of the model parameters. The final section contains the conclusions and the outline for further research.

THEORETICAL FRAMEWORK

General model structure

The model presented here is based on microeconomic theory of consumer behaviour. People obtain some kind of satisfaction from undertaking an activity, denoted by utility. This utility depends not only on the type of activity, but also on the duration, the location and the frequency with which the activity is undertaken. People maximise the utility of their total activity pattern under time and money constraints. The activities can be divided into activities out of home and activities at home. All activities take an amount of time, the duration of the activity. Within the total amount of time available activities have to be scheduled such that all activities take a desired amount of time and the total activity pattern is satisfactory. In our model we obtain for each activity the total amount of time people spend on all activities in a category and together with the frequency of this activity type the average duration per activity occurrence can be determined. Activities out of home are activities for which a distance has to be covered. Activities at home do not generate travel.

In the model people are assumed to behave rational. All activities yield a certain amount of utility. Total utility (U_{TOT}) is a function of the utility of each activity, the disutility of travel and the utility of goods purchased. People will maximise this total utility under time and money budget constraints. The activities considered can be obligatory (*eg* labour, household tasks) or discretionary (*eg* recreation, visiting friends). And activities can be undertaken at home (with total duration T_H) or out of home, such that a trip needs to be made (over a distance d_i), with total duration at the destination T_i and frequency f_i. For compulsory activities there is no choice in whether or not to perform the activity in the short run and sometimes the duration and frequency are fixed (*eg* labour: if one has a job for eight hours a day, one has no choice in whether to go to work and for how long). Only in the long run one might consider it a choice. The model is meant for long term decisions, so obligatory activities can be obtained in the choice model. The same yields for the distance.

In case of optional activities one has a choice in frequency, duration and location. And the utility obtained by these activities depends on these characteristics. The longer the duration the more satisfaction one obtains, with decreasing marginal utility. The longer the distance one is willing to travel the more locations one can reach and the higher the chance that one can reach a location that satisfies the needs (for a longer distance larger and more exclusive shops will be reachable). On the other hand the longer the distance the more effort is needed to travel to the location. So the satisfaction obtaining from an activity should compensate the effort needed for travel. The interpretation is that people need to spend some effort to obtain a higher utility in the end, than when they would have continued with the previous activity. (See Figure 1)

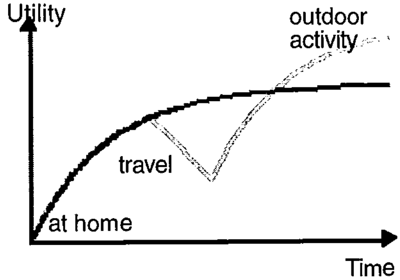

Figure 1 **Utility of activities**

People will undertake a second activity if the satisfaction of this second activity at least compensates the extra effort for travel to the second location. But after a while the need to spend some time at home will be strong enough to stop activities away from home and return home.

The utility of an activity also depends on the frequency. An activity with high priority will be undertaken more frequently than those with low priority. But the higher the frequency, the higher the extra disutility for travel. Obligatory activities (such as labour) have fixed frequencies or at least a minimum value for the frequency.

The contribution of the frequency to the utility differs for different population groups. For example retired people with much leisure time often go out to do some shopping, while people with full time jobs, thus with few leisure time, like to do their shopping only once a week.

Consumer behaviour is considered to be bounded on time and money expenditures. The total time available will be allocated to various activities, both obligatory and discretionary, at home as well as out of home, and to travel. The total amount of money available will be allocated to the activities, travel and other consumption goods. Some activities yield an amount of money (such as labour; in this case the costs (c_i) are negative; $c_i = -wT_w$; with w wage rate), most activities cost an amount of money. These costs can depend on the frequency and duration of the activity and the distance travelled determines the travel costs. More details about these assumptions on the theory and model structure can be found in other work of the author (Kraan & van Maarseveen, 1994; Kraan, 1994, 1995).

Functional form

The general model structure can be formulated as:

$$\max_{T_i,d_i,f_i,\forall i} \; U_{TOT}(T_i,d_i,f_i,\forall i;\; T_H,G)$$

subject to

$$\left\{ \begin{array}{c} \sum_i \left(T_i + \frac{d_i}{v_i}\right) + T_H = T_{TOT} \\ \sum_i c_i(T_i,d_i,f_i) + G = Y \\ T_i,d_i,f_i \geq 0 \quad \forall i \\ T_H,\, G \geq 0 \end{array} \right\} \qquad (1)$$

Here T_i, d_i and f_i are the total time spent (at the destination) on activity i, the distance travelled for and the frequency of activity i, respectively. T_H is the total time spent at home and G the amount of money spent on various goods and services other than travel or out-of-home activities. v_i denotes average speed, such that d_i/v_i denotes travel time; c_i ($= c_i^0 + c_i^T T_i + c_i^d d_i + c_i^f f_i$) denotes the costs of activity i, given by the costs of the activity itself, divided into fixed costs c_i^0 (*eg* contribution for a sports club), costs per occurrence of performance $c_i^f f_i$ (*eg* the price of a ticket for the theatre) and variable costs $c_i^T T_i$ (most recreational activities, *eg* going to a fun-fair: the longer one stays the more money is spent) and the travel costs, variable in distance $c_i^d d_i$. T_{TOT} and Y are the time and money budgets, respectively.

Consider a discretionary activity i, away from home, with duration T_i, distance d_i between home and the location of the activity and frequency f_i. The form of the utility function is described previously. A function that meets the requirements of that form is the Cobb-Douglas utility function and so the utility of activity i is defined by:

$$Z_A(T_i,d_i,f_i) = \alpha_i \cdot T_i^{\beta_i} \cdot d_i^{\gamma_i} \cdot f_i^{\rho_i} \tag{2}$$

where β_i, γ_i and ρ_i are parameters with values between 0 and 1. For obligatory activities with hardly any choice the same functional form yields, but with very small parameter values for β_i, γ_i and ρ_i (approaching zero). But for modelling long term behaviour these activities can be modelled as being more or less discretionary. These parameters define the relative weight of characteristics T_i, d_i and f_i. The parameter α_i defines the relative weight of the priority of the activity, so in case of obligatory activities, such as labour, the value of this parameter will be large.

To reach the location where the activity takes place, the distance d_i needs to be travelled. The effort to do so (denoted as disutility) is a function of by total travel time and total travel costs. The function for the disutility of travel is given by:

$$Z_R(d_i) = \zeta_t \frac{d_i}{v_i} - \zeta_c \cdot c_i^d \cdot d_i \tag{3}$$

where ζ_t / ζ_c denotes the value of travel time. If time is considered more valuable than monetary costs, then the effort caused by travel time ($\zeta_t \cdot d_i/v_i$) will be valued more negative than the effort caused by monetary costs ($\zeta_c \cdot c_i^d \cdot d_i$).

The total time spent on activities at home also contributes to a positive utility, it will place a bound on the time spent out of home. For activities at home we assume a utility function for the duration of all in-home activities, similar to the function of activities away from home.

$$Z_H(T_H) = T_H^{\vartheta} \quad 0<\vartheta<1 \tag{4}$$

The total amount of consumption goods purchased is considered separate. These goods represent the amount of money available for various durable or consumption goods, but also the amount of money saved. It can be seen as a measure for welfare. The higher this term, the higher the utility:

$$Z_G(G) = G^{\chi} \quad 0<\chi<1 \tag{5}$$

The total time spent at home acts like a constraint on the total time spent out of home. And the amount of goods can be interpreted as a constraint on the costs of out-of-home activities and travel. These can be comparable with the flexible budget approach described in Golob *et al* (1981) or Downes & Emmerson (1985), where the time not spent on travel (substituted for leisure time) returns in the utility function as a variable, as well as the amount of money not spent on travel. This approach considers utility as a function of travel (the number of kilometres d_i travelled), leisure time L and goods G purchased:

$$\left\{ \begin{array}{l} \max\limits_{d_i} \sum\limits_i \varphi(d_i) + \psi(G) + \xi(L) \\ \text{subject to} \\ \sum\limits_i c_i^d d_i + G = \hat{Y} \\ \sum\limits_i \frac{d_i}{v_i} + L = \hat{T} \end{array} \right\} \tag{6}$$

Here d_i denotes the amount of kilometres travelled by mode i. c_i^d denotes unit travel costs and v_i average travel speed of mode i, $\hat{T}$ and $\hat{Y}$ are the time and money budgets, respectively. φ, ψ and ξ are concave functions.

From the point of view of travel, leisure time can be seen as the time not spent on travel and the amount of goods purchased is interpreted as the amount of money not spent on travel. Substituting the constraints for leisure L and goods G into the utility function yields:

$$\max_{d_i} \sum_i \varphi(d_i) + \psi\left(\hat{Y} - \sum_i c_i^d d_i\right) + \xi\left(\hat{T} - \sum_i \frac{d_i}{v_i}\right) \tag{7}$$

The time spent on activities at home T_H is in our model regarded as the total time not spent on activities out of home, including travel time. T_H can be compared with the argument of function ξ in (7). The goods purchased is regarded as the amount of money not spent on out-of-home activities, including travel cost. G can be compared with the argument of function ψ in (7). A lot of out-of-home activities, in the flexible budget approach are incorporated in the flexible budgets. In our model all these activities are regarded as explanatory variables together with (and not only) distances.

The difference between the theory of flexible budgets and the theory presented in the paper is that in the flexible budget approach only the distances travelled are considered as variables, while in this paper the total activity pattem is considered and the distances are only part of the total activity pattem. Golob *et al* and Downes and Emmerson consider a positive utility of travel (function φ in 7), the more distance covered, the higher the utility. In other words people want to maximise their spatial opportunities, within their time and money budget. This seems to be in contradiction with most other transportation demand models, where travel is regarded as a resistance, yielding a disutility, which has to be minimised. In our model the distance travelled to and from an activity is valued both positive and negative. The positive valuation is represented through the utility of an activity. People want to cover certain distances to reach the locations where the activities take place. But on the other hand, travel takes time and costs money and thus travel is regarded as a resistance, and people try to minimise these travel time and costs. Travel needed to perform an activity at a certain location is given by the total travel needed, thus travel to and from the location. Because when people decide to undertake an activity at a certain location the distance need to be travelled in both directions. So travel needed to retum home is included in the distance to the location. For an activity combined in a (trip) chain the distance for the second activity can be interpreted as the extra distance travelled, on top of the distance needed for the first activity.

The utility of the total activity pattem over a period T_{TOT} contains the utility of the separate out-of-home activities, the disutility of travel, the utility of activities at home and of the consumption goods purchased. Assuming strong separability between these components of total activity pattem, *ie* (see Deaton and Muellbauer, 1980, chapter 6) there is no substitution between two different, independent activity classes i and j, total utility is given by:

$$U_{TOT} = \sum_i \left(Z_A(T_i,d_i,f_i) + Z_R(d_i)\right) + Z_H(T_H) + Z_G(G)$$

$$= \sum_i \left(\alpha_i \cdot T_i^{\beta_i} \cdot d_i^{\gamma_i} \cdot f_i^{\rho_i} - \zeta_t \frac{d_i}{v_i} - \zeta_c \cdot c_i^d \cdot d_i\right) + T_H^{\vartheta} + G^{\chi} \tag{8}$$

Note that the model does not incorporate personal characteristics as such, but the parameters will be estimated for each population group separately. This means that the parameters express the exogenous characteristics. Another interpretation is that the parameters are functions of the personal characteristics.

The next chapter will describe the estimation process of this model. The next section considers a special case of the model which will be estimated. The first regression results are also given.

ESTIMATION OF THE MODEL

Towards an estimation of the model

Given the model as described in the previous section, the output of the utility maximisation process will be the total activity pattern for a given individual. The model is defined for homogeneous population groups, defined by the composition of their household and personal characteristics like gender, age and educational level. As before the activity pattern is defined by the total durations of all (classes of) activities, out of home (T_i) as well as in home (T_H), the distances travelled to the locations of out of home activities (d_i), the frequency with which these activities are undertaken in the total time period (f_i) and the amount of money spent on the purchase of goods (G).

The values for the coefficients in the function for the costs of activities ($c_i(T_i, d_i, f_i) = c_i^0+c_i^T T_i+c_i^d d_i+c_i^f f_i$ and the value for the average speed (v_i) are considered as input for the model. The same yields for the total amount of time and money available (T_{TOT} and Y). Furthermore, we assume one average speed v and one value for the cost c^d.

The classes of activities (i) need to be strongly separable, to obtain a minimum of substitution effects between the different classes (see Deaton & Muellbauer, 1980, chapter 6). This means that a minimum number of different, independent classes of activities are distinguished. First the category of obligatory activities and the category of discretionary activities are distinguished. Within these categories a more detailed differentiation can be made. All in-home activities are considered alike. The idea of being an amount of time at home (with the family) is considered more important than the type of activity that is performed at home.

Special case

Now let us consider some more assumptions on the model to obtain a special case of the model given in the previous section. This special case can then be estimated in the next section.

Instead of leaving a choice in the total distance travelled, let us consider the distance constant per activity, *ie* for each activity an average, given distance need to be travelled. So every time an out-of-home activity is undertaken, the location, and thus the distance, is fixed. The total distance is then given by the average distance per activity multiplied with the frequency with which the activity is performed: $d_i = d_i^0 \cdot f_i$ The average distance d_i^0 is also called unit travel distance. Considering travel times, instead of distances, this is reformulated as: total travel time (t_t) is the unit travel time (per occurrence of the activity) d^0/v multiplied by the frequency (f_i): $t_t = f_i \cdot d^0/v$.

Furthermore, let us consider only one category of all discretionary out-of-home activities, before or after work. So time will be allocated to "staying at home", "going out" (for a discretionary activity), and travel. The model also determines the frequency with which one is "going out".

The emphasis is on the time allocation, less on money expenditure. Now suppose there is no money constraint and the income is fixed, *ie* not depending on T_W, then we do not consider the costs.

All these assumptions lead to the simplified model:

$$\max_{T,f} U_{tot} = T^{\beta} \cdot f^{\tau} + (T_{tot} - T - t_t)^{\vartheta} = T^{\beta} \cdot f^{\tau} + \left(T_{tot} - T - f \cdot \frac{d^0}{v}\right)^{\vartheta} \qquad (9)$$

The parameter α has been eliminated, because this parameter applies to the relative preferences between out-of-home activities and in this case only one category is considered. For more categories we can take one of the α's fixed and estimate the others relative to that fixed one.

The time constraint $T + t_t + T_H = T_{tot}$ has been substituted (for T_H) in the utility function. Optimising total utility gives us the necessary conditions

$$\frac{\partial U_{tot}}{\partial T} = \frac{\partial U_{tot}}{\partial f} = 0 \tag{10}$$

This is also a sufficient condition because the utility function considered is concave, *ie*

$$\left\{ \begin{array}{l} \dfrac{\partial^2 U_{tot}}{\partial T^2} < 0 \\ \dfrac{\partial^2 U_{tot}}{\partial f^2} < 0 \end{array} \right\} \tag{11}$$

So the solution of (10) will be the maximum of the utility function (9). Solving (10) gives us:

$$\left\{ \begin{array}{l} \beta T^{\beta-1} f^{\tau} = \vartheta\left(T_{tot} - T - f\frac{d^0}{v}\right)^{\vartheta-1} \\ \tau T^{\beta} f^{\tau-1} = \vartheta\frac{d^0}{v}\left(T_{tot} - T - f\frac{d^0}{v}\right)^{\vartheta-1} \end{array} \right\} \tag{12}$$

This gives us the relations

$$\left\{ \begin{array}{l} f = \frac{\tau v}{\beta d^0} T \text{ or } t_t = f\frac{d^0}{v} = \frac{\tau}{\beta} T \\ \text{and } \beta f^{\tau} T^{\beta-1} = \vartheta T_H^{\vartheta-1} \end{array} \right\} \tag{13}$$

Together with the equation for T_H we obtain linear and nonlinear equations for which the parameters need to be estimated. We can take the logarithms of this equation to obtain a loglinear relationship. In that case we need to estimate a simultaneous system of equations:

$$\left\{ \begin{array}{ll} \ln(\vartheta)+(\vartheta-1)\cdot\ln(T_H) = \ln(\beta)+\tau\cdot\ln(f)+(\beta-1)\cdot\ln(T) & \text{(a)} \\ f = \frac{\tau v}{\beta d^0}\cdot T & \text{(b)} \\ t_t = \frac{d^0}{v}\cdot f = \frac{\tau}{\beta}\cdot T & \text{(c)} \\ T_H = T_{tot} - T - t_t & \text{(d)} \end{array} \right\} \tag{14}$$

Where relation (d) yields by definition.

The next section describes the data we use for the estimation of these relations.

Time budget survey

The data used to estimate the model parameters is obtained from the existing Dutch Time Budget Survey. These data contain the time expenditures of people during a week. The respondents of this survey were asked to keep a diary and report their main activity for each quarter of an hour during a full week. If during a quarter of an hour more than one activities were undertaken, the one with the longest duration ought to be stated. In this way short activities of less than $7\frac{1}{2}$ minutes were not reported. This is a shortcoming of this survey, especially for a thorough research on short activities, including short trips. But since we are considered in *total* time expenditures during a week, averaged over population groups, the error made will be ignorable in this study.

Furthermore the respondents were asked to report the location where the activity took place: at home, out of home but at the residence, or out of home and outside the residence. In this way it is not possible to recover the exact distances travelled, but an estimation can be made through travel time and average speed of the travel mode, which both are known. On the other hand the commuting distance for workers is known.

From the data it is possible to require for each individual the total time spent on activities in-home per person T_H^k the superscript k denotes person k) as well as out-of-home (T^k), the frequencies of the activities (f^k), the travel time per person (t_t^k), and the logarithms of these variables. With these characteristics it is possible to estimate the model parameters, β, ρ, ϑ and the value for d^0/v, using the equations of (14).

Parameter estimation

For the model described previously the relevant parameters are β, ϑ, ρ, and d^0/v. The time budget T_{tot} is given by the total number of hours a week (*7*24*) minus the hours necessary for sleep and for obligatory activities (work and study). Then we obtain the time budget for discretionary activities only, according to the definition of the model in the previous section.

Our first, preliminary, calibration took place on the group of students for the cross-sectional data of 1980, 1985 and 1990. We chose the group of students due to their homogeneous behaviour. The time necessary for going to school or to study is more or less identical for all, so the time left for discretionary activities (the time budget in the model) is also more or less the same for all individuals in this group. Also the amount of money available to spend is more or less identical and quite small, *ie* the money budget is small.

For this population group we found a strong correlation in the data between the duration of discretionary out-of-home activities, T, and the frequency, f. Also a correlation was found between the travel time, t_t, and both the frequency and the duration. A small correlation exists between the out-of-home duration, T, and the duration at home, T_H.

Due to the dependency between f and T we can not estimate $ln(T_H)$ as a function of both $ln(T)$ and $ln(f)$, so we need to substitute the first equation of (13) into the first equation of (14). Rearranging the equations leads to the following estimated equations:

$$\left\{\begin{array}{ll} \ln(T_H) = \dfrac{\ln\left(\dfrac{\beta}{\vartheta}\right) + \tau\cdot\ln\left(\dfrac{\tau v}{\beta d^0}\right)}{\vartheta-1} + \dfrac{\beta+\tau-1}{\vartheta-1}\cdot\ln(T) & \text{(a)} \\ f = \dfrac{\tau v}{\beta d^0}\cdot T & \text{(b)} \\ t_t = \dfrac{\tau}{\beta}\cdot T & \text{(c)} \end{array}\right. \qquad (15)$$

These three equations were estimated separately and the preliminary results are given in Table 1.

Table 1 First regression results

1990:	(*a*)	$ln(T_H)$	$= 4.235—0.205*ln(T)$	Adjusted R^2:	0.208
	(*b*)	f	$= 0.695*T$		0.511
	(*c*)	t_t	$= 0.220*T$		0.196
1985:	(*a*)	$ln(T_H)$	$= 4.321—0.230*ln(T)$		0.246
	(*b*)	f	$= 0.741*T$		0.529
	(*c*)	t_t	$= 0.198*T$		0.202
1980:	(*a*)	$ln(T_H)$	$= 4.216—0.193*ln(T)$		0.193
	(*b*)	f	$= 0.766*T$		0.531
	(*c*)	t_t	$= 0.212*T$		-0.021 (negative ???)

We see that the value for the adjusted correlation coefficient (R^2) is small for most equations. This means that it is difficult to estimate the model. An interpretation for this is that behaviour varies a lot between individuals, even if we consider a population group with expected homogenous behaviour. Another interpretation is that there exists a large variation over time: activity patterns vary a lot over the different weeks.

With the mathematical expressions in 15 it is possible to derive the values for the parameters. The relations (*a*), (*b*) and (*c*) give us the values for β, ρ, ϑ (See Table 2).

Table 2 Parameter values

1990:	$\beta = 0.828$;	$\vartheta = 0.951$;	$\rho = 0.182$
1985:	$\beta = 0.842$;	$\vartheta = 0.959$;	$\rho = 0.167$
1980:	$\beta = 0.832$;	$\vartheta = 0.956$;	$\rho = 0.176$

The values are quite stable, they hardly vary over the years. Furthermore, we see that $\beta + \rho \approx 1$ and that ϑ is large (nearly 1). This means that each minute spent at home contributes equally to the utility. The same yields for the time spent out-of-home, if we consider durations of activities together with travel time. For these values total utility (given by (9)) is calculated as a function of duration T. We used the relations (*b*) and (*c*), found with the regression, and (9) for the calculation of the total utility function. We see that total utility is almost constant for a large range of durations (see Figure 2). This means that a lot of combinations of duration and frequency lead to maximum utility and thus behaviour (with respect to time durations) varies very much between individuals. In other words the variation in behaviour between individuals within a population group is large, and perhaps even larger than between population groups. A solution to this problem can be found in incorporating some more explanatory variables (like personal characteristics) to model the allocation of time properly. For example by estimating the parameters as functions of age, education level, income *etc.*

This utility function (Figure 2) also shows that there is a limit in the amount of time spent out-of-home, because for a total duration (of discretionary, out-of-home activities) larger than 40 hours per week total utility decreases rapidly. Above this amount there exists a strong urge to spent time at home.

Combining relations (*b*) and (*c*) we can calculate the unit travel time d^0/v:

$$d^0/v = 0.220/0.695 = 0.317 \approx 20 \text{ minutes (1990)}$$
$$= 0.198/0.741 = 0.267 \approx 16 \text{ minutes (1985)}$$
$$= 0.212/0.766 = 0.277 \approx 16 \text{ minutes (1980)}$$

These results show that during the early 1980s unit travel time was constant, but in the late 1980s it has increased. The value of this unit travel time is very realistic, for every occurrence of a discretionary activity one has to travel a quarter of an hour. Travel time for discretionary activities is approximately one fifth of the total duration (relation *c*), that means that for each hour spent on leisure activities, 12 minutes travel time is spent (including both to and from the activity). The duration of each out-of-home activity is approximately 80 minutes, but has increased slightly, because the number of activities undertaken (frequency) per unit of time duration has decreased slightly (relation *b*).

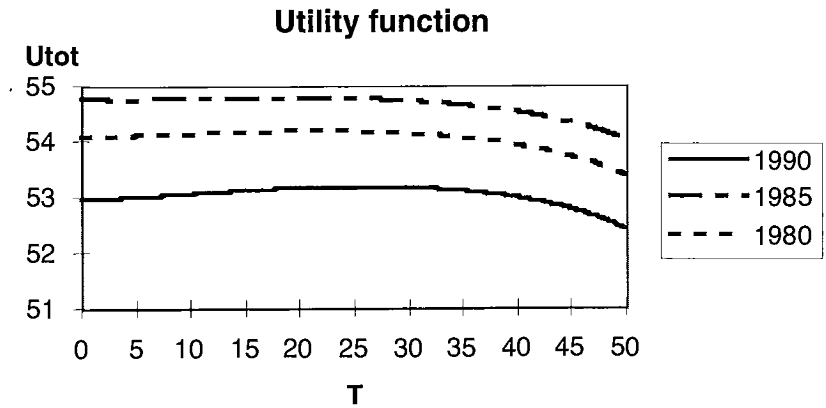

Figure 2 **Total utility as a function of duration T**

CONCLUSIONS AND FURTHER RESEARCH

This paper presented a model for the allocation of time and money on different activities, at home as well as out of home, and consumption goods purchased. The ultimate goal of the model is to investigate whether existing bounds on time and money budgets lead to limits in personal travel.

Therefore the model is defined for homogeneous population groups, based on characteristics such as gender, age, educational level and the composition of households. Beside this the input is given by characteristics of the activities and of travel, such as costs and travel speed. The values of the parameters which define the demand functions for the activity patterns, are estimated for each population group considered, using time expenditure data (Time Budget Survey).

The estimation of the model parameters is tested for the group of students for 1980, 1985 and 1990. Preliminary results show stable parameter values over the three years. Regression analysis shows a small correlation coefficient, which can be interpreted as large variations existing in behaviour. The parameter values found in a first regression show a total utility function that is more or less constant for a wide range of durations. This means that there is a wide variety in behaviour, all leading to the same utility. A next step in the model estimation should therefor be the incorporation of personal characteristics as explanatory variables. But this utility function also shows that there is a limit in the amount of time spent out-of-home, because for a total duration (of discretionary, out-of-home activities) larger than 40 hours per week total utility decreases rapidly.

Once the model is estimated for various population groups, it is possible to analyse the differences in behaviour of these population groups. Using these differences and future assumptions on the composition of the population, an aggregated analysis of time use can be made. Using data of three years makes it possible to obtain time series of parameter values. These series can show a trend which can be extrapolated to future years, in order to explore future activity patterns. Combining both ways (composition of the population and trends in parameter values) the ultimate goal of the model, namely the search for limits in personal travel, can be realised.

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