TIME AND PASSENGER TRANSPORT

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SUMMARY

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INTRODUCTION

Time is money! Applying this common saying to their own sphere of activity, economists, following the example of Gary Becker, have for the past twenty or thirty years incorporated the issue of time into their analytical reasoning. A scarce resource, time is a topic of study that lends itself particularly well to demonstrations based on the principles of optimisation. Allocating time to the individual activities available when we decide upon our programmes of activity leads to varying levels of utility which rational economic man can choose between. Transport economists, following the work of C. Abraham and M.E. Beesley, have rapidly fallen into step with their generalist colleagues. They have done this by treating travel time as a component of an overall trip cost, termed the generalised cost.

Viewed from this standpoint, as we shall see in the first part of this paper, travel speed has become a key variable in overall transport demand, in that an increase in speed can potentially mean a lower generalised cost for the trip. By the same token, the choice of a given mode of transport will take account of relative speed, which will become determining in the modal split and which is closely correlated to the value of time for different categories of user. Transport users will thereby reveal preferences that public decisionmakers will have to take into account in investment in transport infrastructure. Economic logic will recommend that the priority for investment should be areas where time savings are possible, i.e. areas where a collective surplus can easily be achieved. Since one way to increase the collective surplus is to increase average travel speeds, economists have, for many years, argued in favour of introducing congestion charges, where the price paid by the user is designed to create fluidity and hence higher travel speeds that will reduce the time lost in travelling. This proposal has been adopted in many different areas where it has proved the robustness of its premise. However, in the case of urban congestion, problems have been encountered which, while they have not compromised the idea of road pricing, have nonetheless prompted the authorities to adopt a different approach to the relationship between time and transport.

The second part of this report considers the basis, contents and implications of this partial reappraisal, which can briefly be summed up as follows. If travel time, instead of being viewed as a variable that needs to be reduced, is treated as a constant in the activity programmes of individuals then, in certain specific contexts, public policies can be directed towards goals other than that of increasing the collective surplus through a trend increase in speeds. We shall note with interest that this viewpoint, like the preceding one, is based on a microeconomic analysis. This was notably the case of Y. Zahavi, who demonstrated the robustness and interest of a hypothetical double constancy, namely, that of the travel budget and that of the money budget relating to travel. Should the double-constancy hypothesis prove correct, it would have numerous implications for both inter-city and urban mobility. In both cases we are confronted with a very close link between economic growth and growth in the distances travelled. Indeed, this link is so close that, in pursuing the goal of sustainable mobility, we need to determine which modes should be given priority according to their relative energy consumption and emission of pollutants. This example provides a very rich illustration of the relationships between travel times and investment choices. In particular, what will be the coherence of collective choices regarding the value of time, on the one hand, and the discount rate on the other? This question particularly needs to be asked with regard to daily mobility. To counter the negative effects of the increase in the average distance of trips and the ensuing urban sprawl, should we consider another way of charging for trips made in urban and outlying areas? Should the idea that the impact of road pricing is compensated for by the increase in the average speed of trips be replaced, as implicitly recommended by many urban transport policymakers, by that of "charging for generalised cost" in order to increase the two components of this cost, namely, price and time?

1. TIME: A KEY VARIABLE IN INDIVIDUAL AND COLLECTIVE CHOICES

Since transport is considered as intermediate consumption, transport demand from individuals is usually treated as derived demand. In other words, for travellers, transport is a necessary but not a sufficient condition for the performance of our various activities. From this standpoint, economic analysis assumes that individuals will seek to reduce the cost of transport, primarily by increasing travel speeds. The desire for speed increases commensurately with the increase in the value of time, which itself is closely linked to higher incomes. Linking this trend increase in the value of time to another means of measuring the price of time, namely, the discount rate, reveals another dimension to the relationship between time and transport -- one which, by aggregating individual demands in the economic calculation, seeks to assist the decisionmaking process, notably with regard to the strategic issue of transport infrastructure programming. Discounting, i.e. calculating, for a given date, values estimated to obtain in the future, is one way in which to integrate the relationship between time and transport into a collective and intertemporal approach. It is currently a prerequisite for understanding the priorities of public policies -- notably, the reasons for which policies are directed towards the development of transport systems which afford substantial time savings (air transport, high-speed rail, inter-city motorways) and justify the introduction of road pricing, which takes account of the improvement to service quality offered by higher speeds. But is the pairing of speed and road pricing consequently going to become the basis for public policies in all areas where an ability to pay and congestion exist? This is by no means certain, and in this particular area there is undoubtedly no universal answer, as may be seen in the limited use made of urban tolls, despite the fact that they make perfect sense from an economic standpoint.

1.1. Time: a scarce resource with a monetary equivalent

In a famous article published in 1965, G. Becker proposed a general analysis of the allocation of this scarce resource by linking it directly to the monetary components of consumers' choices. By integrating his analysis into the new consumer theory, G. Becker suggested that the utility of an individual did not derive solely from the quantity of goods and services consumed but also from the commodities to which they corresponded (meals, childcare, personal care, golf matches, evenings at the cinema, etc.). The consumer is therefore not a passive being, in reality he is the producer of the commodities he consumes. The production of these commodities requires not only goods and services but also time. These two inputs must therefore be related to the two types of allocation that individuals can make, namely, the allocation of time and the allocation of money. These two allocations are therefore closely linked, since it is possible to increase the allocation of money by modifying the use we make of our overall allocation of time.

This form of reasoning leads us to a classical problem of optimisation. The individual must maximise his utility (U) by combining the inputs X (goods and services) and T (time) which he needs to produce commodities (Z). Commodities number from 1 to n and are indexed i.

Total utility therefore depends on various commodities:

$$U = U(Z_1,...,Z_n)$$

The combination of goods and time must be taken into account for each commodity i:

$$Z_i = f_i i(x_i,t_i)$$

In view of the budget constraint [P stands for prices, W (Z_n) wages, V unearned income],

$$\sum P_i X_i = W\ (Z_n) + V$$

and the time constraint (T = total time available),

$$\sum T_i = T$$

maximising well-being will lead to an optimum allocation of activities that will make the marginal utility of each activity equal to its shadow price, weighted by the marginal utility of income (where λ is the marginal value of income and Π_i the shadow price of activity i), i.e.:

$$\delta U/\delta Z_i = \lambda\ \Pi_i$$

In all, the optimum combination of inputs for each activity is (where τ is the shadow price of time):

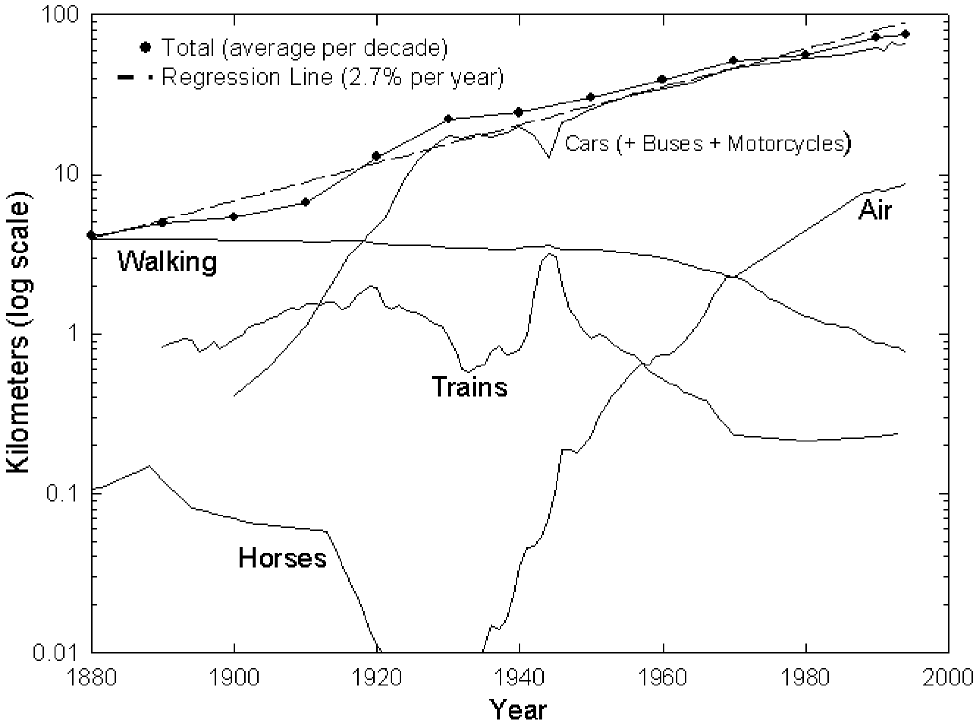
$$(\delta Z_i/\delta T_i)/(\delta Z_i/\delta X_i) = \tau/P_i$$

which means that the relative allocation of time and goods to an activity must correspond to the ratio of the price of time to that of good i.

Choices will therefore depend upon the relative price of goods and services, but also and above all on the wage rate, that is to say, the relative incentive to trade time for income. One of the main conclusions of the work of G. Becker is to show that an increase in the wage rate, or employment opportunities, significantly modifies programmes of activity and, notably, the choices made by women. As soon as the latter are able to obtain a wage outside the home, they will substitute working time for time in the house, which will be replaced by the purchase of goods (washing machine, pre-cooked meals) or services (child-minding, domestic help) that will make this substitution easier to achieve. Reducing the number of children is obviously another way of reducing time spent on domestic tasks. As if to demonstrate the strength of G. Becker's argument, this substitution phenomenon has been noted in all countries experiencing a certain level of development and economic growth. Female employment, lower fertility levels and an increase in the number of single and divorced people are therefore some of the consequences, among others, of the impacts of higher income levels on the allocation of time.

The transport field is also concerned by the substitutability of various approaches to time management. To the extent that transport is primarily an intermediate consumption, in the form of a derived demand related to production of a specific "commodity" (work, recreation, etc.), it will be tempting to reduce the time devoted to this intermediate consumption. In the same way that goods or service can be substituted for time spent on domestic tasks in order to be able to use that time for work, so too can a rapid mode of transport be beneficially substituted for a slow mode. The resultant time saving can then be reinvested in recreational activities and/or work, particularly if the latter affords access to a higher income, one of whose possible uses will be to pay for the increased travel speed[1]. The seminal work of C. Abraham and M.E. Beesley in this area clearly showed that time had a very real value in the transport field. According to their income, preferences and the opportunities for activity and transport open to them, etc., individuals are willing to pay a certain price to gain access to a faster mode. The figure below demonstrates this in the long run. As income levels rise, slow transport modes give way to faster modes which significantly increase the opportunities to diversify our programmes of activity, the basis of the desired increase in utility.

Figure 1. **Trend in distances travelled by person since 1800 in the United States**



Source: Ausubel, J.H., C. Marchetti, P.S. Meyer.

On observing the main trends, reported here in the United States, it can be noted that with economic growth and increased real incomes there is more than simply a substitution effect at work. Slow modes (walking, horses, etc.) are replaced by faster modes but, at the same time, there is an increase in the average distances travelled annually (trend increase of 2.7 per cent). There is, therefore, an income effect in the form of an overall increase in transport demand, a phenomenon that is directly linked to the substitution of slow modes by fast modes. We find ourselves confronted here with the same paradox identified, on the basis of the work of Garry Becker, in relation to leisure time. When wage rates and employment opportunities increase, leisure time must logically be converted into work time, which represents access to new opportunities for our programmes of activity.

In reality, this only obtains if leisure time is a kind of “time-out”, what economics would call an inferior good, whose consumption tends to decline when income rises. If, on the other hand, leisure time is treated as prime time, and therefore a normal good (whose consumption increases in line with income) or even as a superior good (whose consumption increases at a faster pace than income), then we may find both higher incomes and increased leisure time. The same reasoning applies to the transport field. As income levels rise, some types of trip may be reduced because they correspond to an inferior form of transport service. Others, in contrast, will rapidly expand, notably fast modes, as we shall demonstrate below by examining the key role of the generalised trip cost.

1.2. Time and generalised travel cost: Towards a composite monetary equivalent

One way to illustrate the key role of time in the transport field is to examine the relationship between the speed of a transport mode and the resultant volume of traffic. In this area, the gravity model, whereby the volume of traffic between two urban areas can be estimated on the basis of their relative weight (i.e. population) and the distance between them, can be taken as a fundamental given. Even though there are some exceptions to the general line of argument, notably when two urban areas are separated by an international border, gravity models have a good capacity for predicting potential traffic flows. However, in measuring the distance between two urban areas, what matters above all is transport time in relation to its cost rather than the actual number of kilometres. The term “gravity” is therefore explained by the fact that traffic is proportional to the populations of the two interconnected centres and inversely proportional to the generalised costs. Distance is therefore measured by the generalised cost of the trip, which may be expressed as follows:

$$C_g = p + hT_g$$

where:

P	=	Monetary price of the trip between location i and location j;
Tg	=	Generalised time between i and j;
H	=	Monetary parameter representing the average value of time in the eyes of travellers.

It is worth noting that the generalised cost takes account of monetary cost, the full transport time and a term relating to the way in which this transport time is perceived. The aim here is to take account of load breaks, the frequency of services in the case of public transport, number of transfers, etc. There is therefore a qualitative dimension to placing a value on travel time. To take this qualitative dimension into account, according to the mode studied, the Tg parameter can be constructed in greater detail in order to take better account of not only travel time but also the access time upstream and downstream, if necessary, as well as the intrinsic performance and quality levels of the mode in question.

In the case of a trip by rail or by air, for example, the following parameters could be taken into account:

– Travel time in the form of average travelling time between the origin and destination points in zones i and j;
– An indicator of the average interval between two trains (planes) according to the hourly schedule of a day's service;
– The number of transfers (train or plane) the traveller is required to make (load break);
– Frequency of trains or planes on the route;
– A constant representing times at journey ends.

This will provide an aggregate total time, a physical value that must be matched to the price of the trip by choosing an average time value for passengers.

- To measure this parameter, from a theoretical standpoint, the economic analysis is based on the principle that time is scarce. The individual chooses between the various activities possible by comparing the utility he derives from an activity and the share of the total time available to him which is thereby consumed. Consequently, time spent travelling is time taken away from other activities.

- From a practical standpoint, the placing of monetary value on time occurs through the notion of Time Value (TV), or the monetary value of time. This value is established through the study of individual behaviour patterns and may therefore be viewed as a behavioural value: individuals' willingness to pay in order to save time.

The value of time is usually obtained through direct methods of evaluating effects, notably through stated preference surveys or revealed preference methods. The studies which have been conducted, even though they still contain many biases, have provided us with greater insights. Nonetheless, it still remains extremely difficult to distinguish fine classes of uniform individuals in terms of time value, just as it would be equally difficult to segment the customers of a transport route into subclasses and estimate the number of users and the forecast changes in each subclass. Instead, an average approach is used with regard to the opportunity cost of time, by relating the hourly value of time to average hourly salaries.

The value of time, which symbolises the monetary value placed on time by individuals, is therefore the product of a process of simplification. As such, it theoretically depends upon individual social economic factors such as wealth, income, socioprofessional category, reason for trip, mode, etc. It is also common practice to choose different time values in urban areas for inter-city trips, as suggested with regard to France by the Boiteux 2 report, which recommends that a distinction be drawn between three types of reason and that better account be taken of comfort through the introduction of discomfort costs of 1.5 for congested travel conditions (+50 per cent of the cost of time spent travelling) and 2 for waiting times (+100 per cent of the cost of time) in assessments.

For inter-city travel, the time values proposed differ according to mode in order to take account of differences between customers. The time value is, on average, higher in a plane than in a train or a car. The values proposed therefore distinguish between the distance travelled and, in the case of rail transport, class of service (see Tables 1 and 2).

Table 1[2]. **Time value proposed per passenger in urban areas (in 1998 euros per hour)**

Mode of travel	**% of wage cost**	**% of gross salary**	**France as a whole**	**Ile-de-France region**
Professional trip	61%	85%	10.5 €	13.0
Journey-to-work	55%	77%	9.5	11.6
Other trips (shopping, leisure, tourism, etc.)	30%	42%	5.2	6.4
When no details are available of the breakdown of traffic by trip reason, average value[3]	42%	59%	7.2	8.8

Table 2. **1998 time value per passenger in urban areas (in 1998 euros per hour)**

Mode	**For distances below**		**For distances d between 50 km or 150 km and 400 km**	**Stabilisation for d > 400km**
	50 km	**150 km**		
Road	8.4 €	-	50 km<d TV = (d/10+50).1/6.56	13.7
2nd class rail	-	10.7	150 km<d TV = 1/7(3d/10+445).1/6.56	12.3
1st class rail	-	27.4	150 km<d TV = 1/7(9d/10+1125).1/6.56	32.3
Air			45.7	45.7

Because of economic trends in prices, the consumption of main items, income and wealth, the value of time will also vary. The rule for the trend in time value recommended in the Boiteux 2 report is that of a trend in per capita household consumption with an elasticity of 0.7.

On the whole, even though stated preference surveys have been conducted, it is extremely rare that a person is capable of specifying a monetary equivalent for the value of his own time at a given time and for a given activity. The value of time is, in most cases, revealed through behaviours that, in fact, are not quite as rational as analysis might suggest. C. Segonne, for example, has shown how the users of the Prado-Carénage Tunnel in Marseilles overestimate the time saved through use of this toll infrastructure. Symmetrically, non-users overestimate the time they would have saved by taking this new route. However, the fact that the rationale in the field of transport, as in other areas of consumer choice, is limited by the impossibility of having detailed knowledge of the alternatives, does not invalidate the thrust of the analysis: the statements or behaviours of individuals reveal that the latter place a certain value on time. The limits to rationality may result in routine or gregarious forms of behaviour which weaken the capacity for permanent optimisation accorded to actors at the microeconomic level. In no way do they invalidate the notion that individuals try to reduce the costs relating to performance of a given activity, notably by taking account of the associated travel time.

On this basis of a generalised preference for speed, what the transport economist will seek to determine is the elasticity of demand to the generalised cost. Depending upon the type of transport, and more specifically the type of activity relating to that transport, demand for transport will respond more or less strongly to a variation in price. If the “transport” good is a superior good -- that is to say, a good exhibiting high utility -- it is most likely that the elasticity of demand to price will also be high. Any decrease in the generalised cost of transport, made possible by higher speeds and/or lower monetary costs, will fuel strong growth in demand. Thus, if we return to the gravity model, we can say that the volume of traffic between two zones i and j will be expressed as follows:

$$T_{ij} = K \frac{P_i P_j}{C_{g_{ij}}^{\gamma}}$$

where:

P_i and P_j = Respective population of the two geographical zones i and j;
Cg_{ij} = Generalised cost of the transport in question between zones i and j;
γ = Elasticity of traffic to the generalised cost;
K = Adjustment parameter.

The numerator contains the factors of attraction and the denominator the factors of repulsion or resistance, whose values will increase commensurately with elasticity. It is for this reason that some analysts sometimes suggest that the law of gravity applies even more strongly for values of elasticity γ higher than 1 or even around 2. A high elasticity in this instance means high sensitivity to the decrease in generalised costs and, in particular, the reduction in travel time afforded by higher speeds. Since speeds do not rise at the same rate in different modes, it is important to note that, apart from the questions of elasticity, it is necessary to show how the change in relative speeds has a quite significant impact on relative generalised costs and hence the modal split of traffic flows.

1.3. Price-time models and modal choice

To illustrate the key role played by relative speeds, we shall briefly discuss the rationale that has allowed France to make high-speed rail projects an economically credible proposition. Use was made of an econometric model designed to explain the modal split between rail and air for new high-speed railway lines; this model combines a price-time model with a gravity model and therefore takes account of two modes of transport (rail and air).

The first step is to express the generalised costs associated with each of the competing modes of transport, since the model is based on the assumption that a passenger will choose between the two modes according to the value he places on his time and the characteristics of the costs and travel time of each mode. User k will therefore choose the mode with the lowest generalised cost once his time value, hk, has been taken into account.

Let us assume that we are modelling a modal split between rail and air. The respective prices of rail and air are therefore P_F and P_A; T_F and T_A are the respective journey times (including final legs), and the generalised costs for user k are expressed as follows:

$$Cg^k_A = P_A + h_k T_A$$
$$Cg^k_F = P_F + h_k T_F$$

On a given route i, there is a time value h^i_0 such that:

$$Cg_A = Cg_F$$

which is known as the time indifference value on route i. If h_k is less than h^i_0, user k will choose rail, or failing that, air travel.

It is assumed that the passenger population on a given route is characterised by a passenger time value g(h) distribution whose function is:

$$F(h) = \int_0^h f(x)\,dx$$

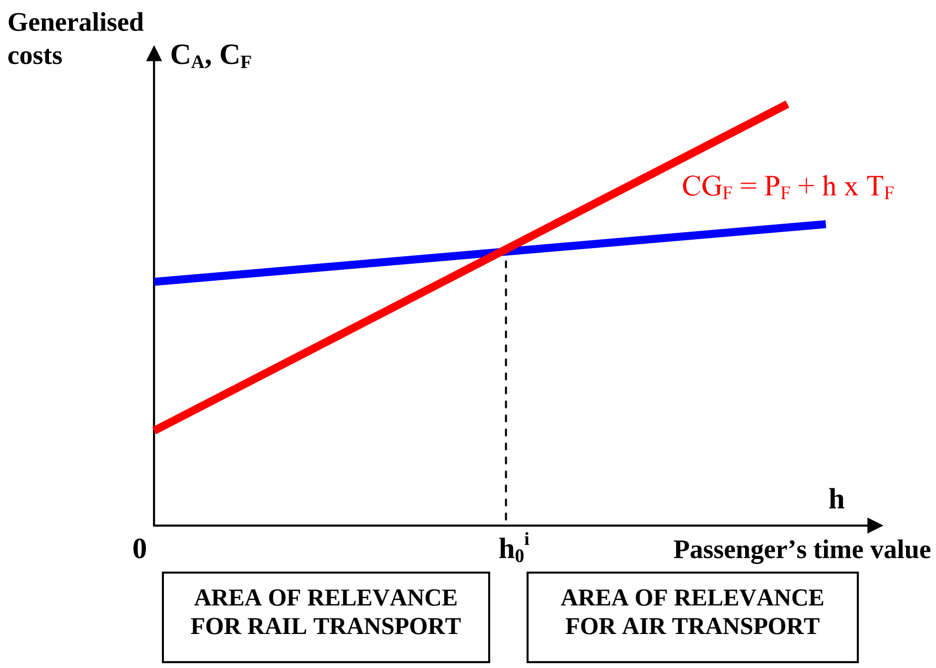
This gives the proportion of trips whose time value is less than h.

Accordingly, the proportion Y_i of air users in total traffic will be given by:

$$Y_i = \int_0^{+\infty} f(x)\,dx = 1\text{-}F(h_i)$$

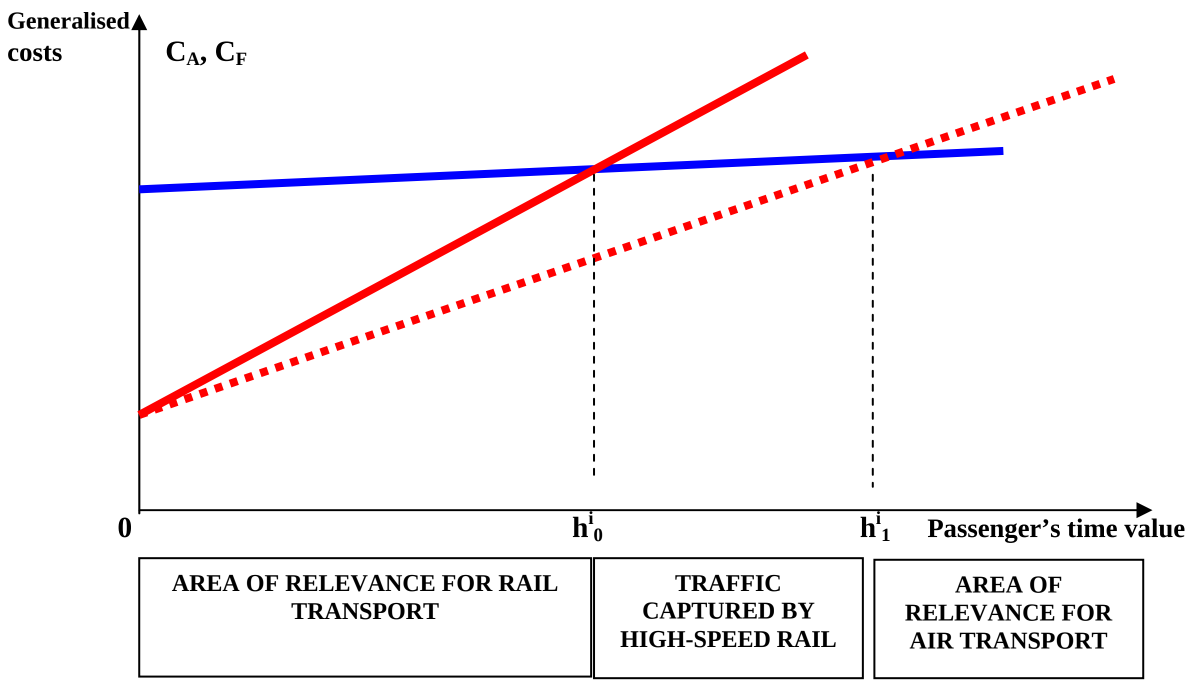
This is illustrated in the two figures below:

Figure 2. **Comparative generalised costs of rail and air**



If we now put in place a high-speed train allowing substantial time savings, this will modify the generalised cost of rail transport, all things being equal. The gradient of line Cg_F now will shift.

Figure 3. **Improvement of the market share of rail as a result of the introduction of high-speed services**



where:

Train $Cg_F = P_F + h \times T_F$
Air $Cg_A = P_A + h \times T_A$
TGV $Cg_{tgv} = P_{tgv} + h \times T_{tgv}$

Figure 4. **Distribution of time values**

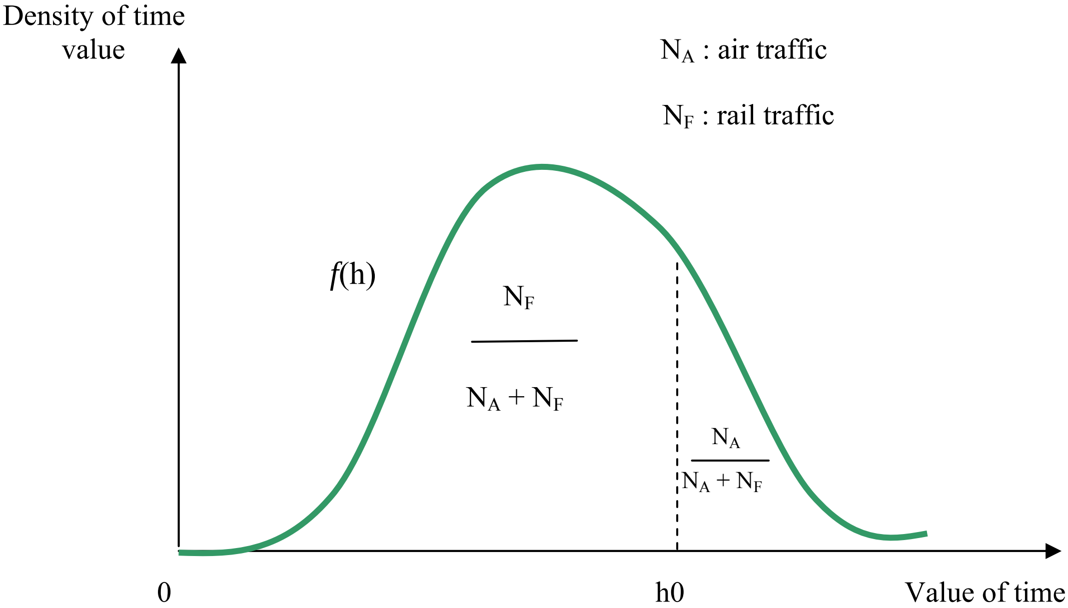
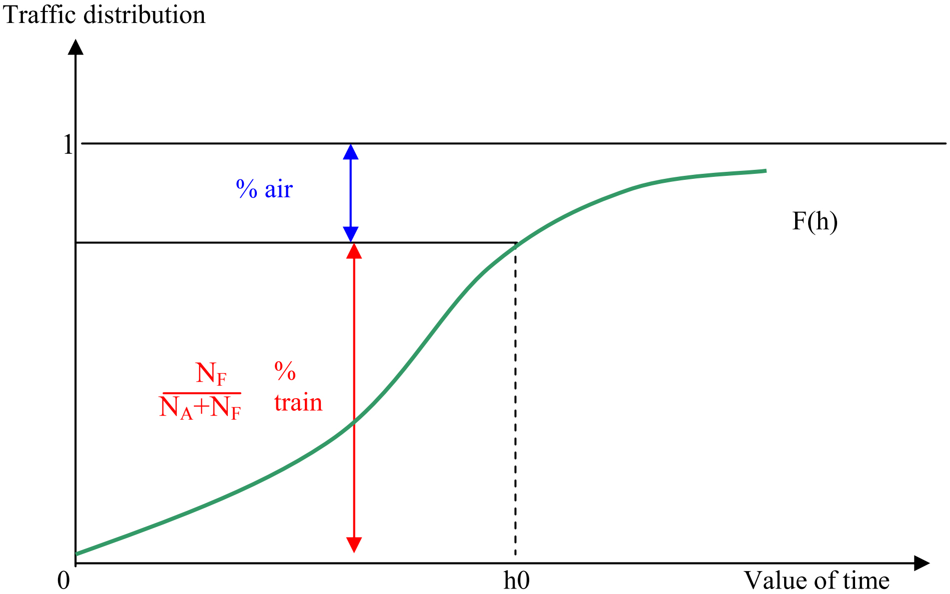


Figure 5. **Distribution of traffic according to time value**



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Because of the wealth of data available regarding income distribution among the population in a large number of countries, we can formulate a time value density function for log-normal *f(*h), that is to say:

$$f(h) = \frac{1}{h\sigma\sqrt{2\pi}} \exp. - \left(\frac{(Logh - Logm)^2}{2\sigma^2} \right)$$

where σ is the standard logarithmic deviation for time values and m the average time value.

Adjustment of the model consists in calibrating the log-normal law parameters, that is to say, the standard logarithmic deviation of time values and the average time value. The calibration must apply to as many routes as possible on which the two transport modes are competing (in this case rail and air). This desired spread in the data collected makes it possible to ensure that the stability of the parameter adjustment is properly verified and, in particular, that a correlation does actually exist in the country concerned between the average time value expressed in constant terms and the volume consumption of households.

This model is aggregated to the extent that it reconstitutes market shares. Once the model has been calibrated, the time value is set at a specific value in order to be able to test various trend scenarios in the transport system. To obtain medium- and long-term projections, the future time value is correlated with the forecast increase in income. It should be noted that there are several variants of the price-time model. What in fact differs from one model to another is the way in which the generalised cost is formulated. This comment suffices to show that the time value is not self-evident in the eyes of the economist; on the contrary, it is a value construction on the basis of what are frequently highly sophisticated lines of reasoning.

Recent studies (De Palma and Fontan, 2001; Bayac and Causse, 2002; Hensher, 2001) have shown that it was possible to improve the account taken of time value in transport demand models. The basic idea put forward in these studies, based on disaggregated models integrating a random dimension into individual demand, is to consider a non-linear relationship between time savings and utility. Their main outcome is not a reduction but rather an increase in the revealed value of transport time and therefore a *de facto* greater preference for speed.

1.4. Time and choice of investment

Time saving is therefore one of the main goals of investment in the transport field. It is essential to take account of time savings when calculating the social and economic viability of a project, that is to say, its viability after account is taken of the collective, and not simply the financial, interest of the project. When extended to the non-monetary aspects of the surplus afforded to the community by new transport infrastructure, cost-benefit analysis focuses on time savings, which usually account for four-fifths of the non-monetary benefits.

1.4.1. Discounting: another economic approach to time

In economics, discounting allows account to be taken of the time dimension and to compare sums at discrete horizons. The discounting principle is analogous to the principle of capitalisation. If a capital C_0 is placed on a market at an interest rate r in year 0, the capital in year n will be C_n where:

$$C_n = C_0 \ * \ (1 + r)^n$$

The discounting procedure uses a **discounting rate *a*** (usually per annum), representing the preferences for the availability of money over time. One euro available in a year is equivalent to 1 + a euros available today. A sum of S_n in year n is only taken into account as S_0 where:

$$S_0 = S_n/(1 + a)^n$$

The discounting rate, and its level, therefore translate a more or less significant preference for the present. An individual whose preference is for the present will have a very high discounting rate, which will severely penalise future goods. Conversely, an individual who gives priority to the long term will have a low discounting rate. It would even be feasible for individuals to have a preference for the future rather than the present, in which case they would have a negative discounting rate.

The first economic studies on discounting are now quite old. Ramsey (1928), Evans (1930) and Hotelling (1931, as part of his work on natural resources), made major contributions, as well as Massé (1946) or Arrow and Kurtz (1970, on the role of public capital). In the light of this work, it can only be said that the discounting rate represents more than simply a more or less strong preference for the present.

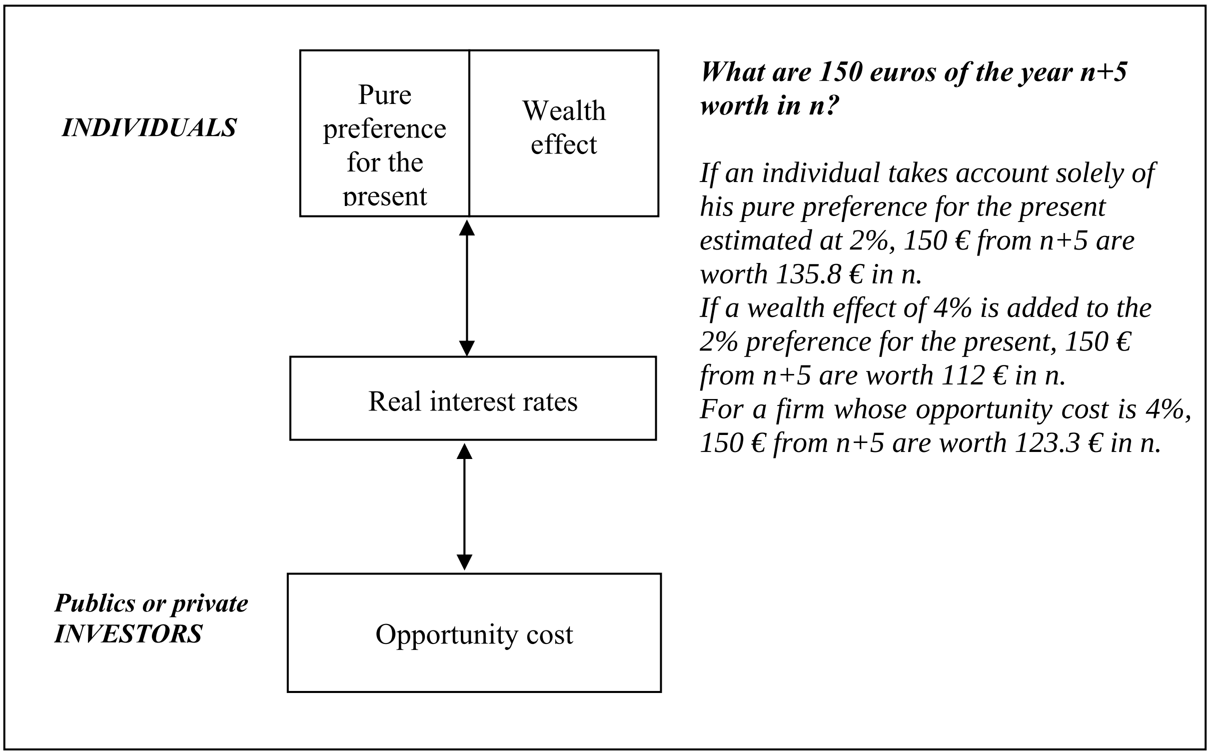
– In the first analysis, the process of discounting may be justified by what economists refer to as the "pure" preference for the present, which in some respects translates the "impatience" of economic agents. An impatient consumer will have a high discounting rate and the immediate consumption of the product provides him with greater satisfaction than consumption at a later time. This pure preference rate, denoted ***p***, is obviously a behavioural value. Arrow (1995 and 1996) proposes, on the basis of ethical and empirical conclusions, to adopt a pure preference rate of 1 per cent. Cline (1999) proposes, for his part, a rate of the order of 2 per cent. Other authors recommend adopting a rate of 0, particularly with regard to moral considerations regarding future generations when projects have intergenerational effects. Proposals may therefore specify different rates according to the length of the calculation. For investments of less than thirty years, the pure preference rate for the present (approximately 2 per cent) may be taken into account in the discounting process. For periods of more than thirty years, it must be taken as 0. Other authors such as Harvey, Heal, Overton and MacFadyen have proposed various formulae for the discounting rate, introducing a variation in the latter over time[4].

– The discounting rate also translates a "wealth effect". Future generations will be wealthier than the present generation. As a result, the utility of consuming a euro today is higher than that which will be derived from consuming a euro in several years' time, even at a zero rate of inflation. This means that the utility of a euro for a "poor" individual is greater than that derived by a "rich" individual from the consumption of the same sum of money. In this respect, the discounting rate must not be confused with the rate of inflation, since we are talking here in terms of constant money. The discounting process therefore does not translate the effect of depreciation of the value of money as a result of an increase in consumer prices. This wealth effect, denoted as $\theta * g$, is often related to economic growth. θ is therefore a term that takes account of the marginal utility of income (the value usually assigned is close to 1.5, which approximately matches the inverse elasticity of the marginal utility of income) and ***g*** is the per capita GDP growth rate (the long-term growth rates usually adopted range from 2 to 4 per cent).

– A third approach to discounting, which embraces the two preceding ones, is that of "opportunity cost". Since the immobilisation of capital is unproductive, the discounting rate can take account of the potential profit to be earned from an alternative use of a given capital, such as investing the capital in a financial market offering a guaranteed return. This justification of the discounting process also takes account of the constraint of scarce financial resources. This opportunity cost of money, generally denoted ***r***, may be related to the real rate of interest in the financial market (the rate adopted may be the actual rate applicable to long-term obligations, i.e. a value of around 4 per cent).

In sum, the discounting rate, as a method of integrating time into economic calculations, may be defined as the aggregation of three terms: the "pure" preference of economic agents for the present at a rate ***p***; the "wealth effect" ***θ*g,*** generated by the action of time; and the "monetary opportunity cost" ***r***. However, such an aggregation does not simply mean adding the three terms, rate ***p***, ***θ*g*** and ***r,*** together. Böhm-Bawerk, followed by Cline[5], suggest that a social discounting rate must be adopted for individuals (or a "pure" discounting rate) to take account of ***p*** and ***θ*g***, i.e. the pure preference for the present and the wealth effect. This rate would not take account of the opportunity cost of money. In contrast, for firms and public investors, it is the opportunity cost which prevails in the determination of the discounting rate. The pure preference for the present and the wealth effect are implicitly part of a wider notion, which is the opportunity cost of money.

Figure 6. **Discounting rate: three approaches to the value of time**



More than a simple economic calculation, specifying the discounting rate to apply calls for specification of the framework for and context in which projects are implemented. For example, the nature of the process of economic globalisation, and to an even greater extent the globalisation of capital, challenges the methods currently used to determine discounting rates (see Lind, 1990; Obstfeld, 1986). The same applies to the account taken of strategic elements; indeed, to such an extent that the choice of discounting rate for major infrastructure projects, while admittedly based on economic rationales, ultimately amounts to a political choice, particularly in the area of transport infrastructure.

1.4.2. Time and public economic calculation in the field of transport infrastructure

The discounting rate is extremely important in public economic calculations, since its level will partly determine the approach adopted by government to investment. The integration of time is not only a feature of the discounting rate, it is also a component of the time savings afforded by increased travel speeds. It can be seen in the equations below, which classically specify the discounted cash flow and the internal rate of return (IRR) in economic and social terms.

The discounted cash flow is the other facet of the Net Present Value (NPV), but takes account of the interest to the community in estimating the monetary value of the various costs and benefits of a public investment. The benefits estimated in monetary terms, denoted Aj, are decisive, in the numerator of the equation below, for determination of the socioeconomic viability of a project.

$$BNA = \sum_{j=t_p-t_r}^{j=t_n-t_r} \frac{-\Delta I_j + \Delta R_j - \Delta C_j + \Delta A_j}{(1+a)^j} + \frac{K_{t_n}}{(1+a)^{t_n-t_r}}$$

Ij	=	Investment during period J;
Rj	=	Income during period J;
Cj	=	Costs during period J;
Aj	=	Non-monetary but monetarised benefits during period J;
Kt	=	Residual value;
a	=	Discounting rate.

All the variables presented are discounted values for a reference year, t_r. For investment in the transport field, the reference year commonly used is the year of entry into service or the year before. In the equation above, t_p corresponds to the year in which work commenced and t_n the last year of operation taken into account in the calculation.

The socioeconomic IRR is the discounting rate that cancels out the NDB. Therefore, any project whose socioeconomic IRR is higher than the reference discounting rate is considered to be viable, that is to say, the project generates a sufficient overall surplus (i.e. its NDB is positive) compared with the initial investment costs.

The way in which time is taken into account is therefore decisive in two respects with regard to the public economic calculation:

– Firstly, the choice of a specific time value, representing a more or less high percentage of the average wage, will significantly modify the outcome of the project; particularly in view of the fact that the time saving often accounts for a non-negligible share of the factors which make the numerator positive in the first term of the equation above.

– Secondly, the choice of discounting rate, if high, can penalise the implementation of long-term projects by encouraging investments offering a speedier return for the community. The reference rate can therefore be interpreted as the community's preference for projects whose impacts are rapidly visible or, conversely, for higher capitalisation of the long-term effects.

By way of an illustration, let us consider the following, albeit somewhat simplistic, example. The authorities wish to improve the link between two major economic centres. They have two possible choices of investment: they can either improve the road link or improve the public transport link, both of which offer similar time savings for the same investment costs.

If the priority is given to short-term considerations with a high discounting rate, the investment will tend to be in favour of an improved road link in that the initial time savings will benefit a much greater number of users (assuming that road is used more than public transport in the initial situation). Even if the external costs rise (pollution, noise, etc.), the surplus generated during the first few years will be higher than that afforded by the public transport project. The longer term may see the emergence of unwanted effects, such as growth in car ownership, changes in the travel patterns of individuals -- who take advantage of the new infrastructure to live further away and therefore to travel longer distances, a decline in the share of public transport and increased congestion and hence pollution. With a high discounting rate, all of these effects (provided that they can be predicted and estimated) are relatively unimportant at the time of the calculation and have merely a limited impact on the rate of return on the road investment project. The road project will therefore remain superior to the projected investment in public transport. In contrast, with a low discounting rate, these long-term effects can have a significant impact on the calculation of viability and can lower the socioeconomic IRR of the road project to a level below that of the public transport investment project, particularly if the external costs (poor safety levels, pollution) relating specifically to the road projects are evaluated at high levels.

To a certain extent, account can be taken of time in a variety of more or less conflicting ways at the very heart of the economic calculation. If a high time value and high discounting rate are chosen, a strong preference for the present and for speed emerges. A modest, if not zero, discounting rate and low time value, on the other hand, work in favour of a preference for the future and low inclination for speed. However, it is also possible to adopt scenarios which partially work against a high time value and low discounting rate or, conversely, a low time value and high discounting rate. In this respect it is instructive, for a given discounting rate, to observe the way in which collective judgements are implicitly made in favour of or against a given time value. When faced with congestion problems in particular, does the objective of increasing speeds remain relevant at all times and under all circumstances?

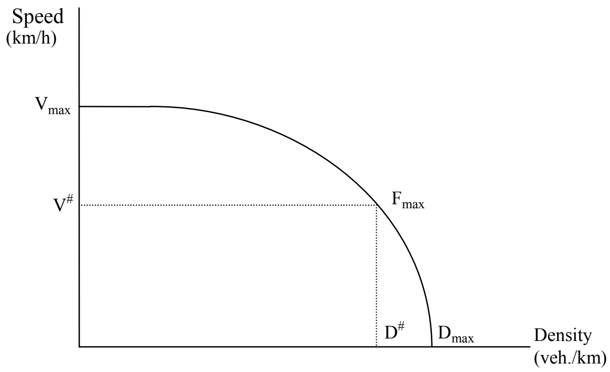
1.5. Congestion charging: illustration or cornerstone of the importance of the travel time variable?

In 1930, when A.C. Pigou presented his famous example of internalising congestion costs, including time losses, through the introduction of a charge, his main objective was to achieve maximum fluidity through the optimum allocation of traffic flows to two competing routes. This approach amounted to establishing an explicit link between engineering and economics, which his successors were to achieve more precisely by making use of the insight provided by the speed-flow curve. Building on this technical foundation, economists subsequently developed their own set of problems by focusing too exclusively on the relationship between charging and infrastructure financing, which reveals the preference for speed. However, in urban areas, this preference faces some major obstacles.

1.5.1. The speed-flow curve and the knowledge gained from traffic engineering

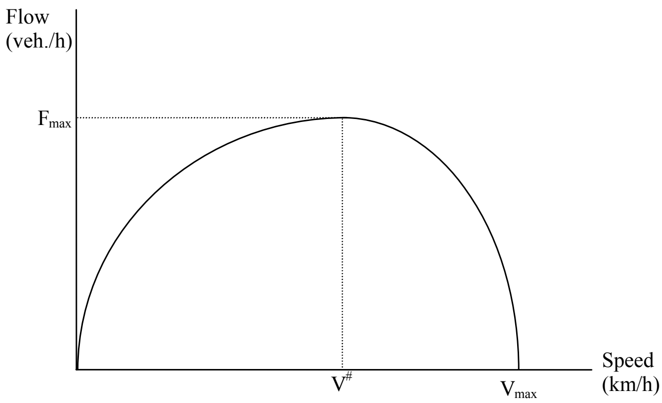
The "standard" static congestion model is a relatively straightforward construction. A given infrastructure is considered to have constant capacity with a single input and single output. The "fundamental" diagram derived from traffic engineering data describes how speed V (measured, for example, in metres/second or kilometres/hour) declines as density D (measured in terms of the number of vehicles per metre of carriageway) increases. The maximum speed, V_{max}, is assumed to be reached for a positive density (which explains the flat portion at the beginning of the curve, and that the maximum density D_{max} corresponds to zero speed (the flow of vehicles becomes a "stock" of vehicles). By analogy with the theory of fluid dynamics, the vehicle flow, F (measured in terms of the number of vehicles per second), is the sum of D and V. Consequently, there is a maximum flow, F_{max}, corresponding to a given combination of speed and density, denoted $V^{\#}$ and $D^{\#}$[6], respectively.

Figure 7. **Speed and traffic density**



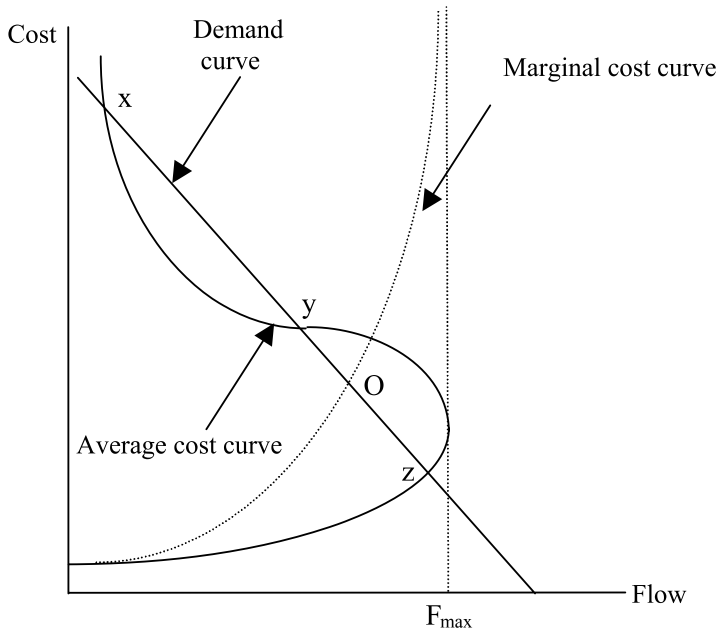
This speed-density curve can be used to derive a speed-flow curve exhibiting a characteristic profile: there is a positive correlation between flow and speed F_{max}, after which the correlation is negative (a flow higher than F_{max} implies a speed lower than $V^{\#}$.

Figure 8. **Speed-flow curve**



If it is assumed that solely time costs determine the cost of the trip made by users, and since travel time is known to be inversely proportionate to speed, it is possible to use the speed-flow curve to derive a curve representing the average cost of the trip for a given distance and time value. This curve is the average cost-flow curve which provides the basis for static models:

Figure 9. **Relationship between flow and the cost of the trip in terms of time**



The maximum flow rate, F_{max}, is based on the assumption that there is a certain amount of congestion. The gradient of the average cost curve in the lower section of the curve is due to the fact that if the number of motorists increases, speed decreases but flow continues to rise. Above maximum capacity, an increase in the number of vehicles on the road leads to a decrease in speed and reduced flows. The difference between the average cost curve and the marginal cost curve represents the external marginal cost of congestion, i.e. the share of the congestion costs imposed by a road user on other motorists. The user chooses to use infrastructure according to the average cost of his trip, which results in "over-consumption", in that the costs borne by the user do not cover all the costs he generates. As a result, the optimum price, or congestion charge, corresponds to the difference between these two parameters.

1.5.2. The problematic introduction of congestion charging

From an economic standpoint, the need to charge for congestion would appear to be a foregone conclusion. It represents progress because it introduces the time related to congestion into the economic calculation made by agents. To justify the substitution of a price logic by free access, associated with tax-based financing, we can turn to Jules Dupuit[7], who is acknowledged as the first to advance the concept of specific charges for transport infrastructure which take account of contributory capacity. With regard to road infrastructure, a distinction needs to be drawn between infrastructure which has been in existence for a long time, and which is more or less amortized, and infrastructure which has not as yet been built or which must be financed even though it is relatively easy to identify its future users. This is the case, for example, for a bridge or a tunnel, both of which are civil works designed to meet a specific need at a specific location to improve traffic flow conditions. Jules Dupuit demonstrates that financing by the user is both possible (tolls) and more remunerative if the charge takes account of the contributory capacities of users, that is to say, if there is a certain degree of discrimination.

Congestion charging is a form of discrimination which consists in differentiating charges over time, according to the degree of congestion in the infrastructure, and therefore to move the charge along the distribution curve of time values. The person who is willing to pay more in order to travel in better flow conditions during peak hours, obtains greater utility than the person who prefers to pay less by changing mode or by changing the time at which he travels to off-peak hours. The temporal differentiation of pricing thus enables the community to benefit doubly:

– Firstly, infrastructure use is optimised by taking account of the differential utility to users. The price signal plays its role to the full by indicating relative scarcities and by selecting between those expressing demand;

– Secondly, it releases the financial resources to cover the cost of infrastructure.

Charging, differentiated according to levels of road congestion, can therefore help to steer both demand, by removing the users who create congestion and thereby reduce service quality, and supply, by giving priority to the construction of infrastructure whose costs can be covered by such charging. The three objectives that charging for public services generally seeks to meet (covering costs, steering demand and redistribution) are therefore concurrently taken into account by this type of charging system, which is why it has been applied for many years in the air transport sector and for high-speed services in the rail sector. Its use is also recommended in the road sector, particularly in urban areas, although such practices are far from widespread.

We must therefore ask ourselves why it is proving so difficult to apply such an effective solution in practice. Is it because public policies lag behind economic thinking? Or could it possibly be because the central role assigned to travel time, and therefore speed, in the above ways of thinking needs to be looked at anew?

Questions on the universal relevance of the price-time model primarily arise in urban areas when a critical look is taken at the objectives of charging.

– When the purpose of charging is to finance the construction of new urban roads, which are generally extremely expensive (tunnels, bridges, etc.), the toll must be set at a level which is generally unacceptable to the vast majority of users. Charging is then confronted with the problem of "three-sided incompatibility", which makes it impossible to have, at one and the same time, daily use of the infrastructure and high charging levels in the absence of any genuine alternative route. If the toll is to be socially acceptable, its level must be reduced. The outcome is insufficient revenue streams, requiring massive public transfers to road as a mode of transport, which is equivalent to subsidising road transport. The time savings and their economic implications thereby become a pretext for subsidies, which might be justified were it not for the conflict with other environmental (pollution, noise, etc.) or urban (urban sprawl, modal split, etc.) objectives.

– In the case of a "pure" congestion charge, designed to ensure a given level of traffic fluidity without building new infrastructure, it needs to be borne in mind that demand elasticity is relatively low during peak hours. Short of raising tolls to extremely high levels[8], the number of vehicles will still be high and the gain in travel speeds low. It should be noted that this low elasticity is more a sign of the captivity of motorists than a real willingness to pay. This was the main reason for the problems faced in introducing a congestion charge, as already pointed out by Baumol and Oates. On average, the congestion charge results in a net transfer to the community. The gain attributable to the time saving afforded by increased fluidity is more than offset by the cost of the charge, if the average value of time is taken as a basis. In other words, solely the small minority of individuals who have a very high time value benefit from a congestion charge, if the latter is introduced in a situation in which users have no other real alternative, in terms of route or time at which trips are made.

In a densely-populated urban area, efforts to use car speeds as a means of reducing the generalised cost therefore raise a number of questions. The pressure of demand for travel by car remains extremely high and any local improvement in fluidity results in an overall increase in traffic. Short of systematically oversizing the road network or imposing socially and politically unacceptable charges[9], it would be vain to adopt the vague and general objective of increasing fluidity, i.e. speed. What recent urban policies can teach us is that, on the contrary, we need to adopt a differentiated approach to the network. While on many routes it is appropriate to maintain a certain speed, the same is not true of the city centre and the roads that lead to the centre. In the first instance, it may be necessary to consider building new infrastructure. In the second, on the other hand, the aim of elected representatives, at present, would seem to be directed more towards reducing speeds, not only for safety reasons but also, and above all, in order to rehabilitate the urban environment. This reasoning might seem paradoxical and even anti-economic, since it consists in curbing the volume of traffic and in reducing the surface area of the road network in order to do so. However, we shall see in the second part of this paper that, under certain conditions, this objective is undoubtedly acceptable -- the problem being how to determine its area of relevance.

2. TRAVEL TIME: A CONSTANT IN ACTIVITY PROGRAMMES AND A DILEMMA FOR COLLECTIVE CHOICES

The objective of minimising generalised transport costs is a key factor in the understanding of individual and collective choices with regard to transport. This mechanism prompts users to give priority to the fastest modes of transport, those which will “save time”. It should not be deduced from this, however, that users spend ever shorter periods of time in the transport system. The situation is quite the opposite since the time saved is, in a certain manner, reinvested in transport, as set out in Zahavi's hypothesis. Taking account of this hypothesis encourages us to look beyond the time spent on travelling and to take a closer look at the programmes of activity of individuals. It is quite plausible that the travel time gained in a typical trip is reinvested in additional distance (greater distance between home and the workplace) or in additional trips relating to new activities. In itself, this type of income effect is hardly surprising in economic analysis. However, to the extent that it has unwanted effects which challenge the sustainable nature of mobility, particularly in urban areas, the question arises as to whether the key objective of reducing the generalised cost of transport should not be replaced by the objective of increasing that very generalised cost, in some cases simply by reducing travel speeds!

2.1. Zahavi's hypothesis

In the 1970s, Y. Zahavi, an economist working at the World Bank, developed two hypotheses regarding the constancy of travel time and money budgets. His subsequent work on this double constancy led him to develop two different types of tool:

- A dataset which tended to confirm the regularity in relation to income of the time budget, on the one hand, and the money budget on the other;
- A traffic forecasting model (UMOT) in urban areas, based on data on the relative speeds of different modes and the trend in income.

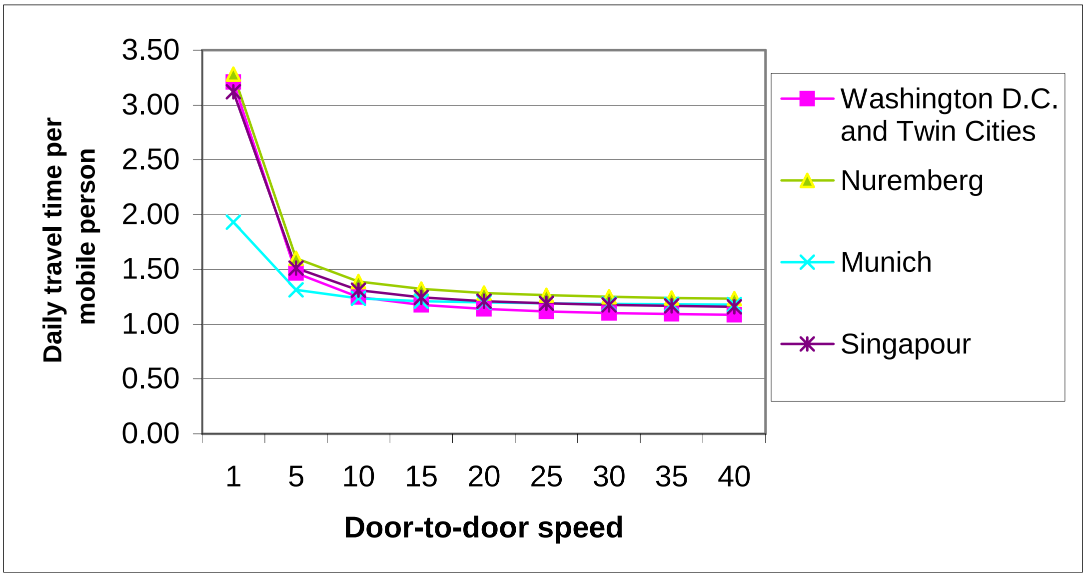
The average travel time budget associated with Zahavi's hypothesis is approximately one hour. To be more precise, the result achieved by Zahavi consists in an approximation of the average travel time budget within a conurbation by means of a decreasing and very rapidly converging mathematical expression of average travel speed. The relationship between travel speed and average time budget is therefore represented by the following function:

$$T = b + \frac{a}{speed},$$

where T is the travel time per mobile person, and *a* and *b* are coefficients to be determined where *b* can be interpreted as the minimum time that an individual will assign to transport. The level of *b* will therefore be slightly below one hour of travel time.

For all the estimates made on the basis of different sample data, Zahavi obtained a very rapid convergence in the average travel time budget to one hour of travel time. In fact, as soon as average speed exceeds walking speed, the time budget appears to be convergent at slightly above one hour of daily travel.

Figure 10. **Travel time per mobile person and door-to-door speed**



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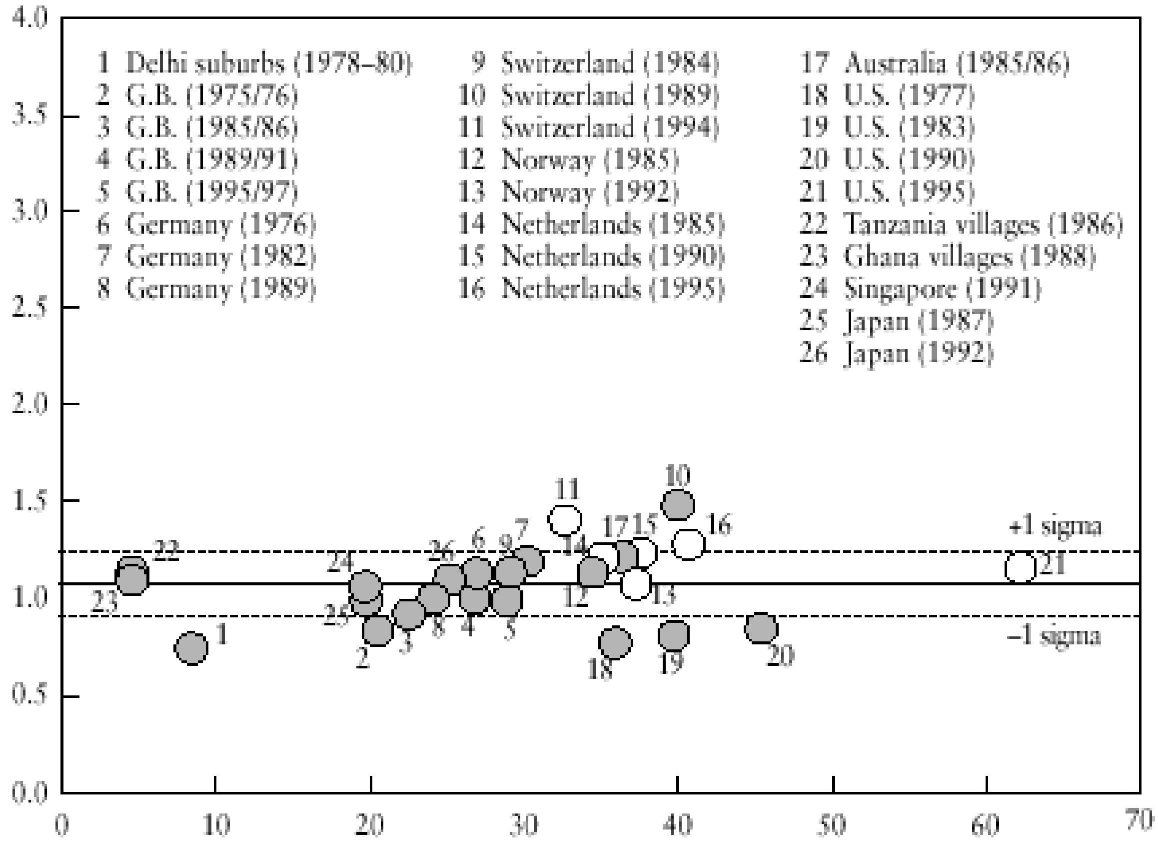
As soon as the speed rises to 10 km/h, travel time budgets bunch together in a relatively narrow interval. The curves accept asymptotic values of *b*, which for these cities are relatively close ($b \in [1.03;1.18]$, in hours of travel time). The coefficient *a* indicates the speed at which the travel time budget will converge. The lower the value of *a*, the faster the time budget will decrease with speed ($a \in [2.01;2.18]$, except in Munich where a = 0.77). However, the level of the time budget depends upon the unit of observation used. For analyses based on mobile people, the time budget is slightly above one hour. However, it has been possible to "illustrate" the constancy of travel time budgets by means of observation units other than mobile people.

In an earlier paper[10], Zahavi focuses on the daily duration of car trips. Taking data from 18 different cities[11], Zahavi found that a critical level of car ownership appears to exist, above which the average duration of car trips are concentrated around the same average of 0.8 h per vehicle per day. The regularity of length of car trips would appear to be confirmed by data relating to vehicles. The duration of daily car trips in developed countries (cities with car-ownership levels above 10 per cent) are concentrated within a narrow time interval (0.70 h-0.88 h), i.e. 42 min-53 min.

The hypotheses and preliminary work by Zahavi have recently been confirmed by the results of work by A. Schafer (2000), who was able to benefit from improvements to transport surveys in the various locations studied. This allowed him to present constant daily travel time budgets in both time and space over a period extending from 1975 to 1997, despite the fact that the distances travelled vary substantially from one country to another and are rising over time.

Figure 11. **Travel time budgets, in hours per person per day**



A. Schafer conducted the same analysis for a wide variety of cities[12]. The figure below reveals an interval of forty minutes within which all the average travel time budgets of the cities studied are concentrated. The level of GDP in the countries surveyed has no significant impact on the level of the travel time budget and, for some cities for which a sufficiently long observation period is available, we can see an illustration of the continued regularity of the time budget, despite the economic growth of countries (Paris, Tokyo, Osaka).

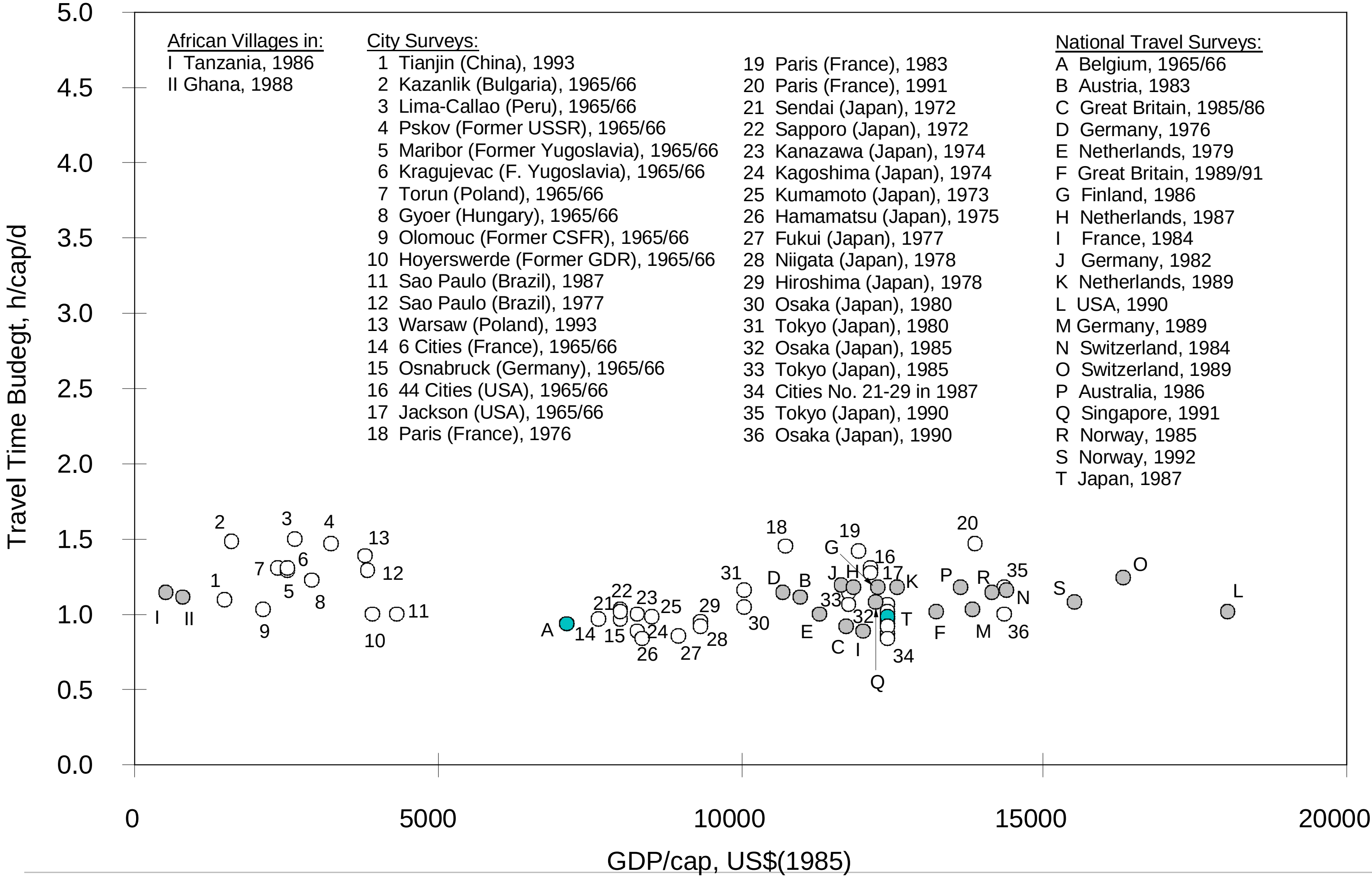
2.2. Value of time and optimisation of activity programmes

It is important to note that, in the argument advanced by Zahavi, the constancy of travel time budgets must not be attributed to sociological or biological considerations. It is not a structural feature that we must accept by virtue, for example, of temporal-biological determinism. On the contrary, we are typically faced with a microeconomic process of optimisation. For proof of this, we need look no further than the fact that there is no convergence in cases where car-ownership levels are either low or zero. After the rise in travel speeds as a result of the use of cars and certain types of public transport, individuals modify their choices, firstly, in favour of higher average speeds that will reduce total travel times and, secondly, in favour of maintaining the same travel time, at either constant or increasing speed, while increasing the distances travelled, a simple but robust indicator of the activity opportunities afforded by trips.

The question of the relative stability of the travel time budget can be analysed, to some extent, as the development in the choice between working time and leisure time (in the broad sense of the term) in developed countries. According to the model proposed by G. Becker, the increase in real salaries encourages individuals, and women in particular, to opt for longer working hours that will make it possible to purchase products capable of reducing the constraint of time spent on housework and child-rearing. However, this process of substitution is short-sighted in that the reduction in the "constrained" time reveals the utility of "non-constrained" time (i.e. leisure, cultural activities, etc.) spent outside the workplace. After reducing the time spent outside the workplace, and above a certain level of income, the substitution effect gives way to the income effect. While access to higher speeds will initially prompt a reduction in travel time, an asymptotic trend subsequently emerges, in that maintaining travel time at a more or less constant level is quite simply the condition for diversification of the activities of the individual and therefore of increasing utility. However, taking account of the time budget alone is insufficient and we must also take account, as microeconomic analysis teaches us, of all resources, including money, in order to determine the central issues in choices and their implications for the programmes of activity of individuals.

In the most classical types of microeconomic model, two resources impinge on the universe of mobility choices, namely, income and available time. The level of mobility chosen by an individual will therefore be the outcome of the relationships between the component costs and benefits of the form of transport he uses. While the value of transport utility is a highly subjective notion, in that it depends upon individual preferences, transport costs can be expressed by a unit of measurement: money or time. And the size of these costs is dictated, firstly, by market prices, for monetary transport costs and, secondly, by the price of transport in terms of time, which will depend upon travel speed and the value of time.

Figure 12. **Average travel time budgets per person**



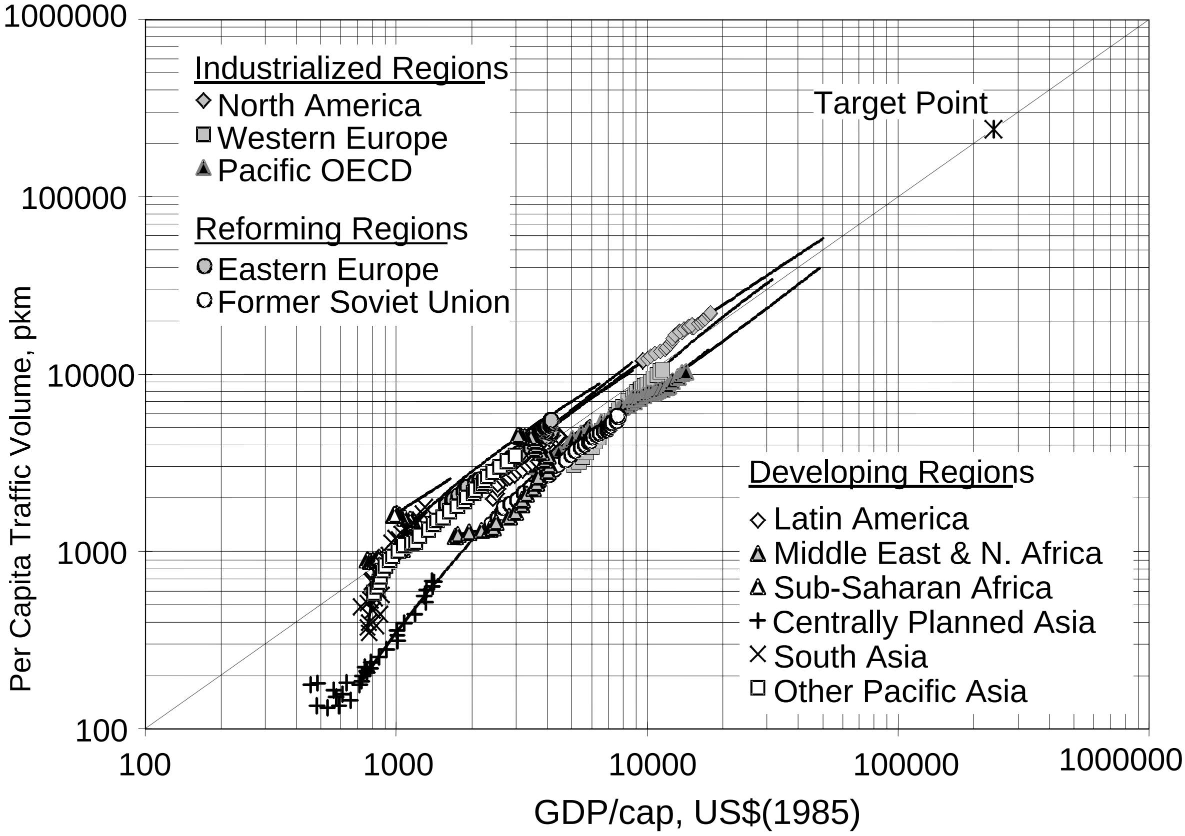
Representing mobility behaviour in this manner describes programmes of activity and individual travel according to five components: monetary costs, time costs, monetary resources and the value placed on travel utility. Any choice of programme of activity must be made with reference to these five components. There is, therefore, a certain type of trade-off between monetary costs and time costs when acquiring higher speed in order to save. Accordingly, persons who are capable of making the monetary expenditure needed to secure higher speed, travel faster and thereby gain in terms of travel time for a given level of mobility. However, the time thereby saved will be reinvested in transport, so that the money budget remains constant. The outcome for these persons is increased mobility, in that during the same period of time (constant time budget) they can travel a greater distance as a result of higher travel speeds. From this standpoint, the general increase in mobility is the result of the reduction in the monetary costs of speed and the trend increase in the latter.

It is therefore clear that postulating the regularity of these two travel budgets amounts to reducing the complexity of mobility behaviour. While individuals do not have the explicit objective of regularity in these two budgets, their behaviour patterns implicitly reveal an average preference of this nature. The reference to the average, without prejudging the accompanying spread, is of paramount importance here. Those in the youngest and oldest age brackets are undoubtedly less mobile than the working population. However, the basic lesson is that any relaxation of the constraints represented by the individual's resources and the prices he must contend with will translate into an increased level of mobility. This therefore provides us with a compelling explanation for the generalised trend towards increased mobility, irrespective of whether such mobility takes the form of long- and medium-distance inter-city trips or daily trips, notably those in urban environments.

2.3. Inter-city mobility: an impossible decoupling of growth and transport

For many years, economists, and particularly transport economists, have stressed the strong correlation between economic growth and the growth in the transport sector, indeed to such an extent that many people, including historians and politicians, have transformed this correlation into cause and effect by claiming that the construction of appropriate transport infrastructure is a prerequisite for economic growth. Throughout the twentieth century this idea has therefore enjoyed considerable currency, as borne out by both the development of transport services (road, rail, air) and the increased mobility of people and goods. Taking the argument one step further, A. Schafer has proposed a common target point for all countries (for the middle of the current century?) of over 200 000 km per year per inhabitant. This target point, as may be seen above, is simply the result of an extrapolation of trends that, in the long term, converge on this focal point where, if we assume a convergence in per capital GDP, most of the major regions in the world would be located.

Figure 13. **Correlation between growth and individual mobility: trends**
Total mobility in passenger-km per year
(Statistics 1960 - 1990; Trends 1960 - 2050)



Source: Schafer and Victor (2000); economic growth rates based on IPCC IS92a/e scenario.

This is clearly a scenario that gives serious cause for concern in view of the impacts that such a dramatic explosion in mobility will have on the environment and/or land use: 200 000 km per year, of which almost a third by high-speed modes of transport (high-speed train and air transport), given that the modes of transport experiencing the strongest growth are also the fastest and the most intensive in terms of energy consumption and therefore those which generate the most pollution (see Figure 1). Let us recall that, excluding walking, per capita mobility since 1800 in the United States has grown at an annual rate of 4.6 per cent, and by 2.7 per cent if pedestrian traffic is included. By way of comparison, the mobility of the French has risen at an annual rate of 4 per cent since 1800[13].

These concerns have given rise to the idea that the link between economic growth and mobility should be severed, a proposal in direct opposition to the argument advanced by A. Schafer. For the time being, the concept of decoupling conveys vague and implicit connotations. What would be the ultimate objective of such a process? Would it be what is termed "absolute decoupling" or would it simply mean severing the link between mobility and energy consumption, or what is termed "relative decoupling"?

– The first scenario would involve an absolute constraint on per capita mobility, possibly by establishing quotas for per capita mobility, in that the main reason to reduce or stabilize mobility is to curb emissions of CO_2 and other pollutants. Absolute decoupling does not mean zero mobility, but rather the stabilization of mobility in absolute terms and, what is more, even during periods of economic growth. If decoupling is viewed as a dynamic concept (elasticity of annual growth in GDP and growth in traffic levels), this means that mobility must be virtually inelastic to economic growth and would correspond to a stabilization of the transport needs of the economy. To do this would require a strong policy towards the management of mobility and spatial reorganisation which would require a substitute for mobility in programmes of activity. Nonetheless, the underlying question is knowing to what extent this absolute decoupling approach would have an impact on economic growth itself. Stabilizing mobility could indeed have severe consequences with regard to growth, which is another way of denying the possibility of absolute decoupling. Would zero growth therefore be the sole means of "doing away with transport" and the impacts of transport on the environment?

– The second scenario offers a negative response to the above question by proposing the solution of relative decoupling, which considers transport and mobility to be inputs that are both necessary and essential for economic growth. The impossible "rationing" of mobility, which would be a direct impediment to economic growth, is avoided by decoupling transport and energy consumption. Just as industry has proved itself capable, since the first oil shock, of increasing the volume of production while at the same time significantly reducing its energy requirements, so too should transport be capable of becoming less energy-intensive. The aim would therefore be to find a technological solution to the problem of the external costs of transport. Mobility would therefore continue to increase. This argument is the same one underpinning the European research programme (Auto Oil II) and, at a more general level, the current hopes of car manufacturers. According to the forecasts drawn up in the Auto Oil II programme, the transport sector would perform relatively better than other sectors in terms of reducing pollution. However, the assumptions on which these forecasts are based are highly sensitive to the rate of growth in demand for mobility. Relative decoupling therefore leaves to one side the resultant increase in traffic volumes, congestion and spatial impacts.

The technological solution would, at first sight, seem appealing since it would simply be a prolongation of current ways of living and thinking. However, it contains the seeds of its own limitations within itself. Such a solution would generate mobility, given that, because the cost of technology constantly declines as a result of productivity gains, we would see the continued operation of the mechanism whereby additional spending power is devoted to the purchase of a faster form of mobility. In addition, the time savings afforded by the optimisation of trips could work to the same effect by pushing back the limits to infrastructure congestion and saturation. Ultimately, the impact that economic growth has on programmes of activity is to achieve a spatial transfer of the problems posed by the regularity of travel time budgets. If, far from being solely a variable which needs to be minimised, travel time is also a constant, then increased travel speeds will lead to increased spatial occupation by individuals. The growth in the absolute value of the money budget for mobility will broaden the scope and increase the number of trips. Through rapid development of high-speed modes of transport and the inexorable growth in leisure mobility, medium- and long-distance mobility clearly has great prospects for the future, as the hypothesis of "double constancy" would appear to suggest to us.

2.4. Daily mobility: travel speed and activity programmes

While the prospect of future growth in inter-city mobility is not a major cause for concern, the same cannot be said of urban mobility. Such mobility is growing in accordance with the same basic principles as medium- and long-distance mobility. As O. Morellet and P. Maréchal have shown, it would be perfectly feasible to include both of these two forms of mobility in a single analytical model (cf. the MATISSE model), capable of efficiently predicting transport demand by classifying demand by major types of trip, primarily grouped according to their price sensitivity and travel times. Overall, wherever speed gains are technically feasible and financially accessible, modes with the lowest generalised costs attract most support from the population. This is notably the case for car use in urban areas. Even though the analytical bases are the same, the implications, notably in spatial terms, of the increase in urban mobility pose specific problems.

In the first analysis, we should welcome the growing role played by the car in the organisation of our mobility, in that it is the choice which enables generalised costs to be minimised. This positive assessment could even be enhanced by introducing the benefits of a trip. It goes without saying that reducing the average generalised cost can also lead to the emergence of new travel opportunities. At a lower cost, certain trips will become attractive, and it is at this point that we come up against the issue of the sustainability of car-based mobility. How can we avoid car-based mobility leading to increased mobility in the form of trips over longer distances, either for leisure pursuits, work or, primarily, choice of place of residence?

To illustrate the latter point, let us take the case of journey-to-work trips in France made by persons who work in a different commune to the commune where they reside. By comparing data from the 1990 and 1999 surveys, it appears that the total distance travelled by intercommunal migrants rose from 165 million to 211 million kilometres a day, an increase of almost 28 per cent in less than ten years. This growth is partly attributable to the longer average distances travelled daily (approximately 7 per cent), but is mainly due to the number of persons making trips (almost 20 per cent). Since there are two movements which are cumulative, the main problems regarding the sustainability of daily mobility are clearly to be found here.

Note that the trend in distances travelled and the number of alternating migrants vary substantially according to place of residence. As may be seen in the table above, the rates of variation differ widely from one area to another, resulting in structural effects.

- A first type of structural effect derives from the fact that residents in urban poles (cities with a centre and suburbs) on average travel shorter distances than others. However, since the rate of increase in the number of intercommunal migrants is much higher in peripheral and rural areas, the total distance travelled is rising at a faster rate in this second category of location (+35.8 per cent as opposed to +20.6 per cent in urban poles), which now accounts for a slightly higher total distance travelled.

- The same phenomenon can be seen within urban poles. In a rather curious development, the average distance travelled is rising faster than the average distance travelled by residents in town centres, on the one hand, and suburban residents on the other. This may be explained by the simple reason that the first category of residents, who paradoxically make the longest trips, is growing faster than the second. It is therefore clear that control over urban mobility, and private-car mobility in particular, must take account of structural phenomena.

Table 3. **Intercommunal journey-to-work trips in France (1990-99)**

	Total daily distance (thou. kms)	**Rate of growth 99/90**	**Number of daily migrants (thousands)**	**Rate of growth 99/90**	**Average daily distance (km)**	**Rate of growth 99/90**
City centres	36 982	+28.0%	1 988	+ 21.8 %	18.6	+ 5.0 %
Suburbs	68 887	+18.2%	5 939	+10.1%	11.6	+ 7.4 %
Total urban centres	105 869	+ 20.6%	7 927	+ 12.7%	13.3	+ 8.1 %
Of which: urban area of Paris	*35 555*	*+11.8 %*	*2 914*	*+ 8.1 %*	*12.2*	*+ 3.4%*
Outskirts	52 003	+34.0%	3 133	+ 29.3 %	16.6	+ 3.8 %
Of which : urban area of Paris	*12 828*	*+ 23.8 %*	*539*	*+ 24.5 %*	*23.8*	*+ 1.3%*
Multi-centre urban areas	15 382	+39.0 %	855	+ 31.3%	18.0	+ 5.9 %
Rural areas	39 377	+36.7%	2 128	+ 33.1 %	18.5	+ 2.8 %
Total excl. urban centres	106 762	+35.8 %	6 116	+ 30.9 %	17.5	+ 3.7 %

Accordingly, current patterns of urban development, which are more extensive and often multipolar, require the population to make relatively long trips on extremely varied routes. Even if the public transport system is efficient, it remains insufficient to cope with demand for mobility, which can only be met by car use. And the more the share accounted for by car use increases, the more it encourages households and firms to move to peripheral locations, there commensurately increasing dependence on car use. Indeed, this explains the relatively high average daily trip distance for the inhabitants of city centres.

Urban structure and mobility are therefore closely linked.

– Firstly, the urban structure provides the space in which all the possible activities pursued by individuals are distributed. The locations of these different activities in relation to the locations of individuals induce certain patterns of mobility. As Zahavi points out, differences in the distribution of employment zones and residential areas may provide an indication of the minimum level of mobility that will obtain. Concentrations of activities, relating either to work or leisure, will generate a large share of trips, and the locations of such concentrations will have an impact on patterns of mobility. Peripheral locations, for example, will lie beyond the reach of public transport services and will therefore be prime sites for generating trips by car.

– Secondly, the urban structure is also where transport will take place and will therefore, in large part, dictate the conditions under which trips are made. In many cases, urban density is synonymous with reduced travel speeds. M. Wiel (1999) accordingly speaks in terms of co-generation between the town and mobility. In his view, urban sprawl can be explained at least in part by the development in increased travel speeds. One of the outcomes of increased travel speeds is an increase in the distances travelled, without any changes in the travel time budget. Urban sprawl, as a response to the phenomenon of property rents, would therefore be the outcome of individuals' taste for increased living space in their homes by extending the limits to their area of mobility.

According to this logic, the way to put a brake on urban sprawl would therefore be to impose speed restrictions, since if speed is responsible for the extension of cities then it should also be capable of slowing down, if not reversing, urban sprawl. Lower speeds should reduce the spatial access of individuals and, as a result, encourage them to modify their choice of place of residence, to the benefit of centres of activity. Such a decision would be expected to restore the density of cities and city centres (both former and new centres)[14]. While solutions are rarely advocated so starkly (i.e. reduce the number of daily trips), it is clear that this type of reasoning has inspired many of the strategic analyses conducted both by experts[15] and by local elected representatives[16]. Both parties based their analyses on the impossible headlong rush towards "ever more" mobility in urban areas.

Reducing speeds has only a limited area of relevance, however. It is perfectly feasible to envisage reducing traffic speeds in city centres, provided that the performance level of alternative modes is sufficient to meet mobility needs. Instruments such as park-and-drive and public transport lines of sufficient capacity can make speed restrictions on car traffic in city centres an operational reality. If public transport can capture a share of the traffic, the increase in congestion in densely populated areas in the centre can be halted. In some ways, restrictions in city speeds can enable the speed of public transport systems to retain their comparative advantage and to limit the return of car traffic.

Introducing this type of measure in peripheral areas is more problematic. On urban ringroads, the supply of many to-and-from trips cannot reasonably be ensured by public transport. Reducing speeds on roads into the centre could encourage a modal shift to public transport for trips towards the centre. However, it could also severely disrupt trips from one peripheral area to another, where public transport cannot readily compete due to the conflict between the level of service required (strong demand for flexibility, frequency, etc.) and the level of patronage which will ensure minimum economic viability.

All of these considerations would clearly seem to show that the question of car speeds in urban areas leads us directly back to the social choices made with regard to the value of time. By the same token that a social value exists for the discounting rate and a social value for time in economic calculations, it all seems as though urban policies currently aimed at promoting public transport were making an adverse selection of time values. Where economic analysis of congestion suggests that, in order to increase fluidity, charges should be introduced in an attempt to eliminate users whose time values are too low, urban policies are substituting a different approach. Without explicitly seeking to drive away users with high time values from city centres, these policies propose another form of arbitration.

What, precisely, are the reasons for the trips made by users driving in the city centre? Whether the trip is from (or towards) his home, from (or towards) his workplace or from (or towards) a shopping or recreational area, the user must be made aware of the fact that the amenities he is seeking in that area are incompatible with the speed of trips by car. At the risk of caricature, it is as though the elected representatives of city centres were increasingly tempted by a social vision of time value of the type that prevails in "Disneyland[17]" or the centre of areas that attract large numbers of tourists. The key signal sent to users of these spaces is that a relative degree of slowness is the price that has to be paid to use the collective good constituted by the theme park. The development of tramways, a relatively slow mode of transport compared with underground railways, is an example of this choice which can be seen today in a very large number of French and also European cities (Barcelona, Geneva, etc.). Abandoning the headlong rush towards higher speeds, what users are offered is a certain quality of urban life which is based on the assumption that trips will be relatively slow. Users (both households and firms) are therefore called upon to reorganise their programme of activity by modifying their route, by making trips at earlier or later times, by changing their place of residence or even by changing their workplace.

The interest in this new configuration, which has already been well-established for many years in cities such as Berne (Switzerland) or Freiburg and Karlsruhe (Germany), is that the decision to make such choices has not ended up stifling the life in city centres. On the contrary, property prices in central areas have risen and their attractiveness as both business and residential locations has remained unabated. The local elected representatives have therefore made a coherent economic choice, aimed at enhancing the value of the public assets they are in charge of managing. The value they have most enhanced is not time but the property assets located within the urban area and they have done this in terms of property values. Given a choice between time and space, they have opted for the latter and this priority takes precedence over the time values implicitly required by users.

2.5. Conclusion: Towards charging for trips at the generalised cost?

We must clearly repeat here that the decision at the local level to reduce car speeds and to place a low collective value on time is not an anti-economic decision, even though it might initially appear to be so. At any rate, it is not anti-economic provided that the area subject to such restrictions is not too large. Just as time values are low in the very centre of Disneyland but high in relation to the access roads which lead there[18], so too the low speed of trips within the city centre are accepted all the more readily in that there are genuine possibilities for transit traffic or suburb to suburb traffic to avoid the centre. It is for this reason that those elected representatives who wish to impose severe constraints on car mobility in the city centre, militate at the same time for the construction of ringroads and motorway bypasses, even if they are extremely costly. There is no inconsistency in such an attitude in that their constraint on speeds and time values does not represent a universal position of principle. At most, it is a contingent choice related to management of property assets in a specific spatial location.

Even though, when presented in this way, this choice is perfectly rational, it is by no means certain that politicians have fully grasped all the implications of such a choice, in that, if we now place ourselves at the level of the conurbation and not the city centre, the model of the spatial segmentation of time values leads to neither a reduction in mobility nor to a stabilization of transport infrastructure needs. While many local transport policies claim to want to substitute investment in public transport for investment relating to private car use, the situation we find ourselves facing is one of complementarity, where we need to increase both components. However, in urban and outlying areas, investment in transport infrastructure comes at a very heavy price. The increased demand for mobility will therefore lead to a heavier cost burden on the community, which will have to be passed on, in one way or another, to users.

Seen in this perspective, charging from trips made in urban areas assumes an entirely new dimension. While the economic rationale for congestion charging is still based on the time savings afforded by a higher degree of road pricing (time versus money), we are gradually moving towards a situation in which, in some cases, it is perfectly legitimate for the two components of the generalised cost of a trip to move in the same direction, namely, towards an increase in the total cost. While such a possibility seems unacceptable from a purely individual point of view, it makes sense if it is part of an overall urban plan, as shown by the examples of large urban areas (London, Oslo, Tronheim, etc.) which have experimented with urban tolls based on the principle of area charges rather than the concept of explicit congestion charging.

As in these conurbations, urban transport policies will, in future, work on several mechanisms at the same time: a differential, although trend, decrease in the average speed of cars in urban areas; highway building restricted to bypass roads; introduction of charges on trips made by car; development of public transport, including intermodal configurations which will help steer the residents of peripheral areas to a small number of major corridors. All of these measures will obviously come at a cost to public finances. Increasing the cost of mobility is therefore a necessity, given that investment is required, not to mention subsidies for public transport. However, this increase cannot, under any circumstances, be seen as a cornucopia that will allow local authorities to reduce other taxes, for example. By the same token, this will not make any fundamental changes to urban forms and the trend towards development on the periphery of towns and cities; in such cases, a supply of efficient public transport services will add to the severity of the problem. No radical changes should therefore be made to current trends, nor should car mobility be dealt a death blow; instead, a coherent set of signals needs to be sent to users. The collective urban project requires that both components of the generalised cost of trips by car -- namely, price and duration -- must be increased, at least at the local level. This can be achieved gradually and in some respects has already been initiated. Surprising at it might seem, the issue at stake consists no more or less than in applying a simple economic principle: increasing the cost in response to scarcity, that environmental considerations could make even more severe.

NOTES

1. We shall dismiss here the argument, advanced by Ivan Illich, to the effect that time attributable to speed would be completely absorbed by the additional work time needed to purchase that speed. The lower unit cost of travel in relation to the average wage is one aspect of economic growth that is not a zero-sum game.

2. A comparison with different European values is available in the Boiteux 2 report.

3. The breakdown of the average value for all trip reasons was as follows: professional trips 10%; journey-to-work trips 35%; trips for other reasons 55%.

4. Harvey proposed the following type of formula: discounting rate = a0*b/(b+t), where a0 is the discounting rate for the year in which the service first starts up, b a constant and t the time after entry into service. Heal introduced logarithmic discounting, which was then formulated by Overton and MacFadyen.

5. See Cline, W., 1992 and 1999.

6. To give an order of magnitude, the maximum flow rate for an urban clearway is 1 800 vehicles per hour and per carriageway at 55 km/h (Hau, 1998).

7. For a detailed presentation of the argument advanced by J. Dupuit, see M. Allais (1989).

8. This is the case of the congestion charge recently introduced in central London (five pounds sterling), whose residents pay solely 10 % of the charge.

9. In this respect, the toll introduced in Singapore is more of a deterrent than a model.

10. Zahavi, Y. (1973), The TT-relationship: a unified approach to transportation planning, *Traffic Engineering and Control*, pp. 205-212.

11. Athens, Baltimore, Baton Rouge, Bombay, Brisbane, Chicago, Columbia, Copenhagen, Kansas City, Kingston, Knoxville, London, Meridian, Pulaski, Saint Louis, Tel Aviv, Tucson, West Midlands.

12. African villages (Riverson and Carapetis, 1991), 44 cities (Szalai *et al.*, 1972; Katiyar and Ohta, 1993; EIDF, 1994; Malasek, 1995; and Metrõ, 1989) and national data (Kloas *et al.*, 1993; Vliet, 1994; UK Department of Transport, Federal Highway Administration, 1992; Stab für Gesamtverkehrsfragen, 1986; Dienst für Gesaktverhekhrsfragen, 1992; Orfeuil and Salomon, 1993; Vibe, 1993; Federal Office of Road Safety, 1998; Olszewski *et al.*, 1994).

13. A. Gruebler (1990).

14. This type of reasoning illustrates the new awareness brought about by the famous curve in which Newman and Kenworthy demonstrate the existence of an inverse relationship between density and per capita energy consumption.

15. See Bieber, Massot and Orfeuil (1993), Kaufmann (2000) and also DRAST, Groupe de Batz (2002).

16. See the Revue 2001 Plus, DRAST (No. 58, February 2002).

17. It is interesting to note that each Disneyland is designed like a town.

18. Eurodisney, in Marne-la-Vallée (Ile de France), has a direct link to the TGV and RER (high-speed regional railway in the Paris region) and Roissy Charles de Gaulle airport is not far away.

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