JOINT TRANSPORT RESEARCH CENTRE

Discussion Paper No. 2009-14
December 2009

The Prospects for Inter-Urban Travel Demand

Yves CROZET
Laboratoire d'économie des transports
Lyon, France

TABLE OF CONTENTS

Lyon, October 2009

Mobility has increased enormously since the early days of the industrial era. Successive industrial revolutions have brought new, faster and relatively less expensive opportunities for both passengers and goods. If a contemporary of James Watt (1736-1819) or George Stephenson (1781-1848) were to return to Britain today, or to anywhere else in Europe, he would doubtless be astonished by the incredible mobility that is such an integral part of our activity schedules. His greatest surprise would not be at the number of our daily journeys (between three and four), or even the intensity – one might say the feverish pace – of our activity. Those features already existed in Europe's major capitals, and Paris traffic jams have been famous for centuries!

The great difference between our journeys and activity schedules and those of our forebears lies in the much longer distances we travel. By road, and even more so by rail and air, nowadays we can cover hundreds or even thousands of miles in a few hours. Inter-urban mobility is directly affected by these developments. Where international travel by coach and sailing ship used to take weeks, and intercontinental journeys sometimes even longer, we now count the time in hours. The transport revolution has played a major part in the economic history of the last two centuries (Niveau and Crozet, 2000), but it must be emphasized that the change has been gradual. Over two hundred years have passed between the stage-coach and the high-speed train, the clipper and the jet, during which technological progress and the higher speeds it enables have spread relatively slowly. Even with key technological revolutions like the railways, the automobile and the aeroplane, it took several decades for them to become available to the population at large.

From this slow percolation of technological progress into the way we live has arisen the idea that steadily increasing mobility is a structural given of modern society. Further, faster seems to have become the general rule, to such an extent that even space travel, so we are told, will become more widely available in the relatively near future. A few very wealthy people have already become the world's first space tourists.

It is the self-evident nature of this long-term trend towards increased mobility that we wish to examine in this report, since a number of factors could well undermine the relatively classic assumption that past trends will continue into the future.

- The first factor that comes to mind concerns energy-related and environmental constraints. Can a world with seven billion inhabitants, and probably nine or ten billion to come, support a way of life currently available to only a minority of its people? Will we have enough energy? Fossil fuels are not inexhaustible. Moreover, and well before they start to give out, they make a major contribution to greenhouse gas emissions and are used extensively in all forms of transport.
- Another issue, partly linked to the first, is that of the sustainability of economic growth. Higher mobility is directly linked to increased purchasing power and hence increased GDP. Aren't there limits to growth, as the Meadows report suggested thirty years ago?
- A third question, that of lifestyles, though related to the other two, deserves particular consideration. It may be posed in an exaggerated form by supposing the first two problems to have been resolved. Even if we have plenty of cheap energy, without any major external effect, and steadily rising purchasing power, are we and our descendants certain to choose lifestyles in which mobility increases continuously? What will mobility actually look like in thirty to forty years' time?

To answer all these questions, and in so doing to paint a picture of inter-urban mobility in the relatively distant future, we shall start by looking back into the past. Understanding the trends of recent decades is essential to understanding how they could develop and change in the future and where the turning points or breaks might lie. In the first part, our glance in the mirror will be informed by a consideration of the macroeconomic dimensions of the coupling of economic growth and mobility (European Commission White Paper, 2001), not forgetting the microeconomic foundations that shed light on individual behaviour.

In the second part, we will look at factors that have so far appeared constant and at the saturation effects that could call them into question. The scenarios that emerge when the mitigation policies needed to address energy-related, environmental and economic constraints are added to these spontaneous saturation effects are not necessarily a carbon copy of past trends.

1. THE COUPLING OF ECONOMIC GROWTH AND MOBILITY: FROM THE MACROECONOMIC PROOF TO THE MICROECONOMIC FOUNDATIONS

Many retrospective studies show that the mobility of people (and goods) is closely correlated with economic growth, giving rise to the idea of coupling between mobility and standard of living. According to this idea, it is impossible to separate rising standards of living from increasing mobility, whether at macroeconomic level, that of nations, or microeconomic level, that of individual choices. By describing the basis for this coupling, we will highlight the key factors of transport demand, especially passenger demand for inter-urban mobility. We will look at the factors first from a macroeconomic standpoint, then from a microeconomic standpoint.

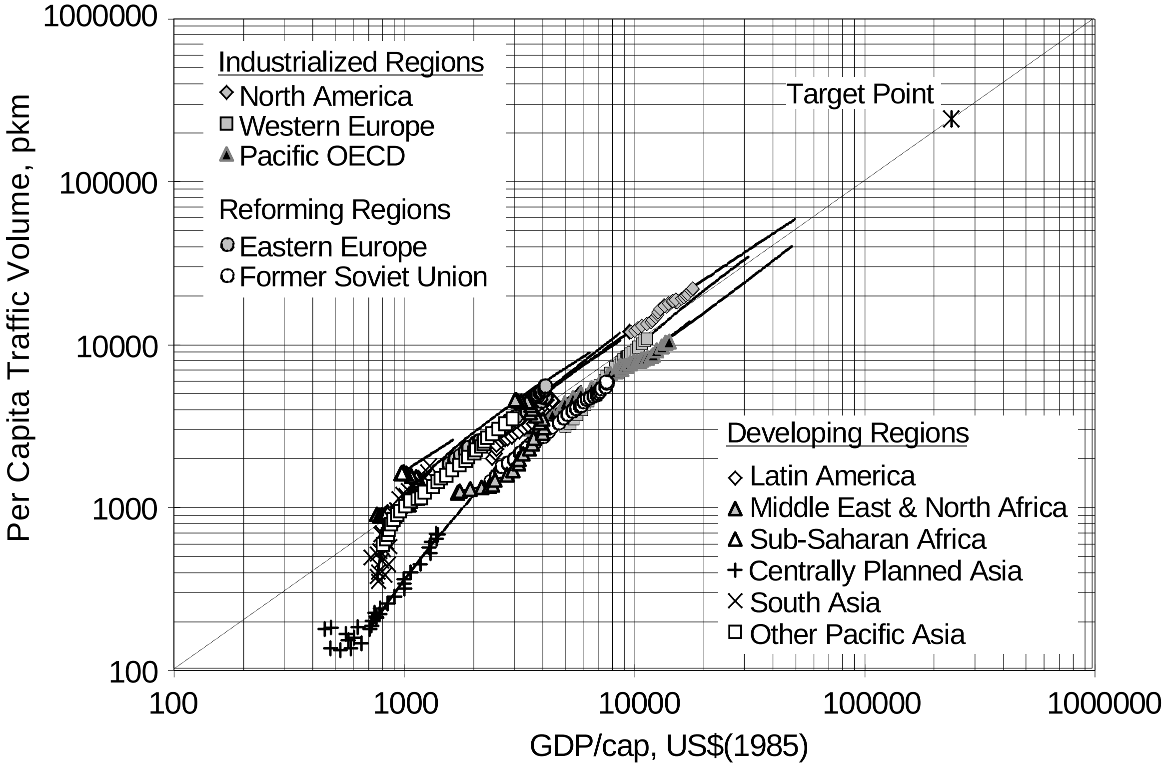
1.1. GDP per capita and transport demand: the "iron law" of coupling

When economists point out that this coupling has been a constant in recent economic history, whatever the country in question, they merely underline the part played by the key factors of economic growth and speed, i.e. the supply of transport and its technological capabilities in particular. We will begin by recalling the proof of coupling before showing that another factor must immediately be added to the key factor of economic growth, namely changes to the structure of transport supply.

1.1.1 Coupling between economic growth and mobility: how things stand

After painstaking data collection, Schäfer and Victor (2000) formally established the direct link between economic growth and mobility in the chart below (Figure 1). Using GDP per inhabitant in constant 1985 dollars as a presentational device, they were able to construct a graph in which the first bisector gives a surprising equivalence between the level of GDP and total annual mobility per capita. As most countries are located close to the first bisector, or approach it over time (from 1960 to 1990), one could almost say "Tell me a country's GDP per capita and I will tell you the average distance travelled over a year: one kilometre per dollar of GDP per inhabitant"! As the chart is constructed on a logarithmic scale, we may directly deduce a distance/GDP elasticity of 1. In other words, a given percentage of growth in GDP per capita is matched by an identical percentage of growth in the distance travelled over a year.

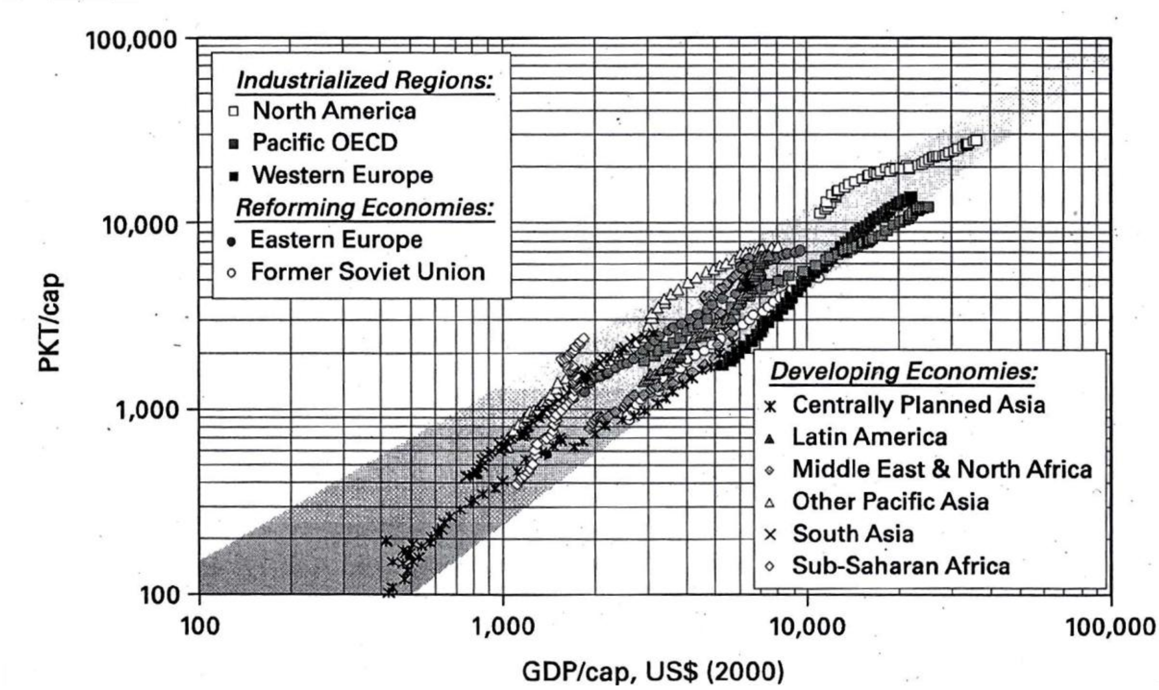
Figure 1 – **Total mobility in passenger kilometres per year**
(Data 1960 - 1990; Trends 1960 - 2050)



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

The data were updated in a recent study (Schäfer *et al*., 2009), this time including data on personal mobility until 2005, as shown in Figure 2.

Figure 2 – **Total mobility in passenger kilometres per year (Data 1950-2005; Trends 2005-2050)**



Source: Schäfer *et al.* (2009) *Transportation in a Climate-Constrained World*, MIT Press, p.36.

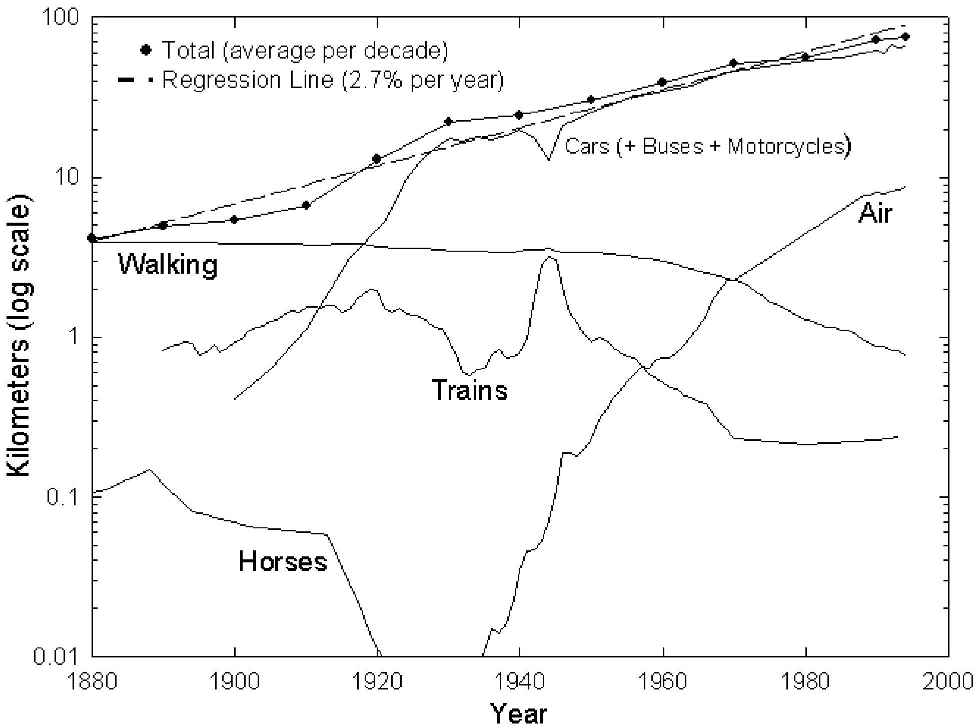
A comparison between Figure 1 and Figure 2 shows firstly that coupling is both real and long-standing. In this version, however, taking into account a calculation of purchasing power parities based on constant 2000 dollars, the first bisector effect is eroded. It becomes more difficult to deduce the level of annual mobility per capita from the level of GDP per inhabitant. Taking a standard of living of $20 000 on the *x* axis, levels of mobility vary widely, from 10 000 kilometres a year for industrialised countries in the Asia-Pacific zone to 20 000 kilometres a year for North America. That makes it more difficult in Figure 2 to establish a target point like the one in Figure 1. Yet that is what the authors do in Chapter 2 of their book. After emphasising the differences between geographical zones and the fact that the level of GDP does not wholly explain the level of mobility, they nonetheless put forward the possibility of a "target point" that could correspond to a distance of 289 000 kilometres per person per year (180 000 miles a year, or 791 kilometres a day!) and a standard of living of $289 000 (constant 2000). This point at which the various countries would converge is no aberration from an economic standpoint. Among economic growth theorists, the idea that affluence is destined to spread on a global scale is frequently assumed (R. Solow). Of course, a level of GDP per inhabitant of nearly $300 000 (constant 2000) currently seems extravagant, especially when the world as a whole and the United States in particular is in the middle of a severe economic crisis. But it would be possible if economic growth ran at 3% a year for 75 years, which would multiply GDP per inhabitant eightfold, more or less what has happened in the United States over the last 75 years!

This would bring us back to the logic of alignment on the first bisector. However, the authors emphasize that their world is a hypothetical one that could exist only if the average door-to-door speed for air transport (including travel to the airport and to the final destination) rose from its present level of 270 kilometres per hour to 660 kph, with a transport time budget (TTB) of 1.2 hours a day. The question of speed and time transport budgets is therefore essential to an understanding of past trends and likely future changes.

1.1.2 The key role of speed and the transport system

According to the French economist François Perroux, economic growth may be defined very simply: it is the growth of an indicator like GDP coupled with structural changes. But these structural changes are often neglected even though they play a key role in the process of per capita output growth. During industrialisation, overall productivity rises only because highly productive sectors account for a relatively greater share of total output. The same applies to mobility, as can be seen from the chart below illustrating the situation in the United States in the 20th century. We can see a steady rise in personal mobility (+2.7% a year), which tracks the rise in GDP per inhabitant over the same period. However, if the average daily distance travelled by an American has risen from 4 km in 1880 to nearly 80 km today (Schäfer, 2009) it is because fast modes have gradually replaced slow modes, allowing the average distance travelled by a person in a year to increase twentyfold.

Figure 3 **– Distance travelled in km per person per day since 1800 in the United States**

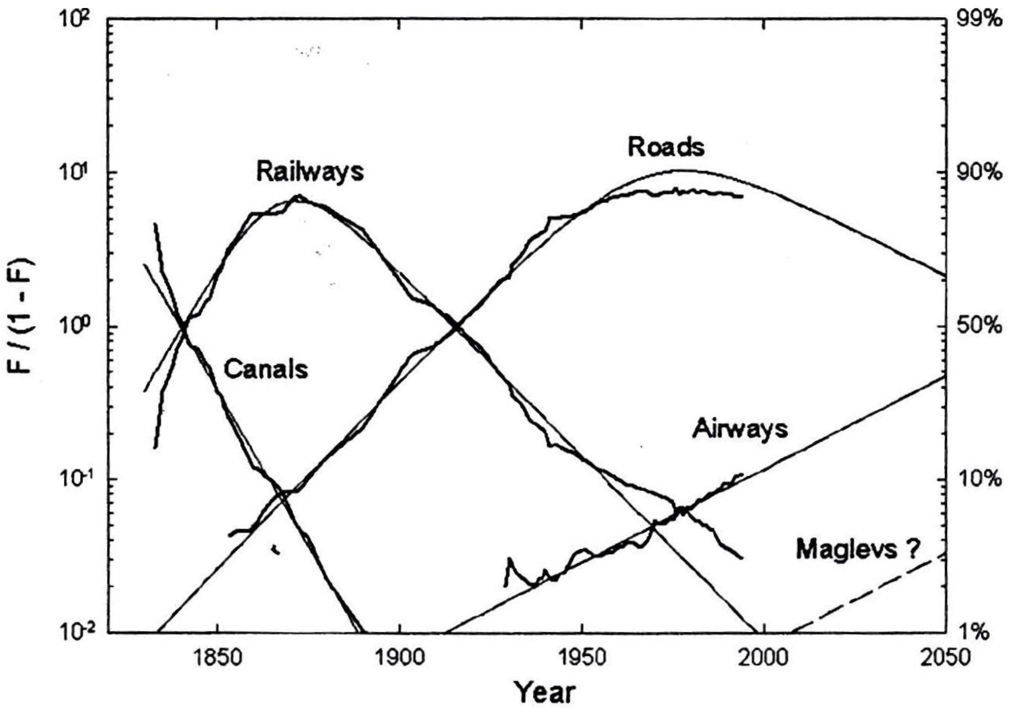


Source: Ausubel J.H., C. Marchetti, P.S. Meyer.

The fact that the coupling is constant therefore presupposes lasting structural changes. The average distance travelled by an American has steadily increased because the automobile has gradually replaced not just the train but also walking and horse-drawn carriages. The construction of a vast network of roads then highways has played a central role in this development. It is not enough for cars to be capable of going fast for journey speeds to rise: transport infrastructure also has to be suited to the capacities of the vehicles that use it.

From this standpoint of permanent structural change, the relative obsolescence that hit the railways in the early 20th century may now be affecting the automobile. In many developed countries, distances travelled by car are no longer increasing, not because total mobility has decreased but because some travel has shifted to faster modes like high-speed trains and aircraft. The growth in the relative share of air transport, perceptible in Figure 1, has been identified as a structural trend by Ausubel, who emphasizes the potential role of magnetic levitation trains[1]. For if it is necessary to continually develop the fastest modes, the history of transport could be depicted as a succession of technological waves. With each new wave, a new transport mode sees its market share increase at the expense of other, slower modes. Then, after reaching a certain level of development, it is itself superseded by another, faster mode.

Figure 4. **Total length of transport infrastructures in the US in market share**



Source : Grübler 1990 (an airline service is considered as a transport infrastructure).

Each new transport mode is faster than the previous one and hence increases the total volume of traffic. The mechanism derives from an implicit assumption that should really be made explicit: the relative constancy of time budgets devoted to mobility. In order for faster average travelling speeds to cause total traffic to rise, it must be assumed that at least some of the time savings are reinvested in additional distance. This hypothesis of the quasi-constancy of time budgets is familiar, in relation to daily mobility, as the Zahavi conjecture. Although it does not directly concern the interregional mobility that is our subject here, we can use the conjecture as an aid to comprehension. We may not

1 On the potential of air transport and maglev, see the papers presented at this Symposium respectively by D. Gillen and by K. Yamaguchi and K. Yamasaki.

yet be able to explain why, but the close link between economic growth and mobility is equivalent to an assumption that speed gains are reinvested in a trend increase in distance travelled (Crozet, 2005).

From the link between distance travelled and GDP, we can therefore move on to another link, namely the one between speed and GDP. If, like Schäfer, we start from the assumption that the total time budget devoted to transport does not decrease, or could even increase slightly, from 1 to 1.2 hours a day, economic growth should be accompanied by an increase in the average speed of travel. In the case of the target point mentioned earlier (289 000 kilometres a year for per capita GDP of USD 289 000), Schäfer *et al.* envisage a speed/GDP elasticity close to 1.

This brings us to the key macroeconomic relationship for understanding how the coupling became so entrenched in recent decades and how it could be called into question in the decades to come. How will the link between average travel speed and GDP evolve in the future? Will the speed/GDP elasticity gradually decline until a certain uncoupling is achieved or, as has been the case in recent decades, will it remain close to 1? In order to answer this question we need to introduce new factors that determine transport demand, including the cost or price of mobility, at the intersection between macro- and microeconomics.

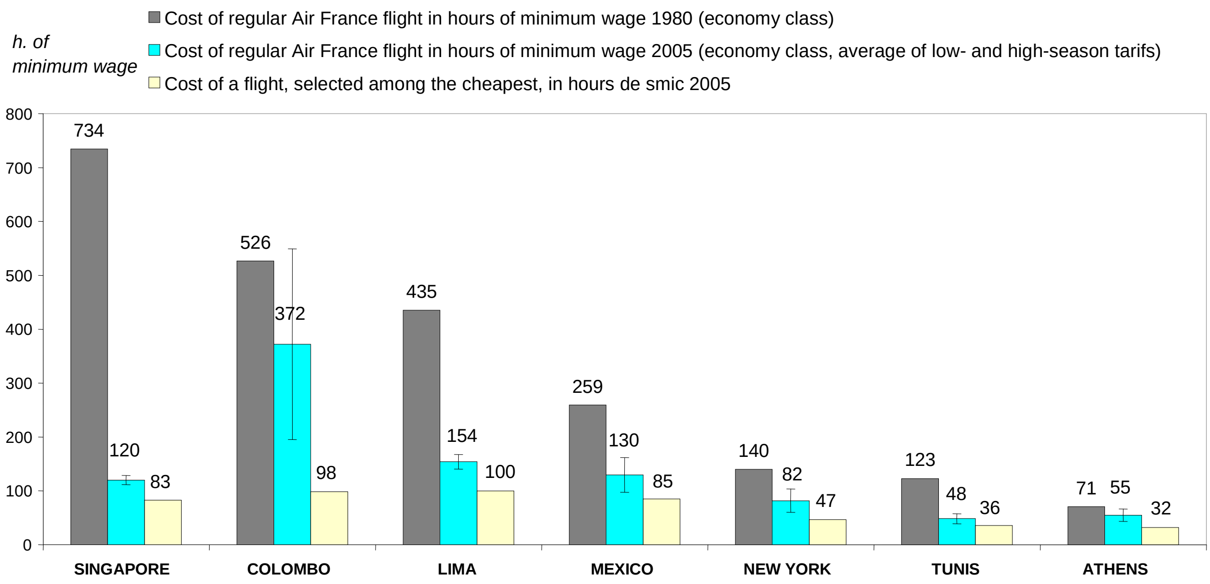
1.1.3 Price and income effects: from the monetary cost to the generalised cost of transport

The target point mentioned by Schäfer and Victor corresponds to a total distance of over 700 kilometres per person per day. Although that is already the case for a handful of frequent fliers[2], is it realistic to suppose that such a lifestyle might become widespread? The question can be asked for the simple reason that transport has a cost not only for mobile individuals – a monetary cost and a time cost – but also for the community, which often has to subsidise infrastructure and in some cases current operations as well.

As regards the monetary cost, Schäfer *et al.* emphasize the trend decline in transport costs. The cost per kilometre of rail travel fell from 20 cents to 5 cents (at constant 2000 dollars) between 1882 and 2002. This fourfold reduction in the real cost should be taken in conjunction with the tenfold increase in per capita GDP over the same period. The experienced cost of mobility has fallen enormously. This combination of price effect and income effect has been a powerful stimulus to mobility. The same phenomenon can be seen in Figure 5 which shows, for France, the change in the price of an air ticket expressed in terms of the number of hours' work needed by a person paid the minimum wage.

[2] The writer himself travels about 100,000 km a year, half of it by high-speed train and a quarter by air, representing nearly 275 km a day for an average transport time budget of about two hours a day.

Figure 5 – **Price of air tickets from Paris to various destinations in hours of minimum wage equivalent (1980-2005)**



Extract from thesis "Optimisation Spatio-Temporelle des Déplacements Touristiques", V. Bagard, LET 2005.

As we can see, the number of hours' work needed to buy a ticket for a typical flight has decreased considerably. The most spectacular fall is in an economy class flight to Singapore, which has dropped from 734 to 120 hours at the minimum wage in France. The reduction is lower for Colombo, a less popular destination for which high- and low-season price differences are still great – so much so, in some cases, as to wipe out the trend decline. It is also instructive to see from this chart that competitors to Air France exist, offering lower prices and leading to an almost tenfold reduction in the cost in terms of hours' work of a ticket to Singapore.

What we have here is a powerful factor behind the growth of air transport, especially as it is less avid for public subsidy than other modes. Most major airports are profitable. To a considerable extent, airport fees and en route charges cover public expenditure on air transport. The same cannot be said of rail transport, especially high-speed trains. The fact that trains require heavy ground infrastructure, which is not the case with aircraft, is a thorny problem for public finances and one to which we will return in the second part. If higher speeds require substantial investment in infrastructure, where is the money to come from? And to what extent can the cost be passed on to users? Should public transport subsidies, which are the rule in urban areas, be extended to inter-urban travel? As we can see, it is not possible to consider the distance/GDP or speed/GDP elasticity without also looking at the question of the cost, for both users and the public purse (Crozet, 2007).

Alongside the monetary cost, the second component of the generalised cost must also be taken into account, namely the cost of time spent in transport. Taking Schäfer's target point, which may serve here as an extreme illustration, travelling more than 700 km a day presupposes very high-speed transport modes. But 660 kph door-to-door may well be difficult to achieve. A significant increase in the time budget devoted to transport must therefore be envisaged. To lay the basis for a forward-looking consideration of inter-urban mobility, we cannot therefore satisfy ourselves with retrospective correlations between economic growth and mobility. We must look for factors that could call past trends into question, and in order to do that we need a better understanding of what motivates individual behaviour. Why does affluence cause us to increase our mobility, including perhaps our transport time budgets? And what mechanisms could undermine this trend?

1.2. When time becomes the "scarcest resource": the "iron law" of diminishing marginal utility

One of the main effects of increased purchasing power is to give us access to a growing number of goods and services. But constantly pushing back the limits of scarcity has not caused the problems of arbitrage that are at the very heart of economics to go away. Encapsulated for Milton Friedman in the famous "no free lunch" quip, the principles of economics do not cease to apply when abundance prevails. Quite the opposite in fact: the very fact that we have a host of goods and services before us will oblige us to make choices, and hence to abandon certain options in favour of others. What are the factors that guide transport demand where inter-urban mobility is concerned?

1.2.1 Intensification of consumption and growth of mobility

Mobility and mobility-related choices present economists with particular problems. The first is linked to the fact that transport is not as a rule sought for itself. Travel demand is derived, a form of joint consumption that is secondary to the linked activity. People do not generally travel for travel's sake but in order to do something else. However, calling travel secondary is probably too reductive for an understanding of transport demand. It would be more accurate to say that travel is subsidiary, insofar as it brings something more to the activity if only by making it possible. So there is something to be gained from studying the demand for travel in itself, taking account among other things of the costs it generates compared to the utility it procures. This can be regarded in two ways.

- From the traditional microeconomic standpoint of consumer choice, it is customary to draw a distinction between inferior, normal and superior goods. These categories help to describe the most commonly observed preferences. As E. Engel then H.H. Gossen showed over a century ago, when income increases consumption of inferior goods declines relative to the other categories. Symmetrically, the proportion of superior goods in household budgets will increase. This applies, for example, to spending on healthcare or education, which ultimately grows faster than income, in contrast with spending on food, which increases much more slowly. Spending on mobility traditionally lies between these two extremes and tends to fall into the "normal" category, where consumption rises more or less in line with income. That is precisely what Schäfer and Victor's chart tells us: reasoning in terms not of a proportion of income but of distance travelled, demand for mobility, a normal good, should increase at exactly the same pace as income.

- As we have already mentioned, however, this trend poses another problem of arbitrage if, like G. Becker or S. Linder, we extend the microeconomic reasoning to the scarce resource of time. If the average rise in speed means that distance travelled can increase in the same way as income without affecting the transport time budget, the arbitrage seems straightforward, in favour of the status quo represented by the constant transport time budget hypothesis. In other words, as time is a scarce resource whose value increases with income, the time component of the overall cost of transport also increases with income. This cost increase should militate against a rise in mobility unless it brings utility gains that exceed the cost increase.

We must therefore take a look at the utility gains resulting from increased mobility. To do so, let us see what S. Linder has to say on the subject. For him, the "leisured class" is not the one described by

T. Veblen in the early 20^{th} century. Like other people – even more so in fact –, the idle rich are confronted with the need to constantly choose between different options. The relative scarcity of time compared to the amount of available income is their chief concern. General affluence has extended this type of problem to a large proportion of the developed world's population, including the working population, to the point where time has become the "scarcest resource". As we recalled earlier, average income increased eight- to tenfold during the 20^{th} century, and even more in many industrialised countries, while life expectancy has risen by only a third. As consumers, we therefore face de facto competition between the goods and services made accessible by higher incomes. Yet using many goods and services takes time. In order to solve this equation, we must achieve a trend increase in the quantity of goods and services used per hour available. That in turn means moving towards increasingly intensive lifestyles.

From this standpoint means of transport, especially fast modes, become a powerful way of intensifying consumption, not only because transport itself is a service but also because it gives access to a much wider range of goods and services. The expansion of tourism, especially to exotic destinations, is a perfect illustration. A few days' holiday by the Mediterranean or even much further afield, in the USA or the Maldives, for example, gives our activity schedules an intensity that bears no relation to what we can get from a visit to cousins in the next village. This leisure-related mobility is based on the same determinants as business mobility, the second key component of inter-urban mobility. Intensification processes are at work in both cases and mutually reinforce each other. The intensification of leisure activity (doing more in less time) becomes the pendant to the intensification of business activity in its classic form of higher productivity. The two movements combine to support economic growth, as if to serve as a reminder that the cause-and-effect relation of coupling goes not only from growth to mobility but also in the other direction.

Taking a look at some indicators of leisure activity, the figures speak for themselves.

- During the 1990s, the "leisure and culture" item in current expenditure rose by 16% in the UK, 13% in the USA, 2% in the Netherlands and 1% in France. Some activities very closely related to leisure, like theme parks, leisure centres and above all air travel, are expanding rapidly. The same applies to package tours and all modern forms of a tourism, which implies systematic recourse to market activities. The most significant outcome is the rise in the number of jobs directly or indirectly linked to leisure.
- For the vast majority of people, leisure time is not in contradiction with the consumer society. Although J. Dumazedier was right to point out that leisure was produced by the trend decline in working hours, his predictions about the "leisure civilisation" do not appear to have come to pass. Although working time has fallen on average on the scale of a lifetime, nevertheless we do not feel that we have more time. On the contrary, the abundance of available goods and services and the growing diversification of possible choices increase the pressure on our time budgets.
- The very notion of a time budget underlines the importance of the economic rationale in our behaviour. A philosopher like P. Sansot may sing the praises of slowness and encourage us not to let ourselves be devoured by the race against time characteristic of modern life, but his book has been only moderately successful. As Linder predicted, if we are dealing with a leisured class it is a harried one, flitting from one activity to the next thanks to mobility.
- What we can see here is the iron law of diminishing marginal utility, and its cutting edge becomes sharper as incomes rise. The greater our purchasing power, the faster the marginal utility of a given activity diminishes because other competing activities exist, made accessible by the higher income. Transport is a condition that allows access to these potential activities, especially if the speed increases and the relative price falls.

So it is not surprising that mobility should increase more or less in line with income, since it is merely the condition that allows the variety economy to develop (R. Gronau, 1975). We may also note that the same symmetrical movement animates both passengers and goods. If people do not travel to consume a particular good or service, the good or service comes to the consumer thanks to a mobility that is no less great than that of travellers – quite the opposite in fact!

1.2.2 Speed and the optimisation of activity schedules

Greater mobility is thus a logical sub-product of higher income. Higher speed is a coherent response to the quest for increasingly varied and intensive consumption. However, intensification in turn imposes particular constraints on activity schedules linked to the trend rise in the value of time. When income rises faster than the amount of time available, the value of time also increases, which means that the time budget we are willing to devote to each activity is potentially smaller. Let us take an example. If you spend four hours a day reading and then buy a television or a computer connected to the internet, the utility of the screen will be compared with that of reading. The time spent reading may well fall sharply, as we can see today among children and young people.

The key problem for individuals in today's world is therefore that of time management. Time is a scarce resource, so how should we allocate it to our various activities? One solution is of course to increase the total amount of time available, for example by cutting down on sleep or spending less time on what we regard as our least interesting activities. Lifestyle surveys tell us that the average amount of time we spend asleep has decreased by about an hour in less than a century. But, as Linder predicted, we have also greatly reduced the time we spend looking after our houses and the goods at our disposal. There are so many goods available to us that we are no longer able to devote a lot of time to each one[3].

Can this reasoning be applied to transport time? Since time is a scarce resource, couldn't we reduce our mobility in order to save time and increase the utility of our activities? That is the advice of the slowness devotee: give time more time, allow each activity time in which to flourish, don't flit continually from one activity to another. Even though it may sound sensible, we need to understand that singing the praises of slowness or duration, like the novelist Milan Kundera, calls into question the central assumption in microeconomics of diminishing marginal utility. That is not something to be taken lightly, since the opposite reasoning consists in supposing that the marginal utility of an activity increases, or at least does not diminish, with its duration. Is that realistic when the standard of living is rising? To answer that question it is crucial not to forget that transport demand is derived, a joint consumption associated with other activities. What is at stake is not primarily mobility *per se* but the growing diversification of activities.

For the time being, what we can see is not a reduction in transport time budgets but a reduction in the average duration of each of our activities. We do more things, spending less time on each. But the time devoted to transport does not diminish because maintaining it, together with higher speeds, is the precondition for the increase in the number of our activities. We will demonstrate the truth of this from the example of leisure, a powerful factor behind the rise in inter-urban mobility.

3 This would explain the growing mess in young people's rooms and, increasingly, in the dwellings of young households.

1.2.3 Rise in the value of time and fall in the average time spent on activities: a powerful factor of long-distance mobility

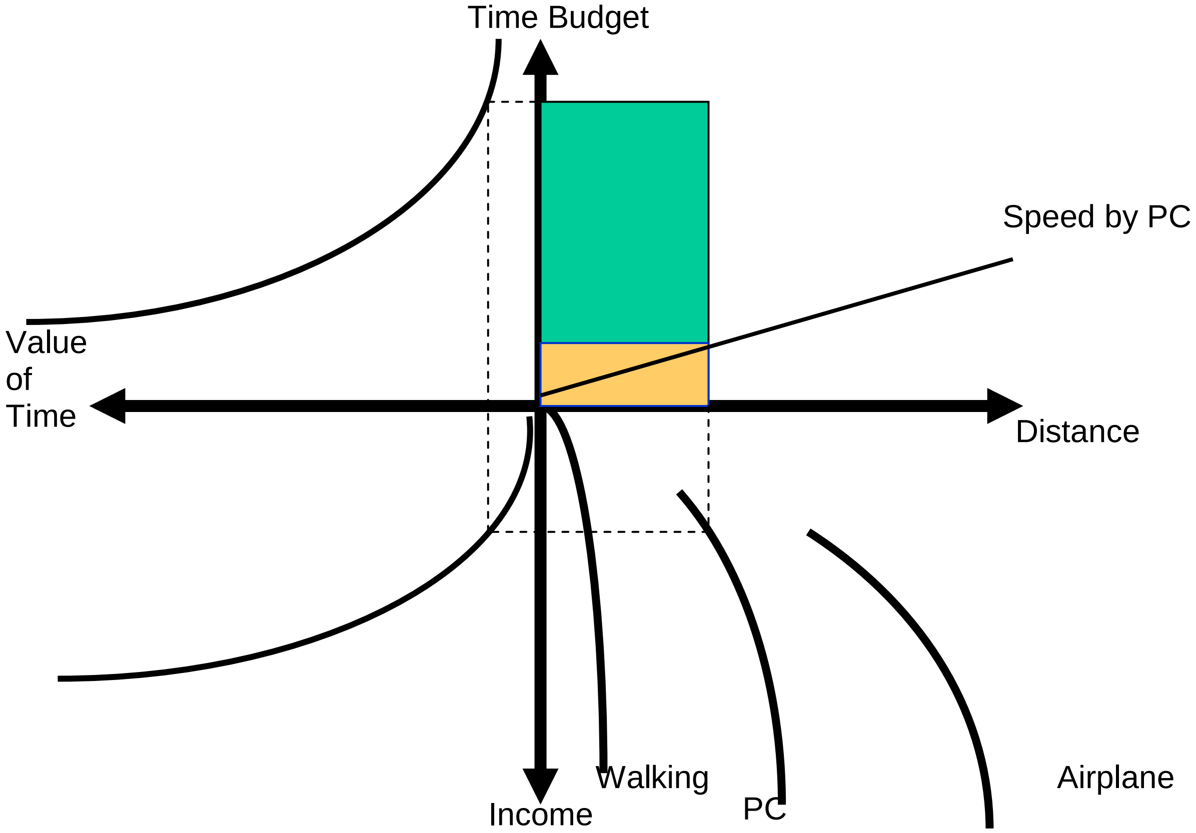
Farther, faster, more often, for shorter periods. Those, in a nutshell, are the trends that underlie our leisure behaviour, as specialists on the subject like J. Gershuny, F. Potier and J. Viard have shown. People take holidays more often but for shorter periods and travel further. How can we explain this paradox, this diversification of destinations coupled with a reduction in the length of stays?

The fact that the trend in our leisure behaviour is towards shorter stays, paradoxically with longer travel distances, is only one aspect of the development of the demand for variety (Gronau and Hamermesh, 2001). The distinguishing feature of modern lifestyles, and what makes them more attractive than previous forms, is the incredible variety of goods and services on offer. But faced with this variety, our choices result from the simple combination of a few key variables. The income level and the value of time combine with the speeds offered by different transport modes as shown in Figure 6[4]. Each axis corresponds to a key variable:

- the south axis represents the level of income;
- the west axis represents the value of time;
- the east axis represents the average distance travelled;
- the north axis represents the length of stay.

[4] This figure takes up and amends an analysis put forward by R. Gronau (1970) which took account of the generalised cost of transport (see Annex 2). As we want to emphasize the key issue of scarce time, we prefer to insist on the average length of stay and average travelling time.

Figure 6 – **Key variables for the length of holiday stays**



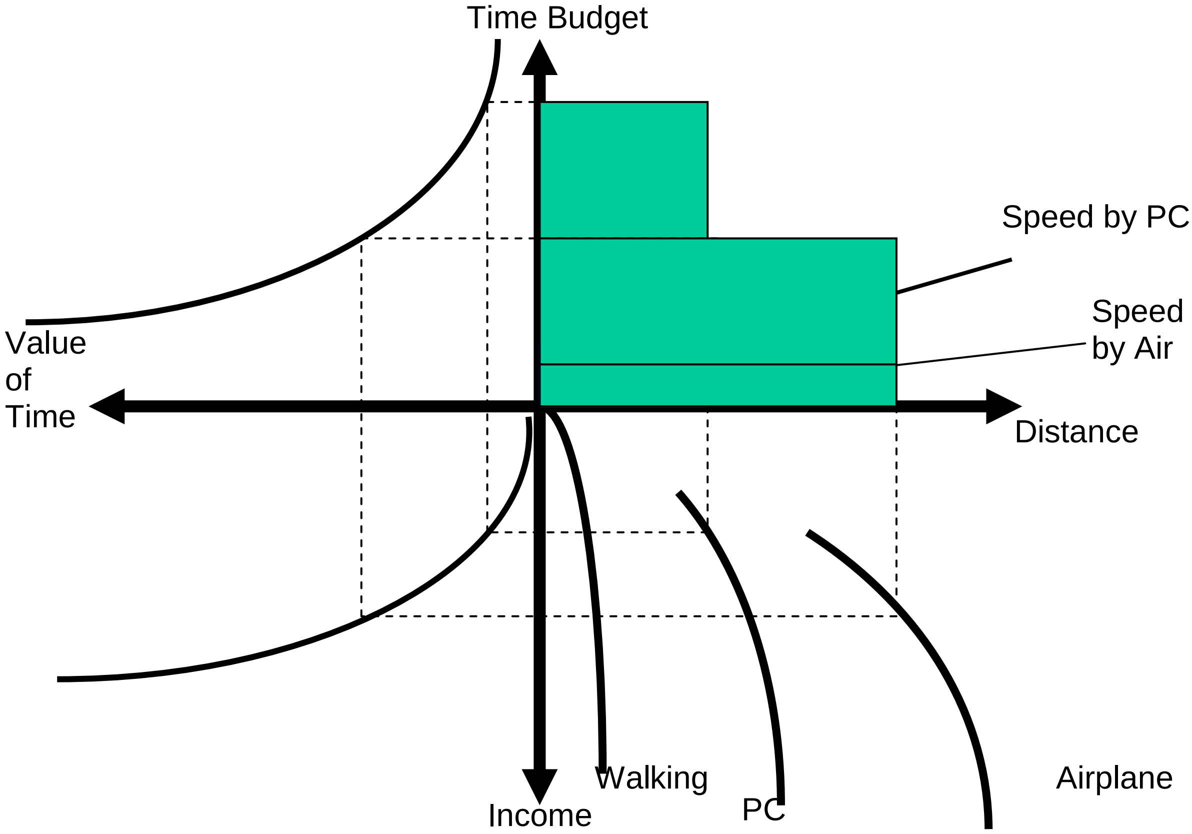
Source: After V. Bagard, 2005.

At the intersection of the axis pairs, each quadrant indicates the typical relations between the variables.

- The south-west quadrant assumes that the value of time increases exponentially with income. In other words, the richer we are, the scarcer and more valuable time becomes.
- The north-west quadrant follows on logically from the previous one. If income and the value of time both increase, the time budget we devote to each activity (in this case each leisure trip) will tend to decrease since the competition between the range of potential activities will cause the marginal utility of each activity taken separately to diminish more rapidly.
- The south-east quadrant shows the average speed offered by each transport mode, represented here by the average distance of possible journeys with a given mode. Walking offers few possibilities at whatever income level. In contrast, rising income progressively gives access to increasingly expensive but increasingly rapid modes, such as road, high-speed rail and air travel.
- The north-east quadrant shows schematically the outcome of the interaction between the different variables, giving an average length of stay determined by the level of income, the value of time and speed (the distance of accessible journeys). All these are linked to a ratio which reveals that transport time represents a certain part of the total length of stay.

The stylised facts summarized in Figure 6 are typical of the way family holidays used to be in the 1960s or 70s: a car journey for a relatively long stay (two to three weeks) in the same place. The rise in incomes and in the value of time, combined with new, rapid transport modes, would gradually change this situation, as shown in Figure 7. Access to higher speed was first reflected in an increase in the average distance travelled. Holiday destinations became more and more exotic. But as the increase in speed went hand-in-hand with a rise in the value of time, and hence a reduction in the average length of stay, the result was not a fall but a rise in the ratio of journey time to total length of stay. At the risk of departing from the constancy assumption in this ratio (Mokhtarian, 2004), higher speeds result in the leisure sphere in an increase in transport time as a proportion of the total time spent on the activity. Given the increased utility drawn from the long-distance journey, a higher transport cost is accepted and the transport time budget is pushed up. It is one more reason why time scarcity becomes more acute with the increase in speed and income.

Figure 7 **– Key variables for the length of holiday stays with access to air travel**



Source: After V. Bagard, 2005.

The businessmen and women and academics who read these lines are familiar with what is going on here. Thanks to the speed of air travel, they will often make a two- or three-day trip from one end of Europe to the other or from Europe to the United States for a conference, seminar or thesis committee meeting. The same rationale applies to business trips (which, let us remember, are included for statistical purposes in the general category of "tourism") as to family holidays: farther, faster, more often, for shorter periods. Will the trend continue in the years to come?

2. OUTLOOK FOR INTER-URBAN MOBILITY: SATURATION AND MITIGATION AT THE SERVICE OF DECOUPLING?

At a time when sustainable development stands at the top of the agenda, not only for governments but also for business and consumers, there is clearly something to be gained from asking whether mobility can keep on increasing indefinitely.

One simple answer to the question is sometimes given under the heading of degrowth, or zero growth. Proponents of this idea consider that coupling is not merely a correlation but a cause. Economic growth, they argue, lies behind mobility growth. For mobility to be more sustainable, all you have to do is stop growing (Georgescu-Roegen, 1979)! The reasoning behind such a view may seem seductive in its simplicity, though it verges on the simplistic: economic history teaches us that a relation between two variables is not necessarily linear over a long period. The real interest of the notion of sustainable development as described in the Brundtland Report lies in the fact that it goes beyond the simplistic idea that you have to stop growing in order to solve the problems. Sustainable development does not reject growth but seeks – and this is more difficult – to modulate its impacts, as is the case with the notion of mitigation now used extensively in research into environmental issues. In the transport sphere mitigation takes the form of decoupling, which boils down to studying the conditions under which the relationship between economic growth and personal mobility would no longer be linear. Let us therefore maintain the hypothesis of continuing economic growth, even if we are currently in the middle of a full-blown recession.

The fact that the current economic crisis has cut not only air travel but also high-speed rail and even motorway travel should not distract us from the need to take a long-term view. Even if the recession were to go on longer than hoped, and even if the recovery were to be slow, resulting in lower long-term trend growth, that does not mean that we should stop thinking about decoupling, if only because economic growth is continuing in many countries around the world, like China and India, and is accompanied by strong demand for mobility. Fast transport modes like high-speed rail and air travel are continuing to expand. Many countries are building new high-speed rail links. In the air transport sector, companies like Ryanair and EasyJet are carrying more and more passengers despite the crisis.

On the supply side, factors that encourage mobility growth will undeniably be present in the coming years. But it is worth recalling and comparing other factors that could impede the continuation of past trends and even lead to a certain uncoupling of economic growth and mobility.

- First, there is the environmental factor and the commitment to reduce greenhouse gas emissions. One outcome could be tighter restrictions on transport modes that consume the most fossil fuel, which emits large amounts of CO_2.
- Next comes public policy, which is very closely linked. Public policies, in the form of charging, taxation or regulation, can play an important role, especially by encouraging a shift towards transport modes that are not only cleaner but also use up less public space. Modal shift is often sought as a means of reducing the adverse effects of mobility. This would not be decoupling per se (i.e. economic growth with no mobility growth) but a relative decoupling

resulting from a favourable structural effect. The replacement of existing technologies with new, cleaner technologies would allow for an increase in traffic while reducing the external effects of transport, especially CO_2 emissions. The other question that arises, apart from that of the transport mode, is the cost of mobility. Higher energy prices together with less generous subsidies or new taxes, like a carbon tax, could encourage a certain degree of decoupling.

- Changes in individual behaviour will be decisive. Linked to public policy but also as a result of spontaneous changes in preferences, what can be expected from mobility demand? Can we look forward to a certain saturation of demand for inter-urban transport?

We will start in Section 1 by looking at individual behaviour and saturation before describing some scenarios for mobility in France to 2050. This will generate visions of the future (Section 2) in which saturation and mitigation are combined.

2.1. Decoupling and saturation: moving towards a change in individual preferences?

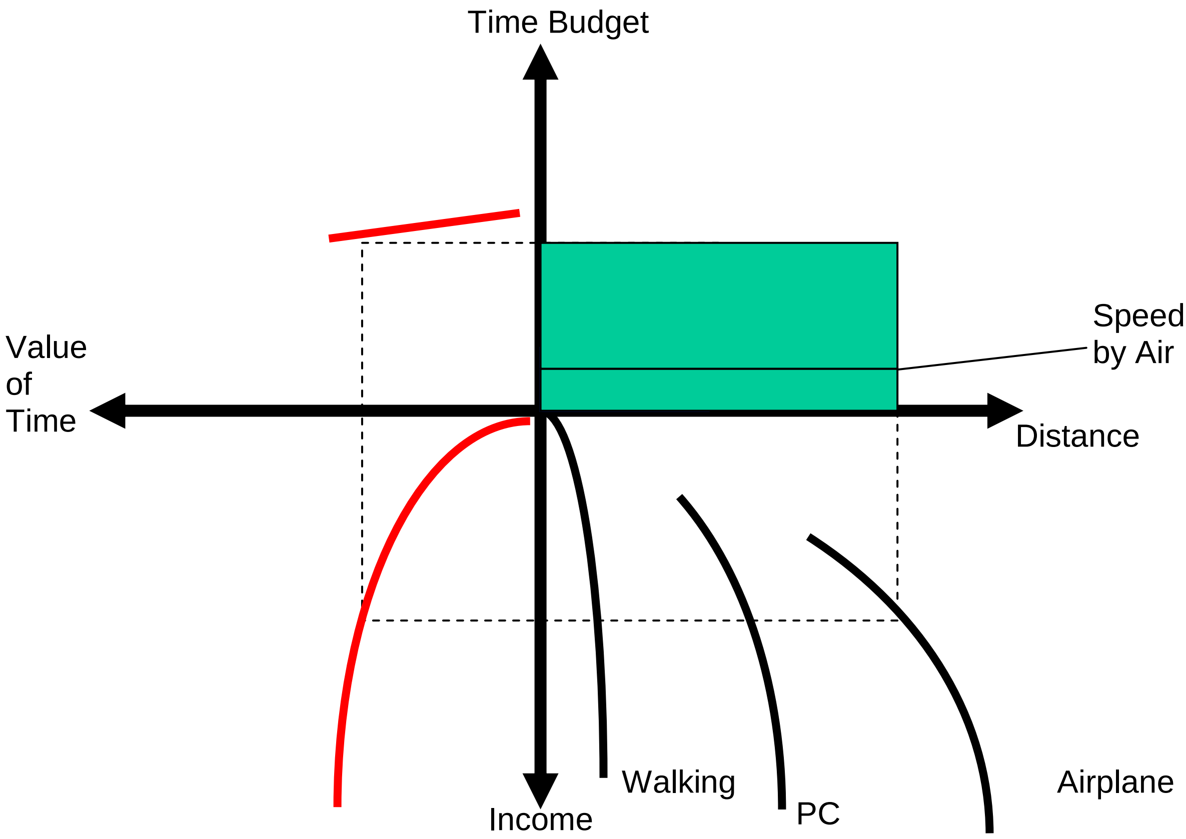
Taken literally, the phrase "farther, faster, more often, for shorter periods" poses logical problems. As we have seen, one trend effect of a rise in the number of activities is to reduce the amount of time spent on each one until it becomes very short. If it also leads to a trend increase in the ratio of transport time to activity time, it is easy to understand that the quest for utility cannot be a permanent quest for speed and more activities. Would it not be possible, then, to imagine a saturation effect which, by limiting the number of activities and hence of journeys, would encourage a minimum amount of time to be spent on each activity? Such an effect may already be at work in the industrialised world, especially in Europe, where automobile traffic has barely increased since the early 2000s. Is it the first sign of uncoupling linked to a saturation of demand for mobility?

2.1.1 The limits to variety and to the fragmentation of activity schedules

With the effects of the economic crisis, a reduction in business travel has been observed since late 2008. Many firms have sought to cut travel expenses and to replace long-distance travel with communications and video-conferencing. Even before the recession started to bite, sociologists like S. Kesselring had observed a certain "disenchantment" among heavy business travellers. The growing amount of business travel and the associated cost in terms of fatigue is starting to become a specific human resource management problem in firms. In the academic world, we are starting to see thesis defences in which some committee members participate by videoconference. Likewise, with the economic crisis, travel agents and tour operators have noticed a fall-off in demand for travel to exotic destinations and symmetrically, especially in France, a preference for nearby tourist destinations.

This downturn in demand for long-distance transport, perceptible in the decline in air traffic, is for the time being consistent with the stylised situations shown in Figures 6 and 7. Lower income is logically reflected in a decrease in distance travelled and average journey speed, accompanied by a reduction in the value of time and a lengthening of stays. In this instance the trends are still driven by coupling, where economic growth and mobility move together in the same direction, whether up or down. The question is therefore whether the economic crisis is merely a parenthesis or whether it could herald a lasting shift in behaviour towards a certain frugality. Could we see in the future both a rise in income and a saturation of mobility? Figure 8 sketches an initial theoretical answer to that question. As we can see, the key issue is the value of time and its impact on the trend towards the fragmentation of stays.

Figure 8 **– Income, speed and the value of time: another relationship between the variables?**



Source: After V. Bagard, 2005.

If, as we can see here, the value of time grows not exponentially but rather logarithmically in relation to income, the relation between value of time and length of stay could take a different form, with the emergence of the equivalent of a minimum duration. The crux of the matter is whether such a hypothesis is realistic. What could prompt people living in developed countries to reduce mobility growth and the associated diversification of activities? The answer could well lie in the limits reached by the fragmentation of activity schedules and the related "zapping". An ageing population could be one factor that triggers such a trend reversal, though it should not be linked to the diminished physical capacities of older people. On the contrary, all the indicators point towards an increase in life expectancy without disability, and retired people are not those who least use cars, trains or aeroplanes for long-distance travel.

What we need to envisage with ageing and affluence is rather a certain wisdom in the use of time, for example by questioning the tendency to reduce the average duration of each activity. Consumption could be intensified not by increasing the number of activities but by giving each one the amount of time it needs to flourish. As S. Linder has suggested, a wise attitude towards growing affluence does not only consist in constantly increasing the quantity of goods and services consumed per hour. For some activities, can we not also seek to preserve a minimum value for the ratio of time spent per quantity of goods or services consumed? The question is worth asking for long-distance travel, where transport time most eats into the length of stay. Among those who already have access to it, might we not see a trend saturation in this type of travel?

2.2. Is decoupling of GDP and passenger mobility already taking place?

Where car journeys are concerned, that question can be answered in the affirmative. If the most recent report from the European Environment Agency is to be believed (EEA Report No. 3, 2009), decoupling in relation to passenger mobility in Europe has already started.

Figure 9 – **GDP and total passenger mobility in Europe**

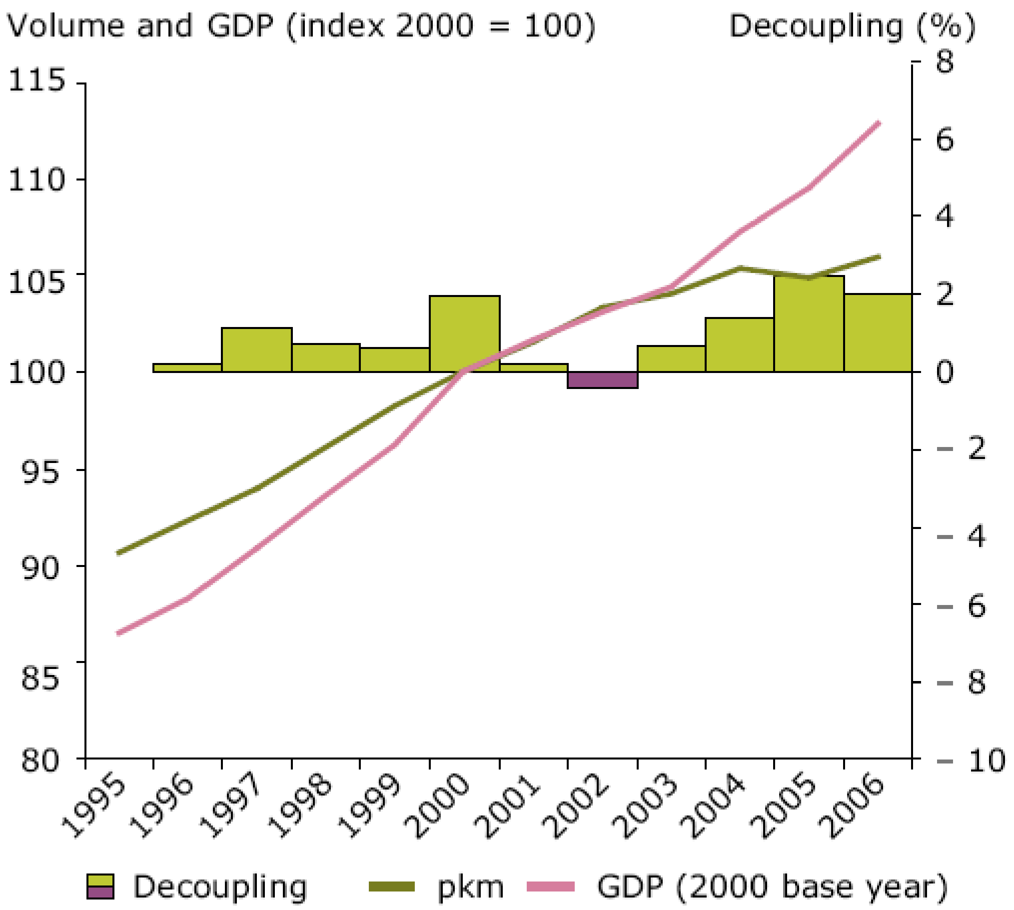


Figure 9 shows that for passengers, unlike freight, GDP growth is generally significantly higher than the trend in overall traffic. The difference between the two confirms the decoupling hypothesis except in 2002, when coupling occurs. The new situation is mainly attributable to relative saturation. Table 1 shows passenger mobility in the major EU countries. In Germany, the UK, Italy and France, domestic passenger traffic has been more or less flat since the early 2000s.

Table 1: **Passenger traffic in the major EU countries (in billion passenger-kilometres)**

Year	1995	2000	2001	2002	2003	2004	2005	2006
Germany	954.8	975.7	997.1	1001.9	996.6	1009.6	998.9	1014.1
France	737.3	812.2	840.1	848.9	853.1	855.3	848.1	848.7
Italy	745.7	867.2	860.0	854.8	854.6	865.2	840.2	845.5
UK	692.6	725.4	740.3	763.9	766.2	770.3	770.4	773.0

Source: European Environment Agency, 2009.

This relative levelling-off of mobility is all the more remarkable insofar as it occurred in a period of fairly significant economic growth. However, it also corresponds to a period of rising fuel prices that hit car drivers particularly hard. The phenomenon accelerated in 2008 when forecourt petrol prices soared in the space of a few months. The number of cars sold in Europe declined significantly over the same period. It was as though the automobile, which accounts for the vast majority of passenger kilometres, had reached a relative obsolescence marking the end of a golden age. Rising petrol prices, combined with constant congestion and speed limits, revealed a trend towards relative saturation. Journeys in urban areas were most affected, together with long-distance journeys facing competition from air and high-speed rail travel. So is this saturation of automobile use really the sign of decoupling or does it merely mark a transition towards fast modes like high-speed trains and aeroplanes?

2.1.3 The persistent growth of long-distance mobility

The European Environment Agency data in Table 1 must be set in context since they relate to domestic traffic in each country. The results are not the same if international traffic, especially air traffic, is included. Sufficient evidence can be obtained by comparing data on transport-related greenhouse gas emissions included in and excluded from the Kyoto Protocol.

- For the 27 countries of the European Union, the former rose from 779 to 992 million tonnes between 1990 and 2006, an increase of 27%. The spread around the average is considerable: -1% for Germany, +17% for France, but +100% for Portugal and +89% for Spain. Not all countries are at the same stage of economic development.
- Still for EU 27, emissions in the latter category rose from 176 to 305 million tonnes, an increase of 73%. Of this total, emissions from air transport alone rose from 66 to 131 million tonnes, with maritime transport accounting for the remainder.

Thus, all transport sector emissions for EU 27 between 1990 and 2006 rose from 955 to 1,297 million tonnes, over 36%. Of this amount, domestic and international air transport emissions rose from 83 to 157 million tonnes. They now represent 12% of total emissions, compared with 8.6% in 1990. This gives us two important signals.

- First, decoupling does not apply to demand for air transport – far from it, in fact. Until the recent economic crisis global air transport was rising faster than global GDP and, given the probably expansion of supply by airlines, the trend is most likely to continue in the years to come. The same is true of high-speed rail travel. Here again, traffic growth has been significantly higher than economic growth in recent years, to the point where many European countries (Spain, Italy, France and Portugal to name just four) are stepping up the construction of new high-speed rail links.

- Second, the very success of air transport will pose problems because of its growing contribution to greenhouse gas emissions. The problem is all the more crucial in that the mode is doubtless far short of reaching saturation. From the standpoint of significantly reducing greenhouse gas emissions, will it not be necessary to take restrictive measures, to go down the road of mitigation?

2.2. Decoupling and mitigation: towards a new set of collective preferences. Three scenario families for inter-urban mobility in France to 2050

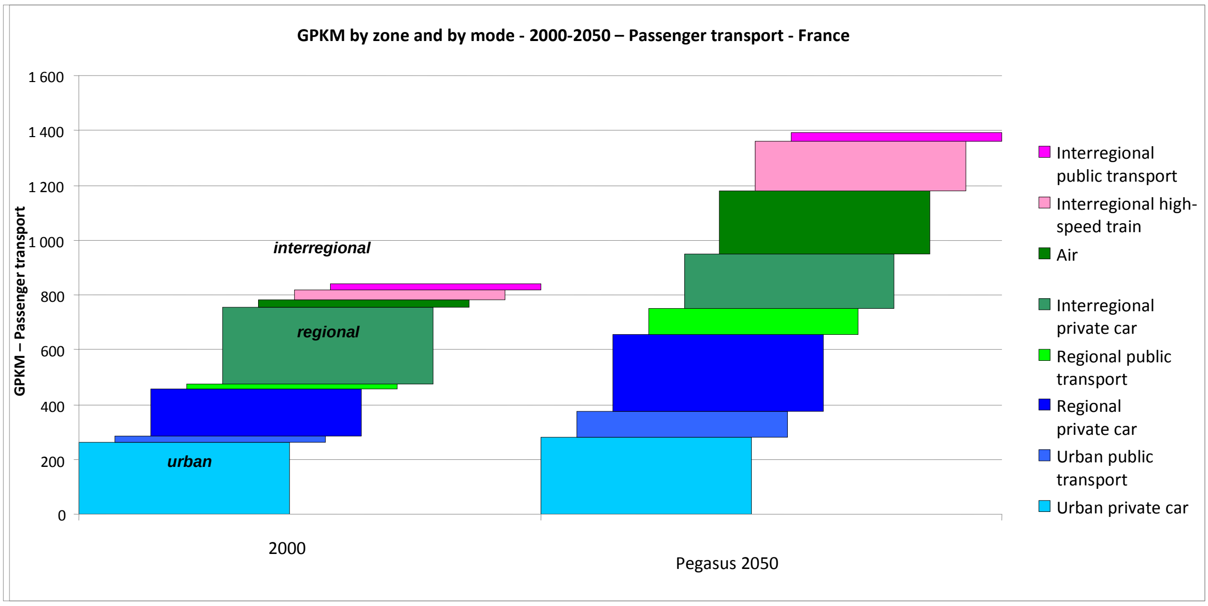
The information presented in the following section is taken from projections drawn up for the French Ministry of Ecology and Sustainable Development (Château *et al.*, 2008). It is based on a TILT model (Transport Issues in the Long Term), the broad outlines of which are described in an annex. As always with projections, the model is not supposed to say what will happen: it is not predictive. Its interest lies in its capacity to link a large number of variables while seeking to maintain an overall coherence between them that takes account of various types of constraint which mobility will have to accommodate in the coming decades. More specifically, the approach uses the "backcasting" technique (Clement, 1995, Hickman & Banister, 2005). Bearing in mind the objective of reducing transport-related CO_2 emissions, an objective common to all industrial countries, what developments could take place in aspects such as mobility, modal split and public policy and how might they affect each other? As is customary in this type of work, we started by establishing a trend-based scenario, then developed two scenario families marking inversions of or breaks with previous trends.

2.2.1 Pegasus: trend scenario and key variables to 2050?

To underpin our projections, let us first assume that the current organisation of our economy and society will remain more or less the same. To encapsulate what is a simple extension of past trends, we named the scenario after a symbolic figure of Greek mythology: Pegasus, the winged horse that enabled Perseus to cover long distances quickly. Are we not already in such a situation, since the average French person nowadays covers over 14 000 km a year, or more than 40 km a day?

Let us start by looking at the results of the TILT model. The Pegasus scenario, which has an infinite number of variants, is summarized in Figure 10.

Figure 10 **– Passenger mobility in France 2000-2050: Pegasus scenario**



In relation to the baseline year (2000), the chart shows strong growth in regional and above all inter-urban passenger transport (over 40%). Urban traffic increases by "only" 25% and is marked by a sharp rise in the use of public transport. Growth in travel by high-speed train, bus, metro or tramway is much higher than growth in automobile travel. This corresponds to a shift in mobility choice towards collective modes, not primarily for environmental reasons but because they are the modes where improvements will be seen in the coming years, especially in terms of speed. For in this scenario family we have kept the idea that there is a non-zero elasticity between the average speed of travel and GDP. Rather than Schäfer's hypothesis of an elasticity close to 1, we have taken the actual speed/GDP elasticity in France over the period 1970-2000, namely 0.5, to deduce an arbitrary value of 0.33 for the period 2000-2050. In doing so, we have de facto incorporated a certain saturation of mobility. Because of the pursuit of speed gains we have not limited the growth in air transport, which is a highly effective way of increasing total distance travelled without increasing transport time budgets.

As Figure 10 shows, fast modes gradually replace slow modes. The modal choice shifts systematically towards faster modes (high-speed rail and air travel). As Figures 6 and 7 suggested, higher passenger mobility in terms of kilometres per capita per year is a direct consequence of higher average transport speeds. That is why the saturation rates of different transport modes vary in relation to the speed/GDP elasticity. In other words, relative saturation would occur for long-distance automobile travel. This has already been the case since the early 2000s in France, where the total volume of road and motorway traffic has remained more or less flat. Indicatively, in this scenario CO_2 emissions from passenger transport could be cut by two-thirds or a little more despite rising traffic (see Figure 12) thanks to advances in vehicle technology (automobiles and aircraft) and the emergence of second-generation biofuels. The substantial increase in TGV traffic plays a crucial role here. The scenario therefore concurs with the conclusions presented by Hickman and Banister in the VIBAT project. A forecasting exercise carried out for the UK to 2030, VIBAT indicates that half the targeted reduction in CO_2 emissions can be achieved through technological progress.

However, reducing CO_2 emissions by a factor of three would not be sufficient to comply with Kyoto Protocol commitments and those that will doubtless be made at the Copenhagen climate change conference in late 2009. If global CO_2 emissions are to be halved by 2050, the countries that have been industrialised the longest will have to make a greater effort since they are chiefly responsible for past emissions. From that standpoint, let us take a closer look at scenarios that are more restrictive of personal mobility, especially inter-urban mobility. Changes of behaviour are needed in order to reduce CO_2 emissions by more than the amount made possible by technological progress alone. How are they to come about? To answer that question, we have made modifications to some key parameters in the model – modifications that are apparently benign but presuppose major changes in individual preferences.

The modifications introduced in the two new scenario families concern the following variables.

- First, we suppose that the speed/GDP elasticity becomes zero, **which represents a major break with previous trends**. It is reflected in a small increase in total distance travelled. In the first alternative scenario family, called Chronos, the increase in distance is mainly attributable to a 20% increase in transport time budgets. We have taken up one of the hypotheses put forward by Schäfer (2009), though without linking it to an increase in speed. It offers the possibility of continuing the increase in distance travelled, albeit at a slower pace and without any increase in the average speed. It is because the continuing embrace of mobility is time-consuming that this scenario family has been named Chronos.

- The second scenario family, baptised Hestia, makes the same assumption of a zero speed/GDP elasticity. But going further in the change of behaviour, it is not matched by an increase in transport time budgets. The reduction in average speeds will therefore severely limit the trend increase in distance travelled, indicating a return to proximity activities. This explains the name Hestia, the Greek goddess of hearth and home.

2.2.2 Chronos: lower road speeds but economic growth still coupled with mobility

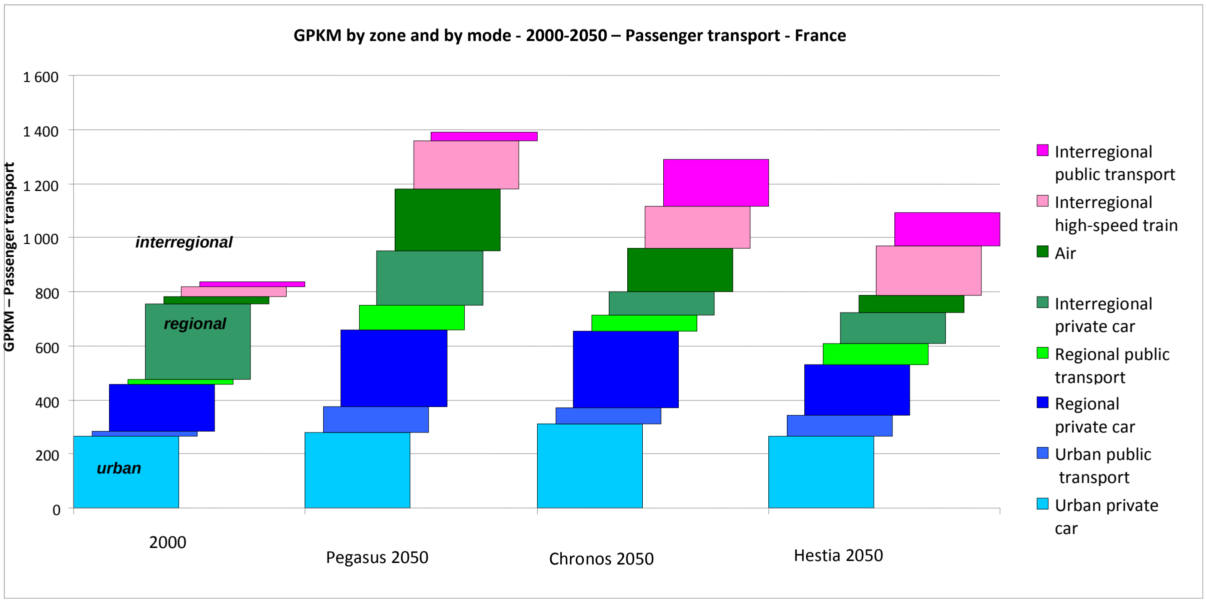
In Chronos, the underlying rationale for passenger travel is that a rise in the price of automobile use causes an increase in the use of public transport. The modal shift changes the household budget as the gains from the switch to a relatively less expensive mode are reinvested. Some of the gain will be reinvested in relocation (to get closer to public transport infrastructure) and some in fast long-distance transport services, especially air travel.

Thus, the system seeks to strike a balance by playing on the modal split in order to minimise cost. Chronos proposes an arbitrage between the need for speed (which increases because there is no saturation) and public limits on speed in the context of mitigation policies designed to encourage the use of cleaner transport modes and hence to improve the carbon footprint of transport as a whole. The public policy goal is therefore to achieve a large-scale modal shift, in favour of high-speed trains in particular, while keeping a more or less constant journey speed. In the French tradition of promoting high-speed trains, this is reflected in accelerated growth of rail travel while road speeds remain flat or even diminish. In this type of scenario, substantial investment is required in order to develop rail travel. Far-reaching changes to the organisation of the sector are also needed. So it comes as no surprise that in late 2007 the French president announced the construction of another 2 000 kilometres of high-speed railway lines.

The announcement was presented as an environmental response to the risks arising from an increase in air transport emissions. However, it is also a way of targeting speed gains on a particular mode, namely the high-speed train, and a particular type of travel, namely inter-urban journeys. The rise may be seen as offsetting the fact that the average speed of daily mobility journeys will fall, either because automobile mobility will be increasingly restricted or because the modal shift to local public transport will reduce the average journey speed. This scenario family therefore assumes the ongoing coupling of economic growth and mobility. As Figure 11 shows, total distances travelled increase almost as much as in the Pegasus trend-based scenario.

If economic growth and CO_2 emissions are decoupled (see Figure 12), it is mainly due to technological progress and a significant modal shift towards public transport. Nevertheless, the share attributed to air travel greatly changes the results. Although it is possible in the Chronos scenario family to approach Factor 4 for passengers, air transport must be severely restricted and replaced by high-speed rail. It is a rationale that we will find in an even more acute form in the Hestia scenario family.

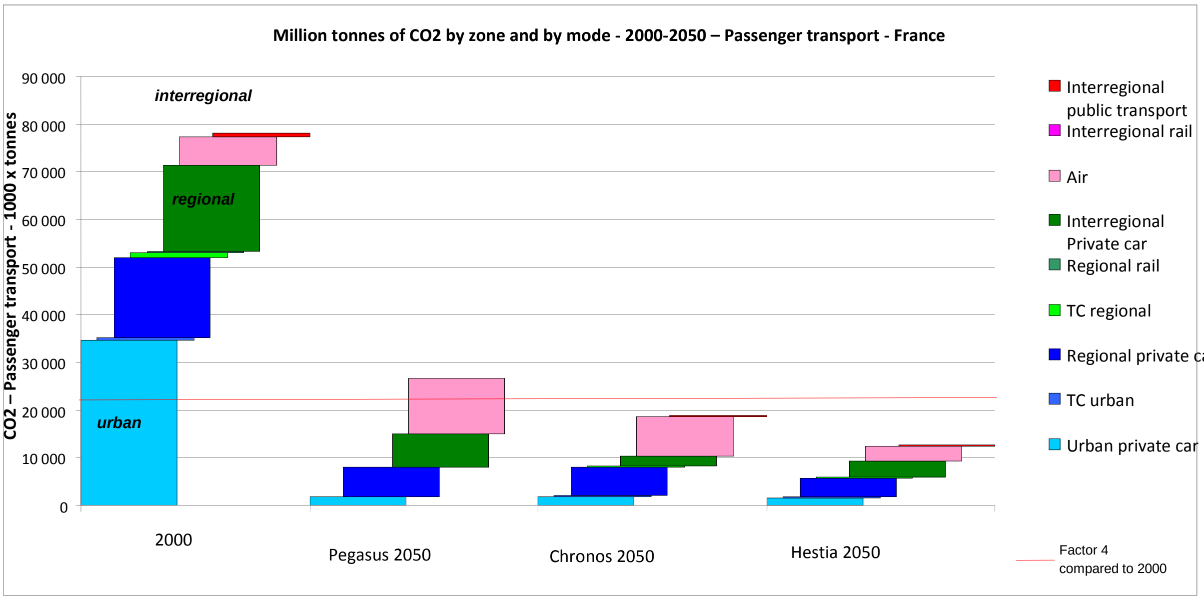
Figure 11 **– Passenger mobility 2000-2050: Pegasus, Chronos and Hestia scenarios**



2.2.3 *Hestia: decoupling and mitigation. To what extent can air transport be restricted?*

A comparison of Figures 11 and 12 is instructive for more than one reason. We can see the key role played by restrictions on air transport in whether or not the objective of reducing CO_2 emissions by a factor of four is achieved. Air traffic increases sharply in the Pegasus scenario family and that has a knock-on effect on the sector's total emissions. In contrast, in the other two scenario families it is the drastic reduction in the relative share of air travel that makes it possible to achieve and even exceed the objective of a fourfold reduction in emissions, symbolised in Figure 12 by the horizontal line just above the 20 million tonnes of CO_2 mark.

Figure 12 **– Greenhouse gas emissions in 2050: Chronos and Hestia – Passengers**



The outlook in the Hestia scenario family is one of more restricted mobility. This is achieved not only through pricing and taxation but also through quantitative restrictions with, for example, the widespread introduction of tradable permits, reckoned to be more effective than a carbon tax. Facing what would amount to a complete break with the past, the system of individual preferences could have to change in favour of a reduction in distance travelled. Thus, an adaptation of the system through transport time (Chronos) would be replaced by a trend towards reduced distance (Hestia).

As we can see in Figure 11, the rationale is very similar to that of Chronos. The difference lies in the extent of the reduction in demand for transport by private car for regional and long-distance journeys. Once transport becomes too expensive, individuals express a preference for reduced distances because speed has become less accessible. If we look at Figures 6 and 8, this in fact brings us back to the logic of a reduction in purchasing power. The changing preference in favour of proximity does not come out of the blue but is the result of new constraints.

Consequently, the increase in distance travelled is smaller in Hestia than in Chronos and Pegasus. In Hestia, proximity comes into play: the arbitrage concerns not only public policies that encourage the use of cleaner modes but also the geographical location of dwelling places and places for leisure activities and consumption. The main difference with the Chronos scenario therefore lies in the smaller rise in total distance travelled in relation to 2000. Passenger car traffic diminishes significantly but does not disappear altogether, in particular because air travel has been much more restricted than in the preceding scenario. But is such a decree of constraint possible? Backcasting shows us the path we ought to take, but as things stand at present there is little likelihood that we will do so, as the difficulty of reaching an international post-Kyoto consensus shows.

CONCLUSION

In 1825, when the British engineer George Stephenson put the first locomotive on rails (with a speed of 24 kph), the German philosopher J.W. Goethe (1749-1832) expressed his concerns about the risks of the race for speed. Seeing it as diabolical, he coined the word "velociferic", suggesting that the quest for speed (velocity) had something in common with the devil (Lucifer). Has modern man assumed the guise of Mephistopheles? Nearly two centuries later Milan Kundera picked up the same thread, quoting Goethe extensively in a novel (*Immortality*) in which he also insists on the death-dealing tendencies of speed, engaging in a regular critique of the road and the behaviour it induces in drivers.

How should we view these romantic strictures against the quest for speed after what we have just said about the past and future of mobility? At first sight, Goethe does not seem to have understood what was at stake. Higher speeds have profoundly changed standards of living and lifestyles, not always in a diabolical way. But Goethe and Kundera are probably right to suppose that there are limits to the quest for speed. There are physical and energy-related limits, as can be seen from the scrapping of supersonic commercial aircraft like Concorde. But there are also limits related to individual preference and the optimisation of activity schedules. That is why we are unlikely ever to attain the 791 kilometres per day envisaged by Schäfer in one of his hypotheses. However, that does not mean that personal mobility will level off in the years to come, especially where long-distance mobility is concerned. The accessibility gains offered by fast transport are such that demand for high-speed rail and air travel will remain strong. The extent of their relative growth will essentially depend on public policy, on the investment that public authorities are willing to finance or not, on the restrictions they might impose on the use of fossil fuels. Mitigation policies will have to be all the more proactive insofar as we are still a long way from reaching saturation point.

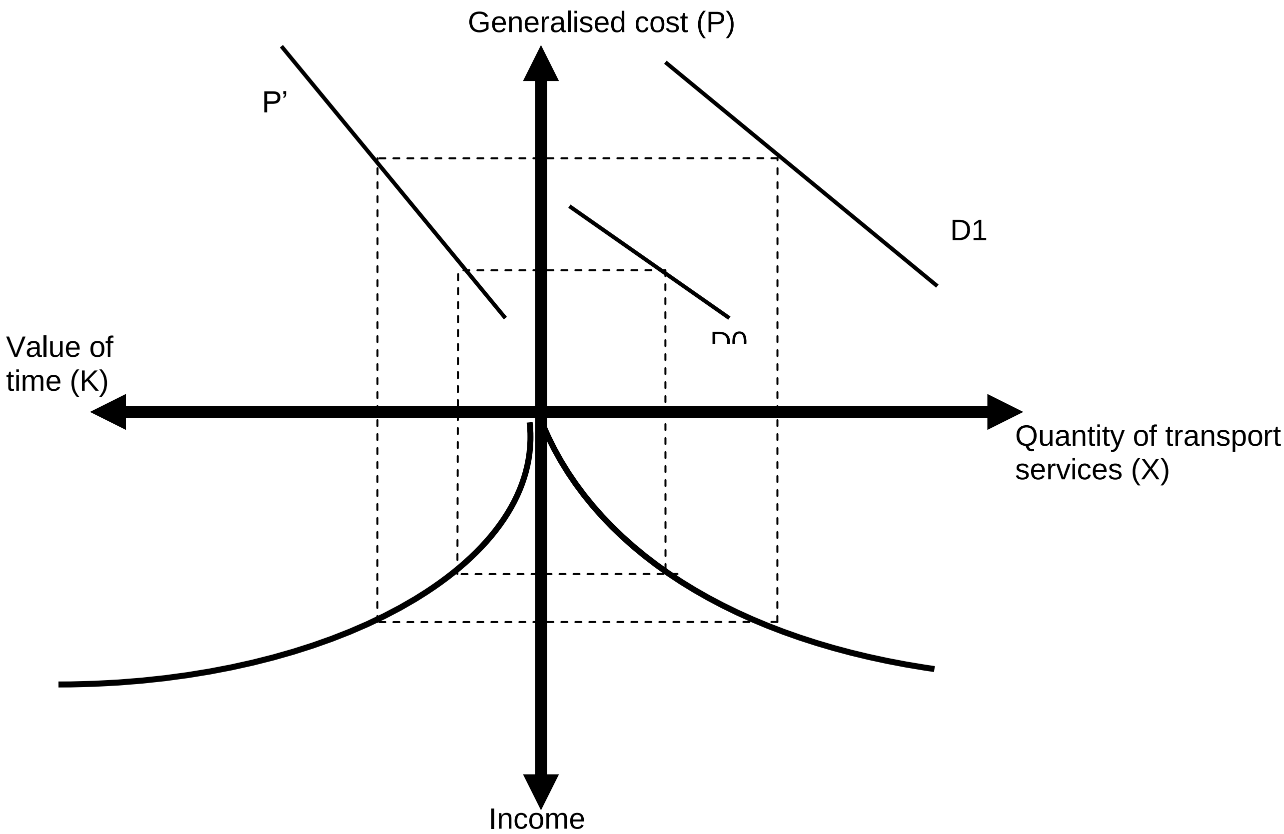
ANNEX 1

Spatio-temporal optimisation of recreational and business trips

Figures 6, 7 and 8 of the paper are derived from the thesis written by R. Gronau (1970) under the supervision of G. Becker, and from the thesis written by V. Bagard (2005) under the supervision of Y. Crozet.

R. Gronau's original model focused on long-distance transport demand by comparing bus and air transport when income increases. He examined the reasons for which we prefer a fast mode of transport and the logic on which they are based. Figures A and B summarize the stylised facts.

Figure A. **Stylised facts relating to demand for long-distance transport**
Initial situation where bus transport is the only option
(after Gronau, 1970)



The four key variables are income (Y), the value of time (K), the generalised cost of transport (P) and the quality of the transport services consumed (X). Between these four key variables in each quadrant lie the major stylised facts, whose logic will be easier to follow if we start with the income axis and then proceed in a clockwise direction around the diagram.

- The value of time increases more than proportionately where income K = f(Y) (bottom left-hand quadrant);
- The generalised cost P increases with the value of time for a given speed, in this case that of bus transport (top left-hand quadrant). The generalised cost (P') also takes account of the cost of the ticket;
- Demand for transport is a decreasing function of the generalised cost (top right-hand quadrant);
- The quantity of transport consumed tends to rise with income because higher income levels provide access to new goods and services in new areas requiring greater mobility (bottom left-hand quadrant).

The main interest in Gronau's reasoning lies in the emphasis it places on the two-fold impact of higher income. When individuals become wealthier, the increased value of time drives the generalised cost of transport upwards (top left-hand quadrant). However, higher income means access to a greater variety of consumer goods and services, which often require travel. Transport demand therefore rises from D0 to D1. The outcome is that if the bus is the only means of long-distance transport, the quantities consumed will rise but the increased cost in terms of time will act as a deterrent since the generalised cost rises rapidly if speeds remain low. This deterrent, which limits the quantity of transport consumed, is lessened if a significantly faster mode of transport, such as air transport, is available. In the latter case the quantity of transport services and, in particular, distances consumed can indeed rise sharply without increasing the amount of time spent travelling. A new balance is therefore struck, as shown in Figure B.

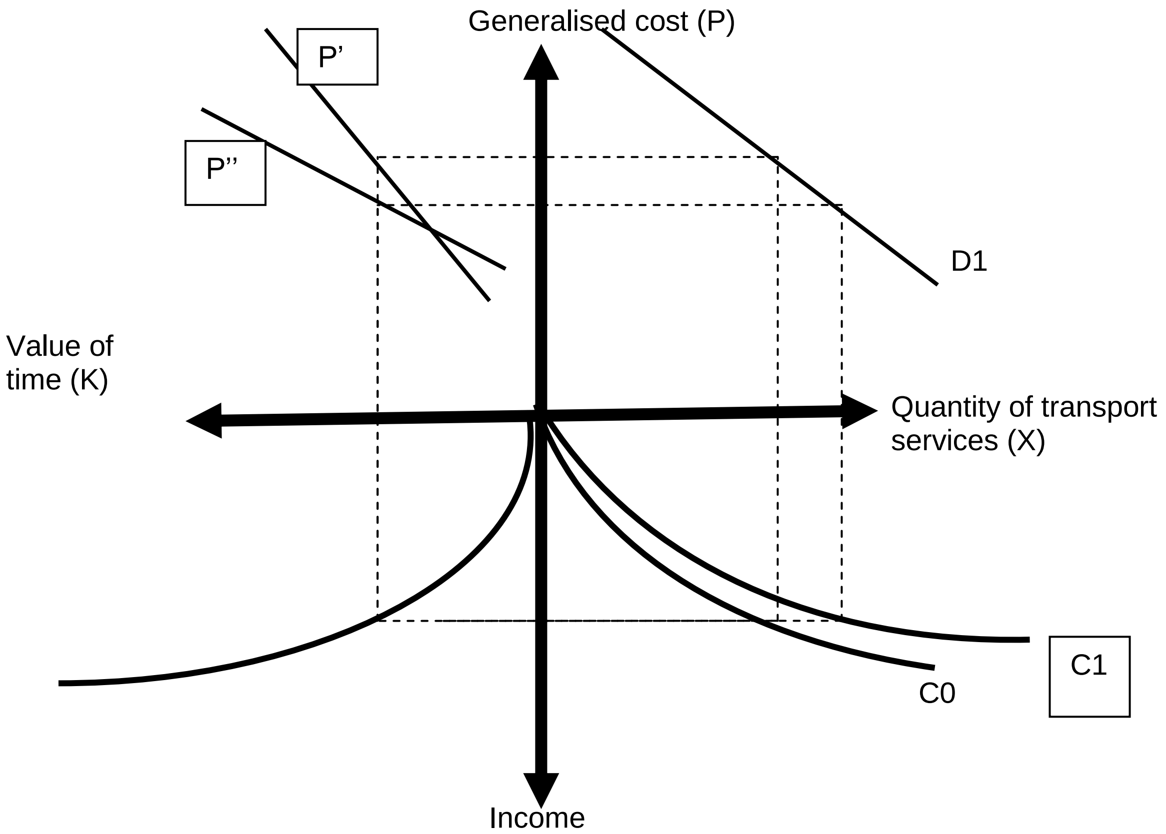
In this Figure, the new mode of transport, i.e. air transport, is responsible for two changes in typical relationships:

- In the top left-hand quadrant, the new line P" has a different gradient to line P'. This is due to the fact that the increased speed of air transport reduces the relative weight of time in the generalised cost. Since we have assumed that the cost of the ticket is not exorbitant, we obtain a relationship in which the generalised cost increases more slowly in relation to the value of time. To be more precise, when the value of time is low, the relative generalised cost of air transport is higher than that of the bus in that the only factor is the higher cost of the ticket. When the value of time increases, the generalised cost of air transport increases too, although at a slower rate given the shorter travel time.

- In the bottom right-hand quadrant, the impact of the lower generalised cost can be seen in the fact that for the same given income it is possible to consume a greater quantity of transport services. The relationship between the quantities X and income Y therefore changes from C0 to C1.

The new balance presented in Figure B takes account of these two changes. It can be seen that the outcome of this is a lower generalised cost of transport and an increased quantity of transport services for the same given income and therefore the same given value of time. Specialists will recognise an income effect, which has moved the position of the demand line, and a price effect related to the change in the structure of the generalised costs. The two effects combine to drive the quantities of transport services consumed upwards. Gronau finds an explanation here for the powerful development potential of air transport.

Figure B. **Stylised facts in demand for long-distance transport, from bus to air transport** (after Gronau, 1970)



On the basis of this diagram, V. Bagard's thesis sought to emphasize the consumption of time and space in relation to the consumption of recreational transport services. He therefore proposed different stylised facts given that the key variables had changed. While income and the value of time were retained (bottom and left-hand axes), the top and right-hand axes were changed:

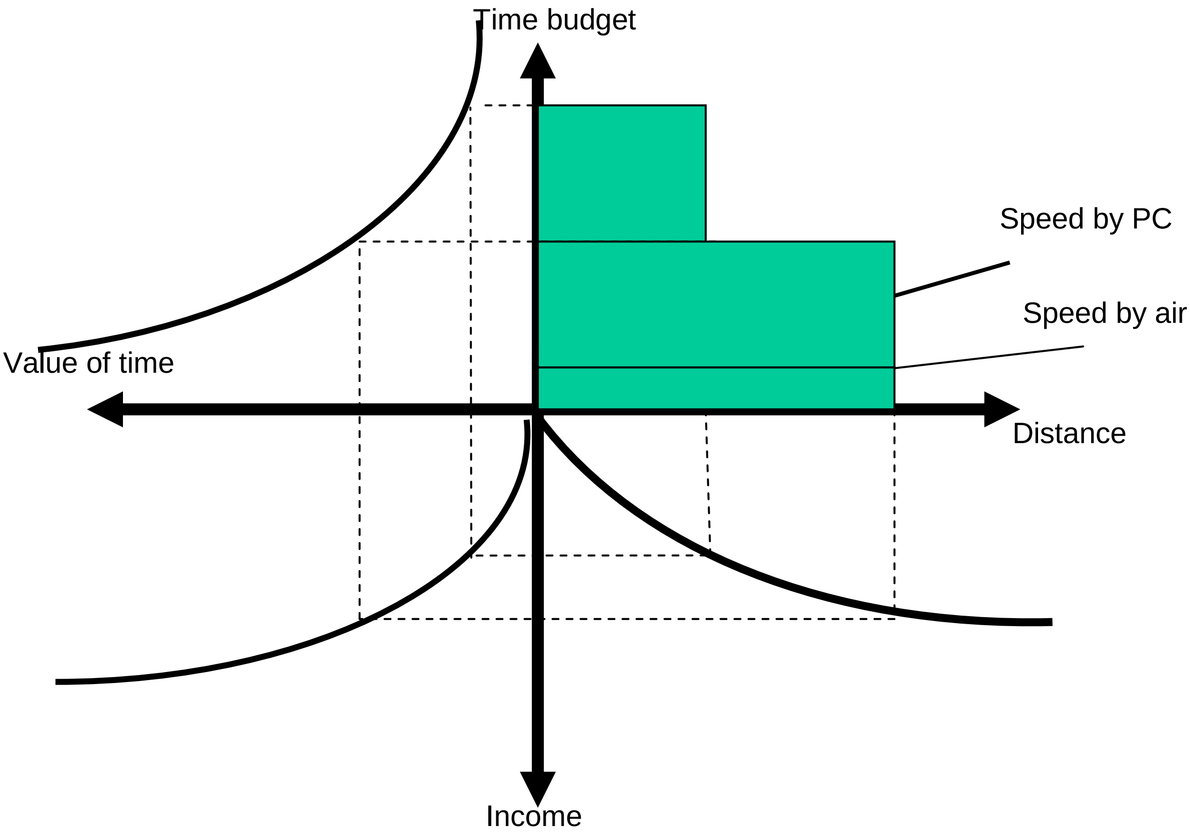
- The top axis was used to represent the time budget allocated to the recreational activity, as well as its transport component. This total time budget is limited.
- The right-hand axis was used to represent the distances travelled every year.

As Figure C shows, this produces the following relationships:

- Bottom left-hand quadrant: as with Gronau, the value of time rises commensurately with income;
- Top left-hand quadrant: the time budget allocated to a given activity decreases against income as a result of competition between activities;

– Top right-hand quadrant: the distance travelled depends on the average speed offered by the mode of transport (illustrated by gradient) and the value of the ratio between travel time and total recreational time;
– Bottom right-hand quadrant: distance increases with income because an increase in the latter provides access to increasingly faster modes of transport
.

Figure C. **Supply of speed and growth in distances for recreational travel**
(after V. Bagard 2005)



Figures 6 and 7 in the paper resume this line of approach but seek to stress the improbability of an exponential increase in distances in relation to income. Account does indeed have to be taken of the fact that speeds do not increase ad infinitum. For each trip, a given mode can only increase distance up to a certain level linked to the time budget available. Saturation mechanisms therefore do exist. This is what the bottom right-hand quadrant of Figure 7 shows in the paper. It can be seen that the increase in income is no longer accompanied by an exponential increase in distances for a given trip. The distance travelled increases in steps whenever a new and faster mode of transport emerges, which then itself levels off. This echoes the comment by A. Schäfer to the effect that the continued increase in distances travelled would require a sharp increase from 200 km/h to 600 km/h in door-to-door travel time for air transport, which would be highly unlikely! Saturation phenomena therefore do exist. Figure 8 considers another form of saturation which could combine with the previous form to slow growth in mobility. If the increase in the value of time were to level off too, like the increase in speeds, demand for trips over longer distances could indeed gradually become saturated. However, this threshold has not yet been reached, given that the share of the global population with access to fast modes of transport (high-speed train and air transport) still remains very low!

ANNEX 2
THE TILT MODEL (TRANSPORT ISSUES IN THE LONG TERM)

The basis of the TILT approach lies on the proposition that a Speed/GDP elasticity implies different modal split possibilities. This is based on the growing importance of higher speeds as affluence and freight value grow (Schafer, A., Victor, D.G., 2000). Moreover, the modal split in transport is directly linked to the idea that modal speed, transport times, transport management and localizations determine modal shares. In this manner, transport modal saturation rhythms can be varied in the model - through public policies affecting localisations and the speed/GDP elasticity - which has proved to be fairly stable over time and very similar from one country to another (LET-ENERDATA, 2008).

Furthermore, in order to have a more precise view of the effects of public policies on each scenario, TILT has a microeconomic substructure that allows further analysis of demand determinants behind each scenario's modal split.

The TILT model has been designed to be a long-term equilibrium model by combining a macroeconomic and microeconomic structure in a backcasting approach that takes into account new motor technologies and facilitates sensitivity and impact assessments through five modules that work on three different geographical scales (urban, regional and interregional):

- A macroeconomic module based on a re-foundation of the energy-environment modelling structures in order to properly assess long-term modifications of demographics as well as social and cultural preferences in relation to transport needs.
- A microeconomic module based on a discrete choice and demand evolution that takes into account transport cost, infrastructure capacity and quality of service in order to asses changes in agents' transport choices.
- A vehicle fleet dynamic and technology evolution module that analyses technological impact based on market penetration probabilities and vehicles' survival rates for different motor technologies and different transport services (road, rail, sea, air, inland waterways).
- A public policy module that joins a sensitivity analysis (for policy categories) and multicriteria analysis (for specific public policies) in order to offer a detailed impact assessment of actions on CO_2 emissions.
- An impact assessment module based on an input-output equilibrium analysis that details impacts on employment and production by sector.

The TILT model structure enables the user to calculate energy consumption and pollutants emitted by transport activity (freight and passengers) on different geographical scales. The model has three important functions:

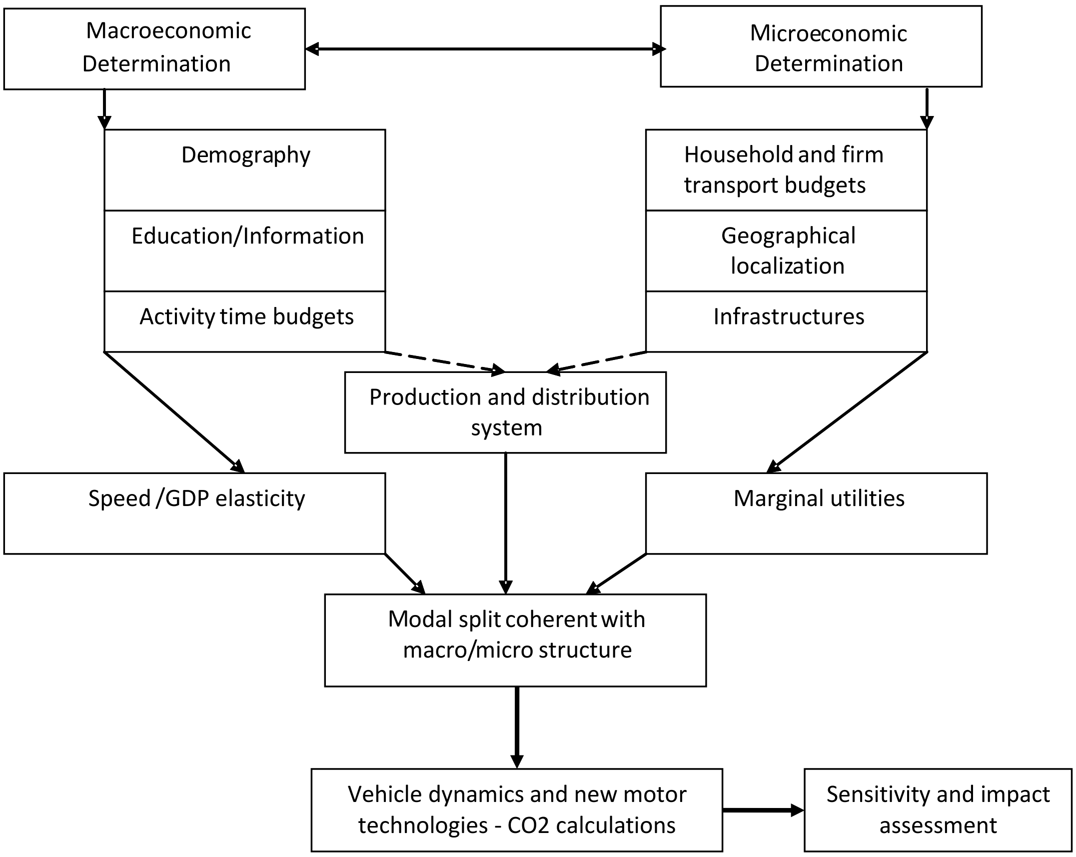
- Modelling passenger-kilometers and ton-kilometers coherent with a micro/macro equilibrium structure according to motor technology used for journeys and area of service.
- Modelling the vehicle park according to: age; motor technology; and year of production (for freight and passengers).

- Modelling and assessing public policy impacts on CO_2 emissions, infrastructure investment needs as well as overall impact on the economy.

By joining these three functions and the different TILT modules in a micro/macro equilibrium structure, it is possible to build scenarios that:

- Quantify the consequences of transport on the environment whilst detailing the systems' structure according to behavior and organizational changes, technology used, vehicle park dynamics, nature of a journey and vehicle age.
- Give a precise view of traffic by motor technology, gas consumption and emission levels for each type of transport according to service distances, type of vehicle and transport cost.
- Build policy pathways based that have different impacts in each scenario configuration and on the economy.

TILT Model Structure



These results coupled with the model's structure make TILT a powerful tool for building and exploring scenarios. The utility of the TILT model lays not only in its capacity to be flexible concerning political transport measures, changes in demography, behavioral differences as well as changes in transport structure and cost but also in its capacity to integrate new technologies' influence according to their year of entrance on the market and their ability to penetrate it. Furthermore, on the basis of its modelling structure, TILT is able to deliver a clear assessment of public policy sensitivity and infrastructure needs.

BIBLIOGRAPHY

AUSUBEL J.H., MARCHETTI C., MEYER P.S., (1998), *Toward green mobility: the evolution of transport*, European Review, Vol. 6, No. 2, pp.137-156

BAGARD, V. (2005), *Spatio-temporal optimisation of tourism practices,* doctoral thesis in economics supervised by Y. Crozet, 322 pages. www.univ-lyon2.fr

BANISTER D., STEAD D., STEEN P., AKERMAN J., DREBORG K., NIJKAMP P. & SCHLEICHER-TAPPESER R., 2000. *European transport policy and sustainable mobility*, Spon Press, 255 p

BANISTER D., PUCHER J., LEE-GOSSELIN (2005), M. *Making sustainable transport politically and publicly acceptable: Lessons from the EU, USA and Canada.* Book Chapter. (http://www.itls.usyd.edu.au/)

BANISTER D., HICKMAN R., (2005) *Towards a 60% Reduction in UK Transport Carbon Dioxide Emissions: A Scenario Building Backcasting Approach.* http://www.ucl.ac.uk/~ucft696/documents/eceee_paper_04.05%20final1.pdf

BANISTER D., HICKMAN R., *VIBAT Study*. http://www.ucl.ac.uk/~ucft696/vibat2.html

BECKER G., 1965, Time and Household Production: a theory of the allocation of time, Economic Journal 75, September, 493-517

CHATEAU B., CROZET Y., BAGARD V. & LOPEZ-RUIZ H., (2008) Comment satisfaire les objectifs internationaux de la France en termes d'émissions de gaz à effet de serre et de pollution transfrontières ? Programme de recherche consacré à la construction de scénarios de mobilité durable. Rapport final. PREDIT, Paris, www.let.fr .

CLEMENT K. (1995) *Backcasting as a Tool in Competitive Analysis*. University of Waterloo. ISBM Report 24

COMMISSION OF THE EUROPEAN COMMUNITIES, 1992. *A Community strategy for "sustainable mobility"*, Green Paper, European Community Publications

COMMISSION OF THE EUROPEAN COMMUNITIES, 2001. *European transport policy for 2010: time to decide*, White Paper, European Community Publications, 136 p

CROZET Y. (2005)., *Time and Passenger Transport*, 127th Round Table of ECMT, Time and Transport, OECD, Paris, pp. 27-69

CROZET Y. (2007), *Strategic Issues for the Future Funding and Operation of Urban Public Transport Systems*, in "Infrastructure to 2030, Volume 2, Mapping Policy for Electricity, Water and Transport", OECD, pp. 413-462

DUMAZEDIER J. (1962), *Vers une civilisation du loisir ?* Paris, PUF (in English, *Towards a Society of Leisure*? London, Macmillan, New York Free Press, 1967)

EEA, European Environment Agency (2009), Transport at a crossroads, TERM 2008: indicators tracking transport and environment in the European Union, EEA Report N°3/2009, 52p.

EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORT, 1993. *Transport Growth in Question*, 12th International Symposium on Theory and Practice in Transport Economics, OECD Publications, 700 p

EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORT, 1997. *Which Changes for Transport in the Next Century?*, 14th International Symposium on Theory and Practice in Transport Economics, OECD Publications, 509 p

EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORT, 2000. *Key Issues for Transport beyond 2000*, 15th International Symposium on Theory and Practice in Transport Economics, OECD Publications

EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORT, 2001. *A baseline scenario for transport in Europe*, OECD Publications, 54 p.

GEORGESCU-ROEGEN, N. (1979), La décroissance : entropie, écologie, économie

GRONAU R. (1970), *The Value of Time in Passenger Transportation: The Demand for Air Travel*, National Bureau of Economic Research, occasional paper n°109, Columbia University, New York and London, 74 p

GRONAU R., HAMERMESH D. (2001), *The Demand for Variety Transportation : a Household Production Perspective*, National Bureau of Economic Research, working paper no. 8509

GRUEBLER A. (1990) The rise and fall of infrastructure: dynamics of evolution and technological change in transport (Heidelberg: Physica)

INSTITUTE FOR TRANSPORT STUDIES, University of Leeds (Oct. 2000), *Separating the Intensity of Transport from Economic Growth*, Report on the Workshop. University "La Sapienza", Rome.

KESSELRING S. (2008), The mobile risk society. In: Canzler, Weert; Kaufmann, Vincent; Kesselring, Sven (Hg.): Tracing Mobilities. Aldershot, Burlington: Ashgate , pp 77–102

KESSELRING S., VOGL, G. (2008): Networks, Scapes and Flows - Mobility Pioneers between First and Second Modernity. In: Canzler, Weert; Kaufmann, Vincent; Kesselring, Sven (Hg.): Tracing Mobilities. Aldershot, Burlington: Ashgate , pp 163–180.,

LINDER S. (1970), *The Harried Class of Leisure,* New-York and London Columbia, University Press.

MOKHTARIAN P.L., CHEN C.(2004), *TTB or not TTB, That is the Question: A Review and Analysis of the Empirical Literature on Travel Time (and Money) Budgets*, transportation Research A, 38(9-10), pp. 643-675

NIVEAU M.A., CROZET Y. (2000), *Histoire des faits économiques contemporains*, Paris, PUF, 847p

POTIER F. (1998), *Les évolutions de la mobilité liée aux loisirs*, ECMT, Round Table no. 111, OECD, pp. 97-132

SANSOT P. (2), *Du bon usage de la lenteur*

SCHÄFER A., HEYWOOD J., JACOBY H., WAITZ I. (2009), *Transportation in a Climate-Constrained World*, MIT Press, 329 p

VEBLEN T. (1899), *Theory of the Leisure Class*, Penguin edition, 1994

VIARD J. (2003), *Le sacre du temps libre*, Editions de l'Aube, 212 p

VIARD J. (2006), *Eloge de la mobilité*, Editions de l'Aube, 252 p

ZAHAVI Y. & TALVITIE A. (1980), Regularities in Travel Time and Money, Transportation Research Record 750, p.13-19.

ZAHAVI Y. (1979), *The 'UMOT' Project*, report for the US Department of Transportation and the Ministry of Transport of the Federal Republic of Germany.