Tourism/ Leisure Greenhouse Gas Emissions for 2050 : factors for change

Call for Manuscripts: Transport and Tourism: the sustainable development dilemma

Journal of Sustainable Tourism Special Issue

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Abstract

The paper presents some sensitivity tests for French tourism/ leisure mobility demand in 2050, and its associated greenhouse gas emissions. The tests rely on a modeling of tourism/ leisure mobility, calibrated for the year 2000 situation and based on household mobility patterns, made up of different kind of mobility, each of them bestowed with four modes of transport. A sensitivity analysis was conducted to quantify the evolution of GHG emissions under various hypotheses related to demographics, economic situation, international security context, transport technology and policy, the tourism market and lifestyles and cultural change. The results show the high sensitivity of the model to the economic situation : French passenger transports still have a considerable potential for growth. Technology gains could be offset by the absence of investment in transport infrastructure and by a permissive transport pricing. A summing of all medium hypothesis, displayed as a preliminary step to scenario development, show that French tourism/leisure GHG emissions increase by 90% in 2050, and passenger.km traveled by 200%. The core of the sustainability problem caused by tourism transport are very long distance trips and air transport. A minority of great travelers are responsible for the majority of emissions.

Keywords

greenhouse gas emissions, modeling, tourism, transport, sustainability

Introduction

The access to tourism is now regarded as a right. An international organisation such as the World tourism organisation has striven to have this admitted (UNEP-IE 1993 ; Dubois & Ceron 2000 ; OMT 2002).

It took some time until tourism's impacts on resources and the global environment were identified. Tourism still tends to be presented by various stakeholders as an environmentally benign activity generating high benefits for host societies as well as a privileged means of development for a great number of third world countries (Iwand 2003), or, at most, as an activity whose sustainability can be questioned and dealt with at the local level of destinations (Afit 2001). Such statements have been questioned in recent years (Ceron & Dubois G. 2003; Gössling 2002 a ; Gössling et al 2004; Peeters 2003). The global environmental effects on tourism particularly on the climate, mainly through the energy used to travel between home and the destination, started being assessed (Dubois & Ceron 2005 ; Becken & Simmons 2002; Becken, Simmons & Frampton 2003; Hoyer 2000).

Beyond tourism, which is defined as travel out of daily environment, with at least one night stay, all leisure motivated transport, with or without night stays, in the immediate environment or further away should be assessed with regards to its contribution to greenhouse gas (GHG) emissions. An important issue for future climate change policies is the possibility of substitution between the diverse uses of time, between tourism and home-bound leisure, and globally between leisure and other uses of time, whether these substitutions stem from voluntary trade-offs or are determined by societal evolutions (technological, economic, etc.). Since tourism is a component of our ways of life, its stake and its own future should be examined in relation to other components, such as work, family life and leisure near the home.

Though WTO forecasts (WTO, 2001) predict a continuous growth of international tourism worldwide, there are still major uncertainties regarding the speed and regional distribution of this growth, as well as the evolution of domestic tourism and other leisure trips.

Scenarios, forecasts, and sensitivity analyses of tourism/leisure GHG emissions to a set of societal and technological factors can help in foreseeing the future need for regulation. The time horizon considered in this paper for the modelling of tourism/ leisure mobility demand and its associated environmental impact is 2050. This is accomplished by referring to the French context. It should be remembered that France as source market has some strong specificities that do not allow to extend without serious precautions results even to neighbouring countries (a high proportion of trips taken within the home country, the importance of private accommodation, a high degree of self-organisation…). This work can nevertheless give some indications of the stakes in the evolution of tourism and leisure mobility in other markets.

This present work is linked to research in progress for the Scientific Directorate of the French Ministry of Transport,: « Temps hors travail, loisirs, tourisme et mobilités : scénarios à 20-30 ans ». A three-step methodology was taken :

a) the elaboration of individual mobility patterns, taking into account recent trends observed in the French demand (Ceron and Dubois (2004) ;

b) the shift from an approach focusing on individual leisure travellers or households to a more universal approach of French demand for mobility and its associated impact. This involves consideration of household sizes, repartition of patterns in French demand and individual mobility within households. The methodology entails a computer model for French tourism

leisure mobility, its calibration with the year 2000 situation, and the analysis of the sensitivity of mobility to various factors until 2050 ;

c) the elaboration of consistent scenarios for 2050 following this sensitivity analysis with associated story lines and the discussion of impacts such as congestion, infrastructure requirement and pollution.

The second step of this research, with a focus on GHG emissions, is presented here.

1. A MODEL FOR TOURISM/ LEISURE MOBILITY DEMAND

Forecasts for tourism are usually based on past trends, whereas the elaboration of scenarios is often a more qualitative exercise (CGP 1998, Blue Plan 1995). The former analyses mainly aim at informing marketing and therefore they focus more on tourist behavior and bed-nights rather than on tourist travel. Forecasts on transport and associated GHG emissions (Walsh 1993) often rely on an extrapolation of transport fleets, and thus, do not account for socio-economic variables and do not enable to distinguish between the purposes of traveling: personal, professional, day and tourism trips. They tend to treat each mode of transport individually, which does not "*account fully for the dynamic competition of different transport modes…. to supply the demand for passenger mobility"* (Schafer and Victor 1999, p 658.).

Modelling is an appropriate method for forecasting personal transport and its impact on the global climate, and it is also useful for developing quantitative scenarios. Carlsson-Kanyama and Lindén (1999) used a mobility model based on age segmentation, in order to test the compliance of future Swedish travel patterns with sustainable development targets. Schafer and Victor (1999), who noted that the "*lack of appropriate methods partially explains the near absence of long-term projections for personal mobility*" (p.658), developed a model to forecast regional and world travel and its impact on climate change. Their model was based on a combination of Travel Time Budget (the average daily time devoted to travel is assumed to remain constant in industrialised countries) and Travel Money Budget (share of net income devoted to travel) whose relationship with GDP per capita was forecasted. Additional assumptions were made on the improvement of the energy efficiency of transport modes. The model is a "*simple model that roughly predicts world travel demand over long time periods"*. The coarseness of the model is due to a "*lack of historical data needed for model calibration*". The results can for example overlook critical variables, such as the ageing and generational effects on travel, the rapid development of a high-speed train network and cultural changes. Our results are compared with Schaefer and Victor's findings in the last section of this paper.

What is not possible for a regional and global model might work at a national level. The relative richness of French data on tourism (from 1965), travel and socio-economic changes made it possible to develop a more sophisticated analysis for the future demand of tourism, accounting for the interrelations between factors of change, such as demographic and economic factors, transport technology and policy, the tourism market, or the evolution of lifestyles and cultural change regarding travel.

The model was developed using the following steps:

- The model refers to all leisure motivated travel of French households (short and long distance mobility). This excludes international tourism to France and business tourism by French households, but includes day trips and short distance leisure mobility for sports, leisure related shopping and cultural mobility within the city of residence.
- The model is based on households, which are the basic unit for transport decision-making. This would assume that all members of the household have the same tourism and travel behaviour, i.e. they do the same trips. In practice, this is not the case. For example parents take short breaks without their children, who may go to summer camps, and so forth. We have corrected this for car transport (considering its high impact on GHG emissions) and differences of travel behaviour within households are also taken into account through the

existence of various mobility patterns in the model. In 2000, France had 23 000 000 households with an average size of 2.4 persons.

- Rather than taking as a starting point the average consumption patterns of French households and examining their future under contrasted socio-economic scenarios (and thus forecasting trends), the first step of the research was to develop some contrasted tourism/ leisure mobility patterns (Ceron & Dubois 2004). This took into account recent sociological trends observed in France and in Europe (Urbain, 2002 ; Viard, 2002; Boulin, Dommergues & Godard, 2002; Asher & Godard 2003). The patterns do not reflect a statistical typology of current tourism demand, but have been designed as contrasted attitudes to travel, enabling a modelling of demand to be made. Consistency with the current situation was ensured by a calibration test.
- The mobility patterns result from the summing of a number of trips for five types of mobility : short distance leisure mobility near the home (SD), outings (O), long distance trips (LD), very long distance trips (VLD), bi-residential mobility (BR). Each of them is allocated an average distance derived from national tourism and transport surveys, and associated with a modal distribution for each type of trip. In this model categories of mobility/travel differ from the usually applied definition of tourism : they include leisure without night stays, and attempt to show awareness of the reality of travel, thus correcting the frequently misleading by current tourism statistics. A trip from Nice to Italy (50 km distance), for example, will be accounted as an "outing", while a trip from Paris to Nice at 900 km is accounted as a "long distance trip".
- Five patterns are defined: a *conventional* pattern, derived from the mass behaviour of the last two decades, a *great traveller*, or "Parisian" pattern (high income and frequent departures), a *home-centred* pattern, combining an increasing attraction of home-centred leisure, associated with a still important desire for exotic destinations, a *bi-residential* pattern, relying on frequent trips between a main home and a second home (there are 2.3 million second homes in France) and a *home-bound* pattern, involving households which, by choice or by constraint do not travel. The tourism demand is finally segmented in this model in 100 sub-markets, i.e. 5 patterns X 5 types of mobility X 4 modes of transport.
- GHG emission factors per passenger-km for planes, trains and buses are extracted from various European sources (van Essen 2003; Eurostat 2000; Pulles et al. 2002; Ademe 2001). For planes, trains and coaches, average emissions factors per passenger-km were used. For cars a per vehicle-km average emission factor was used (Ifen, 2000). Using a passenger-km average factor would imply that a four-person household travelling by car would emit four times more pollutants than a single traveller, though this is not the case. Nowadays, trips are increasingly individualised within the household, which means more personal vehicle movements, and thus more GHG emissions. A 1.5 correction factor can thus be assumed, i.e. one tourism trip of the household is tantamount to 1.5 car trips.

Table 1 : Emissions factors used in this study

Transport mode	**Emission factor (kg eq CO2 per passenger-km)**
Plane- Mid Haul	0.432
Plane- Long Haul	0.378
Train	0.026
Coach and others	0.019
Car	0.18 (per vehicle-km)

2. CONSISTENCY OF THE MODEL WITH THE YEAR 2000 SITUATION

The model was developed and calibrated for the year 2000 using two tourism and transport surveys. The SDT ("suivi de la demande touristique") survey is an exhaustive survey of French tourism demand, based upon a 20 000 persons panel interviewed on a monthly basis about the trips of the previous month. Day trips have been surveyed since 2002 (Delort 2003, 2004). The Transport Survey is a detailed survey of personal mobility, with a specific monitoring of private vehicle mobility, short distance and long distance (over-100 km) mobility. The latest Transport Survey was undertaken in 1993, and it was used to input data on leisure near the home (short distance mobility), which represents a minor part of overall mobility.

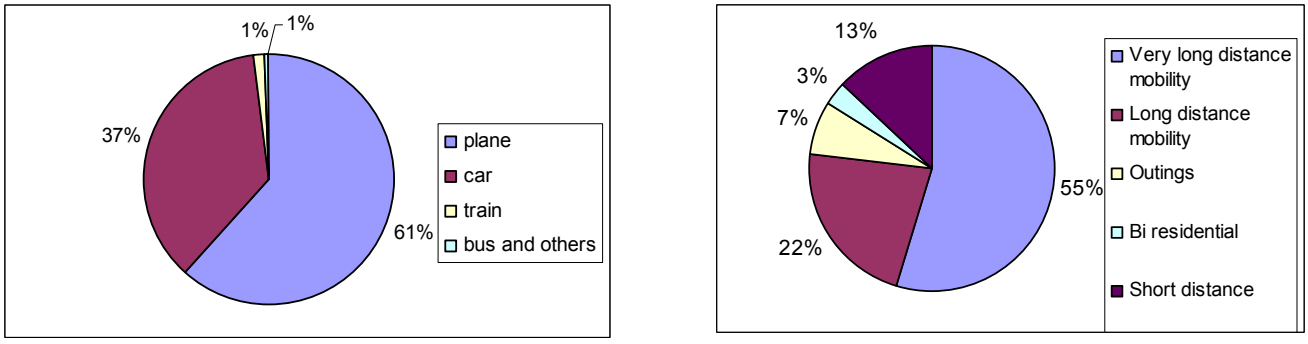
Due to the approach taken to define categories of mobility, calibration data were not readily available from the literature. As calibration values covered fields diverging from the modeled value, a correction factor was used. For example, the model covers all tourism trips by French to all distances [1], whereas the data obtained from the SDT Survey only covered tourism trips over 100 km from the main home (excluding 29% of trips and 5% of passenger-km) and for the French over 15 (20% of French population was under 15 in 2000).

Excepting bus transport (marginal in French demand), calibration results range from -5% to +24% for the year 2000. The calibration led to the serious revision of primary assumptions, for instance for average distance of VLD trips, which jumped from 6 000 to 10 000 km. The model was calibrated with 11 values (e.g., number of trips by transport mode, travel distance by transport mode, tourism trips, trips to secondary homes, number of personal trips >100kms).

The results of the model for GHG emissions in2000 (after the calibration tests) are displayed in **Erreur ! Source du renvoi introuvable.**. While passenger-km are clearly dominated by road transport, the conventional pattern and long distance mobility, GHG emissions are dominated by air transport, the great traveller pattern and very long distance mobility. Although the French do travel much by air (80% of tourism trips are taken by car), a minority of great travellers (10% of households, 27% of passenger-km travelled in the model) represent 47% of GHG emissions, due to more frequent trips, longer distances, and above all, a more frequent use of air transport.

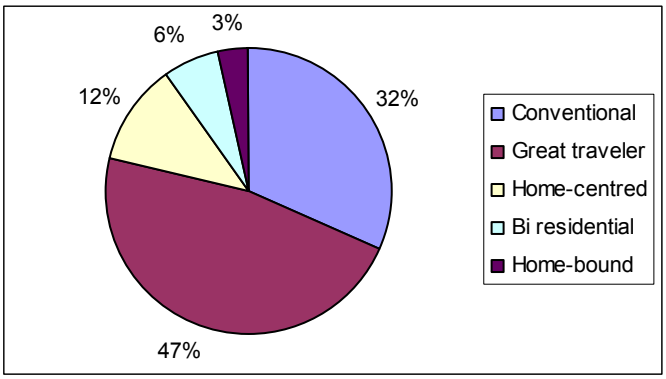
Figure 1: Break-down of tourism/leisure GHG emissions by French residents in 2000

Mode of transport *Type of mobility*



Mobility pattern

[1] In fact, people who live in France, irrespective of their nationality.



3. SENSITIVITY TO TOURISM/ LEISURE DEMAND AND ASSOCIATED EMISSIONS OF GHG TO VARIOUS FACTORS

The model enables us to test the sensitivity of tourism/ leisure GHG emissions to a number of parameters such as total population and number of households, size of households, load factor of vehicles, mobility patterns, modal distribution, and GHG emission factors.

The objectives of the research were to analyse the tourism/ leisure demand as a result of socio-economic forces, for example, economic growth and technological change.

To this end, six categories of driving forces, with thirteen subcategories were defined: 1) demographics (population size, ageing, generational effects, evolution of family structure, 2) economy (growth, unemployment and inequalities, diminution of working time), 3) international security context, 4) transport technology and policy (technological change, transport infrastructure, transport pricing), 5) the tourism market, and 6) society and lifestyles (habitat, cultural change towards travel). For each subcategory, a central assumption was made, often related to bibliographic sources, and a range of minimum and maximum effects on GHG emissions could be defined. The results by category are the combination of the results by subcategories.

The effect of one particular factor in 2050 must be understood as its effect isolated from the interactions with the other factors. For example, the ageing of population is applied to the size of population in 2000. In a second step, it is then legitimate to combine it with the size of population expected in 2050 and to analyse their joint impact. In certain cases, however, the impacts of factors are so interrelated that it is impossible to individualise them completely. The generational effect (increase of departure rate at the same age) for example, is a demographic factor, linked to cultural change, to the experience to travel, to economic growth, but also to the improvement of net income and the reduction of social inequalities. Such interrelations can sometimes complicate the summing of factors: this will be a decisive issue to tackle when building scenarios (next step of the research as mentioned above).

For each factor, we define three trends, according to their outcome in terms of GHG emissions: a minimum, a maximum and an intermediate (central) trend.

Factors for Change

1. DEMOGRAPHICS

- *Population growth.* The total population (58,7 millions in 2000) could reach 64 millions in 2050, according to the central scenario of the National Statistic Institute (*Insee*) (Brutel 2001, Brutel and Omalek 2003). According to different assumptions of fertility, mortality and migration, the French population would remain in a range of 57-70 millions in 2050, with the same number of persons per household as in 2000 (2.4).
- *Ageing of population.* In Insee's central scenario for 2050, the proportion of French people over 65 (16% in 2000) will reach 29.2%, and the share of people over 75 will increase from 7.2% to 18.1%. This will tend to diminish the rate of departure on holidays, especially for the over-75. Ageing could, together with unemployment, lead to more home-centered lifestyles. Duplicating the current departure rate could be considered as the central trend. This would lead to a diminution of average departure rate for an ageing French population. The maximum would derive both from a higher birth rate, i.e.more young people in the population, and also from an improvement in the health conditions of the elderly, which would lead to more departures. The minimum would arise from a growing proportion of disabled elderly people without suitable access to tourism and travel. Ageing can also change the distribution of patterns. There could be more "home bound" households as well as a growing proportion of younger retired people adopting a bi-residential way of life, favored by the absence of work constraints. Ageing should also have contrasted effects on very long distance trips, according to the diverging hypotheses that can be made on health conditions. This factor could also impact on the respective share of means of transport possibly increasing the use of bus and train.
- *Generational effects.* Past trends show that departure rates at the same age improved gradually with wealth and the experience of travel. The departure rate increased faster for the elderly than for young people (Rouquette 2000).The central tendency should, therefore, be a continuous increase of travel for middle-aged people (50-65 years), and a slower growth, limited by old age and disabilities, for those over-70. From this general trend, a range can be defined, from a maximum in which all generations would experience frequent trips, including very long distance mobility, to a minimum, in which the tourism market would not supply adequate products for the elderly (stagnation of the over-70 departure rate). T In the latter context, the new generations (the "Internet generation" and those after) would be less likely to travel, due to lower income and the availability of virtual travel (Salomon 1998),to home-centered lifestyles and the excessive standardization of tourism places.
- *Evolution of family structure.* The evolution of the average number of persons per household shows a continuous decline, from 3.2 in 1962, to 2.4 in 2000 (Cristofari and Labarthe 2001). It is uncertain whether this trend will continue at the same pace. An ageing and the increase in the divorce rate generates more single person households and this will tend to confirm the trend. Conversely, the healthy French birth rate may overtime increase the family household size. More households means more individualised travel, and thus more road mobility for the same amount of bed-nights (lower load factor of cars). The intermediate trend would be a moderate diminution of household size, from 2.4 to 2.1 persons. The maximum equates to a strong diminution in household size, i.e. more single people and "Dinks" (Double income no kids) would probably imply more "great travelers". The minimum reflects a return to family values, a high birth rate, and thus leads to a growing share of "home-centered" patterns and also "conventional" patterns.

Table 2 Factors for change : demographics

	Trend	Hypotheses		Results		
				Passenger .km	Road traffic	GHG emissions
1.1	*Increase of population*	Medium	64 millions, 26 600 000 households	15.9%	15.9%	15.9%
		High	70 millions, 29 160 000 households	26.8%	26.8%	26.8%
		Low	57 millions, 23 750 000 households	3.3%	3.3%	3.3%
1.2	*Ageing of population*	Medium	Diminution of departure rate. Home-bound +7%, conventional -7%	-7.6%	-2.2%	-12.4%
		High	Home-bound +4%, bi-residential + 3%, great traveler +1%, conventional - 8%, more VLD trips, more train and buses	8.7%	-5.5%	15.6%
		Low	More very old disabled people. Home bound + 9%, conventional -10%, bi-residential +1%	-13.1%	-76%	-18.1%
1.3	*Generational affect*	Medium	Home-bound -4%, bi-residential +2%, great traveler +1%, conventional +1%, more train and bus, more VLD trips	20.8%	7.0%	23.1%
		High	Great traveler +4%, bi-residential +2%, conventional +2%, home-bound -8%, more VLD mobility for all patterns, more train and buses	51.9%	14.7%	78.7%
		Low	A new generation less interested in departure. Home-bound 0%, home-centered +2%, great traveler -2%, bi-residential -1%, conventional +1%	-4.4%	-8.2%	-9.7%
1.4	*Evolution of family structure*	Medium	Household size 2,1 (26 285 000 households)	-0.9%	-0.4%	4.0%
		High	Households size 1,9, great travelers +3%, conventional -1%, home-bound -2%	8.3%	1.8%	25.1%
		Low	Household size 2,4. home-centered +3%, bi-residential +1%, conventional -4%	4.3%	1.9%	7.8%
1.	***All demographic factors***	Medium	Population 64 millions, households size 2,1. Conventional -7%, great traveler + 1.5%, bi-residential +4%, home bound +1.5%, more train and bus, more very long distance mobility	**24.6%**	**13.2%**	**33.4%**
		High	Population 70 millions. Household size 1.9, conventional -7%, great traveller+8%, home-bound -6%, bi-residential +5%. More VLD trips. More train and bus.	**68.4%**	**31.2%**	**111.6%**
		Low	Population 57 millions. Household size 2.4. Home-bound +9%, conventional -13%, bi-residential +1%, Home-centered +5%, great traveler -2%, more train and buses	**-2.4%**	**-10.1%**	**-0.7%**

2. ECONOMIC CONDITIONS

Three factors are important in this context. First, the economic growth in general, second effects of unemployment and inequalities in society and third the impact of changes in working time.

- *Economic growth*. Between 1960 and 1990, France experienced a continuous growth of departure rate on holidays, from 44% to 61% (Rouquette and Taché, 2002). Half of non departures can be explained by financial reasons (Rouquette, 2000; Boudet and Le Scouarnec, 2000). A maximum would rely on strong economic growth (3.5% increase in GDP per year), which could largely, though not completely, alleviate financial constraints : the growth of tourism would be limited by the fact that an important minority do not access international travel. The departure rate could reach a maximum of 74% for long stays 74%, (86% if adding short stays). A very hypothetical minimum linked to economic stagnation would imply the same departure rate for 2050 as for 2000. The central trend (+2.5% per year) would imply that half of the maximum would be reached i.e. 67% for long stays, 83% including short stays. In every case the saturation of long distance and outings mobility (Graham 2000) and the growth of very long distance, proximity leisure and bi-residential mobility are assumed. In a business-as-usual trend very long distance and proximity leisure mobility would increase by 50%, by 100% for the maximum trend, by 0% for the minimum.

- *Unemployment and inequalities*. Since 1990, the departure rate of the French is stagnating and even tends to diminish for certain categories of people: those who live in Paris and its conurbation and people between 30 and 50 years. There is also a growing polarization between those who earn money but do not have time to travel, and those who have more spare time but less income (e.g. retired people, students and the unemployed). French domestic tourism annual demand decreased by 57 millions bed-nights between 1983 and 1999. Following current trends would assume a persisting economic and social polarization, with very long distance trips abroad for a growing minority of rich employees, a conventional pattern for the majority, and short distance leisure mobility, outings, and home-bound patterns for a still important share of society. A maximum would assume the progressive disappearance of unemployment (unemployment persisting at still around 10% in France in 2000) and the diminution of the working population due to an increasing share of retired people. A fairer distribution of wealth would lead to the adoption of a great traveller pattern for a larger percentage of the population, and, across all patterns, to more frequent departures. Globally the WTO forecast of a 3-4% of annual growth for international tourism would be reached ; it would be lower for a mature" market such as France, which leads to a 150% increase of very long distance mobility in 2050. A minimum would probably involve social tension and violence and the ensuing insecurity : a minority of wealthy people would try to escape from this context by travelling abroad, or they would buy secondary homes in preserved areas. Short distance leisure mobility would probably be limited by these social tensions.
- *Diminution of working time*. The diminution of working time is a long term trend in modern societies (WTO, 1999 ; OECD, quoted by Viard 2002). In France, this movement has been particularly rapid, since the country occupies the third rank for waken non working time, among OECD countries. The 1999 law setting up a 35 hours working week, accelerated this development. The first surveys did not show a direct impact on tourism (Boulin and du Tertre 2001; DARES 2001). Additional time was mainly used to limit daily time constraints : for example taking one afternoon in the week for doing the housework, and freeing the week-end, or doing shopping more slowly etc. Outings, short stays and bi-residential mobility were clearly favoured, while the growth of long distance and very long distance mobility was hindered by the consecutive limitations on wage increases. The business as usual trend assumes a slow continuation of reduced working time until 2050, limited by the larger number of retired people. Forms of mobility such as outings, shorts stays, and bi-residential patterns would develop. The maximum relies on a rapid reduction in working time (e.g. to foster job creation), which would finally impact on all forms of mobility, including very long distance trips. The minimal trend would assume the same average working time in 2050, and thus a limitation of tourism trips, especially for middle-aged workers.

3. INTERNATIONAL SECURITY CONTEXT

For years tourism has experienced numerous crises: economic recessions, health crises (SARS, foot and mouth disease), environmental crises (oil spills, natural disasters), terrorism and war. Tourism statistics (Ifen 2002) show a high sensitivity of tourism in the short term, but also its strong resilience in the mid and long terms. Some substitutions between products, international destinations, or between domestic and international tourism have, however, been observed (ONT 2003).

Past trends show that very long distance mobility is the only form of tourism not to experience saturation in most developed countries (Steer, quoted by Graham 2000, p.113). Security could, therefore, constitute a limiting factor.

- The current situation shows a persistent context of geopolitical tensions and terror alerts, and the subsequent uncertainties about the safety of travel. If the reactions to this situation remain constant long distance or very long distance mobility will not be seriously limited. Substitution between international destinations impacts on neither the amount of passenger.km travelled, nor the amount of GHG emissions.

- The maximal trend assumes global prosperity and peace, safer travel and more welcoming societies. Very long distance mobility could positively boom as average incomes increase, and tourism consumption could become more and more individualised.
- A minimal trend admits that global insecurity could hinder very long distance mobility, or limit it to inter-OECD countries. Domestic tourism would appear as a substitute: less great traveller patterns, more conventional ones, but with more long distance trips, and trips within Europe. Airline companies' profitability would be at risk, since increasing security demands would drastically increase their costs. This would in turn lead to a diminution of their market share.

4. TRANSPORT TECHNOLOGY AND POLICY

- *Technology.*
  - *Air transport.* The IPCC central emission scenario forecasts for 2050 a multiplication by a factor of three of aviation emissions, with a wide range of 1.6 to 12 according to different scenarios. Worldwide, civil aviation could emit 15% of total CO2. Potential improvements in aircraft energy efficiency relate to the improvement of aircraft and engine design, traffic operations and the possible use of alternative fuels (Peeters 2002; Wedantham and Oppenheimer 1998). Two time horizons should be distinguished. For 2020, forecasts rely on existing technology and past trends. Kalidova and al. (1998), assume an improved aircraft energy efficiency of between 22% and 40%, with a baseline scenario of 34%. IPCC (1999) predicts a lower average of 20%. For 2050, forecasts are more uncertain, and depend on the possible introduction of liquid hydrogen aircraft. Given the increased fuel cost and growing environmental constraints, hydrogen technology is expected, but timeframes are unclear (Pohl 1995 ; Peeters Advies et al., 2002). Hydrogen propulsion would not emit CO2 during the flight, but implies more water vapor, contrail formation, and the primary energy to produce hydrogen might not be carbon neutral. The IPCC (GIEC/IPCC 1999, p.12) is therefore cautious about the final effect on climate change. IPCC assumes a total improvement in efficiency of 40-50% by 2050. In our model, a minimum would imply that hydrogen would not be introduced, a maximum would rely on a good penetration of hydrogen (20% of aircrafts in 2050), with hydrogen produced through renewable energies. Schafer and Victor (1999) assumed a maximum penetration of 70% to be reached in 2050.

  Road transport. The fuel efficiency of car engines has improved by 1% per year in the past 30 years. Improved energy efficiency was, however, offset by declining load factors and features such as weight, four wheel drive and air conditioning. Globally the energy efficiency of road passenger transport has remained constant since 1970. In our model, however, the load factor parameter is taken into account separately, by changing the "size of household" parameter. Thus, a "business as usual" trend would replicate this annual 1% improvement until 2050, which would lead to efficiencies increased by 60%. A minimum trend relies on strong incentives to reduce emissions, for example by reducing car weight, improving environmental norms (120 g of CO2 per km, as proposed by the European Commission), reducing speed on highways, and using low impact or alternative fuels

  Train and Buses. For train travel, Bek and Sorenson (1998) assume a progressive electrification of the network and only a slow improvement of diesel engines, because of the long life of locomotives. The weight of trains could decrease by a factor of 2.5 by 2020, and the emissions of electrical power generation would diminish by more than two. A 30-60% diminution is thus assumed.

- *Infrastructure choices.*

The travel sector experiences a phenomenon of "path dependence" : initial infrastructure choices shape the future and limit the rate at which one mode can be substituted with another. The two factors that influence the modal split and possible substitution effects are accessibility and price.

- *Air transport availability.* There are two major trends. Firstly, the upsoar of a "mass model" using jumbo jets (e.g., A380). This could tend to reduce the emissions per passenger.km but, as these planes rely on a "hub and spoke" model, which increases both the distances for each trip and the number of take offs/landings, the ultimate effect on emissions remains up to now unclear. Secondly, although in the long run the high speed trains could compete with mid-haul travel, France has, in recent years, experienced a fast development of low cost companies which relies on regional airports that are substantially funded by regional authorities.

- *Road accessibility and substitution by trains.* The TGV is able to divert a substantial part of road and air transport. The long term perspectives on French transport infrastructure development are given by the national spatial planning directorate (DATAR) showing a spread to the west and east of the High speed train network in 2025, which, for example, would put Italy or Spain within only 4-5 hours from London. They also indicate the continuation of the highway coverage of the country, with all points at less than 30 minutes from a highway entry. With the expected increase of road congestion on North/ South itineraries, a "business as usual" trend assumes a diversion of 15% of long distance mobility and outings using the train network. A voluntarist prospect would assume a strong investment in high speed and regional trains, with special attention being given to soft mobility at tourism destinations, resulting in incentives for tourists to leave their cars at home. The concentration of tourists in big coastal and mountain resorts rather than in remote countryside areas would lead to a more frequent use of collective means of transport, and terminating subsidies to low cost airlines would subsequently benefit train systems. The substitution rate of trains for cars for long distance trips could reach 30% in 2050. A minimum would assume a moderate investment in the rail network and a growing market share of low cost companies. The substitution could reach only 5% which would be essentially diverted from car traffic.

– *Transport pricing*. Transport pricing is linked to various factors, such as fuel, operational and security costs, the volume of demand, new vehicles, and taxation. A future with increased transport fees could lead to a general reduction of tourism and travel demand. The loss would not be linearly linked to the distance per trip or to the price per trip. Since very long distance trips are rare, exotic and desired, the price increase would probably have to be steep to lead to a drop in demand. In France and in Europe, except for railways, where a more open market could increase competition, the transport prices are not set to diminish. Air transport has benefited from low price fuel, international competition, and a low level of sky congestion, but the outlook is for increased full and operational costs and the endangered profitability of major airlines does not suggest a competition on price. For road transport, in Europe, fuel taxes currently represent around 80% of fuel price. They are not likely to increase significantly at least in the short term. Increased crude oil prices and taxes on polluting vehicles could, however have an impact. So, the "business as usual" trend suggests a slight increase of travel costs, which could marginally impact on modal distribution. Low cost companies could be less prevalent, there may be fewer trips to secondary homes, and a modal split might favour the train for long distance mobility. A maximum trend would stem from cheap energy and general deregulation. This would maintain the share of road transport and develop air transport owing to low operational costs and no internalization of environmental costs. A minimum trend would assume that oil crises and environmental constraints, such as carbon taxes for aircraft, would increase by 50% the average prices of road and air transport, and thus, tend to diminish long and very long distance mobility, and favor travel by trains and buses. Great travellers patterns would be at their lowest market share, and home-centered ones would be reinforced.

Table 3 Factors for change : Transport technology and policy

	Trend	Hypothesis	Results

				Passenger. km	Road traffic	GHG emissions
4.1	*Technology*	Medium	Energy efficiency : Air : 55%, road 65%, train 45%, bus 28%	0.0%	0.0%	-58.8%
		Low	Air 70%, road 75%, train 60%, bus 35%	0.0%	0.0%	-71.5%
		High	Air : 40%, road 55%, train 30%, bus 22%	0.0%	0.0%	-45.3%
4.2	*Infrastructure choices*	Medium	Substitution road to train (LD + O) : 15%, air (LD) to train : 25%. Average distance per trip +20% (+10% for VLD)	17.4%	3.7%	8.0%
		Low	Substitution road to train (LD + O) : 30%, air (LD) to train : 40%. No changes in average distance (fast transport is costly)	0.0%	-27.7%	-10.6%
		High	Substitution road to train : 5%,air to train : none. Average distance per trip : +35% (VLD +20%)	31.1%	28.3%	23.7%
4.3	*Transport pricing*	Medium	Less trips to second homes (15 a year rather than 22), air transport share for LD decrease by 20%, less road and more train.	-1.5%	-14.9%	-5.9%
		High	More plane for LD, outings and bi-residential, more VLD trips	20.1%	-0.9%	51.0%
		Low	Less LD and VLD mobility (-15%), average distance decrease by 10%, share substitution of 20% of road and air to train and bus	-18.2%	-25.0%	-29.0%
4	***All transport technology and policy factors***	Medium	Emission factor of 4.1 medium+ combination 4.2 and 4.3	**15.6%**	**1.7%**	**-55.7%**
		High	Emission factor of 4.1 high+ combination 4.2 and 4.3	**52.5%**	**28.3%**	**-3.9%**
		Low	Emission factor of 4.1 low + combination 4.2 and 4.3	**-15.3%**	**-36.9%**	**-79.0%**

5. THE TOURISM MARKET

French tourism is quite specific in Europe. It is, in spite of high average incomes, first characterized by a reluctance to travel abroad. The diversity of tourism destinations in France explains that most tourism trips are taken within the country itself. The French, as a result, occupy the 3rd place within UE 15, for holidays taken within the home country, after Greece and Spain (OECD, 2001, p. 13). Most trips are also self-organized : only 9% of the domestic trips (but 59% of trips taken abroad) used the services of a tour operator or a travel agent (SDT Survey 2001). Private accommodation, therefore, accounts for an important share of the demand. In 2001, secondary homes hosted approximately 10% of stays and accommodation provided by friends or relatives 53%.

These features impact on the profile of mobility demand. Individualism implies a more than important share of road transport: up to 80% of trips use road transport. Secondary homes encourage frequent departures from the main home. Fewer trips abroad imply a lower market share of air transport (6.5% of stays and 34% of passenger-km in 2000 (SDT Survey). On the contrary, powerful tour-operators with cheap packages and good promotion or marketing could, in the future, be strong promoters of international tourism, as would healthy airline companies.

The maximum trend reflects the behaviour of the French converging with that of northern Europeans : more trips abroad (more great travelers), more organized tours, and thus collective means of transportation, not only by buses and trains, but also by planes. The opposite trend would assume a strengthening of French specificity, namely a crisis of commercial accommodation being increasingly in competition with residential development which is currently reported in coastal areas (Dubois, 2004, 2005) and a substitution of secondary homes and other private accommodation to commercial accommodation. This would imply more bi-residential patterns, more car use, a stagnation of long distance trips and an increase of outings. These trends have been observed since 1990. The overall departure rate would stagnate. An intermediary trend would consist of a mix of the previous trends: a persistence in self organization and secondary homes for most long distance trips, but also more packaged tours to remote destinations.

Table 4 : Factors for change : the tourism market

	Trend	Hypothesis		Results		
				Passenger .km	Road traffic	GHG emissions
5	***The tourism market***	Medium	Bi-residential +1%, Great traveler +1%, conventional -2%, 10% more VLD trips in all patterns, 15% more outings. Average distance per trip +5%	26.5%	1.1%	49.3%
		High	Great traveler +2%, conventional -2%, substitution of 15% of LD trips to plane, train and buses, 20% more VLD trips in all patterns. Average distance per trip +10% (+30% for LD trips)	46.1%	13.8%	80.4%
		Low	Bi-residential +2%, great traveler -1%, conventional -1%, more outings (+30%) in all patterns, less LD trips (-20%). Slight increase of automotivity. Average distance per trip for LD and VLD -10%	-5.4%	1.4%	-8.8%

6. SOCIETY AND LIFESTYLES

- *Habitat.* Housing conditions significantly improved over the last decades (Omalek, Le Blanc 1998 ; Omalek. et al. 2000). The proportion of one-family homes increased, as has the average space per person, (from 31 to 37 m² between 1984 and 2002) (Insee, housing surveys 1984 and 2002; Chaleix and Madinier 2000; Jacquot 2003; Louvot-Ruvanot 2001). The French own 12 to 13 millions gardens (Aubert C., Marzin L., Fleury A. 1999 ; Creux 2001). 56% of the French own their house or apartment. The home is more and more adapted to leisure, and statistics show that there is an increase in the time devoted to meals with relatives and in the times to visit them. The change in the relationships between the quality of housing, the immediate environment (Martin-Houssard, Rizk 2002), and the individual distribution of free time could lead to change in tourism and travel consumption patterns.

In a central trend, a significant part of the population would shift from the conventional pattern to home-bound and home-centered patterns. Weekly distance for proximity leisure would increase by 30%, day trips by 20% across all patterns. In a more extreme configuration the new leisure functions of the main home would be transferred to a second home as well.

Conversely, if the environmental conditions of the main home worsened because of urban pollution, crime etc. and if real estate costs and mortgage limited the access to private property, as currently observed in French southern cities, the gains in home comfort could be largely offset. Households would compensate this low quality of life by more massive departures, notably among those who currently stay voluntarily at home. Tourism thus would fulfill its function of a temporary escape from unpleasant living conditions.

- *Cultural change, values and cultural attitudes to travel.* Forecasting cultural change, especially in the long term, is even more challenging than forecasting technology or the economy. It is possible to consider some factors that could seriously change the tourism and travel consumption, such as attitudes towards health, the environment and exoticism, and towards travel itself.

The habits of tourists since the thirties have been strongly driven by a quest for sunshine, however, attitudes towards sun bathing have changed over time, for example in relation to health (e.g. skin cancer). It is possible that such changes could continue and alter the climatic expectations of tourists, especially with regards to sun and beach tourism. The cultural requirements of tourists regarding some features of climate appear to be quite uncertain, as are their effects on mobility.

The second factor influencing cultural attitude to travel is environmental consciousness, although the impact of a greater sensitivity to nature is uncertain. On the one hand it has been pointed out (Gössling 2002 b, Urry 1995) that an improved knowledge among the public of global natural environments might lead to visitors loosing their sense of place and as a result travelling unceasingly

with huge environmental consequences. Alternatively, an environmental consciousness of the impact of travel might burgeon, following environmental catastrophes or dramatic price increases in air travel[2]. Such events could lead to a decrease in travel demand, a rise in virtual travel, or even a substitution of travel with spiritual activities[3].

Attitudes towards travel have also evolved during the 20th century, from the Grand Tour of the aristocratic class, which corresponded to a single extended trip in one's life, to the current hyper-mobility implying short breaks in remote destinations several times a year. Past trends suggest that the peak of hyper-mobility is still to be attained, with the unaltered attraction of remote destinations and ecotourism, the acceleration of life, the high-speed technologies in travelling and the access of information. Extended travelling continues to be a signal of social status. Promotional campaigns attempt to show a near future when people will gamble in casinos while settled in super jumbo jets such as A380. Alternatively recent trends show emerging attitudes towards travel such as the popularity of car-free vacations and travel with substantial nature activity components. It is possible that the answer to every-day pressures favours the demand for a totally different tourism experience ("slow tourism") (Matos-Wasem 2004).

These types of cultural changes would, in all probability, lead to a downturn in the conventional pattern, which could be compensated for in different ways.

- In the intermediate trend, compensation would be by a growth of very long distance, very individualized mobility to remote destinations, with the expected growth in "ecotourism" products, and also by more home-centered lifestyles. Long distance mobility would stagnate, as would outings. Home-centered and great travellers patterns would steadily increase their market share.
- In a maximum trend the growth of very long distance tourism could be boosted by a growing attraction for adventure tourism, increase use of technology, without a real awareness of the environmental impact of such tourism. This would also increase the on-site impact of tourism. The great traveler pattern would reach a maximum share.
- In a minimum, slow tourism would emerge as a considerable market. In spite of the continuing important attraction of remote destinations and the need for authenticity and discovery, combined with the awareness of environmental impact of such travel, translated in prices, this would lead to less frequent departures abroad, but for longer periods. Home-centered patterns (which imply VLD mobility) would attain the maximum, and the use of the car would decrease for all kinds of mobility and thus for all patterns.

Table 5 Factors for change : society and lifestyles

	Trend	Hypothesis		Results		
				Passenger .km	Road traffic	GHG emissions
6.1	*Habitat*	Medium	Home centered lifestyle, voluntary-non departure. Conventional-8%, home centered +4%, home bound +4%. SD weekly distance +30%, day trips +20% in all patterns.	7.6%	8.2%	9.6%
		Low	Home bound –10%, conventional +3%, great travelers +5%, biresidential +2%, increased distance for VLD and LD trips 10%	26.6%	13.1%	40.7%
		High	Secondary homes. conventional-10%, home centered +5%, biresidential +3%, home-bound +2%	8.4%	3.9%	15.3%
6.2	*Cultural change*	Medium	Conventional –12%, home bound +3%, home centered +5%, great traveler +4%.	8.1%	-5.3%	24.4%
		Low	Conventional –8%, home-centered +9%, great traveler –3%, home-bound +2%, less VLD trips for all patterns, less car transport	-6.0%	-11.3%	-12.5%

[2] Some social scientists fear that catastrophes are the only means by which mankind will take into account climate change (Dupuy 2004). These might happen in a future nearer than that expected : one can recall that extreme climatic events such as El Nino and la Nina are associated with changes in temperature of 2.5 to 2 °C, and that France has known since the beginning of the 20th century a significant warming of 1°C

[3] J D Urbain reminds that in French we use the term of « voyage intérieur » (Urbain 2002)

		High	Conventional –16%, home centered +5%, great traveler +9%, home-bound +2%	17.9%	-6.4%	46.5%
	All societies and lifestyles factors	Medium	Conventional -20%, home-centered +9%, great traveler +4%, home-bound +7%	**7.6%**	**-9.9%**	**29.2%**
		Low	Conventional -5%, great traveler +2%, home-centered +9%, home-bound -8%, biresidential +2%	**21.1%**	**11.4%**	**33.4%**
		High	Conventional -26%, great traveler +9%, home-centered +10%, biresidential +3%, home-bound +4%	**26.3%**	**-2.5%**	**61.8%**

Synthesis and discussion

France is considered a mature tourism market. Notwithstanding it appears to conceal a high potential for increasing GHG emissions. Combining all the medium hypotheses in the model would lead to an increase of 88% in emissions by 2050 (Figure 2). Given that WTO (2001) predicts that tourism develops less in Europeans countries than in emerging markets, this suggests some worrying prospects in terms of the world-wide emissions from tourism, even if it is remembered that for emerging markets domestic tourism tends to be the first to develop.

The greatest effects linked to demography are not those of an increase in population (26.9% in the high version, for instance), but changes in the structure of the population (ageing, generational effects, family) appear to have a greater influence.

On the contrary the direct effect of economic growth are striking: a rate of 3.5% per year, or even 2% over half a century ensures almost a trebling or a doubling of emissions. Yet the diminishing of working time and the employment factor have, together, an impact which amounts to the 2/3 of economic growth (in its maximal trend): transport and emissions from tourism seem to remain coupled to economic growth. The international context appears to be a factor of great influence, in particular since it is uncertain as to what extent western societies could remain calm while facing international tensions. Our results show that this is the main factor, which apart from cultural change could really restrain people from travelling for leisure especially to remote and politically unstable destinations (-28% in the case of high political instability). Aviation also is perceived as a vulnerable means of transport. The way the tourism market is organised also appears to be an important factor, roughly in the same order of magnitude as demographics. A crisis of commercial accommodation, accompanied by more local leisure patterns would reduce emissions. Conversely, an increased strength of commercial stakeholders would tend to lead to more travel and high impacts

The lifestyles factor has, within the model, a potential impact which remains in the same order of magnitude as the previous factor. This does not reflect the fact that it is an inescapable factor for achieving sustainability. The assumptions made are “reasonable”, which means they do not consider a dramatic increase in environmental concerns that would be linked for example to catastrophic climatic events. The model does not reflect either the change in lifestyles that would be necessary to divide approximately by a factor four (Von Weizsaecker and al. 1998 ; Grassl, H., Kokott J., Kulessa M. and al. 2003) anthropogenic emissions of GHGs, which is said to be necessary if climate change is to be kept within acceptable boundaries.

The model clearly shows that technological progress is not likely to offset the increase in emissions due to other factors, even if very optimistic assumptions are made for year 2050. Not acting on transport pricing or infrastructure could even offset the gains in energy efficiency of vehicles. This is a major conclusion and one that is rather easy to reach but which stakeholders both in the tourism and in the transport industry are not ready to accept (Iwand 2003) or to draw from it all the conclusions it implies[4].

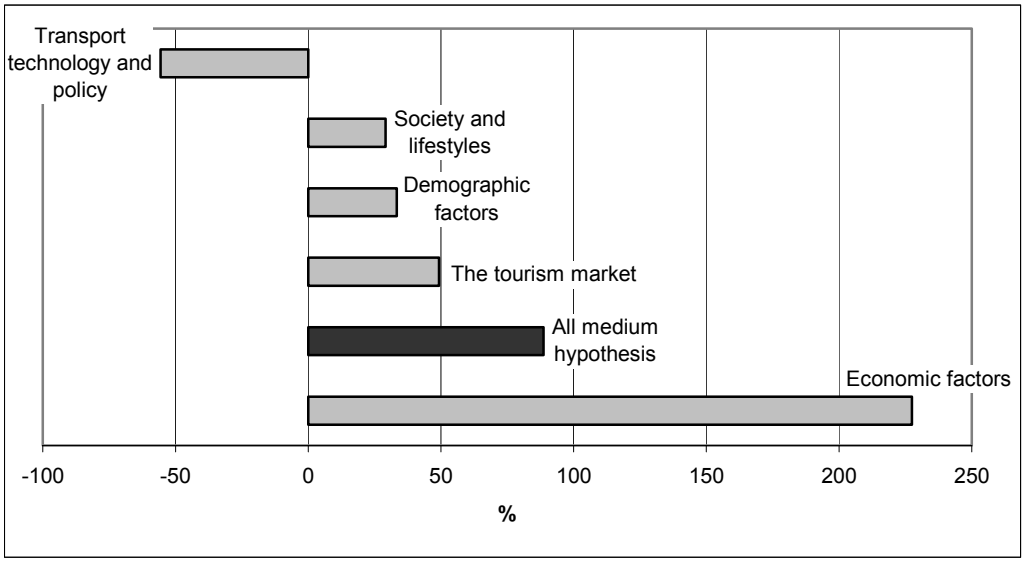
[4] Some appear to think simply buying tradable GHG permits would be the solution

The importance of air transport, now and in the future explains a major part of the emissions, and it seems that the evolution of a majority of of factors considered would call for a greater use of the plane. Air transport would account, in a combination of all medium hypothesis, for 86% of emissions (61% in 2000), clearly associated with the burgeoning of very long distance mobility : distance combines with high impact modes of travel to produce high impact situations. Only a minority of travellers currently use the plane and their holidays account for the greater proportion of emissions: this is clear whether GHG emissions themselves, or passenger.km or patterns are considered. A majority of the prospects imply that this minority of travellers could increase and the associated impacts would escalate. Impacts from aviation are particularly difficult to mitigate. Carbon neutral energies at hand (renewable or nuclear are not adapted to aviation and no one risks dates for fuel cells (Peeters Advies and al. 2002), so aviation should remain dependent on carbon fuels for a long time. Whereas solutions seem achievable in offsetting the emissions of many submarkets (an investment in train infrastructure for long distance trips for example), this minority of great travellers is clearly a problem for the sustainability of tourism.

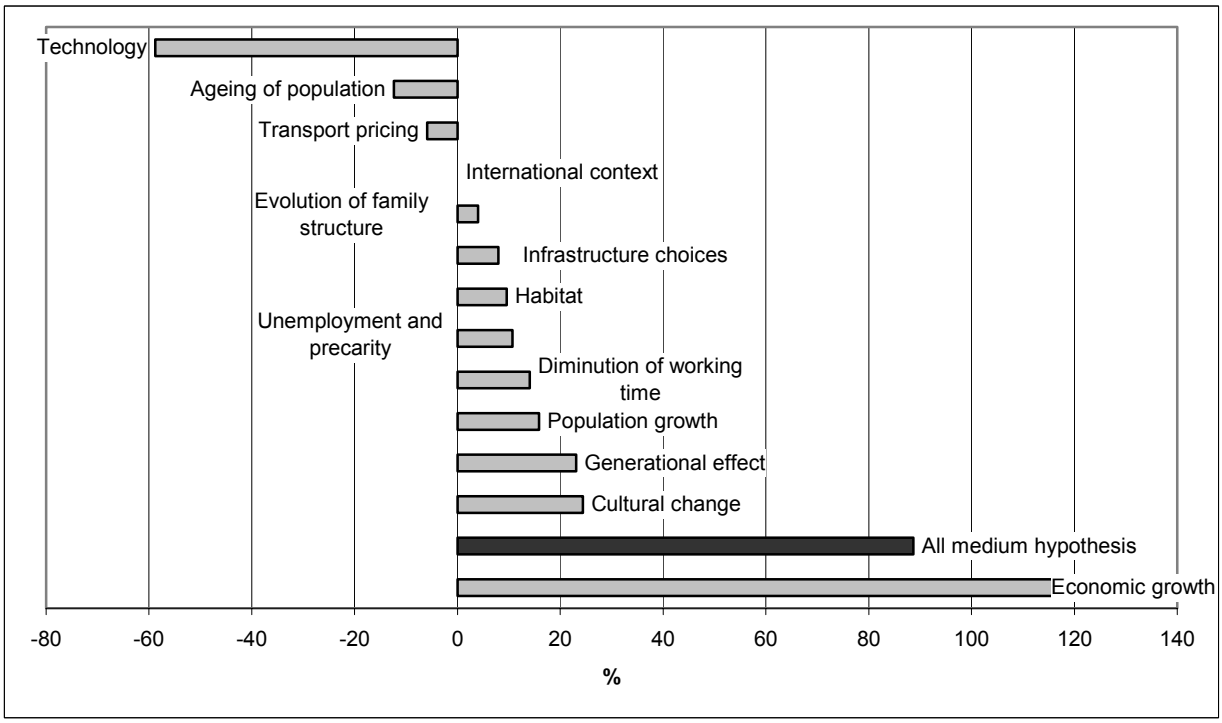
The case for car transport appears quite different. The emissions from cars appear to remain constant in absolute value for almost all non technological factors (with the exception of economic growth). This means, that for a country such as France, the use of the car for leisure and tourism purposes might be progressively reaching a peak. The share of emissions from cars in tourism and leisure mobility thus decreases in a number of the sensitivity tests (37% in the basic model to an extreme of 10% for a very favourable international context). It even diminishes when technological progress is tested, which reflects the greater difficulty of technological progress to curb total emissions from aviation. In combining all medium hypotheses, passenger-km travelled by road transport still increases by 47%, due to a combination of an increased number of trips enabled by higher income and increased free time for outings, and the extension of the number of secondary homes, but their emissions decrease by 20%, due to improved energy efficiency and transport pricing. There is an agreement, therefore, with Schaefer and Victor's (1999) prediction of a decline in automobility but certainly less agreement with the prospect of the stabilisation of GHG emissions resulting from tourism and leisure for industrialised countries. This divergence is linked to the strong potential for a development of air travel even though it would appear that this potential might be higher for France than for adjacent countries whose tourists currently use the plane more frequently than the French do.

Figure 2 : Evolution of GHG emissions from tourism and leisure in 2050, medium hypothesis

Categories



Sub categories



Conclusions

The hypotheses tested above are all plausible, although we acknowledge that by nature the type of exercise presented in this paper is somewhat ambiguous. The results presented here are not an

attempt to forecast the mobility patterns and greenhouse gas emissions from tourism in 2050. However, the presented research is useful as it highlights future problems and key factors determining any changes in GHG emissions from tourism. These analyses stimulate discussions about possible futures. The construction of the model followed a very different method from that employed by Schafer and Victor (1999), who considered that the time devoted to leisure related transport remains constant, alongside with GNP, and demand elasticity. Our model was build to test the sensitivity of future transport demand to a wide range of parameters.

Our analysis showed that none of the hypotheses tested indicated that tourism and leisure would contribute in building a sustainable society. The limitations of personal mobility that led to reductions in greenhouse gas emissions were typically of a undesired nature. For example, the factors of economic stagnation, ageing of population[5], war and terrorism, unemployment and inequalities led to reduced mobility and emissions. The only exceptions to these rather negative societal trends, were the increase popularity of more home-centred lifestyles and a general cultural change with regards to travel. These developments, however, would need to be pushed much further to result in significant impacts on GHG emissions. Lifestyle changes are certainly at the core of a sustainable future for tourism, leisure and associated travel. Other important areas of development include transport technology, policies (e.g. infrastructure and pricing) and the organisation of tourism as a whole. An important step in this context is to internalise transport's environmental costs regarding climate change. Apart from this, the only solution seems to lie in the unlimited availability of clean energy, for example through fuel cells fed by solar energy. Until this is reality, it has to be stated that tourism will continue to contribute to GHG emissions and impact on the global climate.

Our work briefly explores how far it is possible to conciliate environmental constraints with people's appeal for the mobility tourism and leisure imply, i.e. to maintain in a context of foreseeable climate change that particular component of welfare. The conclusion is that it calls for imaginative answers which will draw very different pictures of tourism and leisure than the current ones. Such prospects should not be considered as impossible to manage: a look at the history of tourism shows how much it can adapt to changing contexts and the large extent to which related societal values can evolve within a few decades.

The next step of this research is to assemble all factors into consistent scenarios, which will involve a more qualitative methodology, i.e. making strong assumptions about interrelationships between factors and predominant effects, and assessing contradictions and undesired cumulative effects between factors.

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[5] Carlsonn et al show for Sweden that the only sustainable mobility patterns are those of aged women

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