Climate change, tourism and air transport

Globally sustainable tourism requires clean air transport

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1 Air transport as risk to tourism

Most attention for sustainable development of the tourism sector goes to tourism destinations (see for example APAT, 2002; Cohen, 1978; Theuns, 2001; Tour Operators Initiative, 2002; UNEP, 2002). From several recent papers and articles it has become clear the transport between the place of residence and the tourism destination dominates the effects of tourism (Becken et al., 2003; Ceron, 2003; Gössling, 2002; Peeters, 2003). In this paper the dominance of air transport within the total effects of tourism on climate change will be shown. The energy efficiency per tourist day decreases as distances travelled per vacation increase and the length of stay decreases. Thus the dependency of the sector on cheap oil supply is increasing, adding to the risks of (international) tourism as posed by international terrorism, war and infectious diseases like SARS. Most sectors are working on opportunities to radically reduce the emission of greenhouse gases. The one exemption so far is air transport. Growth exceeds about three times the energy efficiency gains likely for the coming decades. Zero climate effects air transport is technologically feasible, but requires action now, will take 30 to 40 years to develop and an investment of 100 billion or more. This means volume reduction will have to play a role if targets preventing further climate change are going to be reached at medium term. Those targets, like those set by the environmental sustainable transport (EST) project of the OECD (Wiederkehr et al., 2000) ask for a reduction in 2030 of greenhouse gas emissions with 80% with respect to the 1990 levels.

With effects of climate change becoming more and more visible and economically disadvantageous, also for tourism itself, stronger measures against greenhouse gas emissions become more likely. The more the tourism sector depends on burning oil, this poses a risk to the profitability of the sector. Specifically when long haul destinations are developed and become inaccessible due to these measures.

In this paper 'tourism' is defined as the leisure related part of tourism. The international definition often used in tourism statistics is broader, defining every visitor staying between one night and one year outside their usual environment as a tourist visitor (UN, 2001), thus including most business travellers as well. However in transport statistics normally leisure and tourism related transport (L&R transport) is distinguished from business related trips as is the case in this paper.

2 Volume of leisure transport

In 2000 the volume of total world passenger transport was 26000 billion passenger kilometres (pkm) for all public and private transport modes together (Schafer et al., 2000). Of this about one third may be attributed to L&R transport (Gössling, 2002). For air transport the share is higher. About 45% of all air transport passengers is leisure related (excluding business, conference visits and visits to friends and relatives) according to the annual statistics report of Schiphol Airport (Schiphol, 2002). On markets like the European-United States market the L&R share may be 80% (Humphreys, 2003). The world-wide average share of L&R air transport pkm is estimated to be 50% to 65%. In 2000 this results into a air transport share of 20-26% of total world-wide L&R transport. The car is used for 51-55% of pkm, leaving 23-25% for other modes (rail, bus and ferry).

Recent projections of air transport volumes in 2020 suggest a total transport volume of between 8,300 billion pkm (Airbus, 2002; Boeing, 2003) and 9,500 billion pkm (Pulles et al., 2002). Older projections suggest much higher volumes for 2020 like the 13,000 billion pkm given by Lee et al. (Lee et al., 2001) and about 15,000 billion (high growth scenario's of the IPCC (Penner et al., 1999). Using the recent projections 9,000 billion pkm air transport in 2020 has been estimated.

It is likely the L&R share of air transport will increase in the future. The Vision 2020 project (WTO, 1998) concludes the share of long-haul tourism will increase from 18% in 1995 to 24% in 2020. Both short haul and long haul markets are likely to shift towards longer average travel distances. Both increase growth rate of leisure related transport. The L&R share of total air transport is estimated to increase from 55-75% in 2020. The result is a share of air transport pkm for L&R transport between 22% and 28% in 2020, which is equivalent to 4950 to 6750 billion pkm per year.

3 Climate change effects

Human induced greenhouse effects of motorised transport are caused by emissions from burning fossil fuel. The emissions of carbon dioxide (CO_2) are directly proportional to the kind and amount of fuel burnt. The effects of carbon dioxide on climate change are well understood (Houghton et

al., 2001; Penner et al., 1999). Also other gases like nitrogen oxides (NO_x) and water vapour have effects on climate. The effects of these are mainly determined by the characteristics of the engine and the altitude they are released at. Aircraft emit most NO_x and water vapour at cruising levels of 10,000 to 14,0000 meters, where these gases play a role in the forming of contrails and cirrus clouds, with strong but poorly understood effects on climate (Houghton et al., 2001; Penner et al., 1999; Williams, 2002).
The total effect on climate change is normally expressed in carbon dioxide equivalents (CO_2-e), using the 'equivalence factor', the effect of all emissions divided by the effect of CO_2 only. For surface transport (road, rail and shipping) this factor is about 1.05 (Gugele et al., 2003; Heart et al., 2000). Due to the contrail and cirrus forming the equivalence factor for air transport is 2.7 (Penner et al., 1999; RCEP, 2003: 15, 16).
A world average for fuel consumption and emission factors for the three modes of transport (air, cars and other) are difficult to give. Eurostat (Eurostat, 2000) gives ranges for the European context (second column in Table 1). For car transport an average of 100 gram CO_2 per pkm has been assumed. For aircraft a world average passenger aircraft emission factor for 2000 has been established by combining data from several sources (Boeing, 2003; IATA, 2002; Pulles et al., 2002) to be 138 gram/pkm. For the other modes of transport the average of the European range given has been chosen.

Transport mode	CO_2 (range for Europe)	CO_2 (average value)	Equivalence factor	CO_2-e (average value)
	gram/pkm	gram/pkm	-	gram/pkm
Car	25-144	100	1.05	105
Air	82-482	138	2.7	373
Other	13-77	45	1.05	47

Table 1: emission factors for leisure and tourism related transport modes (sources: see text).

These emission factors will change in the coming two decades. From the difference between car travel growth and related fuel consumption growth as given by World Business Council for Sustainable Development, 2001, the efficiency increase will be 0.7% per annum. The world-wide increase in energy efficiency for railways and busses has been somewhat arbitrarily assumed to be about 1% per annum. Based on information given by Lee et al., 2001; Penner et al., 1999 and Pulles et al., 2002 an average fleet fuel efficiency increase of 1.3% per annum has been assumed. From these assumptions the world-wide CO_2-e emissions have been calculated for L&R transport (see Table 2).

Transport mode	2000		2020		Growth rate
	CO_2-e (Gton)	Share (%)	CO_2-e (Gton)	Share (%)	%/annum
Car	0.491	40 (33)	1.131	41 (35)	4.3
Aircraft	0.634 (0.889)	52 (60)	1.421 (1.938)	52 (60)	4.1 (4.0)
Other	0.096	8 (7)	0.184	7 (5)	3.3
Total	1.221 (1.475)		2.737 (3.253)		4.1 (4.1)

Table 2: total emissions of CO_2-e for leisure and tourism related transport (values between brackets for the maximum air transport case).

It appears the share of air transport to climate change is the largest one at 52-60% of total leisure and tourism related transport, both in 2000 and 2020. Another important fact is the large growth of greenhouse gas emissions from L&T transport with over 4% per annum. The total 2020 amount of L&T transport contribution to greenhouse gases is 45-55% of the target sustainable transport target of he OECD for 2030 (Wiederkehr et al., 2000). When L&T transport emissions continue to grow at the same rate up to 2030 this share will be 70-80% of the target in 2030. Over half of this is caused by L&T air transport.
The contributions of tourism to climate change consist not of only transport, but also of accommodation and activities. Gössling estimates the world-wide CO_2-e emissions for accommodation at 0.081 Gton and for activities at 0.055 Gton (Gössling, 2002). This means L&T transport takes 90% of all leisure and tourism related greenhouse gas emissions (including the effects of other emissions on climate change). Conclusion is the climate impact share of aviation is

dominates the total impact and therefore sustainable tourism can only be effectively achieved if sustainable air transport is realised.

4 Techniques to mitigate the climate effects

4.1 Sustainable development

To reach sustainable development The OECD has developed four criteria for sustainable development (OECD, 2001):

I. Regeneration: renewable resources are used without exceeding their long-term rates of natural regeneration.
II. Substitutability: the use of non-renewable resources shall be limited to levels which can be offset by substitution by renewable resources or other forms of capital.
III. Assimilation: releases and emissions to the environment shall not exceed its assimilative capacity; persistent and/or bio-accumulative substances shall not be emitted.
IV. Avoiding irreversibility: irreversible adverse effects of human activities on ecosystems and on bio-geo-chemical and hydrological cycles shall be avoided.

Aviation does not meet any of these sustainable development requirements (Upham, 2003). The regeneration and substitutability criteria are not met as aviation depends largely on oil consumption. The assimilation criterion is not met with the growing impact on climate change. Therefore the fourth criterion is also not met as climate change is irreversible, at least for generations to come, and the resulting loss of species is irreversible for many thousands of centuries.

4.2 Technology

To reach sustainable development aviation has to increase its environmental efficiency with over 5% per year to reduce the total impacts. As has been shown this increase is predicted to be 1.3%, gained by all technological means currently available or under development: increased engine efficiency, better aerodynamics and lower aircraft construction weights. Further increases in engine efficiency are hampered by environmental trade-offs between fuel consumption, emissions of NO_x and noise (Lee, 2003). Lower fuel consumption asks for higher engine turbine entry temperatures and higher pressure ratios, but this increases NO_x emission. Lower noise asks for higher bypass-ratios (larger fans), but these add weight and will decrease fuel efficiency of the total aircraft. Another trade-off exists between fuel efficiency and climate change due to contrail forming, as it has been shown efficient aircraft engines seem more likely to form contrails (Lee, 2003).

Airframe and aero-engine manufacturers normally make a trade-off between fuel cost and total direct operational costs (DOC). The kerosene price dictates the amount of fuel saving technology the designer will incorporate into his aircraft design. So, long-term forecasts for high kerosene prices will result in more fuel efficient designs. For example, increasing wing aspect ratio (wing slenderness) will give a strong reduction of aerodynamic drag, but it will increase airframe cost. A higher kerosene price will give a higher aspect ratio for the minimum DOC design point.

As fuel consumption and emissions of CO_2 are proportional, increasing fuel prices may reduce specific emissions of CO_2. As long as NO_x emissions have no price, this will always come at an increase of NO_x emissions.

Lower weight and higher lift to drag ratios increase airframe efficiency. A further reduction of construction weight may be reached by using advanced (composite) materials and more optimised designs. However, more stringent safety regulations and the very high cost for introducing new materials in primary construction reduce opportunities of further weight reductions. As a rule of thumb a 3% empty weight reduction is required for a reduction of 1% of fuel consumption (Peeters, 2000). Aerodynamic efficiency increases are still possible, but also only at high (operational) cost. Technology like advanced winglets or applying ‘riblets’ - plastic foils with a special ribbed surface, reducing friction drag - may reduce fuel consumption by up to 5% for long haul aircraft. All together some 5-10% extra efficiency improvements over the next two decades may be reached with evolutionary technology.

Further technological improvements will have to come from revolutionary developments like alternative fuels, unconventional aircraft configurations and alternative power sources. New aircraft configurations, like the blended wing body configuration – a flying wing – may reduce fuel consumption by an additional 10-20%. The problem is, most of the studies on BWB use advanced technologies that may also be applied to conventional aircraft configurations, making it difficult to see the effect of the configuration change itself.
The use of bio-fuels, kerosene made from plant material is another option. This may reduce CO_2 emissions for the whole life-cycle to zero, if the plant material is produced zero emissions agricultural methods. However the water vapour and NO_x emissions will not change and thus two-thirds of the effect on climate will be unchanged.
Another alternative fuel is hydrogen. Hydrogen is not a source of energy, but a carrier for energy (RCEP, 2003). The environmental effects of the system depend on the production method of the hydrogen. An extensive study on hydrogen aircraft showed the technical viability and the economic and environmental effects of this option (Brewer, 1991). A recent project is the European Cryoplane (Faass, 2001). One of the problems of hydrogen often mentioned is safety. Faass shows safety of a hydrogen aircraft may be much better as for conventional kerosene based aircraft. Hydrogen fires burn very fast with very low heat radiation. Also hydrogen tends to burn upwards, where kerosene flows downwards. This all will bring crash casualty rates down compared to kerosene filled aircraft.
The real challenge of liquid hydrogen for the aircraft designer are its low density, low temperature and high pressure. The Cryoplane is based on the Airbus A310 passenger aircraft with an upward extension of the fuselage to accommodate the high volume of the liquid hydrogen. Also the wing structure has been strengthened because the removal of the stress relieving weight of kerosene fuel from the wings. From the study it appeared the empty weight of the aircraft increases with 20-25%, but the maximum take off weight reduced by 15% (for the long range version). The specific energy consumption increases with 8-15%.
The emission of CO_2, SO_2, CO, soot and unburned hydrocarbons are zero with hydrogen. However water vapour emissions will increase with a factor 2.6 per MJ energy. The emission of NO_x may be reduced compared to future turbofans with 50% to 90% depending on the technology used. Faass calculated the global warming potential (GWP) parameter at several cruising altitudes for both types of aircraft. GWP may be reduced between 35% at 12,000 m and 85% at 9,000 m cruising altitude. Though these are impressive reductions, it is still far from a zero-emissions aircraft and with the high growth rate for air transport the total effect will still be growing.
To reach a zero-emission aircraft a design combining electric engines, unducted fans, fuel cells and hydrogen may be a viable solution (Peeters, 2000; Snyder, 1998). The disadvantages of fuel cells for aircraft are their weight and volume. This will partly be offset by the lower weight of hydrogen and by a low weight for the electric engines, using super cooling with the available liquid hydrogen. Also the total system propulsive efficiency is about double that of the hydrogen turbofan combination. Designing and optimising for the properties of this propulsion system the aircraft will reduce its specific energy consumption with 50% to 65% compared to the current kerosene based state-of-the-art aircraft. Even compared to a highly efficient future design using advanced technology engines, aerodynamics and structures the energy consumption reduction may be between 20% and 50% for long haul respectively short haul aircraft.
The cruising speed of the aircraft has been reduced to mach 0.65 giving a blocktime increase of 10% for a short haul typical flight and 23% for a long haul one. The climate change effect will be virtually zero as the water may be released as a liquid, not vapour.

4.3 Operational efficiency

Following operational options are available to reduce climate change impact of air transport:

- reducing power-on delays at take-off and before landing; reducing flight holding time
- optimisation of routes
- optimisation of flight path and speed/altitude schedules
- network optimisation and fleet composition

The first two options may increase the fuel efficiency with 10% (RCEP, 2003), but do not only require technical, but also organisational and political action. The scattered European Airspace for

example is an obstacle for increasing route efficiency, as is the already over-crowded airspace combined with strong growth.
Airline flight operations controllers will try to optimise the flight paths for low costs, making a trade-off between fuel cost and flight time related operational costs (crew, depreciation, maintenance). Figure 1 shows a DOC optimum for a long range large aircraft. For this flight a cruise altitude of 11.500 m and a cruise speed of mach 0.855. The figure also shows the fuel optimum to be at mach 0.83 and the NO_x optimum at 11.000 m altitude and mach 0.78.

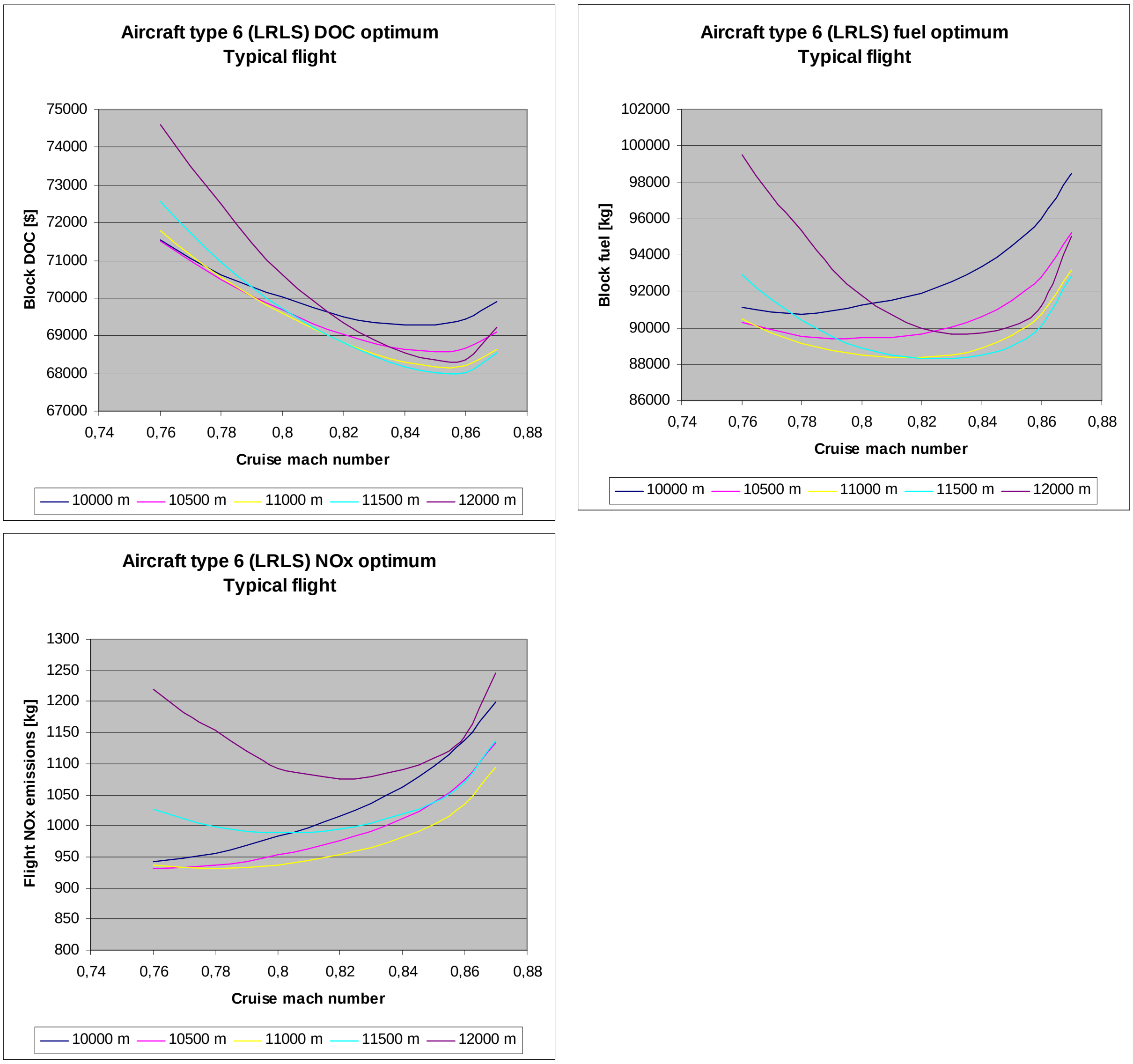

Figure 1: Operational optimum flight schedules for a long range large aircraft at a typical flight (6000 km and 75% seat occupancy; source: Peeters, 2002).

Table 3 gives the effects of diverting from the DOC optimum to the fuel or NO_x optima. Generally spoken the fuel optimum reduces also NO_x emissions, and leads to a small to very small increase of DOC. The NO_x-optimum increases DOC with 3% and reduces fuel consumption, but less as for the fuel optimum.

Type	Fuel optimum			NO_x optimum		
	DOC	Fuel	NO_x	DOC	Fuel	NO_x
	%	%	%	%	%	%
Short range medium size	+ 1,4	-2,9	-6,5	+ 2,6	-2,4	-7,3
Medium range medium size	+ 1,1	-1,5	-5,3	+ 3,6	-0,5	-11,0
Long range medium size	+ 0,3	-3,3	-10,0	+ 3,2	-1,8	-12,4
Long range large size	+ 0,5	-1,2	-4,0	+ 3,8	-0,4	-11,5

Table 3: the relative change to the optimum DOC flight schedule for fuel and NO_x optima (source: Peeters, 2002).

Another way to reduce climate change effects is by reducing cruising altitude and thus avoiding contrails or cirrus clouds to be formed (Williams, 2002). The total elimination of contrails may reduce the air transport radiative forcing with 50%. But there are unfavourable effects as well. The aircraft will be forced to fly at lower than optimum flight levels, causing an increase of about 4% of CO_2 emissions. Though on a yearly base this may be small compared to the reduction of 50% by removal of the contrails, it is important to consider the effects of CO_2 emissions are accumulating year after year, while the effect of contrails is zero at the moment they are dissolved from the skies. Another problem with reduction of the cruising altitude is the exponential increase of air traffic controller work load and the reduction of the capacity of airspace. This may reduce the current growth of air transport especially in the crowded air space over Europe and the United States.

Still another way to reduce climate change effect of air transport is the sort of network chosen. The extremes are a fully-connected network (all relations point-to-point) and the hub-and-spoke network. The fully-connected network gives the shortest distances flown, but also smaller passenger flows and therefore the employment of smaller, less fuel efficient aircraft at lower occupancy rates. The hub-and-spoke network increases distance flown and number of flight cycles per connection (many passengers have to transfer flights at the hub airport), increasing fuel consumption. On the other hand larger more fuel efficient aircraft are used at higher occupancy rates. From a Dutch preliminary study on network effects it appeared the hub-and-spoke network generates up to 20% more emissions for a given origin-destination passenger travel pattern (Peeters et al., 1999). If the total transport volume is calculated as a function of network economic efficiency a higher volume for hub-and-spoke networks is most likely, further increasing total environmental effects of this option. Fleet-composition is a derivative of the kind of networks that develop and has not a specifically influence.

5 policy instruments

Knowing about the air transport volume developments, its climatic impacts, and technical and operational ways to reduce these impacts, the next step is to consider a range of possible policy instruments. These policy instruments all serve the same purpose: the mitigation of the climatic impact of aviation. This implies that the instruments need not necessarily lead to a volume reduction, although such a reduction might be a consequence. This section is mainly based on (Wit et al., 2002).

The first option, technical standards, may at first sight seem a straightforward and logical option, but it has some serious drawbacks. In the past, technical standards were developed at ICAO level to reduce noise and NO_X emission from newly produced aircraft. In particular for noise, these standards have proven effective; the noise ‘footprint’ area of a today’s aircraft is dozens of times smaller than aircraft from the 1960s. But the setting of standards for CO_2 emissions i.e. fuel consumption is much more complex. Noise and NO_X emissions are related to landing and take-off, which is more or less identical for each aircraft, whereas fuel consumption is related to the entire flight, which is highly different for each aircraft. This implies that the development of an adequate fuel efficiency indicator for aircraft is a tough job. Currently one of the CAEPs[1] technical working groups is considering this issue but a solution is not yet in sight. Another drawback is that technical standards only work for new aircraft, so that the existing fleet is not affected. A third drawback is that once the standard is reached, there are no incentives left for further improvements. And fourth: given the history of noise and NO_X standards, it seems hard to imagine that a technical standard for fuel consumption comes in place that is more stringent than today's aircraft performance.

The second option, improvement of air traffic control procedures, is a potentially effective strategy to reduce the climatic impact, especially to avoid contrail formation. Improvements in ATC procedures could reduce congestion and hence avoid useless fuel burn. This could bring benefits in the order of magnitude of 5%. But it is in the field of contrail avoidance where ATC improvements offer most potential. The formation of contrails contributes about one third to the climatic impact of aviation. Besides, contrail formation can be quite accurate predicted as it depends on temperature and humidity of the exhaust gases and on temperature and humidity of the ambient air. It follows that ATC could enormously contribute to reducing the climatic impact by making aircraft fly through air masses with low contrail risks. In case of military aircraft, this is already done for visibility reasons, so strictly technically speaking this improvement should be feasible. But is it also easy to understand that such an extra boundary condition to flight movements greatly complicates ATC flight path allocation procedures (see also section 4.3).

The third and probably most discussed option is economic incentives to reduce climatic impacts. Options discussed here ticket charges (e.g. VAT), taxes of fuel, emission charges and emission trading schemes.

Ticket charging could be justified from a fiscal point of view, but is not a very efficient tool to reduce emissions. International aviation is not subject to VAT, contrary to normal international economic activities. This exemption could be considered an indirect subsidy to aviation, which makes (privately bought) airline tickets cheaper than they would be without this exemption. The UK has a so-called Air Passenger Duty (APD) in place which is a fixed charge on passengers leaving the UK and is often considered a repair of the VAT exemption. Such ticket charges however, give no incentives to airlines to use cleaner and more environmentally efficient aircraft and therefore they are not particularly efficient tools in mitigating environmental impacts.

Fuel taxation is often mentioned in the debate around aviation and climate change as a logical policy option, but is in practice hardly feasible. The option is logical as a) other transport modes pay fuel taxes as well and therefore face a competitive disadvantage and b) the fuel tax is directly related to CO_2 emissions and therefore is a more efficient policy tool than the ticket charge which was previously discussed. However, the fuel tax instrument has two serious drawbacks. The first is that it provides incentives to buy fuel outside the charged area and take it inside (tankering) which leads to both economic distortions and to extra emissions from the excess fuel carried. This might certainly be the case when the fuel tax rises to substantial levels. The second drawback is that numerous bilateral Air Service Agreements (ASAs) prohibit taxation of aircraft fuel used for flights between the countries, which implies that all ASAs should be revised, which is at best a slow and at worst an impossible process. And finally, it is far from clear who would get the revenues and what should be done with it.

Emission charging has been in discussion from the time it became clear that the fuel tax is problematic. The principle of emissions charging is territorial, which means that all emissions released in a certain airspace – e.g. EUROCONTROL airspace - are charged. This avoids the problem of economic distortions that a fuel tax has: identical aircraft flying the same routes are charged the same amount. Emissions charging can be designed in a revenue raising way – as a kind of emissions tax – and a revenue neutral way. In the latter case, an environmental efficiency baseline for air transport operations needs to be set, for example grammes of CO_2 emissions per revenue tonne kilometre carried. Airlines that perform better than this baseline receive a rebate, where others pay a fee. Both revenue-raising and revenue-neutral incentives score better than fuel and ticket charges on criteria such as environmental efficiency and legal feasibility.

Emissions trading is gaining interest following the Kyoto Protocol and the European emissions trading directive issued October 2003. The aviation sector has expressed its interest in an open trading regime, which means that it should be possible to trade emissions with other sectors, for example under the provisions of the Kyoto Protocol. A problem here is that currently CO_2

[1] CAEP: Civil Aviation and Environmental Protection, one of ICAO's committees

emissions from international aviation fall outside the scope of the Kyoto Protocol. Hence a specific solution for aviation should be developed under the framework of the United Nations Framework Convention on Climate Change (UNFCCC). The legal and practical feasibility of this, and of the role of ICAO, are rather uncertain.

In developing these options, currently the two most active players are the European Union (EU) and the UN's International Civil Aviation Organisation (ICAO). As climate change is a global problem, all parties agree that global solutions are preferable. But the uncertain authority of ICAO to effectively implement an emissions trading regime under its authority, the numerous provisos it attaches to other economic incentives, and the difficulties of achieving global consensus make the global process very slow. Therefore the EU is currently considering whether or not to introduce an environmental incentive scheme on top of the EUROCONTROL charges, or an own emissions trading regime for intra-EU flights. The future will learn what options will be applied, and at what geographic level.

6 Socio-economic effects of reduced air transport growth

De Villiers, deputy Secretary-General of the WTO said in his opening speech at the World Tourism Organisation seminar on tourism and air transport in may 2000 (WTO, 2000: page 9): "good and efficient air links are vital for the development of tourism". At some twenty major tourism destinations 70% of international tourists arrive by air transport, according to De Villiers. However, as has been shown in section 2 of this paper, air transport is responsible for only 20-28% of all L&T passenger kilometres travelled. In terms of number of trips this share is much lower, because the average travel distance with aircraft is high compared to other modes of transport. As world-wide statistics on total numbers of international and domestic holidays, length of stay, distance travelled and mode of transport are not available it is difficult to find a number for this. In the Netherlands the share of air transport for all trips for long vacations (more than three consecutive nights) is 19%. For total international tourism this share is between 18% and 23% (based on IATA, 2002).

At macro economic levels, global measures reducing the amount of passenger air transport may have not much negative effects. Most important variables for the sector are the total number of leisure days available, the accommodation used, the total amount of money spent on activities and on transport. The number of kilometres travelled is only loosely related to the total travel cost, so the number of pkm is not a main driving force for the sector as a whole. Of course some subsectors or individual enterprises may suffer from such measures, but others will gain from it.

Another often mentioned objection to reducing air transport for tourism is negative impact on developing countries and poverty. WTO and UNEP want to use tourism to eliminate poverty (see the ST-EP programme, WTO, 2002). As billions of tourists are required world-wide to make any difference on poverty, and most of these tourist will originate from the developed world, requiring intercontinental air travel, such a development may boost air transport ten to fifty times beyond its current volume. This is not unsustainable, and seems economically and practically impossible. Of course tourism may have beneficial effects on the economic position of developing countries and may reduce poverty, but it should be based on short haul markets within the region for mass-tourism and exclusive long-haul tourism generating large local revenues with small numbers of tourists. An important parameter to relate poverty and sustainable tourism would be the amount of the tourism revenues going directly to the poor divided by the total greenhouse gases emitted through the tourism product (for transport, accommodation and activities).

Socio-economic impacts may be limited provided that the socio-economic constraints are predictable in the long term so that airlines and tourism industry can anticipate in their investments in cleaner technology, better operation and slower growth of traffic volume.

7 Conclusions, discussion and research recommendations

7.1 Conclusions

The primary global environmental problem with tourism is the climatic impact of air transport: its growing share is now about half of total climatic impact of tourism. The total GHG emissions of leisure and tourism related air transport is in the same order of magnitude as the target level

defined by OECD in the EST programme (-80% to the 1990 level). This projection includes trend development of fuel saving technology. Advanced technology may reduce specific emissions with an extra 10-20%. Technology may also be developed to create zero climate-impact aviation, but this will take decades to happen and may cost in the order of one hundred billion of Euros to develop. The fuel cell aircraft will be slower and more expensive to operate.
If air transport seeks to become sustainable, current growth of impact has to be reversed to a reduction using operational efficiency increases and especially volume growth control. This requires multilateral and global action, like emissions trading at European or global level, or emission incentives and ATC improvement both at EU level. Emission incentives may also be used to directly or indirectly raise funds to develop zero GHG emissions aviation technology.
The socio-economic impacts may be limited provided the socio-economic constraints are predictable in the long term, enabling airlines and tourism industry to anticipate on it with investments in cleaner technology, more efficient operations and reduced growth of transport volume.

7.2 Discussion

Tourism becomes more dependent on energy, primarily due to the increased use of cheap air transport. The advantages of this are short term growth and competitiveness for some of the larger players within the tourism industry. However this may result in risks for the industry: in the long term the world will inevitably run out of cheap oil - which does not mean run out of oil - both due to physically exhausting oil fields and the likely political action on increasing visibility and socio-economic impacts of he deteriorating environment.
Effective measures will directly or indirectly increase cost for oil, ending the cheap air transport era. How disastrous such developments will turn out to be for the tourism industry is primarily determined by the extend of dependency of tourism on air transport. A tourism sector, based on short haul travel, coupling regional origins and destinations will not suffer too much. Long haul tourism is more vulnerable to international political developments, terrorism and war as is short haul tourism. Aiming at increased shares of intercontinental tourism means aiming at growing economic risks for the sector and adds to the strong economic cycles of the sector and the destination area's. The disadvantages of these risks and cycles are more detrimental for the vulnerable economies of developing countries as for developed countries.
Aviation seems to be about the last sector to leave the fossil fuel era. Being the last one will come at a cost. Other sectors investing now already in low emission technology, may demand from other sectors to do the same and to stop spoiling the total effect of emission reductions. Of course it is wise to start reductions within sectors where the cost per ton reduction is low. But also for these sectors an artificial high cost for oil or emissions will be necessary to give an incentive for the transitions required for sustainable development. These incentives will of course also effect also aviation.

7.3 Research agenda

The effects of tourism on climate change are not systematically known. The ESF-LESC workshop in Milan 2003 (Viner et al., 2003) sets the following research priorities: development and evaluation of public education campaigns; determining greenhouse gas emissions attributable to tourism; and GHG mitigation strategies for the tourism sector. On almost all research levels knowledge is required:

A. Theoretically on the interrelation of sustainability, tourism/tourists/enterprises and mobility.
B. Basis economic, social and environmental data.
C. Models and tools based on A. and B. for tourism and transport behaviour on global, national and regional levels to support developing policies for sustainable tourism and transport.

For air transport many theories exist both on the technological, economic and social sciences. Also data on air transport is readily available, both on transport volumes and economics. Models are available for projecting growth of transport volumes and social and environmental effects. However these are all on an aggregated level with respect to travel motives. Therefore almost no data, theory or models are available on the relationship between air transport, tourism and climate change.

To solve the data knowledge gap it is proposed to extend the standards for tourism data collection (TSA, Tourism Satellite Account) of the WTO/OECD (UN, 2001). Extra data are required on environment. Environmental data are transport energy consumption, emissions CO_2 and NO_x or some substitute variables from which these data may readily be derived. Also data should be included giving information on distance travelled, travel time, travel cost and variables indicating other costs made by the traveller, like reliability, comfort levels and number of transfers/changes. Based on these data and existing transport theory, models may be developed for the world tourism industry, relating tourism attraction to tourist travel flows and distribution between origins and destinations. From these models the social, economic and environmental effects of policy measures and global developments caused by climate change for the near and far away future may be derived.
Another important issue for research seems to be the relationship between air transport, tourism sector prosperity, impact on climate change and phenomena like 'holiday happiness' and the 'value of distance' within the social and psychological destination choice processes. The importance of accelerated increase of travel distances is often supposed, but seldom demonstrated by the sector and may play a role within the political system of transition to a tourism sector with less or no climate effects.

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