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The future tourism mobility of the world population: Emission growth versus climate policy

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ABSTRACT

Much of global passenger transport is linked to tourism. The sector is therefore of interest in studying global mobility trends and transport-related emissions. In 2005, tourism was responsible for around 5% of all CO_2 emissions, of which 75% were caused by passenger transport. Given the rapid growth in tourism, with 1.6 billion international tourist arrivals predicted by 2020 (up from 903 million in 2007), it is clear that the sector will contribute to rapidly growing emission levels, and increasingly interfere with global climate policy. This is especially true under climate stabilisation and "avoiding dangerous climate change" objectives, implying global emission reductions in the order of −50% to −80% by 2050, compared to 2000. Based on three backcasting scenarios, and using techniques integrating quantitative and qualitative elements, this paper discusses the options for emission reductions in the tourism sector and the consequences of mitigation for global tourism-related mobility by 2050. It ends with a discussion of the policy implications of the results.

1. Introduction

The current development of tourism-related mobility is a serious challenge for global climate change mitigation. Tourist mobility contributes considerably to transport levels. Tourists include domestic, international, leisure and business travel involving at least one overnight stay (for the definition of tourism and a tourist see UNWTO–UNEP–WMO (2008, p. 121)). Globally, tourism's emissions have been estimated at around 5% of overall CO_2 emissions, with 75% of these the result of tourist mobility and 25% due to on-site consumption, including accommodation (21%) and tourist activities (4%) (UNWTO–UNEP–WMO, 2008).

While 5% of global emissions may appear insignificant when compared to other sectors such as agriculture, tourism is characterized by rapid growth. International tourist arrivals increased from 25 million in 1950 to 534 million in 1995, and 803 million in 2005. In the 2005–2007 period alone, international tourist arrivals grew by 100 million, reaching the 903 million mark. If this trend continues, tourism emissions will increase by over 150% by 2035 (UNWTO–UNEP–WMO, 2008). This growth in emissions must be considered in the context of emissions reduction targets as outlined by the IPCC (2008a,b), which recommends to reduce global emissions by 50–80% by 2050. This is likely to lead to a situation of contraction and convergence, where growing emissions from what is currently a relatively small sector, tourism, will rapidly become more important both in relative and absolute terms. Overall emissions decline, while tourism emissions will

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continue to grow (see e.g., Bows et al., 2006b; Tight et al., 2005). Understanding and controlling emission growth in tourism will consequently become increasingly urgent.

Emission reduction targets are outlined in the Kyoto Agreement. Although there is a general consensus that global warming of more than ±2 °C is likely to lead to dangerous interference with the climate system (cf. Meinshausen et al., 2006), optimal emission reduction levels to be reached by 2050 are still under discussion. Until recently, it was thought that a 50% drop in emissions (compared to 1990 levels) by 2050 would be likely to prevent atmospheric CO_2 concentration of 450 ppm, or what is considered to correspond to a warming of 2 °C. However, some recent publications have recommended that world-wide emissions be reduced by 80% by 2050 (Parry et al., 2008). Other authors have reasoned that the long-term CO_2 concentration levels necessary to avoid dangerous interference with the climate system should not exceed 350 ppm (Hansen et al., 2008). In other words, they advocate a level lower than current atmospheric concentrations of CO_2. If this goal were adopted, emissions would have to decline by about 3% per year after 2015 (Hansen et al., 2006).

Climate change is to a considerable extent addressed by modelling and scenario building techniques. With regard to transport, trend extrapolations or "business as usual" scenarios (Ceron and Dubois, 2006; Dubois and Ceron, 2007; Peeters et al., 2007; UNWTO–UNEP–WMO, 2008) all point to rapid growth in emissions in the order of a factor 2 to 3 over the next 30 years. Consequently, "avoiding dangerous climate change" objectives increase the need for backcasting techniques (Åkerman and Höjer, 2006; Anderson and Cavendish, 2001; van Notten et al., 2003; Swart et al., 2002) and normative scenarios (Coates and Glenn, 2003; van Notten et al., 2003; Prideaux et al., 2003) to identify pathways that could lead to emission reductions. Moreover, the time horizon involved (50–100 years) means that adaptive models that can capture changes in critical parameters must be built. Finally, ambitious emission reduction targets – both those proposed by the IPCC (2008a,b) as well as those adopted by governments – imply the need not only to consider developments in infrastructure and technology (quantitative changes relatively easily integrated into models), but also to explore the diversity of qualitative socio-cultural factors that shape, together with economic factors, current and future tourism demand. In future studies two cultures have emerged (Bradfield et al., 2005): a dominant quantitative culture, and a more qualitative culture (De Jouvenel, 1964; Godet, 1997; Hatem, 1993; Mermet, 2003, 2005). The best way forward seems to integrate both, which presents a methodological challenge (Raskin et al., 2005). Regarding tourism futures, various attempts have been made in this direction by either academics (Buhalis and Costa, 2005; Bows et al., 2006a, 2007; Ceron and Dubois, 2005; Cooper and Hall, 2008; Hall, 2005a,b; Dubois and Ceron, 2007; Laboratoire d'économie des transports and ENERDATA, 2008; Lyons et al., 2000; Peeters et al., 2004; Schafer and Victor, 1999; Timms et al., 2005; Yeoman, 2008; Yeoman et al., 2007) or by tourism and transport stakeholders (e.g., Conseil Général des Ponts et Chaussées, 2006; ENERDATA, 2004; Futuribles, 2005; KUONI and Gottlieb Duttweiler Institut, 2006; Shell, 2002; Thomson; UNWTO–UNEP–WMO, 2008; WBCSD, 2004). An analysis of these studies reveals similar approaches, but also considerable differences and some potential shortcomings:

- The year 2050 is a time horizon frequently used, allowing consideration of long-term environmental issues, but avoiding the uncertainty of long-term societal change. For tourism, however, 2050 may already pose major challenges in making assumptions, for instance concerning consumption patterns.
- Many studies are hampered by a lack of data, which explains why tourism development scenarios are usually based on qualitative assumptions.
- National studies tend to focus on domestic transport, ignoring the development of international aviation. This is a major omission, given that air transport represents 40% of global tourism emissions, and implies a significant underestimation of transport volumes.
- Both backcasting and forecasting techniques are used, but seldom with an exclusive focus on tourism. Within tourism, transport is paid great attention due to expected growth patterns and the difficulty of using non-carbon energy sources.
- There are very few long-term scenarios that focus on both climate change and tourism.

Table 1 presents a sample of tourism and transport scenario-based surveys, illustrating the above summary.

Finally, very few long-term scenarios dealing with tourism and climate change exist. Of those that do, none consider "avoiding dangerous climate change" objectives. Existing works are also limited in scope. Some only assess the driving forces behind emission reductions (like technological progress or behavioral change). Others only deal with parts of the tourism sector, such as aviation (Åkerman, 2005; Henderson and Wickrama, 1999; Vedantham and Oppenheimer, 1998). Many use quantitative forecasting techniques based on more or less fixed relationships, for instance between GDP and mobility, even though these relationships may be affected by climate and socio-cultural changes (Joly, 2008; LET/LASURE, 2006; Schafer and Victor, 1999). Simple demographic effects like, for example, the effect of an ageing population on the number of trips, are not accounted for in these fixed relationships.

2. Methodology: the scenario factory

2.1. General framework

This article attempts to build three scenarios based on an analysis of tourism and transport, using backcasting techniques to explore ways of attaining a global objective to "avoid dangerous climate change". Methodologically speaking,

Table 1
Tourism and transport scenario surveys overview.

Source	Scenario type	Quantitative/ qualitative	Timeline	Geographical scope	Thematic scope	Focus	Authorship
WBCSD (2004)	Forecasting scenarios	Occasional quantification	2030	World	Mostly ground transport	Sustainable development	Automotive industry
Conseil Général des Ponts et Chaussées (2006)	Forecasting	Quantitative	2050	France	All transport	Emissions	Administration
Laboratoire d'économie des transports and ENERDATA (2008)	Backcasting	Quantitative	2050	France	All transport	Emissions	Consultants
Schafer and Victor (1999)	Projections	Quantitative	2050	World	Passenger transport	Mobility Emissions	Academics
Peeters et al. (2007, 2004)	Projections	Quantitative	2020	EU, Switzerland, Norway, Bulgaria and Rumania	Tourism and transport	All environmental impacts	Academics
Ceron and Dubois (2006)	Forecasting, backcasting	Quantitative/ qualitative	2050	France	Tourism, transport	Sustainable development, emissions	Academics
UNWTO–UNEP–WMO (2008)	Forecasting, backcasting	Quantitative/ qualitative	2035	World	Tourism	Emissions	Academics

the innovation of this study is to integrate two sectors, transport and tourism, traditionally analysed using either mainly quantitative or qualitative approaches. While transport analyses depend heavily on quantitative (statistical) models like logit-models, tourism analyses are mainly based on simple extrapolations of historic developments and qualitative assumptions. Indeed, the integration of narrative discourse ('narrative-based' or 'qualitative' scenarios) and quantification ('modelling-based' or 'quantitative' scenarios) appears to be one of the main challenges facing the discipline of future studies. In the framework of the Millennium Ecosystem Assessment, Raskin et al. (2005, p. 40) critically assessed global scenarios and found:

> The development of methods to blend quantitative and qualitative insight effectively is at the frontier of scenario research today. The scenario narrative gives voice to important qualitative factors shaping development such as values, behaviors, and institutions, providing a broader perspective than is possible from mathematical modelling alone. Narrative offers texture, richness, and insight, while quantitative analysis offers structure, discipline, and rigor. The most relevant recent efforts are those that have sought to balance these.

Scenario building can be divided into a number of components or steps, depending on their qualitative or quantitative orientation (Nakićenović and Swart, 2000; Raskin et al., 2005). Without referring to any chronology in this process, scenarios can specify 'guiding principles' (A) defined using a set of economic, societal or cultural 'trends' or 'megatrends' (B). These are converted into a number of variables and quantitative 'parameters' (C), which deliver the input to 'models' (D) that produce quantitative 'results' (E), which can be interpreted as 'impacts' (F) (see Fig. 1). Qualitative works tend to privilege steps (A), (B) and (F), while quantitative works focus on steps (C), (D), and (E). Depending on the scenario objectives, analyses can start anywhere from (A) to (F): backcasting means defining goals prior to scenario building (E) and (F); working on 'visions' means beginning with principles (A); seeking better scientific knowledge of a complex process means focusing on modelling (D). Nevertheless, all scenario development exercises start with a description and analysis of past and present trends. The differences in scenario pathways are a result of the development of this input: models for quantitative scenarios versus a systemic representation of variables in qualitative ones. In other words, models produce figures and numbers, which are

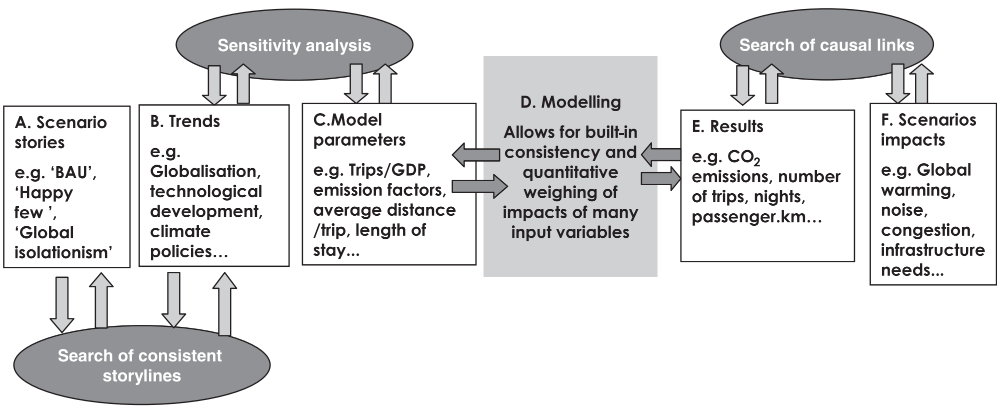

Fig. 1. Stepwise scenario building.

not always considered in their larger socio-economic context. Qualitative scenarios, on the other hand, consider socio-economic contexts but lack quantification to prove their consistency.

In this situation, methodological development should focus on improving links between the various components (Fig. 1) through specific tools (sensitivity analysis) and sound modelling processes. For this purpose, a 'scenario factory' was created, combining an 'engine' – the Global Tourism and Travel Model, advanced version ($GTTM^{adv}$, see also Peeters and Dubois, 2009) – and storylines feeding the model. Consequently, an iterative process between quantitative and qualitative thinking is at the core of the method and of the model rationale. The following sections describe in further detail the 'engine' and storylines.

2.2. The engine: modelling trips, transport demand and emissions

Scenario parameters (box C, Fig. 1), models (box D) and results (box E) were developed using Powersim Studio 7 software. The $GTTM^{adv}$ model extrapolates trends in trip numbers, guest nights, transport volumes, transport modes, and emission factors. $GTTM^{adv}$ is calibrated to represent the results of the 2005 and 2035 projections of global tourism as published by UNWTO–UNEP–WMO (2008, Chapter 11). The model distinguishes three tourism markets: international tourism, domestic tourism in industrialised countries (IC) and domestic tourism in developing countries (DC). The group of industrialised countries consists of the OECD90 countries (cf. IMAGE-team, 2006), in other words, Canada, USA, Japan, Oceania and OECD Europe. Furthermore, three modes of transport are distinguished: air transport, car transport and 'other' (for example, rail, coach and ferry).

Fig. 2 shows the model layout, where index *m* refers to the market and *t* the transport mode. $GTTM^{adv}$ has five modules. All but the first module have both default and manual input functions to allow the user to manipulate scenario results:

- *Module 1*: Population and GDP per capita estimates are taken from the IPCC SRES scenario projections (IMAGE-team, 2006).
- *Module 2:* The default number of trips is calculated per market *m*, by assuming a continuously growing linear relation between the average number of tourism trips per capita and GDP per capita, limited by a maximum number of trips. The coefficients of the linear relationship of trips per capita and GDP per capita are calibrated to the UNWTO 2035 scenario (see UNWTO–UNEP–WMO, 2008). The maximum number of trips above a certain GDP per capita threshold is based on the results of an investigation by TNS NIPO (Mulder et al., 2007) showing that the *individual* number of trips levels off at a higher GDP per capita. We used 1.2 trips per capita per year for international journeys and 4.8 trips per capita per year for domestic journeys. Long-term runs of the model show that these limits will only be reached near the end of the 21st century, and thus have no impact on the results of the 2050 scenarios shown in this paper. Furthermore, the number of trips is assumed to increase with decreasing length of stay (LOS), thus keeping the number of nights about constant. Finally, the user can change the three markets' growth rates by adding a growth parameter (positive or negative) to represent the assumed storyline.
- *Module 3*: The default shares of the different transport modes per market *m*, the modal split, are calibrated based on the UNWTO 2035 scenario. They can be changed by the user by adjusting growth rates per mode and market. The module recalculates the growth per transport mode by maintaining the total number of trips as defined in Module 2. This means that extra growth in one transport mode will be compensated for by a proportional reduction in the two other modes.
- *Module 4*: Calculates the total transport distance by multiplying the number of trips per market-mode combination with the average distance per market-mode combination. Within transport modes (i.e. car, air and other) we do not foresee major changes in average travel speed (e.g., supersonic air transport), but there are some slow default changes, for instance because of shifts between transport modes (e.g., a shift from car transport will generally reduce the average distance travelled by car). The link between speed and average distance resembles the idea of constant time budgets for travel (see Schafer, 2000; Schafer and Victor, 1999). The changes have been calibrated based on the UNWTO 2035 scenario. The user can adjust the growth rates for distance to manipulate the scenario to consider changes in infrastructure or transport costs.
- *Module 5*: The distances are multiplied by default emission factors per market-mode combination to calculate total emissions. The model user may adjust the emission factors to reflect various levels of technological development and innovation.

2.3. Storylines for tourism transport demand

Scenario storylines generally combine various dimensions and/or trends. For example, the IPCC Special Report on Emission Scenarios develops four families of scenarios, defined in line with their position within the "global–regional" and "economy-environment". Individual scenarios are positioned within each family by referring to the value given to key trends, including growth in GDP or population (Nakićenović and Swart, 2000).

First, the SRES background scenarios had to be chosen to generate economic and population growth. We chose the scenario A1 and B2 depending on the storyline chosen (see further Section 3.2). All scenarios are developed assuming strong and ambitious emissions mitigation policies. Furthermore, the aspiration for climate stabilisation implies constraints on consumption (households' disposable income) and production (increased transport costs).

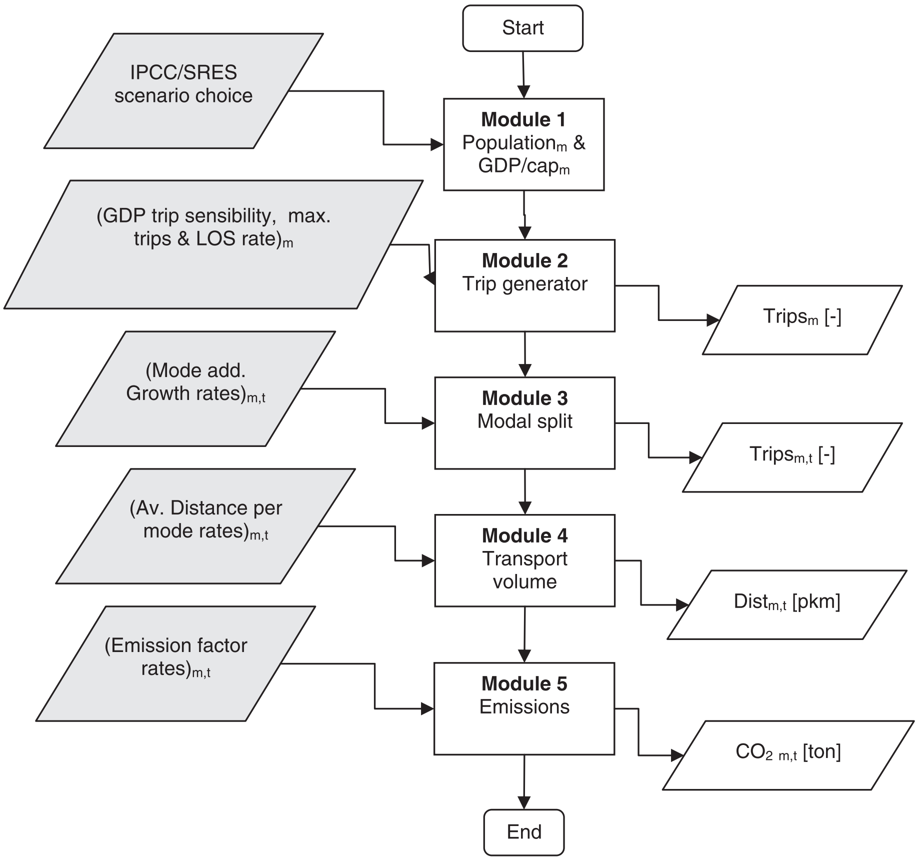

Fig. 2. Model (GTTM^{adv}) scheme showing input (shaded elements), model units (squares) and output (parallelogram). The indices refer to the three markets (m) and the three transport modes (t).

Then, based on a review of existing global tourism and transport scenarios, five megatrends were identified, with 2–3 options for each regarding possible directions under climate change mitigation constraints. The megatrend "tourism and transport policies", for instance, can develop into international long-haul transport and tourism (option 1), or seek a less uneven distribution of mobility, through domestic tourism and ground transport (option 2). Finally, three politically acceptable and internally consistent storylines were identified (Fig. 5). These storylines were different enough to allow comparison of multiple policy options, while leaving room for individual and political trade-offs. Authoritarian policies, like "forbidding air transport to reduce greenhouse gas emissions" were excluded for this last reason.

2.4. Integrating storylines and models

In 1997, a famous chess match took place between Garry Kasparov, the world champion, and Deep Blue, a computer specifically designed to challenge him. Kasparov won the first tournament in 1996 (4–2), but lost the revenge in 1997 (2.5–3.5). This anecdote illustrates the human–machine dilemma in the field of future studies, which, it could be argued, is dominated by a clash between two cultures: a fascination for automated techniques and complicated models on the one hand, and scepticism as to whether any model is capable of representing complex internal relationships on the other hand.

Integrating storylines and models can be done in several ways. Ideally, automated optimisation techniques are used based on simulation models to define the "best set" of assumptions (the non-default input parameters for growth of trips, transport distance, technology, etc.) to reach CO_2 emission targets under predefined constraints. The boundaries of these are predefined (e.g., transport policy leads to a development of train transport between +100% and +300% by 2050), using qualitative expert judgement. It is therefore up to the model to optimise parameters within these boundaries. Preliminary tests have shown that this is possible, but that further research into the method's implications is needed (see Peeters and Dubois, 2009).

Another option, used in this article, is to evaluate expert storylines with a simple model: a step-by-step procedure is used to reach a set CO_2 emission reduction target. The different trends (e.g., technological development) are progressively translated into model input parameters (e.g., air transport emission factors, average distance per trip) and the impacts evaluated (see Fig. 3). Before the next step, this output is evaluated in order to reach a fixed goal of a 67% drop in emissions with respect to the 2005 baseline. If an unexpected evolution is observed, explanations are sought and the parameter input refined. For each scenario, this was done in seven steps, the general idea being that such an iterative method leads to smaller margins of error, as all assumptions are constantly reconsidered – and the modellers learn how the system (i.e. the model) behaves.

Fig. 3 illustrates the step-by-step changes in input and the tracking of hypotheses, exemplified here by the "happy few" scenario (see Section 3). Each individual relationship is justified and recorded. This traceability is often lacking in scenarios

																								Emissions annual rate of change															
Scenario	Trips/GDP			LOS			Additional growth rate									Add. av. dist. growth rate									Acco.			Act ivities			Transport								
Market	Int	IC	DC	Int	IC	DC	Int			IC			DC			Int			IC			DC			Int	IC	DC	Int	IC	DC	Int			IC			DC		
Mode							A	C	O	A	C	O	A	C	O	A	C	O	A	C	O	A	C	O							A	C	O	A	C	O	A	C	O
X1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X2	-	-	-	0	0	0	-	0	+	-	0	+	-	+	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	+	0	0	+	0
X3	+	-	-	0	0	0	+	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	+	0	0	+	0	-	-	-	0	0	0	-	-	-	-	-	-	-	-	-
X5	-	+	0	+	+	+	-	0	+	-	0	+	-	0	+	-	-	+	-	-	+	-	-	+	0	0	0	0	0	0	0	-	0	0	-	0	0	-	0
X6	0	0	-	0	0	+	-	0	0	-	0	0	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X7	-	0	-	0	+	-	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-	0	0	0	-	-	-	0	-	0	0	-	0	0	-	0
Overall	-	-	-	+	+	+	-	0	+	-	0	+	-	-	+	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Fig. 3. Development of the "Happy few" (S1) storyline. +/– and 0 represent changes with respect to the previous step. Note that for emissions, a 'positive' rate of change means lower reductions and 'negative' rate higher reductions. Int = international, IC = domestic industrialised countries, DC = domestic developing countries, A = air, C = car and O = other, Acco. = Accommodations. LOS = length of stay.

attempting to combine qualitative and quantitative elements (EEA, 2008; ten Brink, 2006). The X1 run represents the general trend scenario. X2 and X3 are the first megatrends (globalisation). X4 added technology, X5 climate policies, X6 tourism and transport specific policies and X7 lifestyle components/additional measures to arrive at the emission goal.

Fig. 4 shows the results of the "happy few" scenario from steps X1–7, as an index of the baseline. The graph shows how changes in the various parameters (total number of tourist trips, total tourist nights, and shares of air trips/car trips) result in emission reductions (−80% by 2050).

2.5. Definition of emission targets

Backcasting demands the identification of emission reduction goals. Defining these goals for the tourism sector raises several questions, such as whether tourism should be treated "favourably" within a global emission reduction framework, given its strong growth and limited options for reducing emissions through technology. The following assumptions are made:

- In line with the IPCC fourth assessment report (IPCC, 2008a), atmospheric concentrations of CO_2 should not exceed 450 ppm by 2100.
- The focus is on "allowable" emissions by 2050, not the pathway to achieve these. In other words, the question is not whether emission reductions should be constant (e.g., −3% per year) or whether further growth in emissions would demand more rapid future emission reductions.
- By 2050, global emissions should be 33% of those in 2000. This corresponds to the averaged 50–80% reduction target retained by the IPCC (2008a). It is likely (more than 50% probability) to lead to climate stabilization in a 2.0–2.4 °C warming threshold by 2100.
- Tourism is given special treatment in emission reductions, in that the sector is allowed to use flexibility mechanisms (carbon trading and offsetting) for 20% of its reduction demands. Consequently, the sector itself must reduce its emissions by about half (−54%) (baseline 2000).
- Emissions from tourism amounted to 1.3 Gt in 2005 (UNWTO–UNEP–WMO, 2008, p. 132). Given the 2000–2005 growth of world tourism (+18%), the 54% compared to 2000 leads to a reduction of 67% compared to 2005, i.e. 443 million tons by 2050.

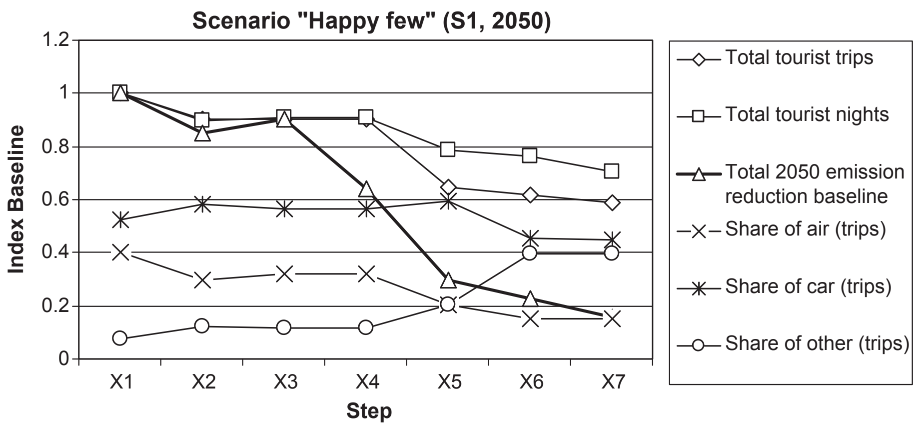

Fig. 4. Stepwise changes in "happy few" scenario (S1).

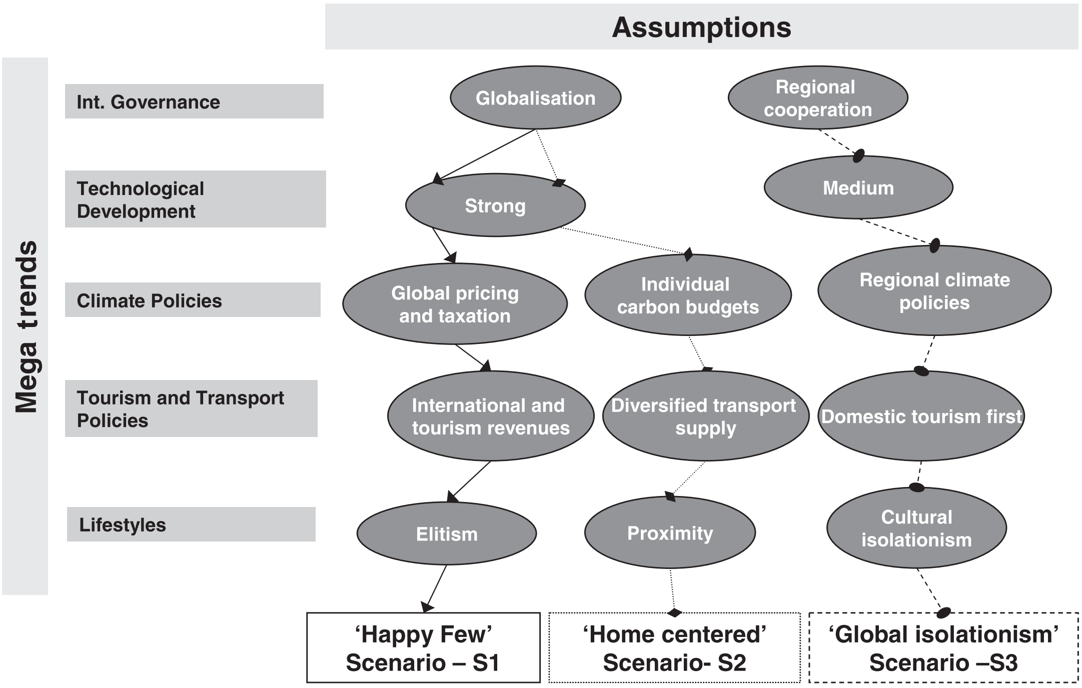

Fig. 5. Scenario rationale and construction pathways.

3. Results

3.1. Developing three storylines

Overall, three scenarios like the ''happy few'' storyline mentioned above were developed (see Section 3.2). They were based on five megatrends: ''international governance'', ''technological development'', ''climate policies'', ''tourism and transport policies'' and ''lifestyles''.

International regulation and integration. Two main options were identified: intensified globalisation (economic, political and cultural cooperation) versus regional cooperation leading to diverging regional blocks.

Technological development refers to transport efficiency. This is a result of factors like economic growth, international cooperation on research and technology transfer, and climate policies. ''Strong'' and ''medium'' technological developments are distinguished.

With regard to *climate policy instruments*, three options for mitigation are distinguished: global climate policies relying on economic instruments such as pricing, taxation and carbon trading; regional diverging climate policies, strong for ground transport but less efficient for international aviation (see the present situation, with the inclusion of aviation in EU carbon trading scheme, but without any global agreement at ICAO); and a global system of individual carbon budgets and quotas (Bows et al., 2006a; Starkey and Anderson, 2005).

Tourism and transport policies may initially target high-income international tourists, and thus favour investments in airports (global hubs). Alternatively, they may promote wider and less uneven access to mobility, leaving individuals to make their own choices based on their time, money and emission constraints. They may only favour domestic tourism and ground transport, be it highways or high speed train networks.

Without changes in *lifestyles and travel culture* it is often impossible to reach backcasting targets using other options (Ceron and Dubois, 2006; Dubois, 2008; Dubois and Ceron, 2007). The problem remains as to how lifestyles and cultures may change in a coherent way. The culture of travelling is the result of several factors: time and money for leisure and travel (e.g., existence of paid leave, disposable income, organisation of working time), incentives to leave home (unattractive houses, neighbourhood, cities or local environments), cultural curiosity, the appeal of exoticism (cultural exchanges or isolationism), education (environmental awareness, generational effects), the impact of advertising on travel fantasies, and so on. We distinguish three general lifestyles.

– In the first, the acceptance of a strong social stratification leads to elitism. Members of a rich class with long working hours who seek to distinguish themselves socially and escape day to day life through short breaks become frequent travellers. There is a polarisation between those who ''have'' and those who ''have not'', especially visible where property is expensive.
– In the second lifestyle, local living conditions are valued much higher than exoticism or cultural exchange. Some desire for exoticism and other cultures remains, but is now connected to infrequent long-haul travel.

– In the last lifestyle the culture is more isolationist, at the cost of cultural curiosity. Travelling becomes more dangerous due to persistent international tensions and more arduous due to failed investment in international transport infrastructure.

3.2. The storylines of the scenarios

3.2.1. The "happy few" scenario (S1)

Global governance vastly improves, including cooperation to cope with climate change. Economic growth is rather high, even if limited by climate policies. Technology transfers are fluid. This is represented by SRES scenario A1 (see IPCC, 2000) as the default option for GDP growth and demographics to feed the 'trip-engine'. In this scenario, individual travel does not suffer from heavy regulatory constraints. Some aspects of life in developed Western countries (like lifestyles and, to a certain extent, values) spread to the rest of the world. Technological progress is high, although no unexpected or highly improbable breakthrough is made. By 2050, it is expected that there will be a 48% reduction in per seat-km emissions for aviation (through improvements to engines, aircrafts, the partial shift to turboprops, and "open skies"). Hybrid cars are adopted early (2010–2012), contributing to a 55% drop in car emissions factors. The energy efficiency of trains increases by 60%. Climate change policy focuses on taxation, which leads to new investments in low-carbon technology and infrastructure. As a consequence, air travel becomes rationed, leading to elitism. While long-haul tourism air transport is still available, it is only for the "happy few". New rail infrastructures (high speed and others) develop at a medium rate, and allow continental travel for the masses. In socio-economic terms, people have to work more hours in order to earn decent salaries, while high incomes are limited to managers. The retirement age increases. The divide between those at work and those no longer at work (pensioners), preparing for work (students) or unable to work (unemployed) grows. Those with money have limited time for holidays and feel they need to pay high prices for their holidays. Others have plenty of free time for cheap vacations at home or for visiting friends and relatives. This reinforces social polarisation.

3.2.2. The "home centred", or "tourism... not too far!" scenario (S2)

This scenario makes the same assumptions for international governance, economic and demographic growth and technology as above (again SRS A1 is used as the default option for trip generation). One major difference, however, is that climate policy introduces individual or household carbon budgets, which can be traded up to a certain limit (20%). The limited global carbon budget is evenly shared, and involves a strong focus on low-carbon technology, and thus faster technological development than in the "happy few" scenario. For individuals with energy-intense lifestyles, marginal costs for more tourism are high; for the wealthier, options to buy permits may be limited. Though long-haul tourism is to some extent maintained by climate policies (i.e. developing countries dependent on tourism may use carbon quotas to subsidize their tourism industries), it is clear that tourism policies in this scenario will strongly favour domestic and continental tourism. Overseas tourism becomes an exception, but is still possible (like one 4 month journey to Asia in a life-time). There is also considerable investment in rail transport, while hybrid cars maintain individual mobility and access to remote domestic destinations in the countryside.

3.2.3. The "global isolationism" scenario (S3)

Global governance is limited to the minimum in a multi-polar world. There is strong competition for access to energy and raw materials, leading to more conflicts, which in turn reduce economic growth. Technological progress is hampered by the lack of cooperation in research and technology transfer, and by moderate economic growth. There is no global convergence between countries; each of them tends to replicate its traditional values and to develop specific ways of life. This can be negative in terms of emissions or positive (for example, it may lead to maintaining high levels of collective transport in developing countries). The lack of international governance results in minimum international climate policy, which prevents the development of strong regional policies. Carbon emissions due to international aviation are therefore less regulated than in previous scenarios; meanwhile, demand for air transport drops and its modal share and average distance tend to decline. Tourism policies are the result of high demand for domestic tourism and proximity leisure, given this reduced desire to travel to long-haul destinations. The loss of cultural curiosity and some isolationism reinforce this picture of future societies.

3.3. Overview model results

The model calculates time series using constant rates of change. Fig. 6 shows time series for both transport and total emissions as a share of emissions in 2005. Clearly, in the S1 scenario, reductions focus on both transport and other tourism factors, while S2 is based on greater non-transport reductions and S3 on greater transport emission reductions. Using the storylines, the rationale behind this is that S1 allows the maintenance of more air transport for the 'happy few'.

Notably, backcasting objectives could not be reached in any of the three scenarios without compromising storylines or applying overly unrealistic assumptions. Total tourism CO_2 emissions resulted in 780 Mt (happy few), 704 Mt (proximity tourism) and 677 Mt (global isolationism), all of them significantly higher than the target of 443 Mt. Expected demographic and economic growth, together with improved access to mobility in developing countries, outpace emission reductions introduced by technology, and investments in infrastructure for collective transport and the assumption about a larger share

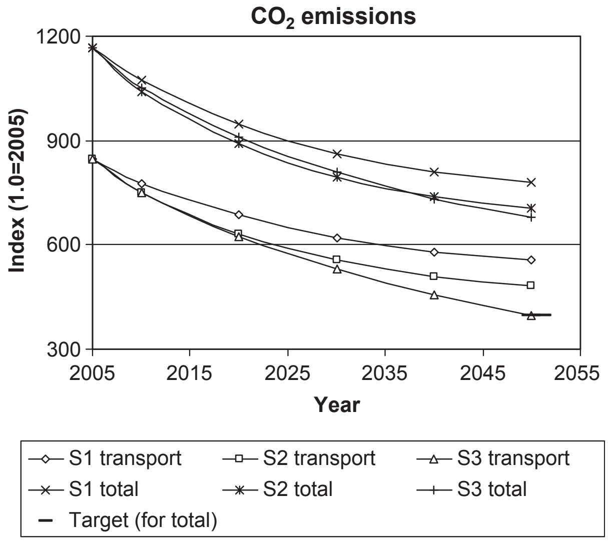

Fig. 6. Time series of the development of emissions per scenario. Transport emissions in the "proximity tourism" scenario tend to increase at the end of the scenario period (2050). All other trend lines are still pointing downward in 2050. Scenarios: "happy few" (S1), "proximity tourism" (S2) and "global isolationism" (S3).

for close destinations. The question is how to reduce emissions by 2% a year, relatively to 2005, when tourism is currently growing at a rate of 4–5% a year.

Fig. 7 shows that, in all scenarios, the number of trips and guest nights, as well as the overall transport volume, is significantly lower than for the 2050 baseline. Compared to 2005, however, growth in trips and guest nights is generally lowest in the "global isolationism" scenario and highest in the "proximity tourism" scenario. In the "happy few" scenario, only the rich travel regularly and freely, leading to a middle ground in emission reductions. In the "proximity tourism" scenario, the average length of stay increases, while the number of trips and kilometres travelled decline. The average emission factor includes not only technological efficiency improvements, but also changes in operations, seat density and seat occupation rates. In "global isolationism", technological development is hampered by the lack of international cooperation and the low market development. In the "proximity tourism" scenario, individual carbon budgets put a strong constraint on the market, thus increasing carbon cost to a high level. This makes investments to reduce emissions more economical than in the "happy few" scenario, which is comprised of only soft (economic) measures to reduce emissions.

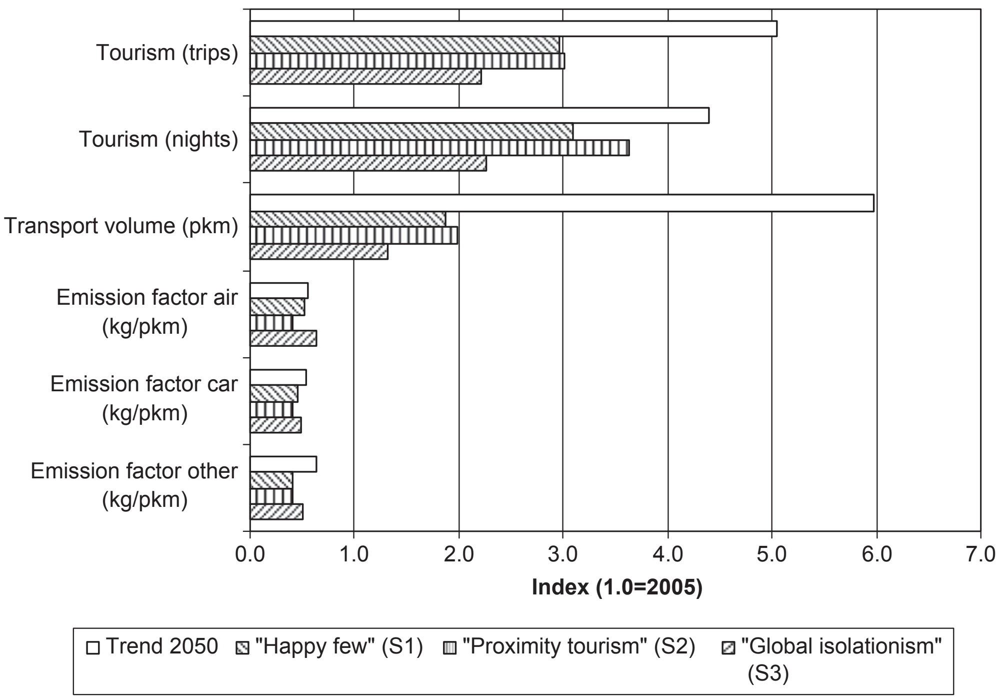

Fig. 7. Results for all three scenarios in 2050 as index of 2005.

The distribution over the three markets and transport modes differs substantially between scenarios. Fig. 8 provides an overview of trip numbers. The "happy few" scenario contains a high share of international tourism and allows for considerable growth of domestic tourism in developing countries. Note that domestic tourism in developing countries will account for more than half of all tourism air transport. Differences in income and the use of energy-intense transport (air and car) remain high in this scenario. The "proximity tourism" scenario equalises tourism even more: given the population growth in developing countries, their overall tourism mobility grows faster than in industrialised countries. This scenario depends even more on rail and coach, based on the notion that (high speed) rail offers a reasonable alternative to air over relatively short distances. The "global isolationism" scenario finally shows a much lower growth for all markets, including international travel. All means of transport remain important, though, with car use increasing faster in developing countries (domestic) than in industrialised countries. The isolationism of these blocks means that, like industrialised countries in the past, developing countries go through all stages of development.

Fig. 9 shows the distribution of emissions. An important result here is that the burden of tourism (and emissions) shifts from the developed world to the developing world in all scenarios. Whereas domestic tourism in developing countries had

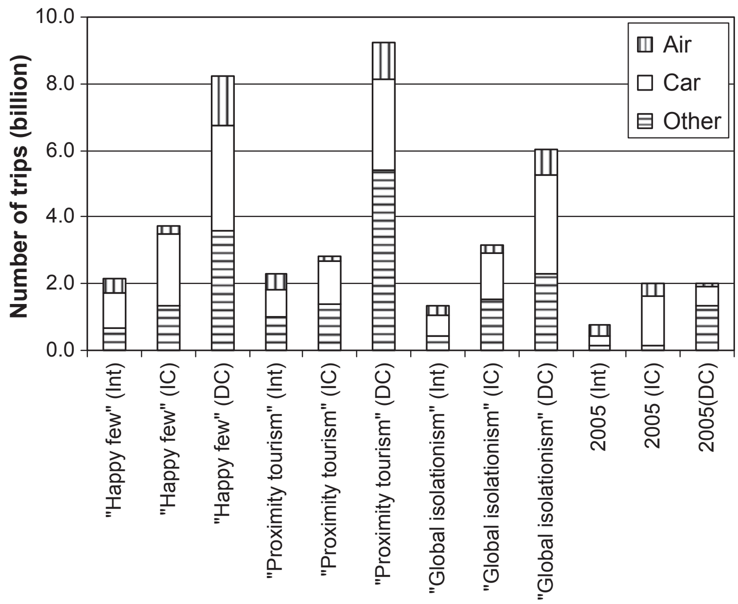

Fig. 8. Distribution of trips over the different markets and transport modes. Int = international, IC = domestic within industrialised countries and DC = domestic within developing countries.

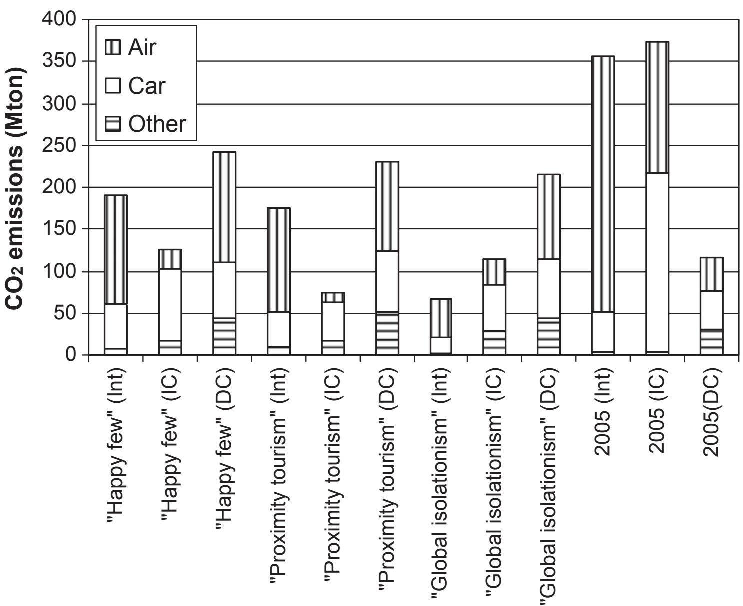

Fig. 9. Distribution of CO_2 emissions over the different markets and transport modes. Int = international, IC = domestic within industrialised countries and DC = domestic within developing countries.

the lowest share of emissions in 2005, it is responsible for most emissions in all scenarios by 2050. Furthermore, emissions from air transport continue to dominate in all scenarios, though their relative share declines. In two scenarios (''happy few'', ''proximity tourism''), international tourism continues to account for the highest share of emissions. In the ''happy few'' scenario, emissions in developing countries are equally high for international tourism and domestic tourism. The emissions of other transport modes become more significant than in 2005, but air transport continues to dominate.

4. Conclusions

The results indicate that in a situation where the tourism and tourism transport sectors are required to reduce emissions by a percentage as high as in all other economic sectors (even with the option of considerable trading and/or offsetting), only substantial changes in the way we travel will lead to (moderate) emission reductions. Clearly, none of the scenarios developed in this article achieves the level of emission reductions climate policy would necessitate. Avoiding dangerous climate change leaves room for tourism mobility, but only if a major shift in the use of transport modes is achieved in combination with a reduction in the distances travelled, and the rapid introduction and development of new low-carbon transport technologies.

More specifically, in all scenarios, air transport will have to grow slower than other transport modes, to the point where growth stagnates or even declines. The most substantial reductions in emissions are achieved in domestic tourism in industrialised countries and in international tourism (slow growth in S1 and S2, stagnation in S3), while domestic tourism in developing countries retained some growth. By contrast, public surface-based transport (train and coach) would see exponential growth by 1.6–4.4% per year up to 2050.

Importantly, the principle of contraction and convergence (i.e. disproportional large emission reductions in industrialised countries to allow for further growth in emissions in developing countries) will mean that current travel patterns in industrialised countries must change considerably. Clearly, neither technology nor investments in infrastructure such as new rail networks will be sufficient to achieve overall emission reductions (for both industrialised and developing countries) in the order of 60% by 2050 (as compared to 2000). Demand management thus becomes increasingly important, with options including new pricing structures and other incentives, or individual emission quotas. Ultimately, the de-carbonization of the tourism system may even imply that societies must reflect on which forms of tourism and transport can still be supported. This may, in many respects, boil down to questions of climate justice: who can travel, for how long, using which transport mode, why, and how comfortably.

Overall, several conclusions can be drawn with regard to the use of scenario building for climate policy development. First, backcasting exercises can help to assess the change required to reach targets, and therefore help raising awareness amongst stakeholders. As the example presented in this article illustrates, the challenge can be enormous. Second, in a situation where forecasts point to a dead-end (unsustainable emission growth), backcasting can encourage stakeholders' to creatively design radical shifts (e.g., Peeters and Dubois, 2009). Lastly, scenarios may help evaluate and put in hierarchical order policy instruments. The scenario exercise presented in this paper, for instance, shows that introducing individual carbon budgets and quotas leads to more even development than the introduction of pricing and taxation instruments.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.tra.2009.11.004.

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