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Trend Analysis of Greenhouse Gas Emissions from the Indian Aviation Sector: A study of the implications of future Civil Aviation Demand.

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Abstract

With a growth rate close 33%, Indian civil aviation is one of the fastest growing economic sectors in the world. Supported by the nation's steady growth in GDP, the Indian Ministry of Civil Aviation forecasts domestic aviation passengers to increase to 200 million by 2020. Though the aggregate number of passengers using aviation in 2008 is less than 4% of the nation's population, it is the growth rates and projections of aviation industry which is of concern. COP-13 road map persuades developing nations to choose nationally appropriate mitigation strategies in the context of sustainable development. If India chose to adopt emission reduction targets, the nation will have to quantify their emissions *reliably* and as well project future emissions. This means prioritization of economical sectors that will have more leverage in emission allowances will be the first step to any such move. The objective of this study was to forecast the future growth of India's civil aviation demand and to examine the implications this demand by 2020 in the context of UNFCCC's COP-13 objectives. Scenarios were used to understand the above mentioned dynamics and the results the scenario based trend analysis is used for recommendations for roadmap towards India's emission reduction policies. A STELLA model was created for the trend analysis. The forecast results indicated tremendous growth in CO_2 emissions from a population that were less than 25% of the nation in 2020. From such a single source, the emissions were 325 $MtCO_2$. Inequity in CO_2 distribution and Policy inadequacies will lead to such a scenario.

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Thank you,
Reshmi Vasudevan

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List of Acronyms

CAE- Central Electricity Authority
CAPA – Centre for Pacific Aviation
CO2 - Carbon Dioxide
DGCA – Directorate General of Civil Aviation
EUC - European Union Commission
GHG – Greenhouse Gas
GOI - Gover nment of India
IATA - International Air Transport Association
ICAO - International Civil Aviation Organization
IPCC - Inter Governmental Panel on Climate Change
IR – Indian Railways
MoCA Ministry of Civil Aviation
MoEA - Ministry of External Affair India
MoF - Ministry of Finance India
MoT - Ministry of Tourism India
MGI - McKinsey Global Institute
NCAER - National Council for Applied Economic Research
OC - Ordinary Class
PATA - Pacific Asia Travel Association
SC - Second Class
UC - Upper Class
UNFCCC United Nations Framework Convention on Climate Change
UNWTO - United Nations World Tourism Organization
USD – United States Dollar
WRI - World Resource Institute
WTTC - World Travel and Tourism Council

1. Introduction

Global Greenhouse Gas (GHG) emissions due to human activities are found to have increased by 70% of the pre-industrial levels, during the period 1970-2004. The critical consequence of increased levels of greenhouse gases is positive *radiative forcing*[1] which is attributed to increase in warming. The period of 1995-2006 is estimated as the warmest years since 1850 and scientists have found that the rising sea level has been consistent with warming (IPCC 1999, 2007). Scientists warn that a one meter sea-level rise alone will displace 7.1 million people in India and 5764 km-sq of land will be lost (GOI 2004). Similarly severe weather changes are predicted that will primarily affect the hydrological cycles and the river basins in South, South-East & East Asia causing severe floods and thus water borne diseases (IPCC 2007). The threat of glaciers loss that supplement rivers, changed weather patterns, increased flooding, water shortage are predicted to cause large-scale loss of dietary sources like wheat, rice and other agricultural and forestry products which form the livelihoods of more than 60% of India's population (Garg *et al* 2007, TERI 2007).

1.1. Background

The 13th Conference of Parties (COP) of the United Nations Framework Convention for Climate Change (UNFCCC) held at Bali in Dec 2007 emphasized that *"resolving"* to the objective of the Kyoto treaty is extremely important, through "*reaffirming*" to the global priorities of economic and social development, and poverty eradication. Thus COP-13 appeals to "*recognizing*" the urgency of large scale reduction of global GHG emissions by "*responding"* to the recommendations of IPCC's Fourth Assessment report. While US emissions alone accounted for 21% of the total GHG emissions, together with the European Union, China, India, Brazil and Russia contributed to 61% of the global GHG emissions (WRI 2005). India and China argue that their *per capita emissions*[2] are much smaller than their developed counterparts and emissions from development necessities are unavoidable (GOI 2004). The IPCC report ascertains that climate change to aggregate *the pressures on natural resources and the environment, associated with rapid urbanization, industrialization and economic development* and hence rapidly expanding populous economies like India and China are in spotlight for their GHG emissions (UNFCCC 2007, IPCC 2007). Thus, the nature of *development* is extremely important from the climate change perspective, such that, as Swart *et al* (2004) points outs, such a *development* should maintain the *elasticity* of environmental and social systems, in order to meet *a complex array* of interacting environmental, social and economic

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[1] Radiative Forcing is the measure that shows the imbalances in radiations to the Earth's climate system caused by anthropogenic activities, indicating the changes to global mean surface temperature (IPCC 1999)

[2] In 2000, India's per capita emissions were only 1.0 tCO2, leaving India at the 120th positions of global per capita ranking of nations' emissions (WRI 2005). Though this value is now calculated to be 1.55 tCO2, it is still one among the lowest in the world.

conditions.

1.2. Aviation and GHG Emissions

Transportation sector becomes important in the GHG emission discussion by the volume of its fossil fuel consumption indicating the Carbon Dioxide (CO_2) produced. EEA (2001) forecasts GHG emission levels to increase beyond 1990 levels in 2010 largely owing to transport emissions (*cited in* Bishop 2002). The sector accounts for 14% of GHG emissions, which constitutes 18% of global CO_2 emissions (WRI 2005). Carbon dioxide emissions from aircrafts were 2% of the total anthropogenic carbon dioxide emissions in 1992, which was 13% of all carbon dioxide emissions from transportation sector.). As Whitelegg (2000) points out, though these figures imply that aviation emission causes only 3.5% of all anthropogenic activities, it is equivalent to Canada's CO_2 emissions from all sources, thus emphasizing the contribution from a single source like aviation, which is rapidly growing. But these figures tend to loose its criticality in the milieu for aviation demand and the rapidity of its growth. However, these greenhouse gas emissions have larger implications with respect to climate change discussions when emissions of gases like NO_x, Ozone, methane, contrail formation, water vapour release etc that occur *in the free troposphere and lower stratosphere* are taken into consideration (IPCC 1999). IPCC Special Report's midrange forecast a 3.8 fold increase in total radiative forcing by 2050 on the levels of 1992 (IPCC 2007)

1.3. The Purpose of the Study

The COP-13 road map urges developing nations to choose nationally appropriate mitigation strategies in the context of sustainable development (UNFCCC 2007). As Claussen (2007) suggests, if countries [like India] chose to adopt emission reduction targets, the nations will have to quantify their emissions *reliably* and as well project future emissions. This means prioritizing economic sectors that will have more leverage in emission allowances will be the first step to any such move. With an average annual growth rate (AAGR) of 33% since 2004, Indian civil aviation is one of the fastest growing economic sectors in the world (MoF 2007). Supported by the nation's steady growth in GDP, the Indian Ministry of Civil Aviation forecasts domestic aviation passengers to increase to 200 million by 2020 (MoCA 2007). Globally, the aggregate energy consumption and GHG emissions from aviation is comparatively low in comparison to motorized vehicles, but Chapman(2007) points out, the growth rates and projections of aviation industry is of a source of concern. In India, the domestic aviation passengers constitute only 4% of the population, but this population has been growing at an annual average rate of 33% since 2004 and the industry expect this growth to continue. Thus the main objective of this study is to forecast the future growth of India's civil aviation demand and to examine the implications of this demand by 2020 in the context of UNFCCC's COP-13 objectives.

The objective of the study will be achieved through:

- Models to project the trends of GHG emissions from the Indian civil aviation until 2020
- Investigation of socio-economic implications of aviation growth in Indian context
- A discussion of probable implications of the analysis in the context of sustainable development

1.4. The Scope of the Study

- In the civil aviation demand research only passenger traffic is considered, which forms almost 80% of the traffic (DGCA 2005).
- The scope of the paper limits itself from researching on demographic characteristics on why people choose to fly, but takes the empirical evidences from literature that efficiency in the form of time, speed, accessibility attracts people towards aviation, along with the other drivers discussed in this study. As well, employment opportunities and benefits from travel and tourism is not included in the study.
- Carbon Dioxide (CO2) and Nitrous gases (NOx) from anthropogenic activities are of utmost concern in climate change discussions. While CO2 emissions are proportional to fuel usage, NOX is dependent on engine technology, causing a trade-off in reduction methods. So this study focuses only on CO2 emissions. All references to GHG would imply CO2 emissions.
- Implications of noise pollution and ground level pollution are not included in the study.
- It is assumed that with the growth of aviation demand, aviation infrastructure will expand to handle the demand.

1.5. Methodology

Scientific bodies like IPCC (1999, 2007) represent the world scientific community, providing empirical data that greenhouse gas emissions cause perilous climatic changes. The idea behind this research is to use existing data on aviation and the greenhouse gas dynamics and forecast future greenhouse gas emissions to quantitatively and qualitatively describe future implications of key drivers and dependent variables. Thus research is important to validate the causal relationship between the variables and their dynamics. Hence a trend analysis is central to the study. The trend analysis uses such a cause and effect dynamics to understand the characteristics of the variables over a given period of time (Raune 2005, p94-9). The impacts of the quantitative results are used for qualitative discussions. Scenarios are created to define the nature of the trend analysis. The data on Indian civil aviation industry obtained are from the secondary research of available scientific literature, officially published online materials from India government functionaries like Directorate General of Civil Aviation (DGCA), Ministry of Civil Aviation (MoCA), Ministry of Tourism (MoT), Ministry of Finance (MoF), international organizations like UNFCCC, Intergovernmental Panel on Climate Change (IPCC), International Civil Aviation Organization (ICAO), United Nations World Tourism Organization (UNWTO), research institutes like National Council for Applied Economic Research (NCAER), McKinsey Global Institute (MGI), news articles and information from other relevant organizations. STELLA[3], a system dynamics modeling tool, is used for constructing the model.

2. Civil Aviation Growth

UN defines "development" as *furthering of human choices* by which an individual has the "*political, economic, and social freedom to opportunities for being creative and productive, and to enjoy human rights*" (IPCCC 2000). Aviation is one such choice. It is characteristic of aviation industry to expand when an air travel network is initiated in a previously 'un-served' region, as it offered a new means of transport thus uncovering the latent demand among the prospective consumers. While the GDP (Gross Domestic Product) growth has been attributed to the expansion of aviation industry, air fare price reduction has also propelled it growth (IPCCC 1999, ATAG 2000). ICAO (2000) hails civil aviation as a catalyst to the growth of economies world wide such that, the global aviation industry is claimed to be valued at a total USD 880 billion contributing to 10% of the world GDP. As well the literature points out that the accessibility of tourist destinations by air transport is integral to the growth of tourism. ICAO (2000) further emphasizes aviation industry thus creates direct, indirect and induced economic benefits through supply chain industry, consumer industries, like hotels, shopping through travel and tourism industry.

2.1. Dynamics of Civil Aviation Demand

Travel behaviours are largely influenced by time and cost, which can be translated into "long distances in short time" (Schafer *et al* 2000). Aviation industry contributes to such consumer choices in distinct ways from other transportation modes by providing alternative forms of travel to long-distance market, increased tourism & leisure opportunities, improved travel efficiency with respect to shorter travel time and increased accessibility of places (Whitelegg 2000). Thus with the expansion of air travel network, people

[3] A modeling software which is applied in the areas socio-economic and public policies
http://www.iseesystems.com/softwares/Education/StellaSoftware.aspx

accommodate work and business habits in distant places, thus incorporating aviation in the leisure and business routines. Nations whose economy has become integral to international trade and business has a higher tendency to integrate aviation into labour and trade (Vedantham & Oppenheimer 1998, IPCC 1999a, ICAO 2002).

2.2. Conceptual Model and Variables

Various models are available to represent air travel market and travel demands. The aim behind this model is not just to extrapolate future CO2 emissions in the Indian aviation sector, which is relatively new in the context of India, but also examine the influence and interactions of important variables on the growth of greenhouse gas emissions. Aviation demand remains central to these dynamics. These factors can be grouped into internal and external influences. External factors are implications of economic, social, demographic and political trends, while internal drivers are those of aviation market, fuel prices.

The CLD illustrates the dynamics between key drivers that drive the aviation demand and the indicators of growth. Aviation demand here is represented by the "Number of people using Air Travel". The idea is to calculate the passenger kilometer (pkm)[4] traveled by air travel from which green house gas emissions will be calculated. **Population** increase does not directly imply aviation growth, but represents the increase in "Travel Demand" which in turn increases air and land travel demand. "**Disposable Income**" on the other hand indicates the purchasing power which increases with the growth of the economy. "Air ticket price" indicates the demand such that with an expansion of the aviation industry more airlines compete in the market thus offering competitive prices to attract more passengers. Tourism is dependent on mobility availability. Thus when more land and air based mobility is available, tourism increases. As well when tourism grows the demand for more mobility also increases, thus reinforcing each other. "Air Travel Demand" is an indicator to show "why" aviation becomes a choice of travel.

Regulatory Variables: Fuel prices in the form of operation costs can affect the ticket prices and other maintenance expenses of the aviation industry, thus the aviation growth. The distortions in the fuel prices in the form of tax incentives are not represented here, but will be addressed later in the policy discussions. "Regulatory Measures" can regulate the GHG emissions with emission control caps and through taxes, thus regulating the growth of the aviation industry. Finally the "Transport Policy Efficiency" indicating the inefficiency of the policies of the land transport sector. This is to indicate that travel efficiency by air travel

[4] PKm (Passenger kilometer) is the product of "the number of revenue passengers carried" and "total distance flown". The resultant figure is equal to the number of kilometers travelled by all passengers (DGCA 1998).

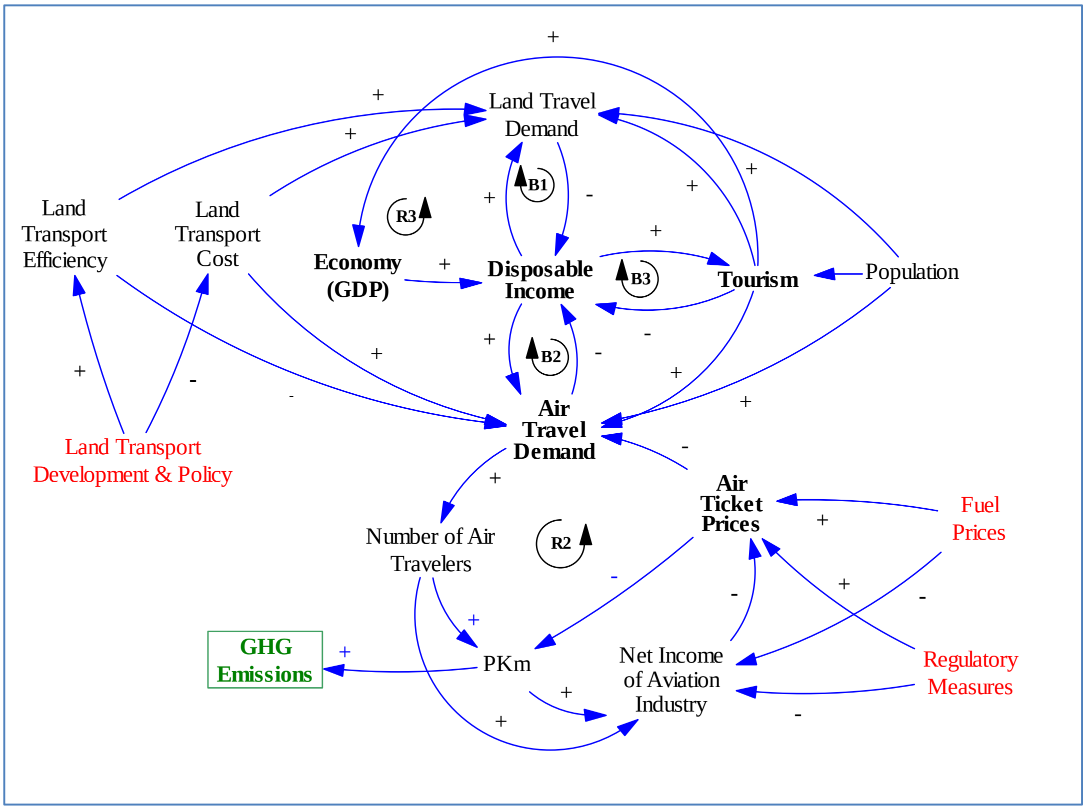


Figure 2-1 Causal Loop Diagram for the Aviation Demand and Greenhouse Gas Emissions

encourages many to travel by air. A detailed CLD on the dynamics of the aviation demand is available in the Appendix (Appendix CLD)

3. Indian Civil Aviation Dynamics

3.1. Aviation Demand in India

The Indian Aviation industry was partially deregulated during 1994-95 which resulted in a small but steady increase in passenger numbers. In 2002, India accounted for only 2.4 million tourist arrivals compared to the global international arrival of 715 million. In its 10th five year plan (2002-07), the Planning Commission[5] of India targeted *"to make air transport competitive and affordable"*. A liberal aviation bilateral regime and a new aviation policy "*to benefit the economy of the country*" through the aviation and tourism industries was conceived (Planning Commission 2002). Subsequently India signed the Open Sky agreement with the US thus liberalizing its international aviation market which lead to "increased passenger and cargo services, and lower-prices" thus enhancing the Indo-US aviation market. Similar bilateral treaties were formed with many other potential partners to enhance greater connectivity to and

[5] Planning Commission of India is responsible for making, assessing, augmenting and formulating plans for the most effective and balanced utilization of all resources of the nation and thus help in determining priorities for the government of India. These plans are aimed for every 5 years. 2002-07 was the 10th plan.

from India (MoF 2007). The emergence of Low Cost Carriers (LCC) in 2005 offering "no-frill" flights with tickets prices 30%-35 % lower than its peers made aviation journeys affordable to a larger public. Such rapid expansion of the industry, as represented in table-3.2, was fuelled by the growth in the nation's economy, such that the domestic aviation passengers grew at an average growth rate of 33% per year, while the international passenger traffic grew at a yearly rate of 25.4% . During 2004-07 while India's GDP grew at an average of 9% per annum the domestic and international passengers doubled in its volume (MoF 2007). The passenger growth is tabulated below in table-3.1 and the growth of per capita distance traveled is shown in table-3.2.

Passengers carried per year	Domestic (Million)	Growth %	International (Million) (Inbound + Outbound)	Growth %	Total (Million)	Growth %
1997	9.52	--	10.66	--	20.18	--
1998	10.06	11.3	11.02	1.8	21.08	4.4
1999	12.68	10.5	11.45	4.1	24.13	14.5
2000	13.71	8.1	12.28	7.2	25.99	7.7
2001	12.85	-6.2	11.91	-3.0	24.76	-4.7
2002	13.95	8.5	13.16	10.5	27.11	9.5
2003	15.67	12.3	14.63	11.2	30.30	11.7
2004	19.45	24.1	17.27	18.0	36.72	21.2
2005	25.21	29.6	20.17	16.8	45.38	23.6
2006♣	36.80	46.0	23.39	16.0	60.19	32.6
2007	48.76	32.5	27.03	15.6	75.79	24.2

Table 3-1 Civil Aviation growth in India (Source: **DGCA 2005, MoF 2006, MoF 2007)**

Year	Domestic	International
2003	927	4032
2004	927	4181
2005	940	4255
2006♦	953	4327
2007	966	4401

Table 3-2 Average Per Capita Distance Traveled (km) (source **DGCA 2005)**

3.2. GDP and Disposable Income

India is the 5th largest economy with a GDP at PPP estimated at USD 2.9 trillion (CIA 2007). The nation saw rapid growth in its GDP compared to earlier years of decadal growth patterns: the 1980s which saw a 3.1% pa growth, while the 90s were stagnant at a 3.7% pa. Since 2002-03 this growth doubled to an average growth of 7.2% per annum. India's GDP grew at an average of 9 % during 2004-06, which

♣ Values for 2006 and 2007 are calculated from the growth rates stated by MoF(2006), MoF(2007)
♦ Values for 2006 and 2007 are calculated on the basis of historical trends (2003-05)

moderated to 8.5 % in 2007 (MoF 2007b, CIA 2007). With an increasing pace of economic development, the change in consumption patterns is evident. The ministry of Finance finds that the consumption growth patterns doubled with the increase in GDP since 2003-04. Table-3.3 indicates the income and consumption growth rates:

Year	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08
Income	2.2	6.8	6.6	7.6	8.1	7.2
Consumption	1.1	4.2	3.6	7.0	5.6	5.3

Table 3-3 Growth rates (%) in per capita Income and Consumption (source **MoF 2007b)**

In its *market information survey of households*, NCAER[6] (2005) focused on the implications of growing economy and household consumption patterns. Table-3.4 discusses the survey findings, where the survey grouped the households into categories based on incomes:

Household Income (p.a.) USD[7]	Households 1995-96	Growth %	Households 2001-02	Growth %	Households 2005-06	Growth %	Households 2009-10 (NCAER projection)
Deprived Below 2270	131.2	3.2	135.4	-2.2	132.3	-13.5	114.4
2270 - 5000	28.9	42.9	41.3	29.0	53.3	41.3	75.3
Middle Class 5000 - 12,600	3.9	131.5	9.03	46.2	13.2	68.9	22.3
12,600 - 25,200	0.65	161.5	1.7	88.2	3.2	93.8	6.2
Rich 25,200 - 50,400	0.19	189.5	0.55	103.6	1.12	114.3	2.4
50,400 - 126,000	0.06	233.3	0.20	125.0	0.45	131.1	1.04
126,000 - 252,000	0.01	300.0	0.04	150.0	0.10	160.0	0.26
252,000 +	0.005	300.0	0.02	160.0	0.05	169.2	0.14
Households in Millions							

Table 3-4 Household income growth (source **NCAER 2005)**

In the above table, the growth trends indicate that households tend to move towards economically sound categories in each period. The growth rate of low income groups like the "Deprived" seems to have reduced from a 3.2% to a negative growth of 13.5%, while the rest of categories showed tremendous

[6] The National Council of Applied Economic Research (NCAER) is an independent, non-profit research institution that assists the Indian government, civil society and private sectors in making informed policy choices and decisions. www.NCAER.org

[7] USD – United State Dollars. All monetary values in Indian Rupees from original sources are converted to USD at 2008 (April) prices

increase, indicating that lesser number of households was deprived. The survey forecast for 2009-10 seems to follow the trends of the earlier growth except for the "Middle Class" category which is predicted to have a 50% increase over the 2005-06 growth rate (i.e., 46.2% to 68.9%). Thus the growth of different economic groups can be attributed to the increased per capita income of the households. The survey found that with such rapid increase of household income an increased demand for consumer goods was observed. This was reflected in the increase in household possession of disposable goods (non-durable commodities, food etc) and non-disposable goods (car, white goods etc). This would also indicate that with the increase in disposable income, goods once considered luxurious became an integral necessity (resources) (NCAER 2005). Human development, according to UNDP, is primarily the access to *resources* needed for a *decent standard of living* to lead a long and healthy life, and to acquire knowledge (cited in IPCC 2000). Here, it could be argued that definition of "resources" is influenced by above such consumption patterns. Assessing the ownership of commodities, the NCAER (2005) survey found 60-70% of the *middle-class* households owned goods like motorized two wheelers, televisions, and refrigerators, compared to the *rich* households whose ownership was 70-90%. This indicates that the ownership disparity is not too large in household goods, but the difference was seen when the survey included ownership of cars. Only 32% of the middle-income households owned a car against an 83% of rich households (NCAER 2005). A car on an average costs 10-50 folds more than an average household appliance. Thus affordability empowered by increased disposable income indicates the tendency among households for possession of more efficient and luxurious goods.

3.3. Air Ticket Prices & Fuel Prices

Though the increase in disposable incomes play a crucial role in the increase of aviation demand, in countries like India and China these incomes come from "relatively low levels" and hence air traffic growth will be largely from domestic and short-haul travel while the long-haul will develop in the long run (IATA 2007). This can be related to the findings in table-3.4, were the movement of "Deprived" and "Aspirers" categories seem to be shifting towards a large "Middle Class". The success of low cost carriers can be largely attributed to catering to this section of the population whose disposable incomes are growing and are probably first generation of aviation users. As Vedantham & Oppenheimer (1998) emphasize, taping this latent demand among the lower income group who has the potential to be aspirers of the benefits of the growing economy is important for the airline industries. Thus the emergence of LCC in the Indian aviation sector has been *along the trajectory* of the nation's economic growth.

Fuel prices have greater implications on ticket *price elasticity*. Globally, the price increase dents in the industry in 2007 were off-set by a strong traffic growth (5.9% for passenger traffic) and even stronger revenue growth of 8.4% (IATA 2007b). IATA[8](2007b) does not expect this trend to disappear in 2008 and continue to rely on economic growth to balance the fuel increase impacts. With India's economic growth forecasted to continue to grow at 8.5% in 2008, the aviation demand is expected to continue to grow. Yet to cater to this demand at low prices will be cumbersome as the industry now estimates the fuel price average for 2008 to be around USD114.2/barrel[9] thus impacting the global airline industry at an additional USD 47 billion (IATA 2008). In the Indian context, the industry has already reported a loss of USD 5 million per year from under-pricing the tickets in the times of increasing fuel prices (Business-Line 2007).

The pricing of ATF[10] (Aircraft Turbine Fuel) for domestic aviation in India is significantly higher than that of international operations owing to high rate of sales tax varying from 20-36% (MoEA 2008). Thus fuel costs represent 40-45% of the operational charges in the Indian domestic aviation sector and to balance the cost, airlines already levy a fuel surcharge on all air tickets (India Today-India eNews 2008). The current fuel price increase of 36% since 2007 (USD 73/barrel) would thus reflect in a 14-16% increase in air ticket prices, which might rise as threat to low cost travel market. A survey by the Centre for Pacific Aviation in the context of increasing fuel price implications on LCC passengers in India found that while price factors influenced the passenger choice, convenient schedules and previous experience equally influenced the consumer choice (CAPA 2007). Though majority of the LCC passengers choose LCC for lower prices, 51% of the surveyed travelers insisted that they would continue to use air travel even if the prices were doubled. The survey also found that 67% of the passengers, who used the regular Full Service Carriers (FSC), opted to continue to use aviation even if the prices were doubled against 51% of the LCC users (CAPA 2007). Historically, when travelers became more acquainted to using air travel, change in prices may not necessarily cause an immediate reduction in the demand. This could be attributed to behavior trends that they have adopted from repeated usage and hence are less likely to change immediately. But changes in travel behavior will be reflected in the *long run when they had time to adjust to the new prices and were able to make alternative arrangements* (Brons *et al* 2002). The CAPA (2007) survey claims that only 38% of the passengers surveyed preferred an LCC because of low prices.

Petroleum market strategies like hedging play an important role in oil prices which can distort the actual costs owing to the uncertainties introduced by the hedging mechanism and other such market strategies

[8] IATA, International Air Transport Association is an international airline trade body. www.IATA.org
[9] April 2008 Prices
[10] ATF is imported in India and is subjected to an excise duty of 16% and also state wise sales tax at an average of 25% on ATF for domestic carriers resulting in a total mark-up of 45% on basic ATF prices (MoCA 2003)

(Peeters *et al* 2007). In 2006, Air India, the national flag carrier, started practicing ATF hedging in the international market. Subsequently, Reserve Bank of India extended hedging through c*ommodity hedging* permitting both international and domestic airlines to hedge, thus enabling the airline sector to safe guard against price volatility (Talking Tarmac 2006, Business-Line 2007a). The Tourism and Transport sector has been lobbying the Civil Aviation Ministry to regard ATF as 'declared goods' as opposed to a 'luxury commodity' so as to curb ATF sales taxes at 4% (India eNews 2008a, Business-Line 2007a). Eventually, in the light of recent fuel price increase, an initiation to curb the ATF price increase has been promoted in India by state governments of Andhra Pradesh and Kerala by bringing down the taxes on ATF from a 33% to 4% (Financial Express- IndianAeroDef 2008). Incidentally, these states earlier had the highest tax on ATF. Aviation industry envisages the rest of the country to follow the suit. Subsequently, the current fuel price increase will be largely negated by the reduction in taxes, thus not affecting the operating cost in general and hence the aviation demand.

Technological innovations are funded if they prove to decrease the direct operation costs by 10% owing to the limitations induced by the cost factor in testing these innovations (Peeters *et al* 2006). Hence the proportion of fuel prices that affect the operational costs will be a key driver for technological innovation. At the same time, jet engine technologies with respect to propulsion are mature technologies such that efficiency improvements are not viable options in the near future indicating that the current fuel usage will continue as most jets have a life span around 30 years (Bows & Anderson 2007). Consequently, IATA stresses that with increasing fuel prices and labor expenses, improvements in productivity and efficiency in non-fuel areas of the industry are necessary to maintain profitability levels that were gained prior to the current fuel price hike. For instance, from a 12% increase per annum in 2004, the non-fuel costs has been reduced to 3.3% increase in 2007 which is expected to further reduce to 2.9% in 2008 (IATA 2008b).

3.4. Population and Travel Demand

A 33% reduction of global CO2 emissions by a successful reduction in global energy intensity since 1970 paled out in comparison to the CO2 emissions from global energy requirements. This high demand for energy was driven by global income growth (77%) and from the global population that grew by 69% (IPCC 2007). Thus the consumption increase of the population had a larger implication. While India's population grew by 88%, Singh (2006) shows since 1950s, absolute motorized mobility grew by 888%. Road-based mobility increased by 9.1% every year against a railway dependent mobility of 3.93% p.a, during 1950-2000. During this period, railway which was the dominant means of transport was almost completely dependent for all travel necessities, declined over the years. In the 1980s, though the railways contributed to 37% of the total passenger-km in India, it reduced to 16% by the end of 1990s. In the mean while road ways grew contributing to the most of the remaining transport requirements (Ramanathan & Parikh 1999, Singh 2006). The forecast on motorized traffic volume in India shows that by 2021, 13,000 billion pkm will be perfromed, out of which 91.7% will be provided by roadways and the rest largely by railways (Singh 2006). Other modes of transport remained mostly negligible till 2002-03, when the civil aviation sector started growing supported largely by the economic growth, as indicated in the earlier discussions. From the figures in table-3.1, in 2007, 48.76 million passenger trips using domestic aviation were made.

The choice of mobility can be argued as one that is based on income and the quality of service. The *quality of service* is often defined by comfort, style, safety, engine power etc (Schafer *et al* 2000). Similarly, the efficiency of travel to the location of service is primarily influenced by "Physical Comfort, Travel Time, Necessary Infrastructure, Resource Consumption and Environmental Implications" (Dhakal & Schipper 2005). Thus cost and efficiency of travel can be argued as the deciding factors for modal split in passenger transportation. Income provides a means to *choice*, primarily enabling one to access basic *services* and hence the level of per capita income is often used to measure socio-economic development (IPCC 2000). A consumer market survey by MGI (2007) in India shows that over a 20 period time (1985 to 2005) the transport expenditure of the household grew by 142%, while the expenditure on food decreased by 29%, such that transportation expenditures are the second largest for any household after the necessities of food and beverages. Increased allocation of funds for transportation could indicate: more travel either for leisure or business or increased transportation expenses. Transportation expenses are largely influenced by fuel cost. A fuel price increase will affect all commodities in general including food and other products and services consumed. However, during this period, expenditure on house hold utilities reduced by 25%, while personal product and services increased by 125% (MGI 2007). It can be argued that, the purchasing power of households has increased and the surplus of disposable incomes after the purchase of basic necessities is large enough to include increasing travel plans. This implies that economic growth has enabled households to allocate more disposable income for transportation and other services.

3.5. Tourism

In simple terms, Tourism can be defined as travel out of one's own daily environment with at an over-night stay (cited in Dubois & Ceron 2006). The purpose of travel could be one or more activities like leisure, recreation, holidays, visiting friends and relatives, business and professional (including travel for study), health treatment, religion and pilgrimage and sports. '*Tourist trip*' or simply a '*trip*' is a visit to any of those destinations and return to the "usual environment" of the tourist (NCAER 2002).

UNWTO defines tourism as an economic and social phenomenon. *Tourism Economy is based on total revenues* (Peeters 2005). With a 10.3% contribution, Tourism plays a substantial in the global GDP (MoT 2006). WTTC (2007) characterizes India *as a very large, least intensive and fast growing travel and tourism economy*. Tourism in India during the 1990s contributed to 2.5% of the nation's GDP, which gained a momentum during 2003-04 that by 2006 the sector contributed to 6.1% of the nation's GDP (MoT 2006). UNWTO attributes this growth to enhanced marketing and promotion of India's tourism in the world market. This helped in increasing the greater awareness about the country thus creating a large *promotion boost demand.* The expansion of LCC market during the same period equally contributed to the growth as well (UNWTO 2007). In 2002, ministry of tourism launched the '*Incredible India*' campaign to promote India's tourism in the international and domestic markets. The goal of this campaign was to incorporate tourism as an engine of economic growth by *generating significantly higher levels of demand from the domestic and international market* (MoT 2006b). By 2005, a 65% increase was registered in inbound tourist arrivals since the launch of the campaign in 2002, indicating that inbound tourism increased at a rate of 21.7% per annum, while the foreign exchange earnings increased by 96% during this period (32% pa growth) (MoT 2006b). From an average annual growth of 4.5% in the 1990s, the international tourist arrival in India grew to an average of 6.5%. After a depression in its growth owing to the global implications of SARS, terrorist attacks and the middle-east war, the rate of growth of international tourists sharply increased during 2003 and 2004 and continued a steady growth during 2005 and 2006 at an average of 13.3% (MoT 2006, UNWTO 2007, DGCA 2005b). Travel & Tourism economy, according to WTTC (2007), continues to contribute 6.1% of India GDP and is expected to further grow and stay at 7.6% pa in the following years to come. At an average close to 16%, India's outbound tourism growth (table 3-5) is one among the fastest in the world (Ibid.)

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
No of outbound Tourists (Million)	3.46	3.73	3.81	4.11	4.42	4.56	4.94	5.35	6.21	7.18	8.34	9.67 ∗
Growth %	13.3	7.8	2.1	7.9	7.5	3.2	8.3	8.3	16.1	15.6	16.2	16.0

Table 3-5 Outbound Tourism – the growth of Indian's traveling abroad (Source **MoT 2006)**

Officially India has 28 million passport holders indicating the potential of outbound tourism (UNWTO

∗ Caculated using 2004-2006 growth rates

2006). PATA's[11] had predicted that all Asia-Pacific destinations will experience tourists increase from India during 2005-2007, such that in 2006, Asia-Pacific region saw highest number of Indian tourists followed by Middle Eastern countries. In 2004, the distribution of Indian tourists destinations were such that 8% headed for Singapore, 6% to UAE, while 5% each toward the United States, UK and Thailand, with 3% each heading towards China, Hong Kong, Malaysia and France (UNWTO 2006, InterVISTA 2006). While the proximity of Asian destinations reflect the cost of travel as a deciding factor of destinations, demographic factors like convenience and the sense of comfort for also influence the choice for many first time travelers (*Ibid*.). Access of many neighboring countries has been made much easier through policy reforms, liberalization of the aviation industry aided by the strong growth of the economy since the last few years. Personal consumption in travel & tourism indicates the spending habits of the residents of a country in their outbound or domestic travel. In 2006, an average Indian tourist accounted travel and tourism for 3.8% of his person consumption expenses. By 2008, WTTC predicts this figure to grow to 6.1%, while business travel by 7.1% (WTTC 2007).

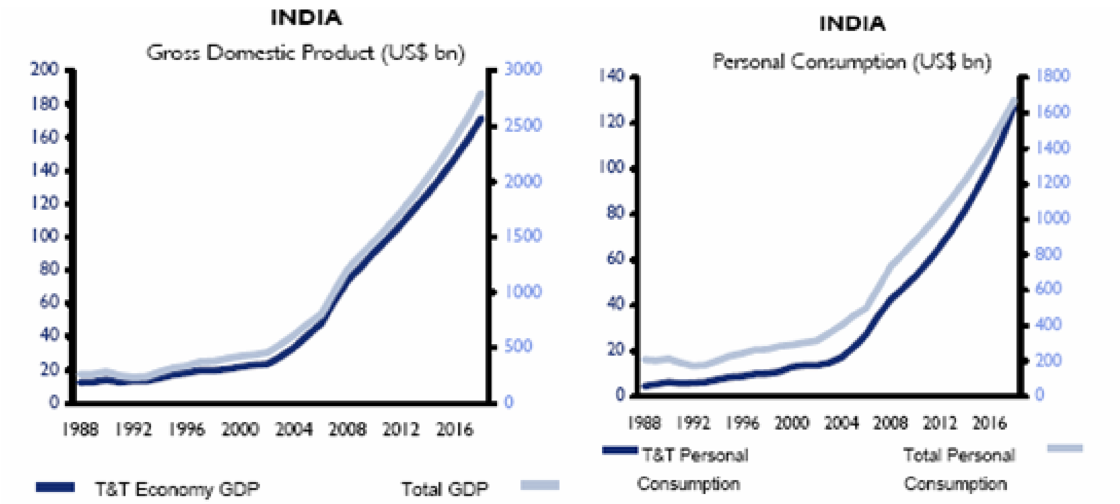
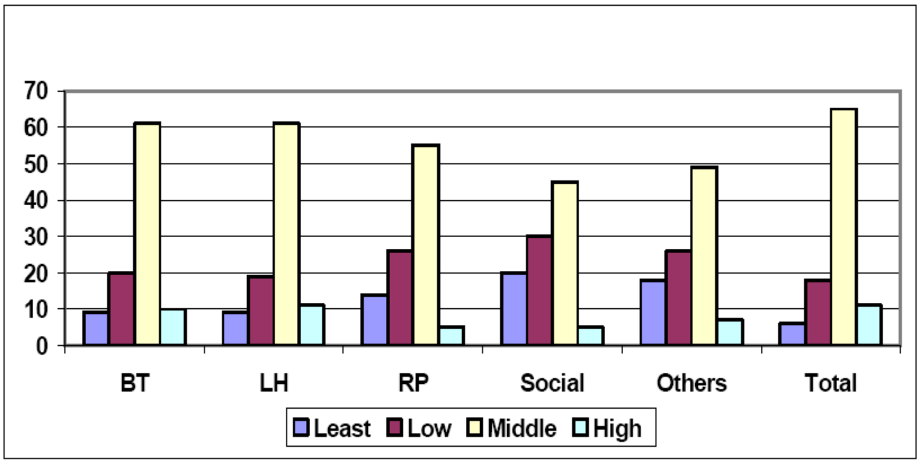


Fig-3.1 GDP- Travel & Tour Personal Consumption (**source** WTTC 2007**)**

As shown in figure-3.1 the trends in personal consumption have followed the trends of the GDP growth to indicate that with growing economy, the disposable incomes has increased from which the share for travel and tourism has consistently increased. This trend explains outbound tourism in India, such that seven million Indians traveled abroad in 2005, indicating a 10.5% of yearly growth since 2001. PATA (2006) attributes this growth *to strong economic growth, new airports, urban heartlands and air liberalization.* India's growing middle class and their lifestyles play an important role in this growth. The ministry of India targets to achieve 760 million domestic tourist visits by the year 2011, such that the number of

11 Pacific Asia Travel Association www.PATA.org

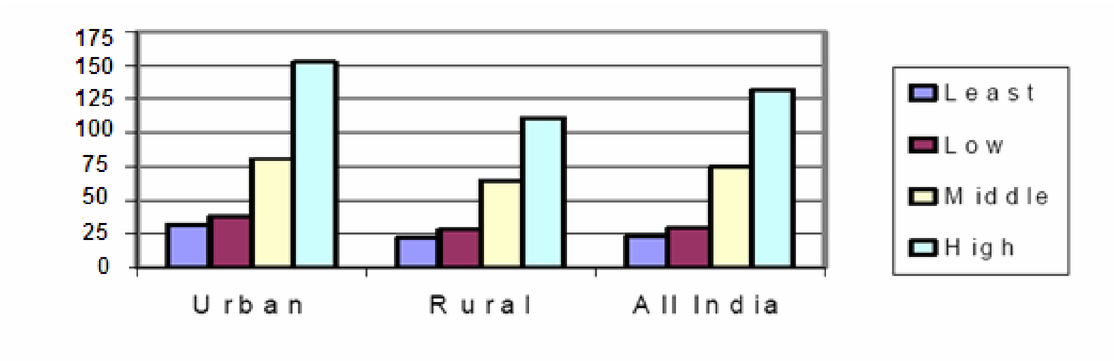
domestic tourist grows at a rate of 12% pa. To reach such a target, the tourism ministry aims to complement international tourism with domestic such that tourism will be year around, rather than seasonal (MoT 2006b). Domestic tourism showed a growth trend of 17.8% in 2006. According to an estimate by the Ministry of Tourism, in 2002 India had approximately 196 million households, distributed across the nation among which only 87 million (44%) were *tourist households*. A '*tourist household*' is defined as a household in which at least one member was a tourist during the reference period (NCAER 2002). Among these tourist households 46.7% of them belonged to the middle income group, indicating that the distribution of travel tendency to be high among the middle income group (NCAER 2002). This is captured in figure-3.2.



BT- Business Travel
LH- Leisure Holidays
RP- Religious Pilgrimage
(Source: NCAER 2002)

Figure-3.2 Distribution of trips (%) by purpose of travel and household income category

But the travel tendencies did not imply that with higher incomes the tendency to travel also increased as the high income households only constituted 10% of the total trips. Therefore income dynamics did not influence the frequency of trips. But the income dynamics showed the expenditure (personal consumption) during travel, as shown in figure-3.3. Though high income households had shorter number of trips, their expenditure per trip was much higher than the lower income groups. For instance, as seen in figure-3.3, for "All India", the least income group's travel expenses constituted less than 20% of the expenses of a higher income group



Fig**ure 3-3 Average expenditure (USD) by income group per trip** (Source: NCAER 2002)

From the fig-3.2, high-income households participated mainly in Business Trips (BT) and Leisure Holidays (LH). It could be argued that BT and LH incurred more expenses than unlike other form of the trips VFR (Visiting friends and Relatives) or Religious Pilgrimage. This could be attributed to the idea that people spent more money while on holiday or a business tour for dining and staying unlike a pilgrimage or VFR. The survey indicated, the average cost of travel was 25% of personal expenditure (NCAER 2002). Hence it could be argued that, here, households with higher incomes had access to more expensive travel modes that were luxurious and efficient. According to the survey, bus and rail transport constituted 90% of the trip, of which two-third was accounted by bus transport. Aviation accounted only for 0.5% of travel mode (NCAER 2002). From the earlier discussed income dynamics of the households, it could be safely concluded that only high income households would travel by aviation. This also means that the remaining 9.5% of high income households are potential consumer category that can afford to use aviation. It has to be remembered that NCAER survey on domestic tourism was conducted in 2002, and the aviation liberalization and the following LCC boom happened in the immediate years after. This transition was evident in table-3.4, especially the middle class households. And as NCAER (2002) survey indicated, the tendency to travel has been high among the middle class households. Thus empowered by economic growth and availability of low cost flights, the migration of these households from motorized or rail transport to aviation is highly probable.

Globally, inbound tourism depends as much as 46% on aviation (UNWTO 2007). UNWTO estimated 5% of global CO2 emissions are from tourism (cited in Gössling *et al* 2008). In 2005, 75% of CO2 emissions from global tourism were from transport among which 40% was from aviation sector alone (Peeters *et al* 2006). In India, 86-90% of the inbound tourism is by air travel as top tourist sources are largely overseas nations like USA, UK, Canada, France, Germany, Sri Lanka, Japan and Australia constituting 52.3% of total inbound tourists (MoT 2006). The problem with such long haul travel, as Gössling *et al* (2008) points out, is that *a single long-haul journey may exceed what can be considered sustainable per capita per year emissions* with respect to IPCC fourth assessment report's findings. Thus, by taking 2005 values as baseline, the current global per capita emission of 4t of CO2 has to start declining the latest by 2015 to reach sustainable levels of CO2. One litre of airline fuel can produce 3.16 kg of CO2 (IATA 2007c). Then, during long distance hauls between continents that cover thousands of kilometres, a single long distance trip by aircraft can easily produce 4t CO2 emission per person. This shows the rapidity of CO2 contribution from the aviation sector with increasing tourism. With the Indian tourism ministry actively campaigning to gear the domestic tourism growth, the population size plays an important role in emissions, as more households would be influenced to become a tourist household. As well with the increase of tourist options and package tours, a single journey can accommodate multiple destinations. Aviation contributes to such travel packages with reduced travel time, such that maximum destinations are covered in a single trip. The implications of such trips, as Peeters (2005) points out, *the number of kilometres travelled per tourism journey grows at a higher pace than the number of tourism journeys.* Thus, as seen in long haul, such journeys with icreased kilometres covered by aviation account for large contribution of CO2 emissions from tourism.

4. Modeling and Trend Analysis

In order to avoid an increase of global temperature by 2-2.4 deg C, global CO2 concentrations (at 350-400 ppm) have to start declining by 2015, while CO2 concentrations in 2005 was already 379 ppm (IPCC 2007). As Gössling *et al* (2008) points out, these figures indicate that each person on earth has already emitted 4 tCO2 in 2005, such that to accredit to IPCC's climate change warning, global per capita emissions will have to decline **to 3.5 tCO2 per year such that a 12.5% per capita emission reduction** has to be achieved by 2020 and further decline is necessary in the years thereafter. Thus India's current per capita emission is *calculated*[12] to be 1.55 tCO2. In 2003, India's per capita emissions were 1.2 tCO2, such that the emissions grew by 46.8% since the 1990 levels (WB 2007). Though bunker fuels emissions are not included in those values, examining the history of India's aviation industry the emissions from bunker fuels is negligible (GOI 2004). But from the above figures, it can be seen that during 2003-07, India's emission grew by 29%, reflecting the growth of emissions parallel to economic growth and development. The objective of the model is to forecast the trends of future CO2 emissions from India's civil aviation sector

[12]Calculation for India's per capita emission: Using current global per capita emission at 4.5 tCO2 (Gossling 2008), the the global CO2 aggregate will be 4.5 tCO2 * 6.6 billion = 29.7 GtCO2.
India's 1.15 billion population contributes to 6% of the global aggregate CO2 emission (a conservative growth rate 1% per year is applied to WRI (2000) that indicates India's CO2 share was 5.5%)
Therefore India's per capita emission = (29.7 GtCO2 * 6 %) / 1.15 billion = 1.55 tCO2.

into a medium range future of 2020, thus affecting this aggregate growth of CO2 emissions. Scenarios are to analyze the implications of the drivers of the model on these trends. A time period of 2020 is chosen influenced to examine the trends and results Kyoto limit for 5% reduction of global CO2 levels since 1990, the forecast limits itself until 2020 as well owing to the uncertainties involved in fuel prices and the fuel market fluctuations. Following features defines the scope of the model:

- The dynamics of the CLD (Figure-2.1) are central to the model
- GDP will continue grow at the current rates (8.5% - 9.0%) during 2008-2020
- Only macro level drivers are considered, as aviation is a broad topic
- Business and leisure travel are not separated
- Fuel will be available and fuel price will remain stable unless other wise considered in the model. When fuel prices remain stable, innovation will slow down as innovations are called for when the direct cost of operations exceed 10%. This could also show that environmental regulations do not mandate emission reduction.
- Environmental Regulations remain nil unless otherwise considered
- Air Ticket Prices will not reduce from 2008 prices (current)
- Lowest ticket prices are considered to reflect maximum demand

4.1. Model Description and Variables

"Aviation Demand" will be the deciding factor in the growth of Greenhouse gas emissions. Aviation demand is characterized by total Passenger Kilometer (pkm) traveled. Thus what drives the number of passengers traveling by air and that which facilitate the increase in distance traveled by air will be important in CO2 emission calculations. Scenarios are used here to examine the Aviation Demand. These Scenarios are primarily created to see the dynamics between the scenario elements and its implications on the growth of Aviation Demand and hence the CO2 emissions. CO2 emissions from aviation are the product of emissions per passenger-kilometer (pkm) and the total pkm. It is also the interest of this study to examine the implications of the growth of aviation demand on the scenario elements.

As seen in the CLD (figure 2-1), aviation demand and travel demand in general is a function of income. This means, people in higher income bracket have higher level of per capita demand, indicating a larger share of income for travel expenses (Vedantham & Oppenheimer 1998). Therefore, the study adopts Schafer & Victor (2002) approach in calculating the per passenger traffic volume (Tv), which is the ratio of *cost of transport* to the *amount people are willing to spend on transport*. Here, Tv is decided by Travel Money Budget (TMB), that which enables a person to travel and the Cost of Travel which should be accommodated by the available TMB. In this discussion pertaining to Air Travel, the cost of travel is the Air Ticket Price (ATP):

Tv = (TMB / ATP) * Z --- (Equation 1)

TMB is the share of per capita income set aside for travel. TMB/ATP gives the maximum "number of trips" a person can make with the given amount of TMB and the ATP in a year. Further details of the equation are available in the Appendix- (Appendix Equation)

Air Ticket Price (ATP) calculated from the real time prices for the model. ATP is constituted from a Base Fare (BF) and a Variable Cost (VC). The "Base Fare" is a sum of "Fuel Surcharge", "Passenger Service Fee" and "Congestion charges". Fuel Surcharges contribute to 20%-30% of the ATP. As Gössling *et al* (2008) indicate, the fuel cost represents one-third of the operational costs and hence contributes to one-third of the air ticket prices. Thus when the fuel prices are high (for e.g., like the current fuel markets), Fuel Surcharge smoothens the burden of increase in ATF prices on the airlines by making the additional cost as a part of the air ticket prices. Thus instead of affecting the VC, the Base Fare is used to absorb the extra cost of fuel, which is maintained at a constant by all airlines and competition among airlines are driven by the values of Variable Cost.

From Bangalore, To	Panaji (Dom)	Mumbai (Dom)	Abu Dhabi	Dhaka	Brussels	San Francisco
Variable Cost	1	2	205	359	508	774
Base Fare Fuel Surcharge	45	51	67	77	135	202
Passenger Service Fee	6	6	12	6	12	6
Air Traffic Congestion	4	4	4	4	4	4
Other Charges	0	0	0	17	0	23
Total (ATP) USD	**56**	**63**	**288**	**456**	**667**	**1009**
Distance (km)	490	836	2752	1800	7724	14013
Unit Cost (USD/ km)	0.11	0.07	0.10	0.25	0.09	0.07

Table 4-1: Air Ticket Price (ATP) composition and distance to domestic (Dom) and international destinations: Actual break up of prices as of April 2008 (source: Go Air 2008, Jet Airways 2008)

The Republic of India covers an area of 3.3 million sq km, such that from the north to south, India measures 3,214 km and 2,993 km from east to west. The northern land frontier measures 15,200 km and the peninsular coastline measures 7,517 km (CIA 2008, Wikipedia 2008). With such wide geographic distances, it is assumed that air travel would be largely used for distances above 500 km. And as well all major airport hubs are at distances not less than 500 km. From the tabl above, it could be calculated that the unit cost for travel by domestic aviation to be 0.07 USD. Here (Panaji & Mumbai) destinations by a low cost carrier (LCC) cost almost only the Base Fare as the variable costs are almost negligible compared to the BF, so the "distance traveled" at a given ATP is calculated using this unit cost. Thus the "number of trips", when multiplied with "distance traveled" for a given ATP gives the maximum distance (in km) a person can travel in a year for the available TMB.

Tourism, here, is an all encompassing terminology which indicates travel for any kind of purpose that would include an over night stay and "Tourists" are travelers who participate in this tourism. Future population projections are based on UN statistics which predicts that India's population will slow down from a 1.6% growth to 1.1% by 2020 reaching a population size of 1.3 billion (UNSTAT 2007b). In 2002, India had almost 549 million domestic tourists, while the population in the country was 1.08 billion (NCAER 2002, UNSTAT 2007b). Thus in 2002, almost 50% of the population were domestic tourists. The model assumes that over the period of forecast, 2008-2020, the number of tourists in the country will increase from 55% to 65% of the population, indicating that the rest of the population may not be economically strong to participate in any kind of long distance travel. The increase in the tourist population implies the higher tendencies to travel, as discussed earlier, largely owing to the increased share of the disposable income that can be used for travel. Following the recent economic trends, the model assumes that the future growth in GDP in India will be between 8.5% and 9.0%.

A baseline[13] is used for the calculation of domestic and international passengers indicating that at any given period, there will be baseline number of travelers always using aviation. CO2 coefficients are adopted from Peeters *et al* (2007), where emissions factor calculations included the fuel efficiency improvements. CO2 emissions coefficient were calculated based on the distances traveled such that distances <500 (0.206 kg/pkm), 500-1000 km (0.154 kg/ pkm), 1000-1500 km (0.130 kg/pkm) , 1500-2000 km(0.121 kg/pkm), >2000 (0.111 kg/pkm).

CO2 emissions are calculated from the product of CO2 coefficient and the total pkm. UNFCCC is yet to include international CO2 emissions into the Kyoto regulations, but suggests that countries make voluntary efforts through ICAO (1999b). International CO2 emission calculations are yet to be mandated by any regulatory frame work owing to the issues in defining the system boundaries. Unclear allocation methods on the grounds of *emission leakage* and *competitiveness concerns* remain central to international emissions allocation (Oberthur 2003). SBSTA[14] of UNFCC identifies the inherent problem in international emission

[13] Year 2002 values are used for the base line. Dramatic growth in the aviation industry was seen post 2002. The number of international and domestic passengers remained almost consistent over the years till 2003. Refer table-3.1.
[14] The UNFCCC Subsidiary Body for Scientific and Technological Advice (SBSTA)

allocation as “appropriate allocation of respnsibility for emissions from international bunker fuels would be connected to inventory and control issues” (IPCC 1999b). Thus in this model it is assumed that an ideal method would have been to calculate the international bunker fuel consumption by Indian Aviation, but owing to the lack of availability of data for recent years, this approach was dropped. As well, available bunker fuel data did not differentiate between maritime transport and international aviation shares. Hence international passenger numbers were used. If international emissions were calculated from bunker fuel consumption, it is to measure the volume of bunker fuels consumed (tanked) by Indian carriers that flew international miles. Alternatively, the international passenger numbers carried by Indian carriers available at DGCA (2005b) are used for calculating international emissions, such that during 2001-05, 40%-43% of the total international passengers were carried by Indian carriers. Alternatively, in the emission regimes scenario, the model considers only the outbound Indian tourists.

4.2. Analyzing the Trends

The future of the current ventures, as Dubois & Ceron (2006) insist, should be *internally coherent* and as well technically, economically, socially and politically feasible. Therefore such a future, Swart *et al* (2004) adds on, “should be scanned in a creative, rigorous and policy-relevant manner that reflects the character of sustainability and incorporates different perspectives”. Thus scenarios can be argued as those descriptive situations on which the future projections will be based and therefore this study employs “Normative Scenarios” to assist its trend analysis. Normative Scenarios are built to lead the analysis to a future which is said to be normative as it is characterized with specific subjective values (Swart *et al* 2004). Thus, though all the scenarios are defined by the dynamics that of the CLD, each scenario is highly characterized by its “normative value” to achieve a *definite outcome*. Three scenarios are used in this study: (i) Emissions Growth and the Implications of Per Capita Distribution (ii) Global Emission Regimes and Implications on India’s International Aviation and finally, (iii) Growth of Aviation Industry and its Implications on Social Equity of Transportation. The latter two have sub-scenarios also.

4.2.1. Growth of Emissions and the Implications of Per Capita Distribution

In this scenario, a linear projection of the passenger numbers and the distance traveled is done using historical trends, and CO2 emissions are calculated from the total pkm. Coinciding the period of economic growth in the India, 2004-07, domestic and international passengers grew at an annual average growth rate of 33% and 16.6 % respectively (table-3.1). During then, the average per capita distance traveled by international and domestic aviation grew by 1.4% and 1.6% respectively, per annum. The objective of this scenario is to use these growth trends and project domestic and international air travel passenger volume and the resultant CO2 emissions by 2020. These results will be used to discuss the socio-economic interpretations of the emissions growth. The resultant values from the model during the beginning and the end of the forecast period are tabulated below in table 4.2 and the per capita emission growth is shown in figure 4.1:

Table 4-2 Per Capita Domestic and International CO2 Emissions

Year	Domestic Passengers (millions)	Domestic km per capita (km)	Per Capita Domestic Emissions (tCO2)	Intl Passengers (millions)	Intl per capita km (km)	Per Capita Intl Emissions (tCO2)	Total Emissions (MtCO2)
2008	64.8	953	0.14	31.5	4327	0.48	23.16
2020	1,985.0	1126	0.16	199.0	5297	0.59	407.67

The total emissions calculated from the total pkm performed are redistributed among the number of passengers to calculate the per capita share. In 2020, the total domestic passenger traffic was forecasted to be 386% more than the international passengers, while the average international distance traveled was 370% higher than the average domestic distance. Yet, international per capita emissions grew faster than the domestic per capita emissions. Though the domestic passenger volume was much higher than the international passengers, the average growth traveled influence the per capita emission rate such that, during the forecast period, while the domestic per capita emissions grew by 14% the international emissions grew by 18.1%. Hence it can be interpreted that the travel patterns of those who traveled by air, changed very slowly. The distance traveled is calculated from the averages and it has to be noted that the dominant values always influence the average value Therefore it could be argued that the travel behaviour of a group of people influence the travel emissions and this group either travel more frequently or are large in size that their travel behaviour collectively characterize the emission growth.

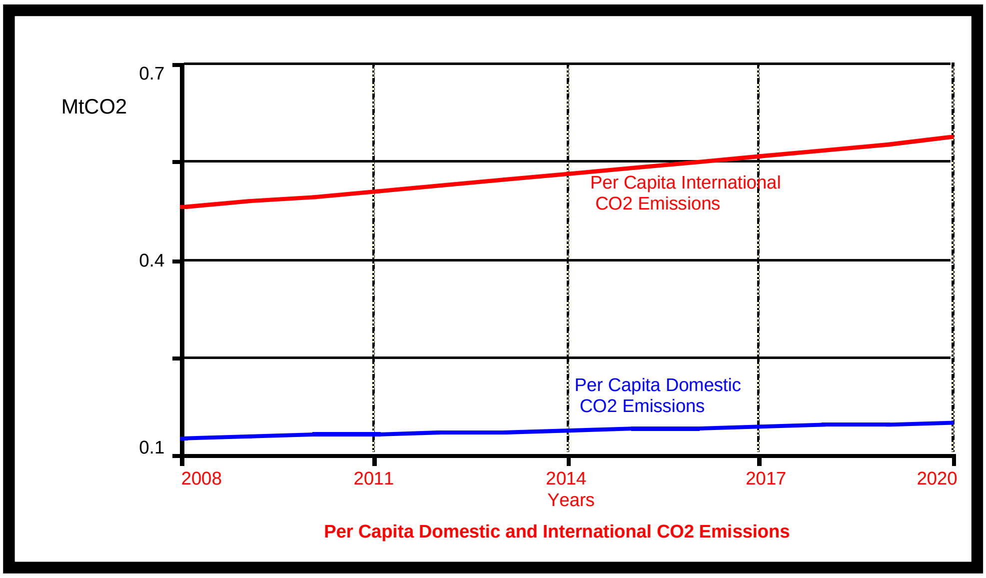


Figure 4 -1 Per Capita Domestic and International CO2 Emissions

International emission growth and distribution is addressed in a later scenario, but the total international pkm (inbound and outbound) was used to calculate the growth of international and domestic CO2 emissions is show below in figure 4.2:

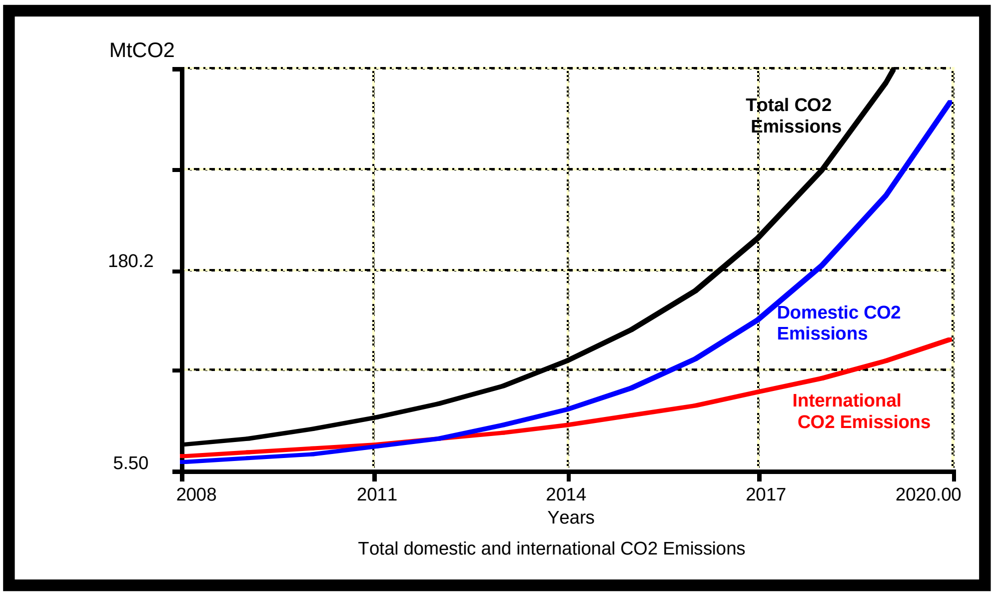


Figure 4.2 Total domestic and international CO2 Emissions

Domestic aviation emissions grew rapidly than the international emissions, while the passenger number equally grew indicating that there will be an exponential growth in the domestic aviation industry if the current trends continue. As discussed earlier, air travel is also a factor of Travel Money Budget, such that these emission figures can be mapped to the income dynamics. From the figures in table-3.4, the growth trends indicate that by 2020 there will be 100 million households distributed among the rich and middle income categories. It is assumed that an average household will constitute of *4.5 people*[15] such that there will be 450 million people distributed across the rich and middle class income households. Assuming that those households in the low income classes will not be able to use air travel, it could be argued that these 450 million will be those who have the financial dominance to use aviation. Thus the 1.985 billion domestic passengers in 2020 can be translated as 1.985 billion trips made by these 450 million people, such that each person would have made 4.4 domestic trips in 2020. Accordingly, the average per capita emission of a person passenger using aviation will be 0.642 tCO2. The Domestic Tourism Survey (NCAER 2002) in 2001 estimated that there were only 2.4 persons per household who were tourists, indicating the number of people who traveled. This could indicate the restrictions posed by travel money budget, cost of travel, purpose of travel (like travel for employment), smaller family size etc. Therefore, in the lights of the economic growth and increase in disposable income, an average of the two (2.4 persons per household and 4.5 persons per household) is considered for a more probable distribution of aviation users and hence there will be at least 340 million people in India who are bound to make 4.4 to 8 trips in 2020, implying that their per capita carbon emissions would be between 0.642 tCO2 to1.17 tCO2.The magnitude of these emissions is realized in comparison to other economic sectors. During 2007-08 the electric power sector in India contributed to 513.3 MtCO2 emissions[16] (CAE 2007). The domestic aviation emissions volume was 1.3% of the total CO2 emissions from the nation's electricity usage. If the CO2 emissions growth from the electric power sector was also forecasted based on its historical growth rates to 2020, the electric power sector would emit 812.92 MtCO2. This means, the domestic aviation emissions would be as large as 40% the size of the nations total electricity requirements and would contribute to 0.295 tCO2 to the per capita share of each Indian resident, while benefited by only 26% of the population. While the disparity of emission distribution is extremely evident, from the climate change perspective, the volume of CO2 emissions from a single source is undeniable.

4.2.2.Global Emission Regimes and implications on India's International Aviation

In India, 90% of its International tourists arrive by air. In a earlier chapter on tourism the relevance of the growing International tourism in India has emphasized the tourism contribution to foreign currency earning contributing to the nation's GDP. Peeters (2006) explains the nature of international tourism as, the

[15] Census India (2001) – in 2001, each household had 5.3 persons. From historical trends and slowing down of population growth, it is projected here that by 2020 an average household will have approximately 4.5 people.
[16] Calculated from historical growth rates (2002-06) of India's CO2 emissions from electricity sector CAE(2007)

increase in the number of people traveling, the increase in number of trips and the increase in the distance traveled by air. It is in the interest of this study to examine the implications of the growth of international aviation. Non-Annex countries like India is not party to emission reduction and international aviation emission reduction is yet to be incorporated into Kyoto mandate for Annex-I countries (IPCC 1999b). This scenario has 2 sub-scenarios: (i) the growth of International Passenger traffic in the context of TMB-ATP dynamics and (ii) Implications of International Regime on International Air Passengers growth.

4.2.2.1. International Tourism and Air Ticket Price

India saw 9.7 million outbound tourists in 2007 (table3-5). According to UNWTO (2006), India has 28 million passport holders, thrice the size the population of current Indian international tourists, indicating the large pool of potential outbound tourists. While, WTTC predicts India to be the second largest outbound market during the next decade (8.8% growth pa), the rapidity at which these tourists choose to fly is once again largely based on the nation's economical growth and. Thus a high growth and a moderate growth of International (outbound Indian) tourists are projected and the implication of price increase is observed here:

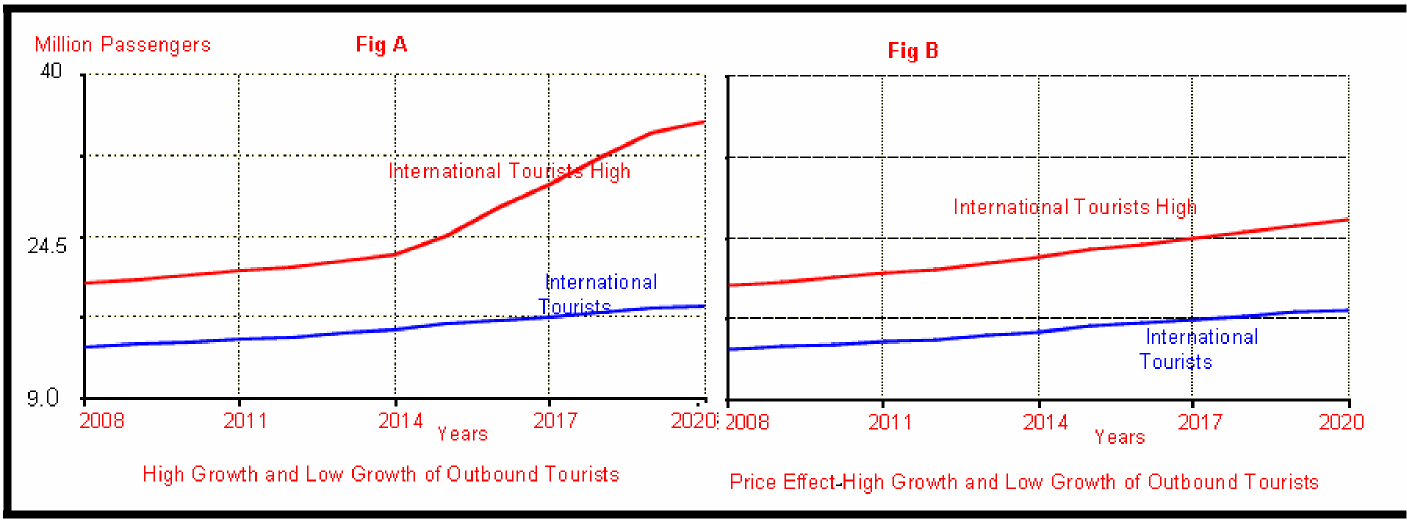


Figure 4-3 (4-3.A & 4-3.B) Outbound Tourist Growth and Effect of Price

The "International **Tourists-High**", indicates a high growth rate in the passenger traffic, while "International **Tourists**" indicate a low or moderate growth of traffic as seen in the figure 4-3.**A**. The tourists' volume for "Tourists-High" increases exponentially, while "Tourists" continue to grow at a moderate growth. The growth rates are influenced by the TMB-ATP ratio. "Tourists-High" indicates that a person would make an international trip at the first instance his TMB increased enough to accommodate an international trip and the number of trips increased with the increasing TMB over the forecast period (from an increasing per capita income), while air ticket prices remained stable. The passenger volume of "Tourist High" did not show any significant growth until the TMB of the larger population was big enough to reflect the growth. This means despite the growth of the economy and per capita income, international air travel is still expensive for many households. "Tourists" indicated a slower growth, which could indicate that either the growth in TMB has benefited only a few number of people or (ii) Not enough people are attracted towards by air travel at the first instance their TMB accommodates an air ticket price. To validate the assumption, ATP prices were highly increased and the observations made are made available (above) in figure 4-3.**B**. To achieve a fall in passenger growth of "Tourists-High", air ticket prices were to be increased by 50%. This indicates that the TMB of international passengers should have increased considerably before they started traveling by air and hence a smaller price reduction would not affect international air travel demand. Price elasticity of international travel is different for leisure and business travel (Gillen 2003). Since there are no substitution for international air travel, business travel is not sensitive to price increase, but leisure tourists might cancel/postpone or travel to closer locations. Thus from the results seen above, one could argue that "Tourists-High" represent the travel tendencies of leisure travelers, while "Tourists" indicate the characteristics of business travelers. Therefore it could be assumed that international business travelers will be largely not affected by international emission regimes, such that CO_2 pricing mechanism will not necessarily cause hindrance to international business practices that are integral to world economies. If the per capita emissions of all outbound tourists were considered, the following table represents the emission growth dynamics (figure 4-4):

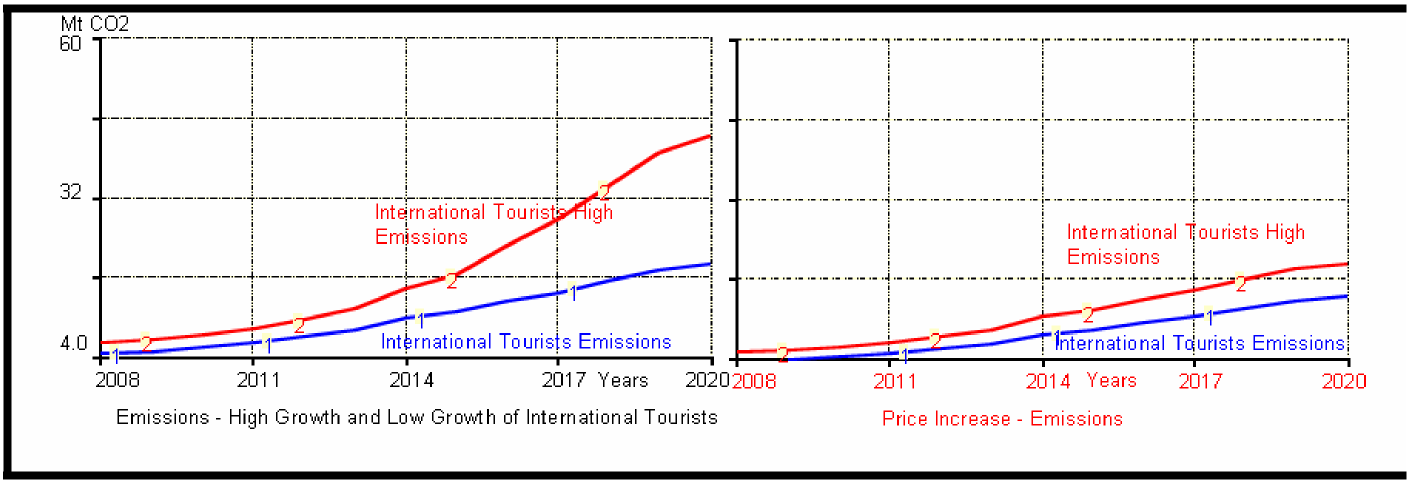


Figure 4-4 Emissions from High Growth and Low Growth of International Tourists and Price Implications

Thus air ticket price is evidently a control measure to emission reduction. Referring back to the CLD (Figure 2-1), the drivers to Air ticket price are Fuel Price, Regulatory Measures and the revenue of Aviation Industry. This study has assumed that the fuel prices will be stable through out the forecast period, while revenue of the aviation industry is largely based on passenger number and distance traveled; indicating, high revenue drives low price ticket competition, which targets large volume of passengers. This leaves regulatory measures as the only viable alternative.

4.2.2.2. Emission Allocation and Passenger Growth

European Union's Emission Trading Scheme[17] (EU ETS) for international aviation of 2012 adopted by the European Commission will be able to legally enforce emission control through GHG emission pricing (EU 2006, Scheelhaase & Grimme 2007, Parker 2008). The Liebermann-Warner Climate Security Bill of 2007, proposed to the US senate by its environmental committee follows a similar scheme as the EU ETS (Air Transport Association, Air Line Pilots Association, Cargo Airline Association, and the Regional Airline Association, *cited in* Gössling *et al* 2008). Australia's ratification to Kyoto treaty prior to COP-13 is a strong indication that industrialized economies are moving closer to achieve their commitments to the Kyoto protocol. Thus in this scenario it is assumed that the world economies will be soon pressurized for emission reductions by their peer nations opting to adhere to Kyoto protocol targets of 2020 and international aviation will be important in that objective. Based on EU ETS *capping mechanism*[18] the total number of emission allowances will be restricted to the average emission level during 2004-06 and beyond that allowances will be bought or auctioned (EUC 2008, Harmeling 2007). Thus it could be argued that the implication of such a directive is that mature industries as that of developed nations have a higher emissions history than India during 2004-06, while India's aviation was still in its infancy despite strong growth rates in the recent past, while the aviation demand continues to have an exponential growth. This will force India into buying allocations much sooner than it's developed counter parts. The European airline industry has already insisted that the ETS measure to be a threat to their growth and profits. Voicing Airliner's concern, Ernst & Young (2007) assessment indicates that from such CO2 pricing or allocation

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17 Emission Trading Scheme is European Union's attempt in meeting its obligations to Kyoto Protocol of 1997 that came into force by 2005, for GHG emission reduction. EU aims to regulate 46% its CO2 emissions from 11,500 energy intensive facilities across 27 member countries during the second commitment period (2008-12). Late 2006, EU ETS proposed inclusion of GHG emissions from the civil aviation sector, such that in 2011 emissions from intra EU flights will be covered and by 2012, the scheme would also include international flights outside EU, i.e., to and from all the EU airports (Scheelhaase & Grimme 2007, Parker 2008). ETS creates a mandatory CO2 cut for all countries under the EU, thereby aiming to reduce its emissions by 183 Mt CO2 by 2020 EU 2006, Egenhofer *et al* 2006, Scheelhaase & Grimme 2007).

18 The allocation mechanism for EU-ETS system proposes two ways; a *capping* mechanism based on *100% historical emissions* and a *benchmarking* mechanism. By the capping mechanism, the total number of emissions allowances will be restricted to the average emission level during 2004-06, such that the cap is set to 100% above the 1990 levels (EUC 2008, Harmeling 2007).

purchase, loss of customers from increased ticket price and eventual loss of revenue from reduced demand are forecasted

This scenario examines the implications of applying EU ETS on India's international tourists. Since the dynamics of TMB and ATP, which is central to the model, influences only the outbound Indian tourists, only outbound tourists are considered as International tourists. Since the outbound tourists constitute one by third of the international tourists (table 3-1 & 3-5), the total emissions calculated in these scenarios can be later extrapolated for total emissions from international air travel.

4.2.2.3. CO2 Pricing, Air Ticket Prices and Passenger Numbers

European Union Commission assures that says that any increase in ticket cost from CO2 pricing can be passed onto the customers as the price increase would not be significantly large EU(2006). As mentioned earlier the airliners argue otherwise while EY (2007). Since the Indian outbound tourist the EUC (2006), EY (2007) and as well the CO2 price estimations by Gössling *et al* (2008) for CO2 allowances during 2012 to 2020. The minimum and maximum price ranges according to each study is listed in table 4-3. Projections are thus done for outbound international tourists, thus to examine the three different CO2 pricing implications on passenger traffic. The EU ETS CO2 capping is expected to come into force by 2012 and hence the scale for the forecast under the EU ETS scenarios starts from the year 2012.

Year & CO2 Unit Price	EUC(2006)	EY(2007)	Gössling *et al* (2008)
2012 tCO2/USD	6	22.5	45
2020 tCO2/USD	45	45	60

Table 4-3 CO2 Pricing with different pricing scheme

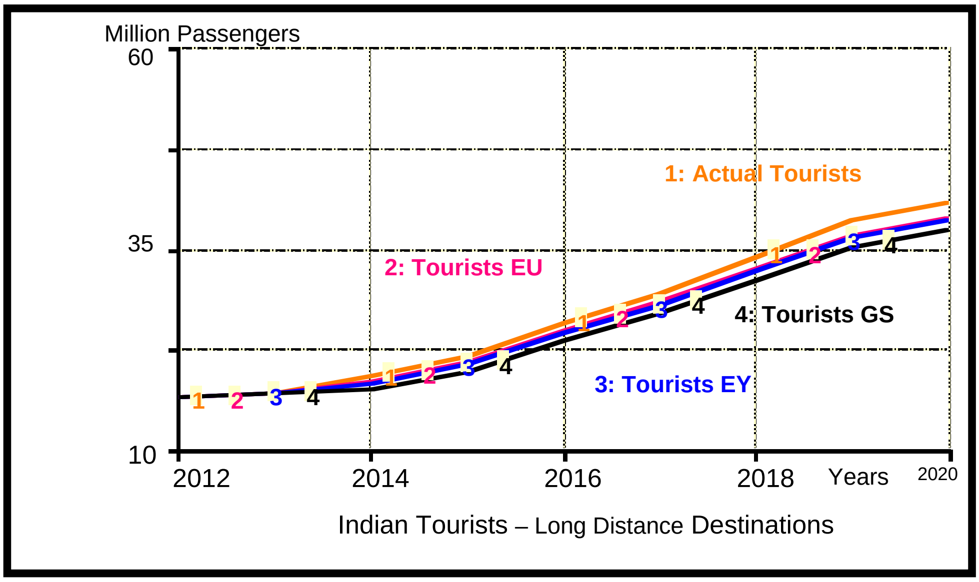

Figure 4-5 Indian Tourists – Long Distance Destinations.

Actual tourists indicate the growth of international outbound tourists without any air ticket price increase, while Tourists EU, Tourist EY and Tourist GS represent the tourists volume under each the pricing by EUC (2006), EY(2007) and Gössling *et al* (2008) respectively. As seen in the graph, figure 4-5, the increase in price is reflected in the decrease of passenger traffic from Actual Tourists. The passenger volume decreased from 40.59 million passengers to “Tourists GS” (by the highest CO2 prices), 37 million passengers in 2020. Though a loss of 3.41 million passengers implies more than 30% of the Indian outbound tourist population in 2007, in 2020, it meant less than 7% of India’s outbound tourists. Thus this scenario showed that emission regimes like EU-ETS for aviation may not necessarily reduce the passenger volume, indicating that (i) either the TMB of majority of tourists are large enough to accommodate the price increase or (ii) the price increase has been very insignificant or all those passengers who continued to travel despite price increase are business travelers. As Brons *et al* (2002) argue that though price is a potential instrument that can be used, such that a price on externalities can reduce the (aviation) demand, but if passengers are not sensitive to such a price, such a policy will have no effect. So the applicability and targets of pricing scheme of EU ETS has to be further examined, which is beyond the scope of the study. But the other two possibilities are of interest of the study: The leisure travelers and the business travelers.

Technological substitutions can reduce many long distance business travel necessities. But provision and infrastructure for such substitutions indicate standard practices which will have to be encouraged and campaigned. Various studies indicate such alternatives are possible, but all fingers points towards policies that encourage and practice such discourses. One the other hand, can tourism be made more entertaining and rewarding that leisure seekers are rewarded sufficiently enough for what they seek in the closer vicinities? The scope of the study limits itself from examining the sustainable alternatives of tourism, but examines the implication of the focus of international tourism in closer vicinities. The following scenario looks into such a possibility.

4.2.3.4 CO2 Pricing and Rebound Effect

In this scenario it is assumed that ETS CO2 pricing would affect the air ticket prices such that long distant international tours become expensive and hence the scenario examines a possible "rebound" effect. As discussed in the tourism section, based on the existing outbound tourist patterns, the frequency of Indian International tourists are largely felt in the Asia Pacific countries; while the geographical proximity also implies the price factor, the sense of familiarity of culture and climate is added attraction for many first time tourists. Thus in this scenario, changes are applied to the distance traveled and hence the air ticket prices and the following results were observed:

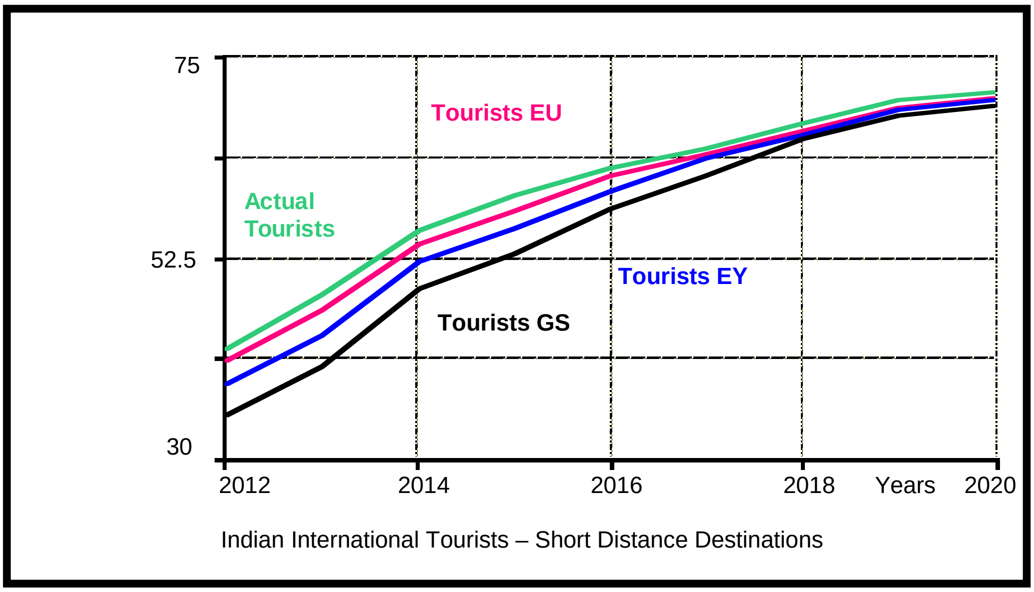

Figure 4-6 Indian Tourists – Short Distance Destinations

The "Actual Tourists" indicate the growth of international tourism to India's neighbouring countries. In 2020, according to this scenario there will be more than 71 million Indian tourists traveling towards international destinations, such that are will be 30 more million people traveling in comparison to the previous scenario . When the distance traveled reduces, the total pkm traveled reduce. Then, with smaller values of ATP, more share of the TMB is available to be spent and hence the exponential growth was expected. The implications of the EU ETS CO2 pricing scheme, brings an interesting nature of the short distance international travel. From the figure above "Tourists GS" represent the effect larger price for CO2 allowances. Subsequently, the increase in air ticket prices reduced the traffic of "Actual Tourists" of 42.2 million passengers to 35.1 million passengers in 2012. But by 2020, the tourist volume, as seen in the figure did not have large differences.

The effect of CO2 prices on air tickets is immediately reflected in the reduction of tourists in the initial phase, indicating that more than 7 million tourist trips were reduced. How ever, the reduction in passenger numbers reduces towards the end of the forecast. Thus as the TMB increases over time, while ATP prices remain largely stable such that implications of CO2 pricing becomes less relevant despite increasing CO2 prices. This once again shows that EU ETS and similar pricing scheme will not be able to necessarily contain the growth of international traffic.

Thus it can be argued that since passenger volume were not reduced significantly by the emission regimes, the resultant CO2 emissions from the long distance and short distance scenarios are shown below to understand the magnitude of the emission growth.

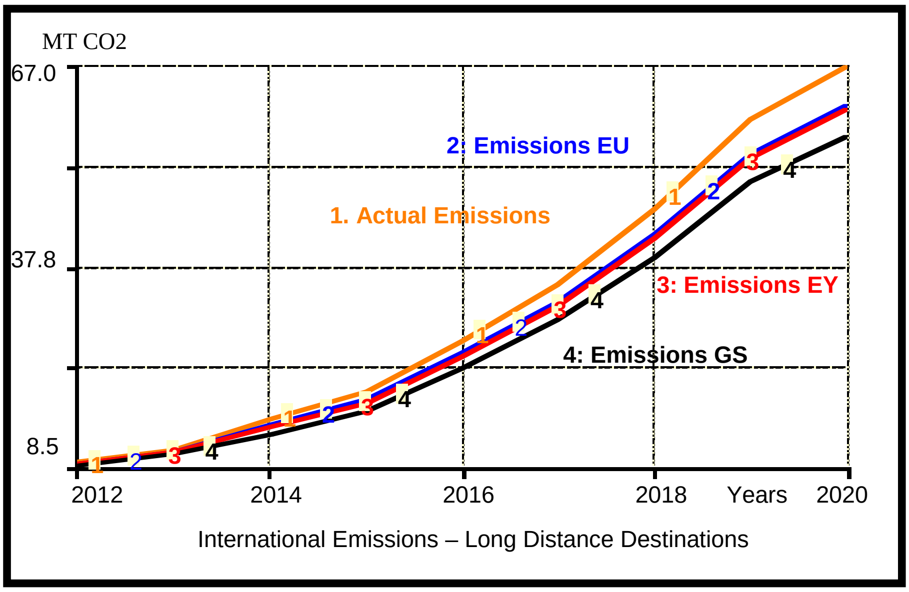

Figure 4-7 Indian Tourists – Long Distance Emissions

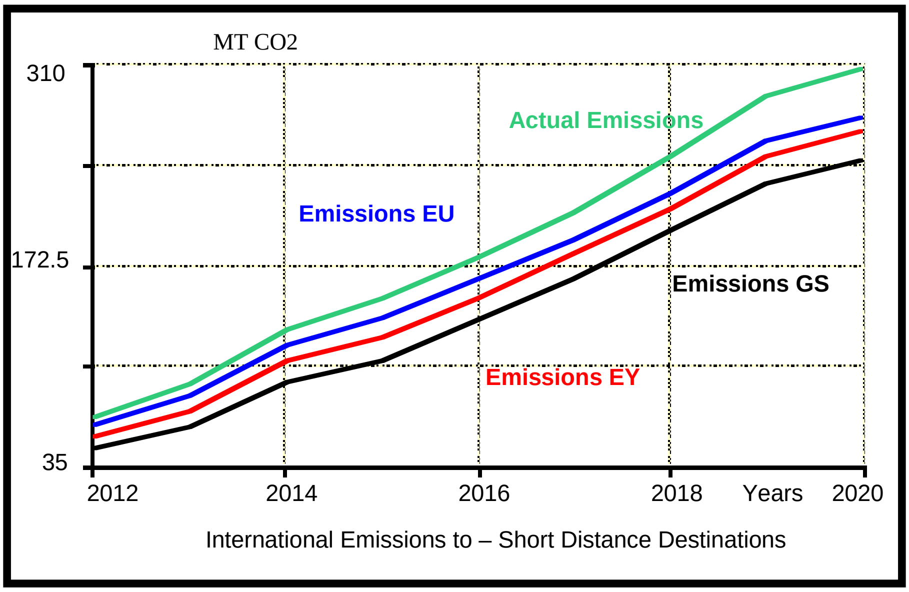

Figure 4-8 Indian Tourists – Short Distance Emissions

Examining the lowest values of emissions, Emission GS, in both scenarios (from high CO2 pricing), in 2012, 35.6 million international passenger traveled to closer destinations contributing to 48.75MtCO2, such that their per capita emissions were 1.37tCO2, which increased to 3.5 tCO2, by the end of the forecast period. Similarly, the per capita emissions of an international traveler to far away destinations, grew from 0.6 tCO2 to 1.5 tCO2 during 2012-2020. Thus the per capita emission shares of tourists flying towards closer destinations are much higher than the per capita emissions from long distance travel. This means, for a given TMB, and lower air ticket prices, a person would make more trips or the travel group would increase in size, thus increasing the passenger volume.

The above results indicate that, increasing air ticket price may not be an effective tool for emission control. The under lying dynamics of income, distribution and demographic characteristics are not reflected while using Air Ticket Prices for discouraging the growth rates of passenger traffic, thus the emission control. This also implies that international emission regimes may not work towards a country’s emission reduction strategy and if emission reduction objective are created, then monetary instruments alone may not be successful, as seen in the emission regime scenarios.

4.2.3. Growth of Aviation Industry and its Implications on Social Equity of Transportation

This scenario seeks to show that domestic aviation growth poses as a danger beyond emission problem, which can undermine a more sustainable public transport system. Public Transport, in the context of this study, indicates buses and trains, as bus and rail transport constituted 90% of the domestic tourist trips in India (NCAER 2002). Railways are often emphasized as the most energy efficient and space efficient form of transporting people and freight (Royal Commission on Environmental Pollution 1994, *cited in* Shaw et al 2003). Indian railway is one of the largest railway networks in the world, spanning a distance of 63,028 route-km and transports 17.8 million people everyday (IR 2006). The prominence of railway network in the country's socio-economic system is such that the Railway Expert Group Survey (2001) found that one in every 10 people in India were dependent on the railways directly or indirectly for their livelihood (*cited* in Sharma & Manimala 2007). Of the total railway passengers 56.5 % are suburban passengers, those commuting within the cities, while the rest are long distance (non-suburban) passengers. Long distance passengers are divided into categories according to services they choose during their journey. The categories are: the luxury section known as the Upper Class (UC), the moderate Second Class (SC) and the basic Ordinary Class (OC): as the names indicate, fares reduce from UC to OC. UC passengers constituting 1% of the total traffic volume contributes to 20% of the total passenger revenue, while, UC and SC together constitute only 12.5% of the passenger traffic but contribute to 72.6% of the total passenger revenue of the railways (IR 2006). The entry of many domestic LCC airlines in India has acknowledged that their target was to capture the passenger luxury class passenger market of railways by providing competitive prices.

4.2.3.1. Travel Money Budget (TMB) Influence: Projection of Railway and Airway Passenger based on the available TMB

This scenario examines the effect of TMB on the passenger growth of both the modes. The unit ATP was USD 0.07 and the unit value for RTP was 0.055 USD calculated from real time prices, such that a minimum ATP was 27% higher than the minimum Railway price for a UC passenger (IR 2007, Table-4-1). The UC passengers were given a linear growth trend. As Vedantham and Oppenheimer (1998) say, air travel has high income elasticity, such that air travel demand increases rapidly when a poor nation experience sudden economic growth. Therefore, the growth for domestic air travelers was assumed to be a logistic growth that grew exponentially initially, but matured towards the end of the forecast.

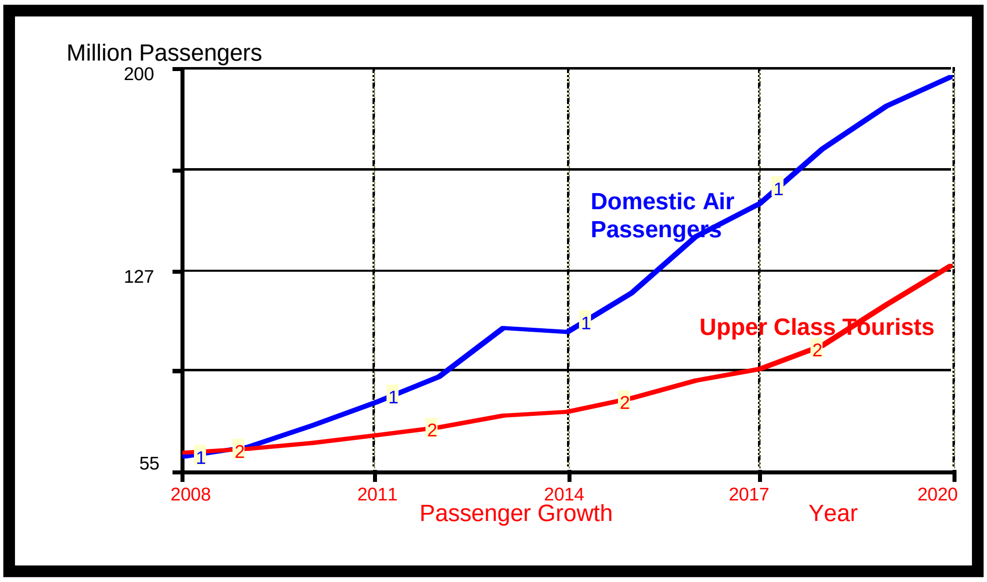

Figure 4-9 Passenger Growths for Domestic Aviation and Rail Upper Class (UC)

The results showed that without the interference of any other factors, the Upper Class passengers grew from 61 million to 128 million during 2008-2020, while the Domestic Air Passengers grew from 59 million to 196 million. Though the RTP fares were 27% lower than the ATP, the cumulative effect of the growth curves on the air passengers made the difference. The added advantage from lower ticket price for UC travelers of railways was not evident as the number of people who used air travel was much higher. Owing to the exponential growth rates in the beginning, the numbers show a large influx of passengers in the initial phase of the growth of aviation. The accumulation of air passengers in that phase influence the total number of air passengers over the forecast period despite very slow growth rates towards the end. This mean a dedicated group of air travelers would have already been formed by the maturation period, as seen in many developed nations. But the effect of this maturation is apparently not immediately reflected in the graph, though a slight downward trend on the curve (domestic air passengers) is observed in the figure 4-9, above. Singh (2006) points out that that with the increase in personal incomes the shift towards private motorized vehicle from public transport has been historically observed in India. The element of efficiency and comfort can be thus the driver for such a modal shift. Though air ticket prices were higher than that of a UC travel price, travel efficiency in the form of less travel time etc could be argued influencing the growth of air passengers. As Brons *et al* (2002) explains that though price is a potential instrument that can be used which can affect or reduce the demand, but if passengers are not sensitive to such a price, such a policy will have no effect. A similar price reduction of luxury classes, as a policy approach exercised by Railway Ministry in the Rail Budget for 2008-09, thus, may not necessarily sustain its passengers for a larger period, under the looming threat of the fast growing aviation industry (TOI 2008, IR 2008).

In this scenario, CO2 emissions from air passengers grew from 15 MtCO2 in 2008 to 273.5 MtCO2 by 2020. These numbers will be significantly greater if we assume the loss of SC passengers to occur to airways in the lights of growing personal income (following the trends of UC passengers).

4.2.3.2. Rail Travel Efficiency (RTE) and Aviation Growth

Travel Efficiency, is largely based on speed, time, comfort, infrastructure and fuel-efficiency, essential for an efficient mode of travel at an optimal price (Dhakal & Schipper 2005). In the context of this study, speed is considered as the efficiency factor, such that infrastructure and fuel-efficiency aid to the speed of a particular mode of transport, while shorter travel time and comfort of travel are manifestation of efficient transport. When income level rises, the personal value placed on time increase and hence time traveled becomes crucial, which often reflects in the modal shift of passengers towards aviation (Vedantham & Oppenheimer 1998). This influence is emphasized when a study in UK showed that severe speed restriction on railway imposed following a derailment increased the domestic aviation passenger growth by 130% in the following month (Starkie 2001). Thus in this scenario, similar trends were created by generating future loss of UC passengers to aviation growth from low Rail Transport Efficiency (RTE): lower the RTE value higher the UC passenger loss. The Railway passenger loss is assumed to be the Airway gain. The implications of Rail Travel Efficiency is examined such that, at an optimal efficiency of maximum speed of 200 km/hour travel will be achieved, during which minimum loss of passengers from low RTE will be 10% of UC travelers[19]. RTE value decreases with decreasing speed. In the resultant graph, below, three factors represent the UC passengers. “UC Tourists”, which is the actual number of rail passengers forecasted. “UC Passengers RTE Loss” represents the UC tourists after the loss of passengers to aviation owing to low RTE such that the number of Rail passengers were only 46 million in 2008 against an actual value 60 million of rail passengers indicated by “UC Tourists”. A third variable “UC Passenger No Return” was calculated from the assumption that those passengers who chose aviation because of low RTE, did not travel by rail in the following year as well. This variable may not necessarily give the exact picture of UC passenger loss to aviation, but approximately implies that passengers who chose aviation would continue air transport extensively. Peeters (2005) emphasizes that new travel habits are easily adopted, than abandoned and therefore habits which change with substitution will remain till another form substitution happens.

19 Sharma (2005) recommends High Speed Railway (HSR) greater than 200 kmph for Indian Railways based on international norms. Park & Ha (2006) indicate 85-90% decrease of aviation users by the introduction of HSR.

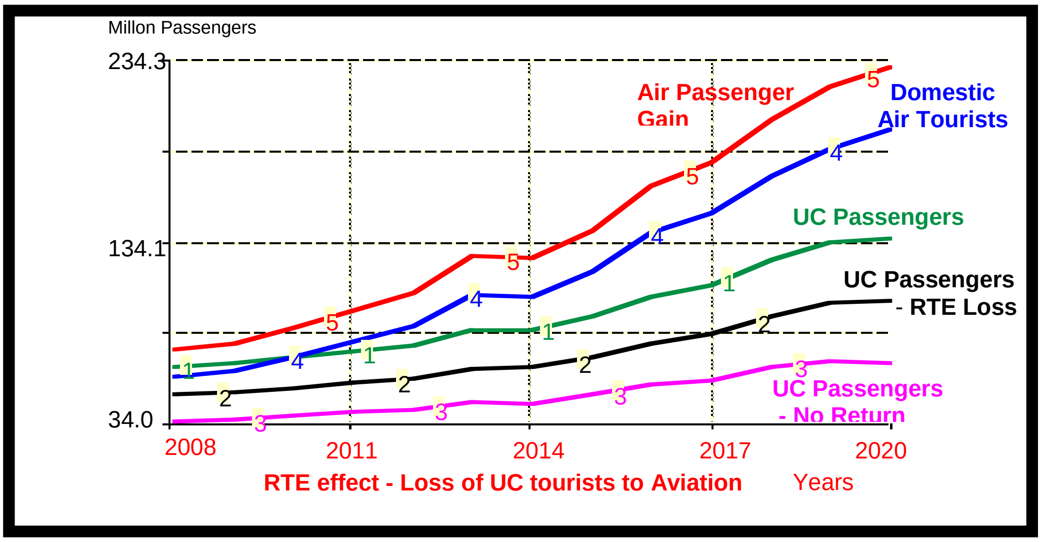

Figure 4.10 Rail Travel Efficiency Effect – Loss of UC tourist to Aviation and Aviation Growth

The idea behind this scenario was to extend the effects of the previous scenario, the assumption that Air Travelers and Rail Travelers can grow as disjoint entities. Instead, for a given price, the demand for a consumer good is mostly based on the possibilities of substitution of that good, indicating its price elasticity (Brons *et al* 2002). So it can be argued that *substitution* is reflected as the choice people make, at a given price. The *cause* of such a substitution was central to this scenario From the forecast results in 2020 the number of Upper Class passengers will be 51 % less than the actual values forecasted using "UC Tourists". The increased volume of air passengers from loss of passengers to aviation is represented as "Air Passenger Gain", which grew from the original "Domestic Air Tourists" with an addition of 14 million UC passengers in 2008, such that in 2008 aviation emission grew from 15.0 MtCO2 to 18.5 MtCO2 and by 2020, with 231 million passengers, the cumulative emissions were at 322 MtCO2.

Based on the income dynamics of Indian households represented in table 3-4, a steady expansion of middle class households indicates that, there will be more SC passengers who will be able to make use of the services of a UC travel. But it in a worst case scenario, following the above forecasted trends, it could be therefore argued that the probability of high percentage of SC passengers choosing to travel by air rather than make any trips by rail, such that once their TMB can accommodate air travel or an UC service. The basis for this argument again points towards travel efficiency. In such a scenario, the resultant revenue loss from reduced high-fare passengers, as UC and SC, together contribute to more than 70% of the railway passenger revenues of a single centralized railway system, would be tremendous. The manifestation of such continuous losses is that the underdevelopment of railways, which is highly probable. Eventually efficiency demand will force passengers in lower-fate categories also seek more efficient means of transport. Quantifying such a scenario, from the figures in Table B-1 (Appendix B), 17 million people travel everyday by the ordinary and the suburban class, such that if their pkm is projected to 2020, this group alone will perform 580 billion passenger-kilometers[20] (Bpkm), which is assumed to shift towards motorized vehicle like cars, two-wheelers and auto-rickshaws. Singh (2006) points out that the carbon intensity of this vehicle-group is the highest and his study already forecasts that by 2020-21, such para-transit and private vehicles in India will perform 6247 Bpkm generating 51.35 MtCO2. Thus it can be argued that the underdevelopment of railways pose a threat of 10% increase to this forecast generating an additional 4.76 Mt CO2[21].

Transport in India is characterized by poverty, equity, political, and social facets, such that despite various subsidies, poorer households end up spending quarter of their income for transportation, which is often necessary to access their mean of means (Tiwari 2002, Dhakal & Schipper 2005). The dependency on railway of this magnitude is defined by the highly subsidized fares, by and large targeting lower incomes groups of the nation. Therefore the Indian Railways are highly dependent on UC and SC passenger revenues to level-off the subsidized fare of other groups (IR 2002). Therefore a continuous loss of revenue passengers to the railways adversely affects the development of railways. This implies that a social exclusion of mobility by the large number of India's low income population is highly probable in the near future.

5. Discussions

The analysis in this study was based on the 3 scenarios: (I) Emissions Growth and the Implications of Per Capita Distribution (II) Global Emission Regimes and Implications on India's International Aviation and (III) Growth of Aviation Industry and its Implications on Social Equity of Transportation; as the titles indicate, highly subjective to their scope such that at the outset these scenarios are disjoint in nature. The ratio of 'Travel Money Budget' to the 'Cost of Travel' (Air Ticket Prices/Rail Ticket Prices) created a selection criterion for the group of people who will travel by air. This implies the economic inequity inherent in the air-travel dynamics.

In the first scenario, the results and discussions showed the misappropriation in per capita emission distribution. The per capita emission of a domestic air traveler will considerably reduce when the total CO2

20 The sum of products of passenger and kilometers of Suburban and OC passengers

21 Carbon intensity of motorized vehicles like cars, auto rickshaws and two-wheelers at 8.22 is the highest (Singh 2006). Thus if 580 billion pkm will be performed on roads would generate (580 * 8.22) = 4.76 Mt CO2.

aviation emissions are equally distributed among every resident of India. If per capita emissions indicate each person's emission share from all activities towards the Gross Domestic Product (GDP) of the nation, then it could be argued each person is responsible for the share of emissions created towards his/her larger welfare. But GDP as a welfare measure is often challenged, as with GDP rise, increasing income inequality has been historically observed (Stockhammer *et al* 1997). In the same lights, it is argued here that the perception of equal distribution of CO2 emissions is misconstrued, as the equity concept in burden-sharing of emissions is distorted.

Global emissions equity indicators are built on the principle of fairness of burden-sharing based on (i) Responsibility Criteria derived from cumulative emissions, total emissions, per capita emissions of CO2 and the estimated growth of CO2 emissions (ii) GDP based standard of living, and (iii) Energy intensity based opportunities (Claussen & McNeilly 1998, Yanki *et al* 2001, Langer *et al* 2007). Though India's per capita emissions are small, its population size influence the aggregate emissions such that India alone contributes to 6% of the global CO2 inventory. "Responsibility Criteria" as Yanki *et al* (2001) explains, is to assign responsibility of emission burden to those with a large history of emissions, often a source of debate between the developed and developing nations. If this was applied at a national level, scenario-I alone indicates that by 2020, the magnitude of the inequity in burden-sharing of CO2 emissions from the travel habits of higher income classes of the society will be hidden behind the per capita emission calculations of the nation, while this group will be less than a quarter of the population. Though the goal here is not ask how much each person can emit, but how much CO2 has a person emitted which is not accounted for? The low per capita emissions of India's population should not be a leveraging ground for higher incomes categories' emissions, if the concept of climate change has to taken be a serious threat. Therefore prioritization of emissions and sources become necessary based on equity.

Equity, as World Bank, World Development Report (WDR) (2006), defines is 'the respect for equal opportunity, combined with avoidance of absolute deprivation (*cited in* Cling et al 2006). This implies a fairness of access to all involved. Similarly, efficient mode of mobility access to everybody is crucial to the socio-economic welfare of that society (Dhakal &Schipper 2005). Scenario III represents a highly probable situation where railways and its development could be destabilized largely from the revenue loss owing to competition generated by low cost aviation industry. As the scenario-analysis indicated, various socio-economic issues can arise from the under development of a mass transit system like the railways. Additionally, the pressure on road transport infrastructure would be tremendous, such that Indian road transport already needs to constantly deal with extremely high congestion problems, air pollution, noise and traffic accidents (Pucher *et al* 2005). The resultant expenditure to the government from infrastructure expansion, pollution control and health bills should be taken for further study. Monetary loss from travel inefficiencies and resource in efficiency resulting from mobility issues should be as well included in the study.

WDR (2006) stresses that, imperfect market, inequality and wealth creates inequalities that lead to inefficient allocation of resources (*cited in* Cling et al 2006). As scenario III indicated the "Travel Efficiency of Speed" is not comparable between the railways and the airways, but in a free market economy, demand characterizes the market. If the increase in aviation demand was a result of fair competition between the railways and the airways, the decline of railways can be largely blamed on itself for not being able to sustain the market competition. But it is a well established fact that globally aviation industry benefits from tax exemptions on aviation fuel, air ticket prices and as well is advantaged by national subsidies (Whitelegg 2000). This was also established in Section 3.3, reaffirming the fuel tax exclusions for domestic aviation in India. Examining the ticket price dynamics by a low cost domestic carrier, as shown in (table 4-1), surcharge fuel prices form most of the ticket price, indicating the revenue made by the aviation industry on individual tickets are meager. Therefore huge passenger volume is required to capture the niche market. The artificial demand thus created through price reductions is therefore against the free market concept, questioning the existence of the industry. Earlier discussions showed that sustaining the aviation industry for the growth of tourism and travel market is a national policy. But the realization and acknowledgement of the problems from the loss of railways does not seem to transcend in the context of increasing domestic aviation. As the Keynesian theory shows, 'if the effective demand for goods and services are reduced by market forces … only governments prepared to take an active role in stabilizing demand by means of countercyclical fiscal spending' can restore the demand (Sandelin *et al,* 2002: 89). Thus, can the market be made to generate demand for railways through investments, better technologies and hence improved efficiency and performance? A study by Sharma (2007) recommends High Speed Railway (HSR) greater than 200 kmph for Indian Railways based on international norms, while Park & Ha (2006) indicates the dramatic reduction of 85-90% of aviation users by the introduction of HSR at 300-350 kmph in Korea. WDR (2006) blames 'institutions for market imperfections' such that these imperfections influence the economic and political resources (*cited in* Cling et al 2006). Thus it is necessary that institutions formulate policies that recognize the imperatives of climate change are necessary.

In India, Garg *et al* (2007) point out climate change still remains a marginal issue to the policy makers in the context of more immediate concerns like poverty, food security, insufficient infrastructure and access to health and education. Hence climate change mitigation is often perceived as a hindrance to any socio-economic development. On the other hand, development itself is often observed as the cause to climate change problems. Thus the method by which environmental problems is conceptualized implies how we try to address them (Lipschutz, 1996:32). This conceptualization can be the analytical framework that defines the policy used to address the problem. While one framework defines aviation industry as an engine of growth (Indian Government), another defines it as a climate change catalyst (IPCC) and yet a third framework sees it as a threat to fundamental socio-economic sector (contemporary research). This disconnect in seeing the socio-economic and environmental implications from the growth of aviation industry can be thus attributed to such disparate analytical frameworks. Therefore policies that integrate such different analytical frameworks towards a common goal, with differentiated approach are necessary. As Halsnaes & Shukla (2008) explain, the problem with such an approach is to find ways through which "climate change concerns can become internalized in economic accounting and other decision making".

Scenario II was used to examine the implication of existing climate change policies and market based regulatory tools on emission control, on India's future aviation. The results showed that monetary instruments like the EU ETS will be successful only when the prices are high enough to discourage the demand. The analysis showed, with the proposed CO2 pricing schemes, the international travel demand in India will remain high in the lights of the nation's growing economy. It can be argued that when pricing mechanism does not reduce the demand, the implied meaning in the ability of a person to fly is that she has the fundamental right to fly as she has paid her dues for her share of emissions. In a similar context of discussion, Pan (2001) argues that such policies and measures are fundamentally against the idea of equity. The Brazilian Proposal of the UNFCCC (1997) suggests a contraction and convergence approach for emission based on the justice principle and responsibility (*cited in* Bode 2004). This means over the longer term, the per capita emissions will have to fall from the current level to much smaller levels. For a fast growing economy like India, with a long history of severe poverty and lack of basic necessities for the greater fraction of its population, development is integral to sustain its economic growth and hence such contraction and convergence is not possible. Alternatively, this paper argues that, based on equity and the principle of justice, economic sectors that benefit the growth and well-being of the population of the nation has to be prioritized. To achieve such an objective, the proponents of such dissimilar analytical frameworks have to be brought towards a common goal, such that a holistic picture of sustainable development is offered to influence their decision making, rather than a peace meal understanding. This means an integrated policy framework that internalizes climate change in their socio-economic development and measures is necessary.

6. Conclusions

This study built up scenarios and argued that the growth of the civil aviation industry, which is often campaigned as an integral element to socio-economic development, can grow into one of the biggest sources of CO2 emissions in a relatively short span of time. Based on historical growth trends of the civil aviation industry, in the lights of the nation's economic growth, the study illustrated that the growth of aviation demand is inevitable. Furthermore, through trend analysis and forecasts, future growth in passenger volume and the resultant dimensions of CO2 emissions were quantified to demonstrate the magnitude of a single source's contribution to India's CO2 inventory. Though the study did not quantify the economic loss or gain from the growth of aviation industry, but quantified the passenger growth dynamics and the emissions such a growth. Simultaneously, the study showed that social stress can happen from such a loss and the resultant inequity. Integrated policy approach with climate change internalized in all decision making is suggested.¨

Thus, to accredit to the spirits of Bali conference, India will have to prioritize her emissions such that sectors that benefit the larger welfare of the people will be necessary. Contraction and convergence is not argued for, at least in the time of much needed development, but social, economic political and economic sectors should move towards high efficient, but low energy systems, which this study argues can be achieved through integrated policy approach with the recognition of climate change in its analytical frame work.

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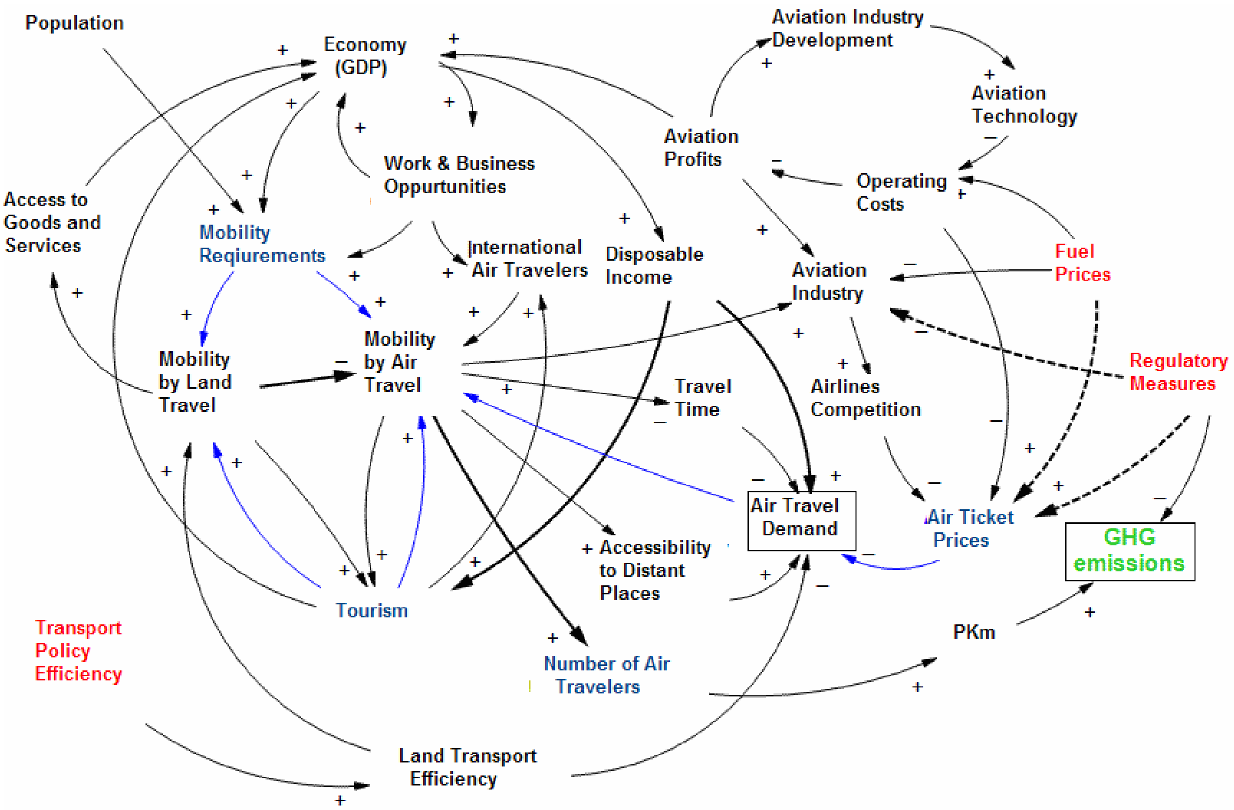
8. Appendix

8.1. Appendix A - Detailed Casual Loop Diagram



Causal Loop Diagram with detailed dynamics

8.2. **Appendix B -** Railway Passengers – Classification and Passenger-Kilometer Data (2000-06)
Table B.1

Year	Suburban Passenger-Km		Non-Suburban Passenger-Km								Total	
	P	Km	Upper Class (UC)		Second Class (SC)		Ordinary Class (OC)		Total		P	Km
			P	Km	P	Km	P	Km	P	Km		
2000-01	2861	31.1	40	659.3	472	471.3	1460	81.7	1972	176.9	4833	94.6
2001-02	2999	31.0	41	695.9	496	485.6	1557	82.8	2094	180.1	5093	96.4
2002-03	2934	30.8	42	689.7	513	495.3	1482	95.6	2037	198.4	4971	103.6
2003-04	2986	32.1	42	676.2	571	456.4	1513	103.2	2126	200.0	5112	105.9
2004-05	3178	32.7	44	570.3	609	449.2	1547	112.1	2200	207.3	5378	107.0
2005-06	3329	32.0	50	558.9	668	437.9	1678	112.7	2346	205.3	5725	107.5
2006-07	3514	31.8	58	585.5	713	467.3	1934	111.5	2705	215.5	6219	111.7

P (Number of passengers in Millions), **Km** (Average per capita distance traveled in km) *Source:* IR 2006

8.3. Appendix Equation – Discussing the Equation to the Model.

The study adopts Schafer & Victor (2002) approach in calculating the per passenger traffic volume (Tv), which is the ratio of *cost of transport* to the *amount people are willing to spend on transport*. Here, Tv is decided by Travel Money Budget (TMB), that which enables a person to travel and the Cost of Travel which should be accommodated by the available TMB. In this discussion pertaining to Air Travel, the cost of travel is the Air Ticket Price (ATP):

Tv = (TMB / ATP) * Z **---** (Equation 1)

TMB is the share of per capita income set aside for travel. TMB/ATP gives the maximum "number of trips" a person can make with the given amount of TMB and the ATP in a year. Further details of the equation are available in the Appendix- (Appendix Equation)

Tv = (TMB / ATP) * Z **---** (Equation 1)

TMB is the share of per capita income set aside for travel. TMB/ATP gives the maximum "number of trips" a person can make with the given amount of TMB and the ATP in a year. Thus, "number of trips" increases as long as TMB remains larger than the ATP, implying that TMB value grows with the economy (per capita income) and ATP continues to be low owing to competition among airlines and the policies that govern the aviation market dynamics. "**Z**" in the equation introduced to include the influence of other socio-economic and technological factors, which will inversely affect the traffic volume (Tv). Future scenarios use "**Z**" to examine the Land Travel Efficiency and Land Travel Cost influence on the aviation traffic volume.

While Tv indicates the *per capita* "number of trips", it also implies the probability of a person flying such that the instance when ATP becomes larger than TMB (Tv less than 1) the person will not take any trip by aviation. Thus the total aviation volume for "n" people in a year will be:

Total Traffic Volume = Tv1+Tv2+...+Tvn

= (TMB1/ATP) + (TMB2/ATP) +…+ (TMBn/ATP)

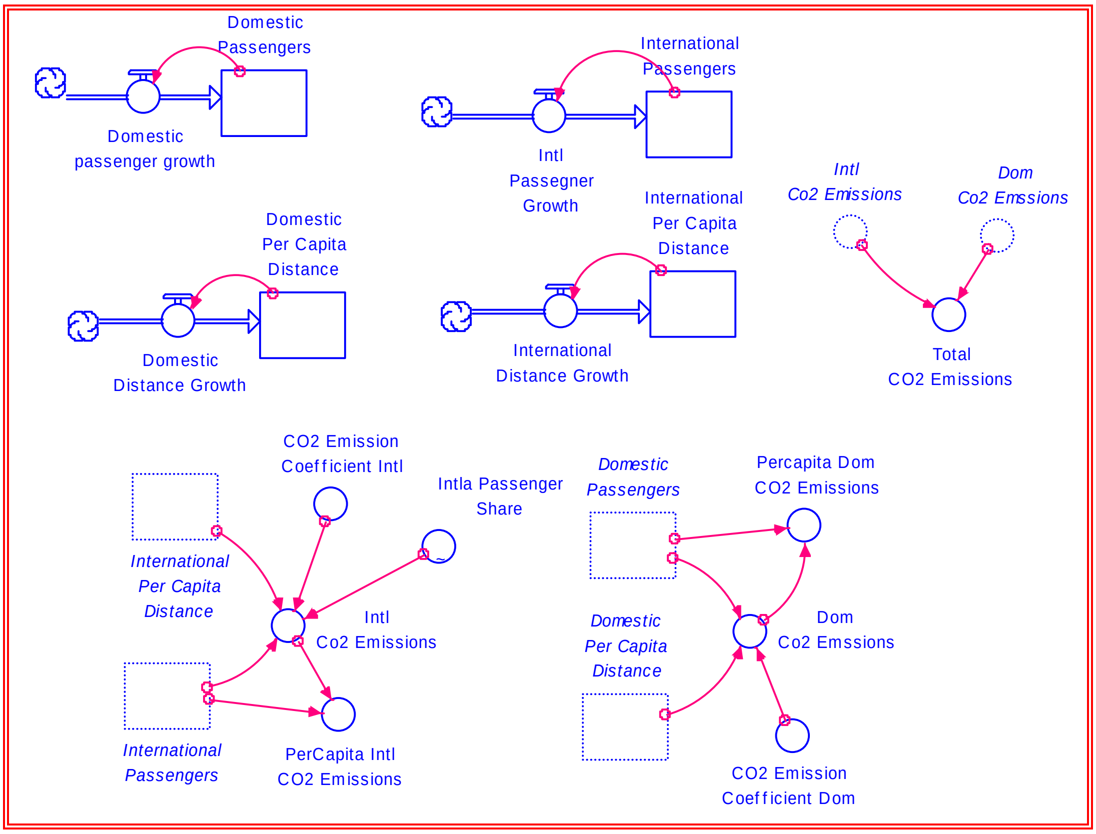
= (TMB1+TMB2+…+TMBn)/ATP

Thus in the above TMB set, the *minimum TMB larger than ATP* (i.e., TMB/ATP >1) becomes the limiting factor in deciding what percentage of the tourists will use aviation. Thus as Singh (2006) shows, per capita *mobility* is forecasted to increase slowly at the lowest income levels (minimum TMB) and then rapidly increase at higher levels of income.

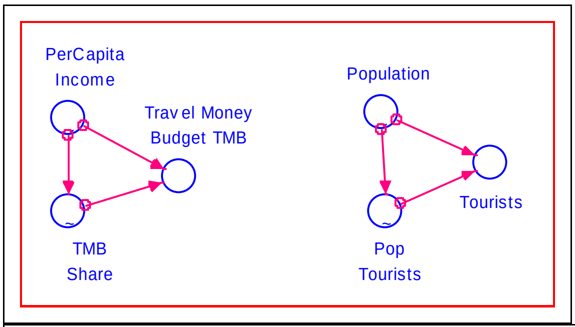
8.4. Appendix C MODEL'

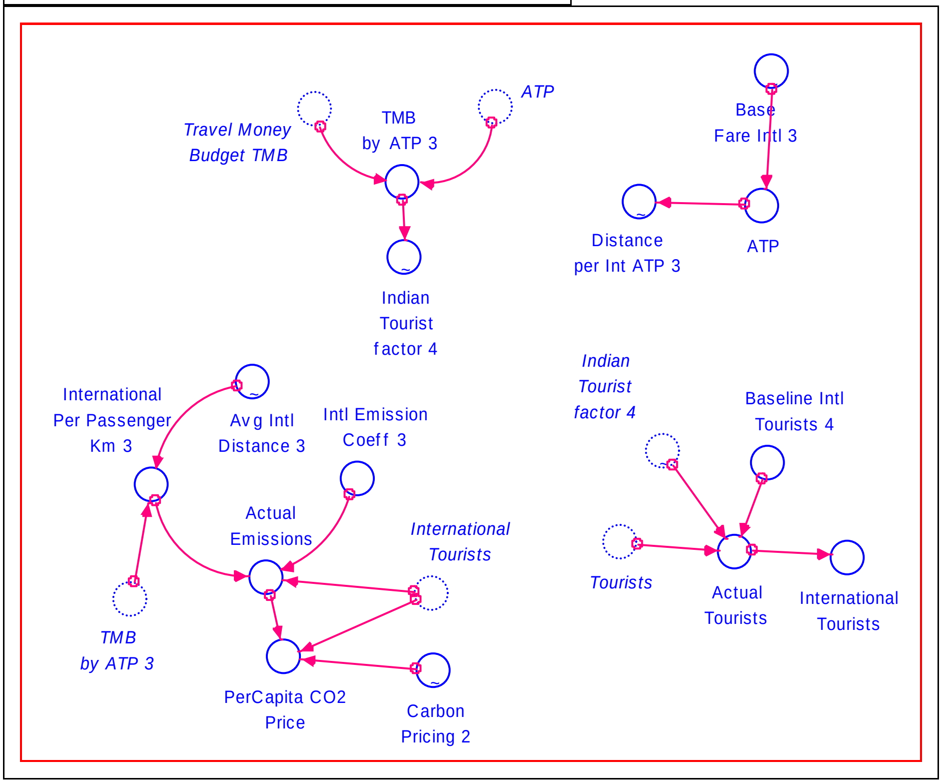
Emissions Growth and the Implications of Per Capita Distribution (II) Global Emission Regimes and Implications on India's International Aviation and (III)

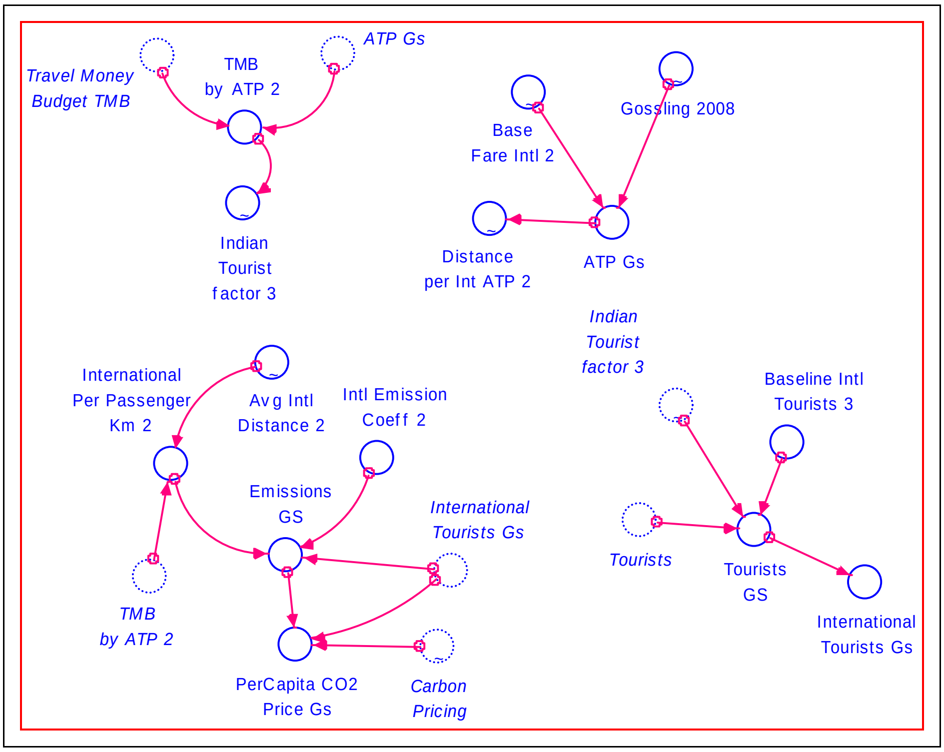
Appendix C: Model-I Emissions Growth and the Implications of Per Capita Distribution

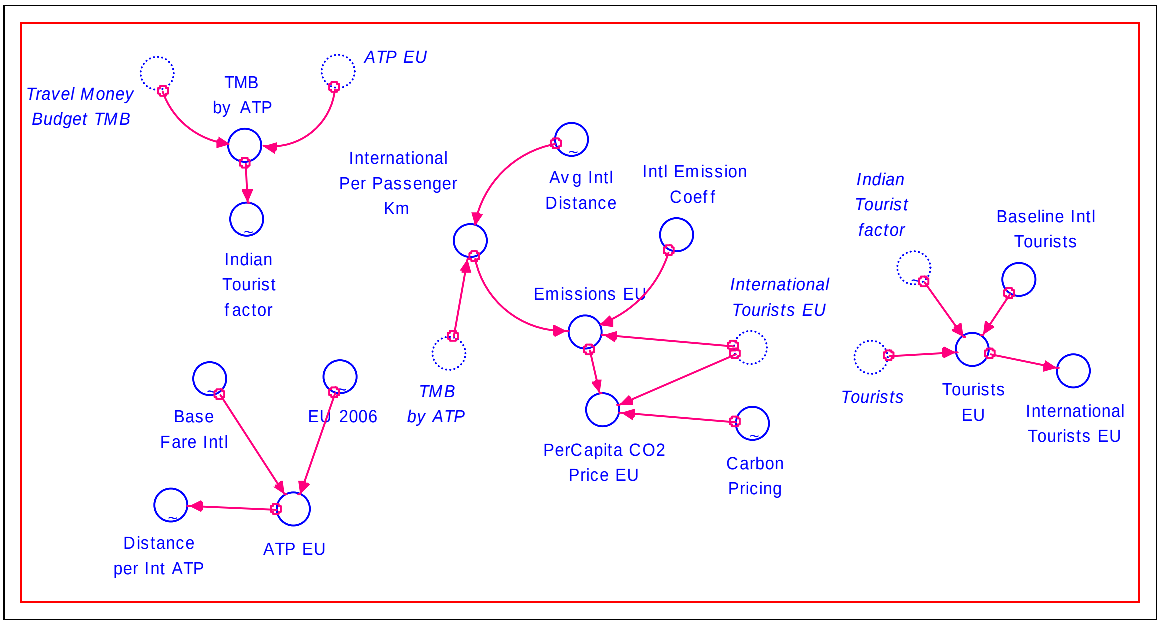


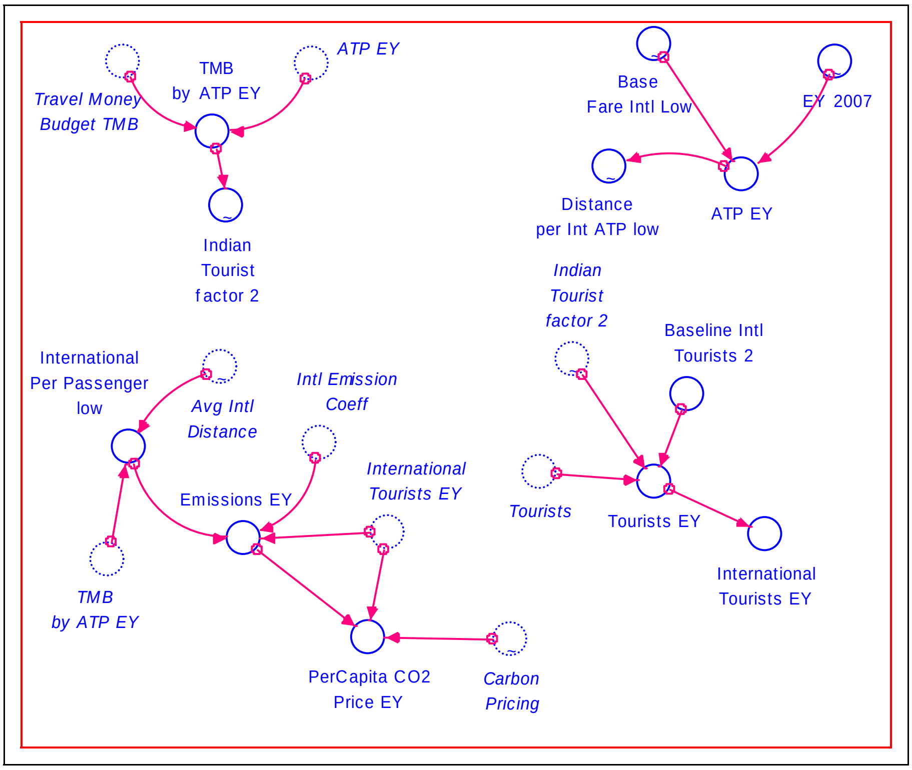
Appendix D - Model – II Global Emission Regimes and Implications on India's International Aviation


PerCapita Income
Trav el Money Budget TMB
TMB Share
Population
Tourists
Pop Tourists

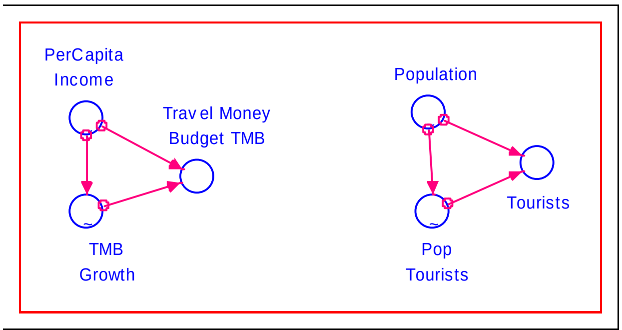

Travel Money Budget TMB
TMB by ATP 3
ATP
Indian Tourist factor 4
Base Fare Intl 3
Distance per Int ATP 3
ATP
International Per Passenger Km 3
Av g Intl Distance 3
Intl Emission Coeff 3
Actual Emissions
International Tourists
TMB by ATP 3
PerCapita CO2 Price
Carbon Pricing 2
Indian Tourist factor 4
Baseline Intl Tourists 4
Tourists
Actual Tourists
International Tourists

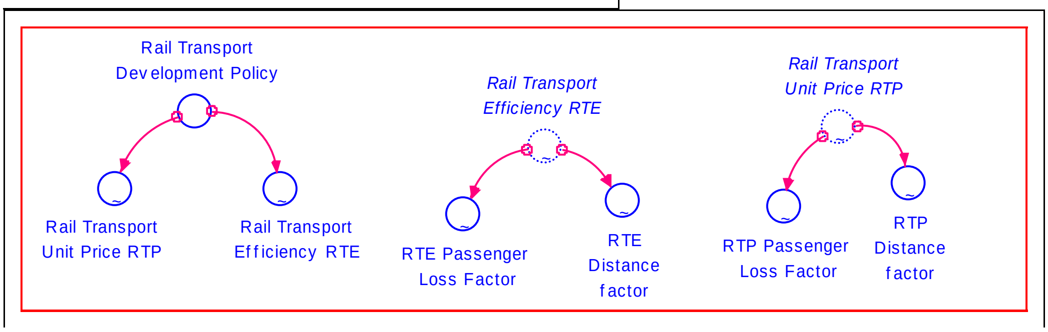

Travel Money
Budget TMB
TMB
by ATP 2
ATP Gs
Indian
Tourist
factor 3
Base
Fare Intl 2
Gossling 2008
Distance
per Int ATP 2
ATP Gs
Indian
Tourist
factor 3
International
Per Passenger
Km 2
Avg Intl
Distance 2
Intl Emission
Coeff 2
Baseline Intl
Tourists 3
Emissions
GS
International
Tourists Gs
Tourists
Tourists
GS
TMB
by ATP 2
International
Tourists Gs
PerCapita CO2
Price Gs
Carbon
Pricing

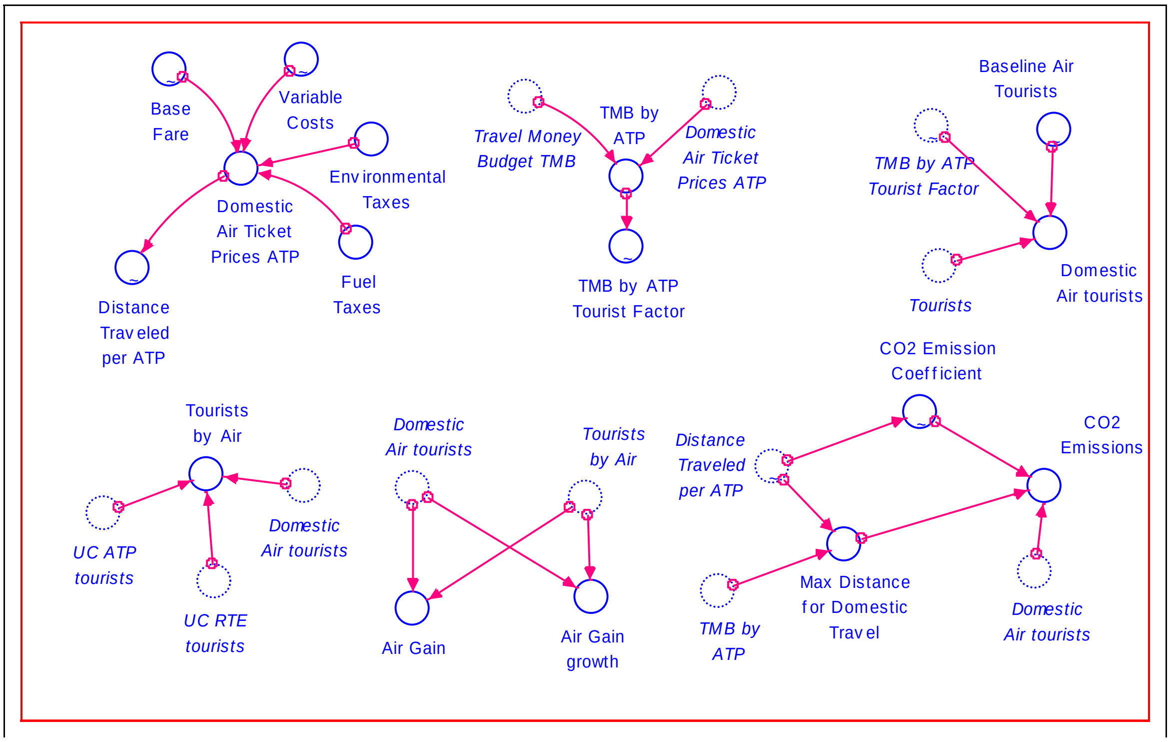

Travel Money
Budget TMB
TMB
by ATP
ATP EU
Indian
Tourist
factor
International
Per Passenger
Km
Avg Intl
Distance
Intl Emission
Coeff
Indian
Tourist
factor
Baseline Intl
Tourists
Emissions EU
International
Tourists EU
Base
Fare Intl
EU 2006
TMB
by ATP
Tourists
Tourists
EU
International
Tourists EU
PerCapita CO2
Price EU
Carbon
Pricing
Distance
per Int ATP
ATP EU

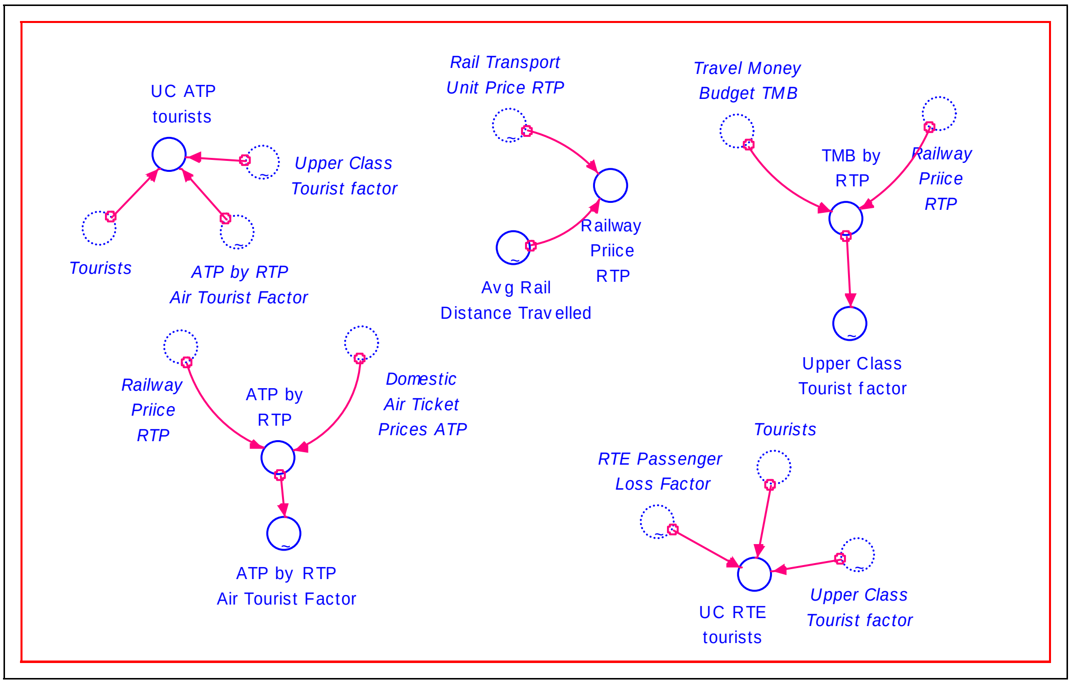


8.5. Appendix E - Model –III- Growth of Aviation Industry and its Implications on Social Equity of Transportation






Base
Fare
Variable
Costs
Environmental
Taxes
Domestic
Air Ticket
Prices ATP
Fuel
Taxes
Distance
Traveled
per ATP
Travel Money
Budget TMB
TMB by
ATP
Domestic
Air Ticket
Prices ATP
TMB by ATP
Tourist Factor
Baseline Air
Tourists
TMB by ATP
Tourist Factor
Tourists
Domestic
Air tourists
Tourists
by Air
UC ATP
tourists
Domestic
Air tourists
UC RTE
tourists
Domestic
Air tourists
Tourists
by Air
Air Gain
Air Gain
growth
CO2 Emission
Coefficient
CO2
Emissions
Distance
Traveled
per ATP
Max Distance
for Domestic
Travel
TMB by
ATP
Domestic
Air tourists


UC ATP
tourists
Upper Class
Tourist factor
Tourists
ATP by RTP
Air Tourist Factor
Rail Transport
Unit Price RTP
Railway
Priice
RTP
Avg Rail
Distance Travelled
Travel Money
Budget TMB
TMB by
RTP
Railway
Priice
RTP
Upper Class
Tourist factor
Railway
Priice
RTP
ATP by
RTP
Domestic
Air Ticket
Prices ATP
ATP by RTP
Air Tourist Factor
Tourists
RTE Passenger
Loss Factor
UC RTE
tourists
Upper Class
Tourist factor