Sustainability of Feeder and Short-haul Air Transportation Systems in India: Emerging Issues and Future Perspectives

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ABSTRACT

The period 2003-08 is characterized in India as very promising for air transport, while the recent recession has put it under distress. However, the Indian Government has taken a decision, to modernize 32 non-metro airports and renovate 125 un-utilized regional airports, as well as introducing in the future, production of smaller capacity aircraft, there by to boost civil aviation industry. This paper will focus on these developments and a need for feeder and short-haul regional air transport network and its operational sustainability. Regional air services can augment better connectivity and will bring air connectivity into a reality, thereby help in further growth of aviation and economy because of multiplier effects (benefits) associated with air transport. The existing common phenomenon of small ratio of air time to total journey time taken to accomplish the short-haul air travel needs to be looked into by improving ground accessibility to/from existing and proposed new airports with rapid high capacity surface transport. The logistics, feeding each mode is necessary to perform a seamless journey and to promote 'sustainable transport system that meets the transport and other needs of the present without compromising the ability of the future generations to meet their needs'.

This paper addresses the following 'emerging issues' having effects and impacts on feeder and short-haul regional air transport operations; (i) economic-political scenario and driving forces of air travel demand in recent days, (ii) multi-modal transport and challenges associated with short-haul air travel for seamless journey, (iii) aviation infrastructure, emerging concept of airport city/ Aerotropolis, and human resources development (iv) regulatory and policy intervention, (v) tourism development/ leisure travel, low-cost fares, etc. Further, the paper elaborates the following 'future perspectives', which are prudent to the success of feeder and short haul regional air systems and to establish sustainable civil aviation growth; (i) rationalization of (a) air networks, (b) air transport demand modeling (c) MRO services, (d) air traffic management, (e) air fares in commensurate with the taxing policies of ATF, (ii) Bench mark to define hierarchy of air transport and its sustainability, (iii) encompassing renewed business models to (a) airline operations, (b) generate non-aeronautical revenue to minimize local impacts of air transport etc.

This type of studies is expected to be a complement to strengthen academic pursuit and research efforts to make feeder and short-haul air transport more attractive with a viable network structure, regulatory and pricing policy.

Keywords: *sustainability, short-haul regional air travel, new civil aviation policy, regional economies/airports/ airlines, multi-modal transport, civil aviation infrastructure development, air transport demand, degree of air network connectivity*

1. INTRODUCTION

Civil aviation in India has been growing at 25-30% annually. The passenger traffic is estimated to grow from the present 90 million per year to 300 million by 2015 and 600 million by 2020. Such growth in civil aviation and associated business can be sustained only if Indian airports and infrastructure are adequately developed along with required human resources (*Aerodrome India, 2008*). There is tremendous business opportunity in this endeavour. The period 2003-08 is characterized in India as very promising for air transport, while the recent recession has put it under distress. However, the Indian Government has taken a decision, to modernize 32 non-metro airports and renovate 125 un-utilized regional airports, as well as introducing production of smaller capacity aircraft, thus enabling avenues for civil aviation industry (*Economic Times, 2009*). The government would continue its efforts to build an aviation grid of airports amidst global recession. There is potential for this because of strong industrial base and the concentration is on short-haul regional aircraft.

This paper will focus on these developments and a need for feeder and short-haul (regional) air transport network and its operational sustainability. Regional air services can augment better connectivity in terrains because it is cheaper to build an airstrip than to provide surface connectivity. This will bring regional connectivity into a reality, thereby help in further growth of aviation and economy because of multiplier effects (benefits) associated with air transport. The studies reveal that for every 100 aviation jobs created, another 73 are created in other industries (*Wensveen, 2007*). Another hypothesis is that employment opportunities in the Civil Aviation services with an efficiency ratio of 1:100 show that there are multiplier benefits. Each of these effects represents a significant contribution to the nation's economy and put role of aviation to a key position among the major industries. The paper analyses all the relevant issues keeping in view the new civil aviation policy of India, present and future market conditions and enabling strategic developments. The existing phenomenon of small ratio of air time to total journey time taken to accomplish the short-haul travel needs to be looked into by improving ground accessibility to/from existing and proposed airports with rapid high capacity bus and rail based transport (*Rallis, 1990; Kodanda, 2007b*). The logistics, feeding each mode is necessary to perform a seamless journey and to promote 'sustainable transport system that meets the transport and other needs of the present without compromising the ability of the future generations to meet their needs'.
Aviation experts are of the opinion that there is a need to develop sustainable strategies for attaining consolidation and growth of civil aviation in the country. Further, this emphasis was considered appropriate with the ever-increasing number of airlines, desirous of operating from India. The literature review indicates that there have been efforts to address similar issues elsewhere but attempted each aspect separately. This paper proposes the need for a comprehensive approach to examine all facets from the perspective of service providers (supply) and users (demand), which can contribute to understand the complexities of feeder and short-haul air transport systems under regional economies, multi-modal, social dimension (positive effects or benefits) and environmental concerns (negative impacts or costs). These types of studies are expected to be a complement to strengthen academic and research efforts to make feeder and short-haul air transport more attractive with a viable regulatory and pricing policy. The paper analyses all the relevant issues keeping in view the new civil aviation policy, market conditions and enabling strategic developments.

2. SUSTAINABILITY

2.1 Sustainability and transport

Sustainability is the yardstick by which the future level of mobility is going to be judged. This concept was formulated in Brundtland report of the World Commission on Environment and Development (WCED, 1987), which stated that any future social or economic activity should be capable of meeting the needs of the present without compromising the ability of future generations to meet their own needs (*Caves and Gosling, 1999*). In terms of mobility, this has been interpreted as working to reduce the harmful effects of providing transport whilst sustaining all necessary social and economic interactions. There is an urgent need to turn attention towards application of the concept of sustainability to transport planning. According to Idaho State, "*Sustainable transportation is defined as a means to satisfy current transport and mobility needs without compromising the ability of future generations to meet their needs*". Transportation Research Board committee (USA) in 2005, used a working characterization that is similar to Idaho's definition: "*a sustainable transportation system is one that meets the transportation and other needs of the present without compromising the ability of future generations to meet their needs*" (*Caves and Gosling, 1999*). In spite of all these, the transport infrastructure is not at par with the ever growing passenger demand in India because of its vastness and demographic profile.

2.2 Air transport and the environment

There have been regulations in individual countries to limit air pollution from transport sources. But, the impact of high growth of urban traffic will lead to vehicles taking more road space to carry even fewer people that can lead to acute traffic congestion and even worst pollution. The studies so far have revealed that due to impressive advances in aircraft technology, the engine exhaust emissions contribute less than 1% of air pollution in the cities they serve and more over the air pollution from small regional aircraft is negligible. This means that the major causes for the pollution around airports are the ground transport vehicles especially in India, where the population is more and there will be ever growing demand for transport. This amply indicates the need to develop improvements in ground transport system to and from airports by bus rapid transit (BRT) or rail based transit modes to mitigate the road congestion/ groundside pollution. In this process, the environmental concerns too will play an important role in shaping the intermodalism between aviation and surface transport (*Caves and Gosling, 1999*).

2.3 Short-haul regional air transport: Issues and Perspectives

This paper addresses the following 'emerging issues' having effects and impacts on feeder and short-haul (regional) air transport operations. This paper will mainly focus on fixed wing aircraft because of passengers perception about safety issues associated with it than on rotary wing aircraft.

1. Economic-political scenario and driving forces of air travel demand in recent days
2. Multi-modal transport and challenges associated with short-haul air travel for seamless journey
3. Aviation infrastructure and emerging concept of airport city/ Aerotropolis
4. Human resources development
5. Regulatory and policy intervention (route dispersal guidelines/social obligation/essential air services, PPP model to build airports, incentives to promoters of regional airlines, integration of air and surface transport policies)
6. Tourism development / leisure travel, low-cost fares and role of feeder air transport in cargo and mail services etc.

Further, the paper elaborates the following 'future perspectives', which are prudent to the success of feeder and short haul regional air transport systems and to enable sustainable civil aviation growth;

1. Bench mark to define hierarchy of air transport and its sustainability
2. Rationalization of air transport systems and services
    i. Air networks (analysis and optimization for establishing the degree of air connectivity)
    ii. Air transport demand modeling (simplified heuristic approaches in estimating passenger traffic, determining suitable aircraft size, and forecast of aircraft fleet requirement)
    iii. MRO services (to maintain continuity of fleet and timely turn around of aircraft services)
    iv. Air traffic management
    v. Air fares in commensurate with the taxing policies of ATF(aviation turbine fuel)
3. Encompassing renewed business models to
    i. Airline operations
    ii. Incorporate value addition of infrastructure to generate major non-aeronautical revenue to minimize local impacts of air transport etc.
4. Some thoughts for future

3. EMERGING ISSUES

3.1 Economic-political scenario and driving forces

The level of air travel for business or leisure purposes is affected by upturns and downturns in the economy. The studies show that there is a direct impact of aviation industry on the economy and its gross domestic product (GDP). In turn, the economic growth has a tremendous effect on the air travel market. The correlation between economic growth and air travel has been recognized by analysts for many years. Economists refer to the air transportation industry as being income elastic (i.e., aircraft sales, RPKs etc are very responsive to changes in economic aggregates such as disposable, personal and national income levels). A generally accepted thumb rule that holds this hypothesis is that there is a 2.5 to 3.0 per cent increase in world air traffic for every 1 per cent increase in world economic growth (in terms of GDP) (*Wensveen, 2007*). Political stability in the country and the bilateral

agreement for air travel opportunities including airspace management can boost positive effects on air transport development. The economic-political scenario and driving forces listed in **Table 1** plays an important catalytic role to influence the short-haul regional air travel demand in recent days. The operational and business integration of airports (airport city/ aerotropolis: *Kasarda, 2006*) with other surface transport modes and business activities is considered to be the new trend that is emerging in the civil aviation. Another issue to be noticed is the integration of regional airline operations into a network of major airlines which seems to produce a more sustainable environment for short-haul regional airline industry. While augmenting domestic air services linking provincial/ major regional cities with national hub or to their respective capitals, due importance should also be given to those routes that undermine the rail competition. The geographical configuration of air route structure keeping in mind the big-city proximity factor is necessary to generate sufficient passenger traffic to support inter-state hub bypass routes.

Table 1. Short-haul regional air transport: Driving factors or forces (*compiled from References and Bibliographies*)

- Purchasing power of employing organization (purchase attributes)
- Purpose of travel and extent of business travel
- Low-cost subsidiaries
- Behaviour and attitude of business travel market
- Air Travel substitution by other transport modes and alternative communication methods
- Government and Corporate policies towards travel expenditure
- Airlines ticket prices/ airfares
- Demographic profile of a region and travellers
- Government and companies provisions for flexible travel
- Effective utilization of regional airports
- Integration of air transport and surface transport modes
- Contribution of airports to their regional economies
- The state of congestion at existing airports
- Competition and complementarity between airports and also amongst transport modes.
- The operational and business integration of airports (airport city/ aerotropolis)
- Airline/ flight schedule driven factors
- The role of regional air services as a strategic tool for major airlines.
- Technological innovations and developments in aviation industry.
- Distinctive attributes of corporate communities and their demands.
- Feeder air routes to hubs
- Increase in the importance of domestic air services linking provincial/major regional cities.
- Location of strong cities within a specific geographic region (big-city proximity factor).
- Need of intra-regional air services in those circumstances dictated by geography/terrains.
- Continuity and reliability of services as well as price competition.
- Price sensitive leisure and short-haul business trips
- Size of companies/ industries in the region.
- Trip or block distances and (cabin) load factors.
- Efficient operation (yield to cost ratio)
- Constant monitoring of airline operational costs and keeping them low.

3.2 Multi-modal transport

Multi-modal transport and challenges associated with short-haul air travel for seamless journey are to be addressed as they play an additional attractive role for the success and sustainability of short-haul regional air transportation system. The airport ground transport system is receiving increasing attention from airport authorities and regional planning agencies. The need to plan airport connectivity and the impact of traffic surrounding the airports, vehicular emissions are forcing airports to consider strategies to mitigate traffic congestion and proper management of ground access traffic. In view of this, there is need for transport agencies to address the integration of transportation modes, including coordination between the air and surface components of the transportation system. Improving access-egress for airport, from the standpoint of travel time, cost, or convenience involves difficult trade-offs (*Gosling,1997; kodanda, 2007b*). There is specific need to address the key issue of having a national institute for transportation in the context, which can coordinate all the transport departments (highways, railways and civil aviation) like the USA/ Australia model of DoT (department of transportation) and DfT (department for transport) model of UK. Hopefully, this could enable the complementarily among the transport modes; the provision for establishing regional connectivity in a better way and also solving the problems at modal interfaces more efficiently. This could further bring fruition to the new civil aviation policy's one of the aims of promoting the feeder and short haul regional air transport in India and make the small transport aircraft operations really seamless and attractive. It is increasingly being felt that air transport is the only mode that tends to be left out in the discussion on public transport and sustainability. As a long-term measure there is a need to bring all transport departments (highways, railways, aviation) under one-umbrella headed by group of ministers (GoM).The establishment of such a system will be of immense help for attaining consolidation and growth of civil aviation sector in the country.

Historically, the planning for each transport mode has been proceeded in a fairly uncoordinated way, with separate agencies responsible for airport development and surface transportation. This has been particularly true in the case of airport planning and aviation generally, where little attempt has been made to view air transportation as part of a larger system. Of course airport planning has addressed the need to link the airport to the ground transportation system, although even this is usually primarily concerned with meeting the needs of private vehicles (*Caves and Gosling, 1997)*.

The existing common phenomenon of small ratio of air time to total journey time taken to accomplish the short-haul travel needs to be looked into by improving ground accessibility to/from existing and proposed new airports with rapid high capacity bus and rail based transport (*Rallis et al, 1990; kodanda, 2007b*). This issue is of utmost importance for time sensitive business passengers. Further, it is also an opportunity to ease congestion on urban corridors, relieve pressure on surface transport modes, and address environmental concerns. The logistics, feeding each mode is necessary to perform a seamless journey and to promote 'sustainable transport system that meets the transport and other needs of the present without compromising the ability of the future generations to meet their needs'.

As larger societal concerns over road congestion and the environmental impacts of traffic have begun to shape transportation policies, many of the larger airports around the world have begun to give increased attention to improving service by public modes, particularly by proving rail links to airports. It is surprising to note that the national civil aviation agencies are often independent of the department responsible for transportation. Even in the USA, where Federal Aviation Administration (FAA) is a part of the department of transportation (DoT), aviation funds are allocated by separate Congressional Committees and aviation tax revenues flow into a separate trust fund that cannot be used for surface transport modes (*Caves and Gosling, 1999*).

3.3 Aviation infrastructure

It was felt that the infrastructure is critical to sophisticated field like aviation/ aeronautics and civil aviation system grows hand in hand with infrastructure as it grows in hand with economic growth. A new concept of airport city/ Aerotropolis (*Kasarda, 2006*) is emerging as a part of aviation infrastructure. Air traffic management infrastructure like trained air traffic controllers; instrument landing (to avoid disruptions due to fog) and night landing facilities also play a vital role. *Kasarda's* article on the Aerotropolis rightly reminds us of emerging new urban forms around airports. *Kasarda* argues that some airports, such as Amsterdam's Schipol Airport have assumed the roles of metropolitan CBDs (central business districts) by becoming major employment, shopping, and business destinations (see **Figure 1**).

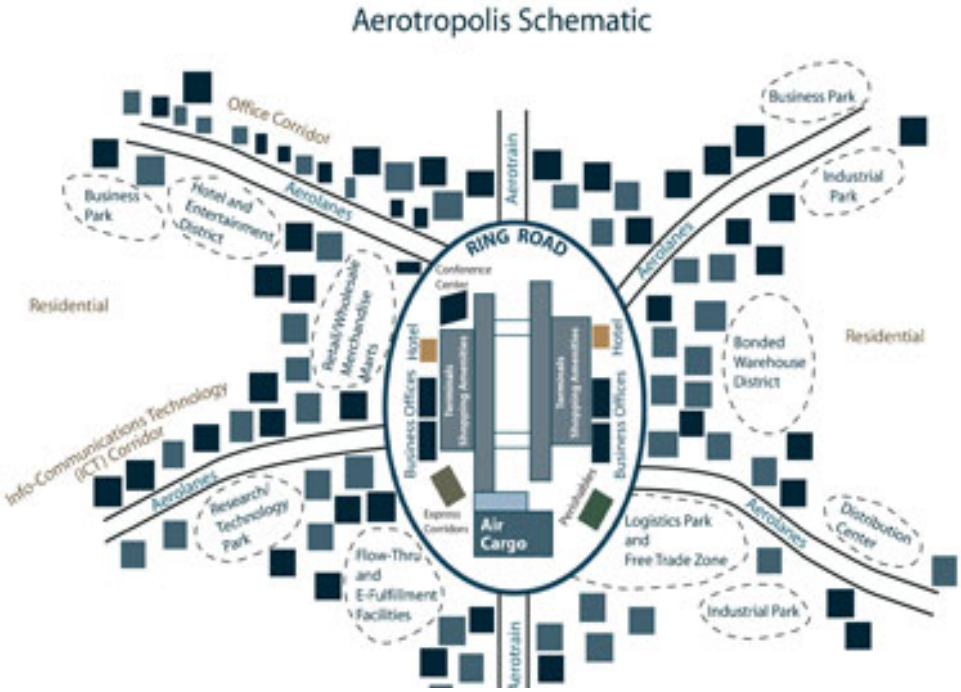

Figure 1. The schematic representation of future new urban airport form *(Source: Kasarda, 2006)*

3.4 Human resources development

Faced with a mounting shortage of over 500 commercial pilots every year, action has been initiated on several fronts to mitigate the problem in India. The DGCA (Director General of Civil Aviation, India) is considering to reduce the time period for acquiring a commercial pilot license(CPL) from 16 to 12 months, and to introduce a multi engine pilot license(MPL). It may

also grant CPL to about 250 foreign pilots. Currently, about 500 pilots are needed per year whereas only 200 pilots are being trained in India. In all about 2500 pilots are working with 11 airlines in India. Whereas it will require about 3000 more pilots in the next 5 years. DGCA plans to increase the availability of pilots to about 400 per year. There are about 39 pilot training schools in India (*Time of India, 2006*). DGCA would be giving trainer aircraft to 11 best performing schools. In addition, NAL (National Aerospace Laboratories-CSIR) has designed and developed a light trainer aircraft, HANSA-3. This is an important move, as it will help in better and speedy training of the pilots. The intake per session for Indira Gandhi Rashtriya Uran Academy (IGRUA) will be increased to 100 from 40 at present. These steps and scarcity of the trained manpower amply indicate that there is a need of human resource development in terms of trained pilots, AMEs (aircraft maintenance engineers). Further, there is a need to maintain the ratio of aircraft acquisition and pilot demand thereby equal play field is achieved between supply and demand. Opportunities also need to be explored for an Aviation University for imparting training and carrying out R&D in the country.

3.5 Regulatory and Policy Intervention

Regulatory and policy intervention regarding route dispersal guidelines/social obligation/essential air services, PPP (public private partnership) model to build airports, incentives to promoters of regional airlines, integration of air and surface transport policies etc. needs attention in the liberalized environment. The government has also a large role to play by addressing the issue of indirect tax structure, specially customs duties, services tax and value added tax (VAT) to make the airline operations and MROs viable.

IATA agents association of India is trying hard to bring in transparency in the operations of airlines in the country. The main demand is formation of a regulatory body for airlines operations in India. The airports economic regulatory authority (AERA) of India will be the new aviation regulator and will settle all issues related to civil aviation sector. AERA has been constituted by an act of Indian parliament, 2008 and has started functioning with effect from January 2009. The goal of this policy intervention is to maintain a competitive civil aviation environment, which ensures safety and security in accordance with international standards, promote efficient, cost-effective and orderly growth of air transport and contributes to social and economic development of the country (*http://indiabusness.nic.in/....website*).

The key question is whether regulatory policies can be enhanced to the point that regulation drives the market for air transport instead of acting as a policing agency. In an industry as the one we have in air transport neither one nor the other role is an easy one (*Macário, 2008*).

3.6 Tourism Development/ leisure travel, low-cost fares etc.

India has tremendous potential for tourism development that may contribute to further growth of air transport. The recent move by the tourism organizations in India to provide `package tourism' will have potential attraction to domestic as well as foreign tourists. These will certainly enhance the propensity to travel to untapped economic and tourist destinations. Tourism development will certainly lead to demand for chartered air services and given an

impetus to leisure air travel markets. In India, the low cost model now has consolidated. Apart from low-cost fares in short-haul regional flights, there is a need to study the role of feeder air transport in cargo and mail air services in the domestic sector. Merely having low costs does not always guarantee success nor is it ordained that all legacy carriers will fail in the future. In other words, past performance is not a guarantee of future success (*Taneja, 2004*).

The low-cost model has now consolidated itself as the future of domestic flying with budget carriers accounting for almost 60 per cent of all air passengers in India. Both Jet and Kingfisher (private airlines in India) are now using a majority of their fleet on domestic routes on their budget brands. The full service (Government run) Air India (domestic) flew 7.3 lakh passengers in January 2010 with leading LCC (low-cost carrier) IndiGo not far behind at 6.2 lakh (*Times of India, 2010*). The sudden increase in air traffic indicates that the Indian aviation is in along term robust growth cycle. In that scenario, more airlines can expect to be profitable in the financial year 2010-11, especially the LCCs. There is a word of caution to airlines to exercise restraint in adding capacity, because the December 2009 growth of 33 per cent has come down to 23 per cent in January 2010, but experts feel that a flat growth may be possible in the middle of the year.

4. FUTURE PERSPECTIVES

India has tremendous potential for air transport growth. With the ever-increasing number of airlines, desirous of operating, it was considered appropriate that the emphasis should be on ‘sustainable strategies for attaining consolidation and growth in the civil aviation sector.

4.1 Hierarchy of air transport and its sustainability

A bench mark to define hierarchy of air transport has been worked out in an attempt to ascertain the sustainability goals associated with short-haul regional air travel. Air transportation is generally categorized as commuter/feeder, short, medium and long haul based on the range and seating capacity (**Table 2**). Regional aircraft (turboprop/jets) designed to fly 35-100 passengers are being increasingly deployed on short-haul routes.

Table 2. Categorisation of air transportation

S.No.	Category	Range (km)	Seating capacity
1	Commuter/Feeder	Up to 800	Upto 30
2	Short-Haul	Upto 800	30 to100
3	Medium-Haul	1000 to 2500	100 to 250
4	Long-Haul	> 2500	> 250

The airline network in India can generally be classified into three categories, namely,

1. Trunk routes (connecting four major metropolitan cities viz., Delhi, Mumbai, Kolkata and Chennai),
2. Major routes [connection between major metros and metros, between metros and metros, between metro and other cities (block distance greater than 500 km)], and
3. Feeder routes [connectivity between major metro/metro/major city and low tier cities (block distance less than 500 km)].

The feeder routes are generally in the range of 100 km to 500 km (this block distance is only an indicative for the sake of convenient classification in the Indian context). As per the 2004 estimates from the data available with the Director General of Civil Aviation (DGCA, India), the number of trunk, major and feeder routes are 6, 78, 76 respectively and the number passengers carried on these routes are 14%, 76% and 10% respectively (*Kodanda, 2007b*). A point, which is to be noted, is that, most of the new entrants also operate in the major trunk routes and serve the metros and the major cities. What appears to have not been tapped is the equally large potential in the short-haul regional sectors, which serve major and small city pairs and also act as feeder to the major hubs. Hence, feeder and short-haul air routes occupy a unique position in the hierarchy of air transport system. A rational integration of regional airline operations would likely establish a sustainable environment for feeder and short-haul air transport system.

4.2 Rationalization of air transport systems and services

4.2.1 Air networks: Analysis and optimization

The objective of this section is to study and make an analysis of air network optimization models in establishing the degree of short-haul regional air connectivity/ configuration, to arrive at an useful figure of merit, for various levels of air ticket price/ airfares and load factors (LF) subject to various levels of aircraft utilization (Uq). The five node regional air network in India linking five cities and operated by ATR72-500 aircraft was taken as a case study to demonstrate a simple network formulation results obtained using cost minimization model (CM), revenue maximization model (RM), and profit maximization model (PM) that were attempted by the author as part of air route structure design problems. The approach followed for problem formulation has been presented in **Table 3**.

The frequencies on some of the links (having higher operating cost) have been reduced or truncated due to the reduction in network system demand, fleet size (max. Uq) so as to satisfy the minimization of cost approach to account for the constraints imposed (**Figure 2**). An attempt has been made to get the minimum set of frequencies to be operated in the network for various levels of aircraft utilization by suitably formulating inequality constraints. Heuristic approach coupled with optimization technique was used in solving this problem wherein at least certain minimum frequencies are maintained on important obligatory links to avoid circuitous routes. The analyses results (modified network structure), listing of frequencies for each city pair are presented in **Figure 3**. The diagrams represent the degree of connectivity of a hypothetical air network for various levels of aircraft utilization. Hence, it is possible to develop hierarchy of network configurations while planning flight frequencies. Each model output in terms of a set of optimum number of flight frequencies between city-pairs, airline direct operating costs (DOC), revenue generated and profit obtained in establishing the degree of regional air connectivity are analyzed and compared.

Table 3. The Problem Formulation (*Source: compiled from Janic 2000; Teodorović, 1988; Kodanda, 2007a*)

Cost Minimization Model	Revenue Maximization Model	Profit Maximization Model
Min.f(x) = $\sum_{i,j,f} DOC_{ij} \times X_F$ Subject to: $AS_q \times LF_{ij} \times X_F \geq P_{ij}$ $\sum_{i,j} BT_{ijq} \times F_{ijq} \leq U_q \times N_q$	$\max \sum_{i,j} \sum_{q} (P_{ij}) \times TP_{ij}$ $\max \sum_{i,j} \sum_{q} (ASq \times LF_{ijq \times} F_{ijq}) \times TP_{ij}$ Subject to: $AS_q \times LF_{ij} \times X_F \geq P_{ij}$ $\sum_{i,j} BT_{ijq} \times F_{ijq} \leq U_q \times N_q$	$\max \sum_{i,j} \sum_{q} Pij \times TPij - DOCijq \times Fijq$ $\max \sum_{i,j} \sum_{q} (ASq \times LF_{ijq \times} F_{ijq}) \times TP_{ij} - (DOC_{ijq} \times F_{ijq})$ Subject to: $AS_q \times LF_{ij} \times X_F \geq P_{ij}$ $\sum_{i,j} BT_{ijq} \times F_{ijq} \leq U_q \times N_q$

Where,
DOC_{ij} = direct operating cost per flight between city `i' and city `j'
X_F = set of flight frequencies in the network
P_{ij} =- average number of passengers on a route between city 'i' and 'j'.
TP_{ij} = average ticket price for transporting a passenger on the route ij.
F_{ijq} = flight frequency between cities 'i` and 'j` with aircraft type 'q'
AS_q = seating capacity of the aircraft type `q'
LF_{ij} = maximum allowed/ or average `load factor' in each aircraft type on route i-j
BT_{ijq} = Block time between 'i' and 'j' for 'q' type of aircraft
U_q = maximum utilization of 'q' type of aircraft per week
N_q = Number of 'q' type aircraft

The problem formulation was solved by developing/writing a code in MATLAB™ using linear programming/ Integer LP coupled with heuristic approaches. Here, the interest is focused on to obtain the preliminary decision parameters while progressing to built higher level models in design of optimal air networks for serving short-haul regional routes.

The approach followed to analysis and compare the three types of optimization methodologies (viz., cost, revenue, and profit models) from cost, revenue and profitability perspective, was helpful to arrive at a typical profitability index (PI) curves (**Figure 4**) based on each model output, and of great utility to both policy makers and air carriers in which they are interested to know the operational efficiency of an airline network. In other words, it will serve as a renewed operating/ business model to look at the extent to which a trade-off can be made to achieve the twin objectives of regional air connectivity (from policy/ social obligation point of view) and retain the interests of air carriers. Further, the analysis can be used to accomplish network structure effects based on the problem formulation for determining optimal flight frequencies for laying down an airline operation policy. An indicative airline problem was presented in this section to evaluate the operational viability of short-haul regional air services from airline yield and profit management perspective.

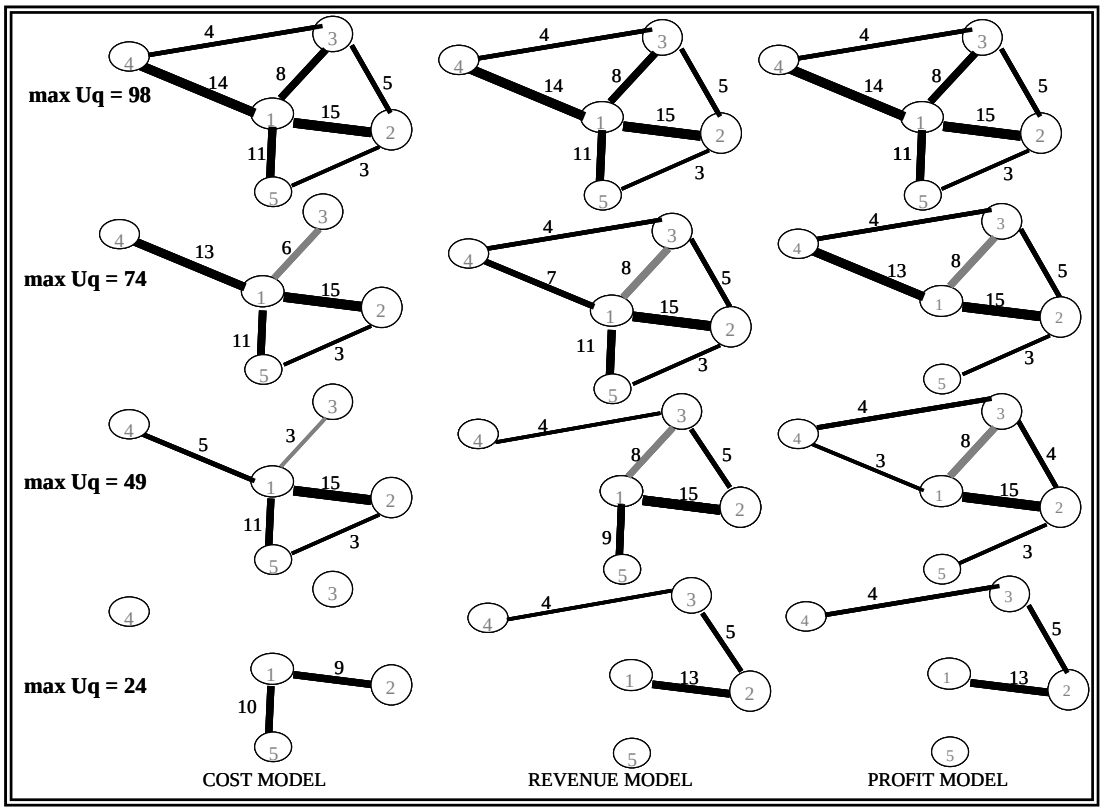

Figure 2. Network Configuration: Cost, Revenue and Profit Models
(Frequencies are indicated against each link)

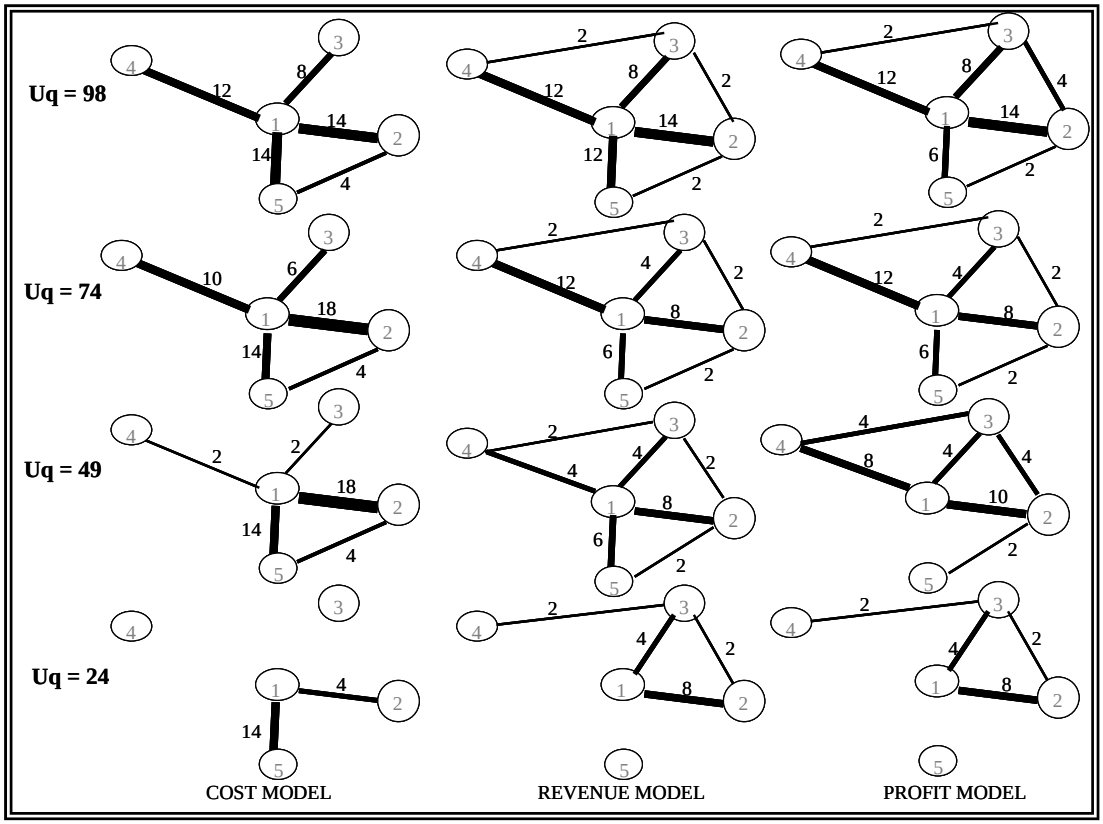

Figure 3. Modified Network Configuration: Cost, Revenue and Profit Models
(Frequencies are indicated against each link)

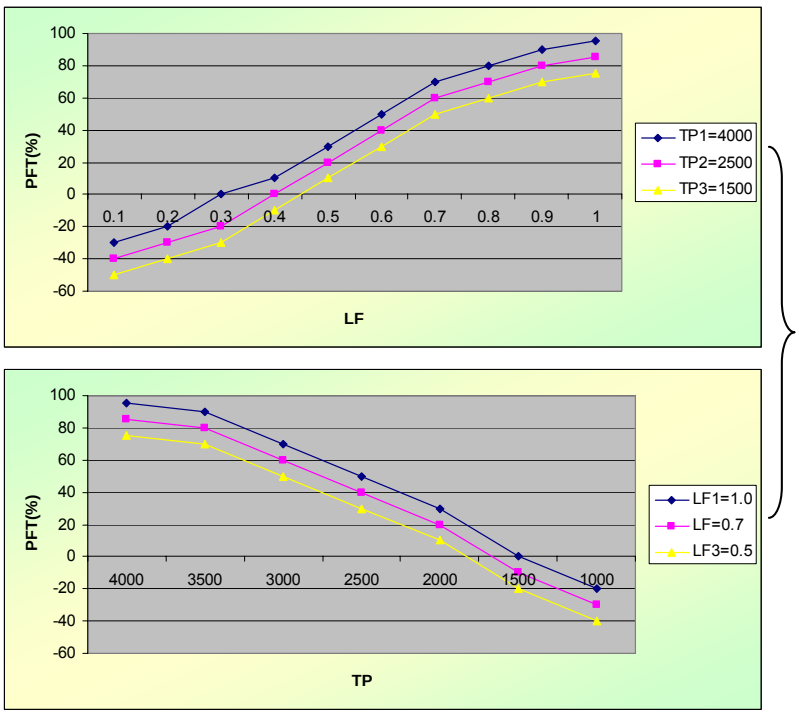

Figure 4.
A typical profitability (PFT) index curves for various levels of ticket price (TP) and load factors (LF) for a hypothetical case.

4.2.2 Air transport demand modeling

Not much research work has been done in this area in India except that an attempt has been made in 1992 by Arasan et al. In their study, a city-pair model for air travel demand has been developed based on the air travel pattern in India (*Rengaraju and Arasan, 1992*). The Airport Economic Regulatory Authority (AERA) of India is now keen to have a reasonably solid way of predicting air traffic growth. AERA is examining various models for this job as it has to determine airport charges for airlines and users fee for passengers. Air traffic is believed to grow 1.5 to 2 times the gross domestic product (GDP) growth rate. That model did not work during the economic downturn. Now, the AERA felt that an accurate passenger forecast is essential for levy of fair charges and other infrastructure development (*Times of India, 2010*). The policy makers are very often confronted with situation where they have to make quick decisions on the proposals for expansion of air transportation systems. Therefore, there is an urgent need to find ways and means of obtaining quick and reasonable estimates of traffic consists of passenger flows, aircraft movements on short-haul regional air transport networks. Taking advantage of data generated through various studies, an attempt has been made to evolve a quick method approach to estimate air transport demand. In view of this, the demand for passenger traffic, suitable aircraft size and expected demand for each aircraft type was arrived at based on a simplified approach and macroscopic aggregate measure.

Air passenger traffic in India:
Based on the analysis of published schedules of airlines in India and the DGCA airport statistics, around 65 cities are connected by air (*http://www.dgca.nic.in*). Analysis of the data clearly shows that all State head quarters are connected. Where there is economic activity, tourism or if a destination has religious importance, there appears to be a connection in addition to DGCA route dispersal guidelines. Population of the cities by themselves is not a condition for it to be connected but classification of cities (**Table 4**) merely allows the pattern to be viewed in one more dimension. Historically, where airports are available and infrastructure has been provided, the airlines have commenced operations. This indicates

that no systematic traffic forecasting/ estimation methodologies are followed. **Figure 5** show the total passengers embarked and embarked load factor (ELF) from a city and this information can provide indicative system load factor of each of the metro/city/town. The findings indicate that certain cities show higher CAGR (compound annual growth rate: 10 percent and above), while there appears to be a decline in CAGR in certain cities. All major metros show an aggregate CAGR of 3 to 5 percent, whereas it is around 2 to 3, 5, 7, 10 percent for metros, class B, C, and D cities respectively (*Kodanda, 2009*).

Table 4. Classification of cities
(*Source: Chandra et al, 2003*)

Class	Population
A*	> 1 million
B	500,000 to 1 million
C	100,000 to 500,000
D	50,000 to 100,000
E	20,000 to 50,000
F	10,00 to 20,000
G	< 10,000
* includes the 4 major metros	

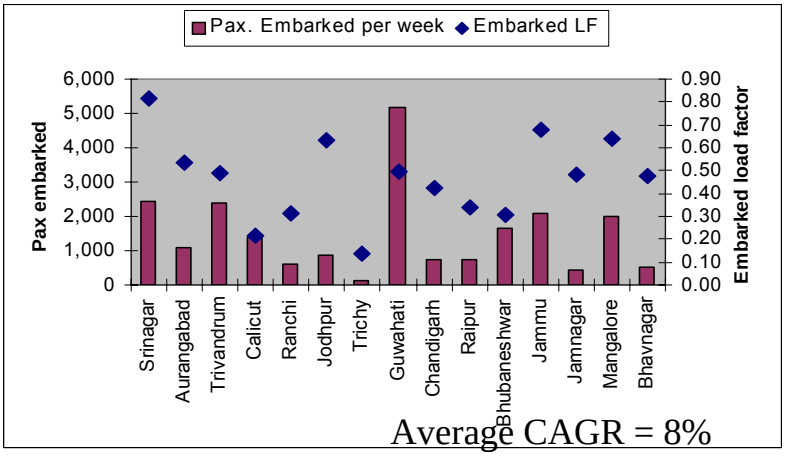

Figure 5. Passengers embarked and ELF for class D cities

In the above study it is observed that the load factors are below 50 percent, in majority of the class B to D (tier-II to IV) cities. This strongly indicates that there is a need to rationalize and introduce the right type of aircraft from an origin city to other destinations, because most of the fleet presently operated with B-737, A-320, ATR aircraft. The feeder services in North East part of India are based on route dispersal guidelines and the operations are not purely governed by local requirement or economics. Sometimes these obligations are traded between airlines. Going by the gross load factors, half of the presently connected cities may not justify the use of bigger aircraft. Hence, short-haul operations in India need a re-look in terms of fleet composition and size, route network, frequencies and fare structure. In this section, issues related to these attributes are incorporated in the analysis.

Modal split in inter-city transport in India:

The extent of transport network reflects a multiplier effect in the economic development of any country (*Zhang, 1998*) and India is no exception to this. Railways, Roadways, and Airlines are the main mode of passenger transport in India. As per the 2005-2006 data, the typical modal split in intercity travel in India in terms of passengers carried are 61 percent by railways, 37 percent by roadways and 2 percent by airlines. The national highways (NHs) are considered to be the backbone of transport network in India and probably a competing mode to air travel apart from rail, especially for short haul travel. Similarly, the comparison of modal split between upper class rail and air transport in India shows that the figures are favourable to airlines, which accounts for 57 percent while upper class rail stands at 43 percent. If we look at the long-term growth of intercity transport for the period 1996–2004 (**Figure 6**), the airlines and railways grew by 7 and 5 percent (CAGR) respectively, while the roadways experienced a negative growth (-2%).

Impact of low-cost carriers (LCC) on upper class rail travel pattern:

The time series data on the growth trends in inter-city rail (upper class) and air transport shown in **Figure 7** clearly indicates that the introduction of Shatabti and Rajdhani rail services in 1990's might have influenced the price sensitive travellers towards these services thereby increasing the share of upper class rail travel. The reverse trend has been observed during 2003 thus marking the start of LCCs in India coupled with the price war among them.

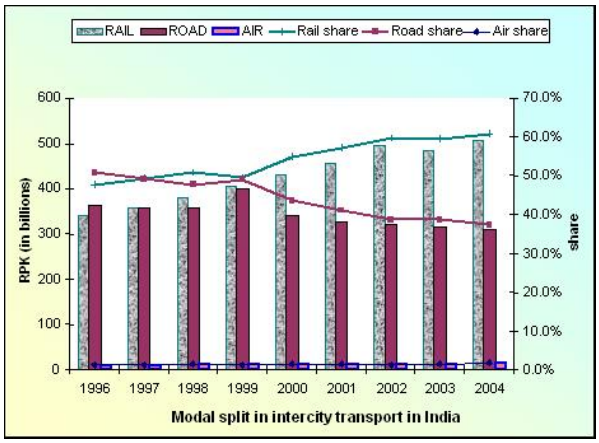

Figure 6. Long-term trends in growth of inter-city transport (pax-km in millions)

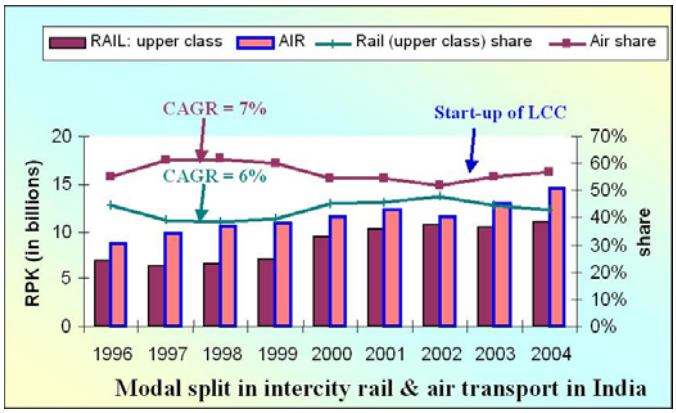

Figure 7. Passenger traffic carried by upper class rail and air transport

Estimation of passenger traffic:

The total traffic on feeder and short-haul routes is arrived at by the addition of rail passengers willing to shift to air travel to the present air traffic on these routes. The expected shift from rail travel is estimated based on price sensitivity curves (*Kodanda, Chandra, Narayan, 2003*) for each region developed as per the study conducted in 1999-2000. The potential cities were estimated based on a prioritization analysis carried out by the author at al (2003) in earlier studies and plotting interaction maps among city pairs for prioritized state of connectivity. Considering the recent price war, the shift from rail to air travel would likely increase further since the premium of air travel over rail travel will decrease with decline in air travel prices. A fresh passenger's survey may be carried out to ascertain the willingness to shift to air travel in the changed scenario due to increase in disposable income levels etc. A forecaset of RPKs (revenue passenger kilometers) both for existing and new city pairs were presented in **Figure 8** and **Figure 9** respectively.

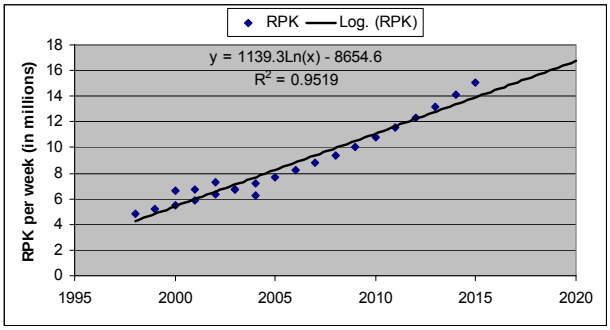

Figure 8. Forecast of RPKs upto 2020 (for existing routes)

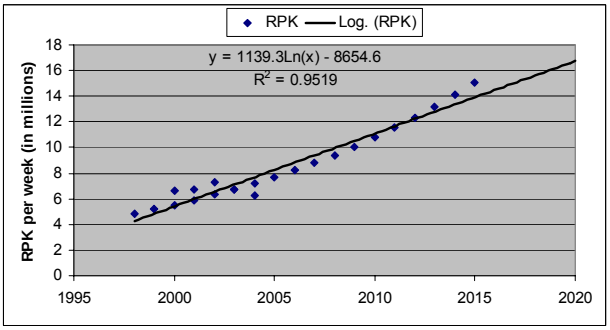

Figure 9. Forecast of RPKs for potential city-pairs based on estimated RPKs

Determination of optimum/suitable aircraft size:

An approach for determining the suitable aircraft size for feeder and short-haul regional air routes is arrived at from the basic principles of airline business (*Janić, 2000; Teodorović, 1988*) and thus obtaining the equation (1).

Step 1: $$LF = \frac{P}{AS \times F} \longrightarrow AS_{ijr} = \frac{P_{ijr}}{F_{ijr} \times LF_{ijr}} \quad (1)$$

Step 2:

Criteria for load factors and flight frequencies (lower and upper bounds)

$$0.5 \le LF_{ijr} \le 1.00 \quad (1a)$$

$$0.5 \le [LF_{ijr} = \frac{P_{ijr}}{AS_{ijr} \times F_{ijr}}] \le 1.00 \quad (1b)$$

$1 \le F_{ijr} \le F_{\max}$, F_{max} = 14 to 42 depending on aircraft type and year (1c)

Where,

AS_{ijr} = Seating capacity of the aircraft deployed on city pair 'i-j' on route 'r'
P_{ijr} = Passenger traffic between city 'i' and 'j' on route 'r' per week
F_{ijr} = Frequency of flights between city 'i' and 'j' on route 'r' per week
LF_{ijr} = Load factor on city pair 'i-j' on route 'r'

It is assumed that 2 flights per day (per direction) and a load factor of 80 per cent as a preliminary step in determining the aircraft size based on the passenger demand. The analysis shows that the aircraft size suitable for the existing traffic pattern varies from 4 to 100 seater (high density metro routes like Chennai-Bangalore etc. are not considered). As this is a wide range, the aircraft size which suits the following criteria are being selected as:

- There should be 2 flights per day (14 flights per week/direction) subjected to minimum and maximum load factors (assumed as 50 percent and 100 percent respectively).
- If the load factor falls below 50%, the frequencies are kept on weekly basis varying from 1 flight per week to 7 flights per week per direction.
- If the load factor exceeds l00% with 2 flights per day, then the next suitable higher size aircraft, which suits again the above load factor and frequency criteria, has been chosen.

In addition to this, the following assumptions were made with reference to the flight frequencies for various types of aircraft on year-wise (long term) basis.

$1 \le F_{ijr} \le 14$, for 10-20, 30-50, 70 seater up to the year 2010
(i.e., frequency varies from 1 flight to 14 flights per week per direction)

$1 \le F_{ijr} \le 28$, for 100 seater up to the year 2010
(i.e., frequency varies from 1 flight to 28 flights per week per direction)

$1 \le F_{ijr} \le 28$, for 10-20, 30-50, 70 seater from the year 2010 onwards
(i.e., frequency varies from 1 flight to 28 flights per week per direction)

$1 \le F_{ijr} \le 42$, for 100 seater from the year 2010 onwards
(i.e., frequency varies from 1 flight to 42 flights per week per direction)

Estimation of fleet requirement: Aircraft demand:

Based on the growth trends of the past five years data and the overall RPKs estimated in an earlier market survey (Kodanda, *Chandra, Narayan, 2003*), the forecast of RPKs are arrived (**Figure 8** and **9**). The steps followed in estimation of aircraft demand were shown in **Table 5**. The estimated RPKs and aircraft fleet size for existing (76 routes) and potential (57 routes) feeder and short-haul routes are presented in **Table 6**.

Table 5. The Approach Followed for Estimation of Aircraft Demand (*Source: Kodanda, 2009*)

Step	Description	Formula
Step 1	Determination of average load factor for predicting the number of each aircraft type	$LF_{rq} = \dfrac{\sum \dfrac{P_{ijrq}}{AS_{ijrq} \times F_{ijrq}}}{C}$
Step 2	Estimation of RPKs performed by an aircraft	$RPK_{rq} = AS_{rq} \times LF_{rq} \times V_q \times U_q$
Step 3	Estimation of number of aircraft	$N_{rq} = \dfrac{\sum_{C} RPK_{ijrq}}{RPK_{rq}}$

Where,
LF_{rq} = Load factor on route 'r' for aircraft type 'q'
P_{ijrq} = Passenger traffic between city 'i' and 'j' on route 'r' per week for aircraft 'q'
AS_{ijrq} = Seating capacity of 'q' type aircraft on city pair 'i-j' on route 'r'
F_{ijrq} = Frequency of flights per week of 'q' type aircraft for city pair 'i-j' on route 'r'
C = Number of routes/ city pairs
RKP_{rq} = Revenue passenger Kilometres on route 'r' for aircraft type 'q' per week
AS_{rq} = Seating capacity of 'q' type aircraft on route 'r'
V_q = Block speed of type 'q' aircraft
U_q = Utilization of type 'q' aircraft
N_{rq} = Number of type 'q' aircraft

Table 6. The estimated RPKs and aircraft fleet size for existing (76 routes) and potential (57 routes) feeder and short-haul routes (*Source: compiled from Kodanda, 2009*)

Year	Region/ Hub		Aircraft size				
		RPK	10-20S	30-50s	70-100s	> 100s	Total
2020	E	3,100,497	12	6	2	-	**20**
	N	9,528,612	12	4	6	2	**24**
	NE	1,792,127	8	2	2	-	**12**
	S	5,075,751	24	8	2	-	**34**
	W	8,172,788	20	4	4	2	**30**
	Total	**27,669,775**	**76**	**24**	**16**	**4**	**120**
Region/Hub:E = East (Kolkata), N = North (Delhi), NE = North East (Guwahati)							
S = South (Chennai/ Bangalore/ Hyderabad), W = West (Mumbai)							

4.2.3 Maintenance, repair and overhaul (MRO)

MRO services are essential to maintain continuity of aircraft fleet and timely turn around of aircraft services. Therefore, MRO operations play a key role in any aviation scenario. According to recent statistics, India's MRO segment is estimated to grow at 10 per cent and reach US$ 1.17 billion by 2010 and US$ 2.6 billion by 2020. The main challenge in positioning India as an MRO hub comes from the indirect tax structure, especially customs duties and service tax. There are a few organizations engaged in MRO services in India for a number of years. The oldest among them is Air Works India, established in 1951. In 2008, it became first Indian commercial MRO to receive approval DGCA for its MRO operations near Banaglore. Air Works Airline MRO has also completed the EASA (European Aviation Safety Agency) approval requirements and is awaiting audit of the facility. Two big MRO projects that are coming up are worth mentioning here. Boeing is setting up an MRO centre in Nagpur and Airbus through its parent company EADS is establishing a MRO centre in New Delhi. Both these are expected to be state-of-the art and capable of serving several aircraft at a time (*Indian Aviation, 2009*).

The advantages of having an MRO in India are several. India offers good skilled workforce at a reasonable low man-hour rates, as well as its strategic global location as India is just in the mid point between the east and the west. The man-hour rates in India are comparable as in China (US$ 35-40) (*Indian Aviation, 2009*). Many other aircraft manufacturers especially in the corporate aviation segment and regional segment have tied up with Indian aviation engineering companies to set up authorized repair centres. Further it is increasing being felt that the MRO centre should be fully equipped with spares and LRUs (line replacement units) etc. This is yet another significant impetus to the Indian aviation.

4.2.4 Air traffic management (ATM)

The literature review indicates that congestion and weather are generally considered as the important factors affecting the air traffic flow. Planning of air traffic flow management (TFM) is a perquisite to avoid cost of delays under multiple time scales at national, regional and local levels and help pilots, Aviation/ Airports Authorities, TFM managers, dispatchers who are involved in decision making to achieve multiple objectives of capacity regulation and maintaining schedule integrity with different business models. Everybody can not fly optimum route because of congestion. The study estimates for USA shows that the cost of delays was US $ 5.9 billion in the year 2005 (*Banawar, 2009*). The following issues were considered.

- Insufficient sharing information between decision makers regarding schedule changes, congestion information, and weight of aircraft and intent information.
- Uncoordinated decision making at national, regional and local level
- Limited automation

The challenges generally considered for future air traffic management are as under:

- Designing the system for three times the current traffic
- Responsive to environmental considerations and weather uncertainity
- Conflict resolution by means of automation

Considering the scientific advances in India, the Indian frequent flyers who bemoan the delays and foggy conditions and bad weather constantly through up, can look forward to

better days. The Indian Space Research Organisation (ISRO) has developed Satellite based regional 'GPS Aided Geo Augmented Navigation' (GAGAN) that will be used for navigation and air traffic management by the Airport Authority of India (AAI). The project is expected to help AAI manage Indian airspace better, save fuel and improve efficiency for airlines. It is expected that it will provide Cat-I approaches with out ground element support. The technology demonstration system (TDS) has been tested, and the final stage of implementation is expected to take place by the end of 2010 (*Indian Express, 2010*). Gagan was endorsed to overcome the limitations of the ground-based system. Gagan will also cover oceanic areas inaccessible to terrestrial systems. The system is expected to increase safety by enabling multiple approach capability. It will improve airport and airspace access in all weather conditions, enhance reliability and reduce delays.

Air traffic services and airports will under severe pressure, concerning to slot management, are forced to accelerate the privatization of ATC (air traffic control) worldwide as a solution to ensure the required investments for modernization of the ATM (*Macário, 2008*).

4.2.5 Air fares vs ATF (aviation turbine fuel)

Considering the recent air turbulence being faced by the civil aviation industry, there is a need to rationalize airline ticket prices/ air fares in commensurate with the taxing policies of ATF (aviation turbine fuel). ATF, that constitutes nearly 40 per cent of the airline operating costs, is one of the most crucial variables that can impact airlines performance. In February 2010 alone, the state-owned OMCs (oil marketing companies) have reduced the ATF costs by 8 per cent on account of softening in global crude oil prices. Now, ATF costs up to Rs. 39000 per kilo litre across cities in India (*sakshi, 2010*). There is a welcome policy attention on the issue of high domestic prices of ATF. The Government of India has constituted a group of ministers (GoM) to rationalize the tax on ATF. The main reason why ATF prices are about 60% higher in India is due to taxes on the fuel especially sales tax, which is highest in the world. Now the civil aviation is far more accessible and air travel is becoming more a necessity than as luxury in the past. The states need to rationalize local levies (sales tax) on ATF. The extant rates are in the range of 28-30 percent. Further, the steep marketing margin charged on ATF varies between 16-21 per cent. The result is that fuel costs add up to as high as 40 to 42 per cent of operational expenses in domestic aviation in India. In contrast, the corresponding figure in abroad is far lower (~25 per cent) (*Economic Times, 2009*).

Lower sales taxes and reasonable marketing margins are clearly warranted given the perspective that the future growth in air traffic is expected to be fueled by feeder and short-haul regional sectors, as the hinterland opens up to industry, service and tourism. The passenger traffic volumes are likely to increase by around 8.5 per cent per annum in the five years, after a drop of 4.7 per cent in 2008, and high-flying growth rates of 46.4 percent and 32.6 per cent posted in 2006 and 2007 respectively (*Economic Times, 2009*). Airlines need to rework their business plans, due to reduction in air passenger traffic and addition of massive seating capacity in recent years. In view of this, there is a strong case for rationalizing/ moderating the local taxes on ATF, competitive retail margins and uniform taxing policies across various Indian States. Further, the strengthening of auxiliary services like transport and storage of aviation fuel are to be done at par with other civil aviation activities.

4.3 Renewed business models

Encompassing renewed business models to airport and airline operations and infrastructure development are gaining much needed impetus in the modern civil aviation era. Some thoughts associated in this respect are presented in the paper. Now a days, in a more commercial and private environment, with an increased pressure on the awareness of the meaning of a business model for airports and airlines, these complex operations and infrastructure are increasingly dependent on non aeronautical revenues, and thus perceiving passengers as segment of their primary customers. As *Macário* rightly refers that inter-modality plays an important role in cost efficiency of the services provided and obtaining enhanced effectiveness through economies of scope that offers an increased number of destinations without any burden to the productive structure. This is mainly due to shifting of focus from service to process, thus giving priority to seamless flows of passengers (*compiled from Macário, 2008*). The elements of differentiation of the air transport industry from the business perspective are presented in **Table 7**.

Table 7. Elements of differentiation of the air transport industry (*source: compiled from Macário, 2008*)

S.No	Past Characteristics	Present Perspective
1	Air Transport seen as a national strategic asset (considered as a public service)	Air Transport seen as a corporate asset with alternative business models
2	Closed Markets	Open markets
3	Companies closed in their own networks with interline agreements	Productive and commercial assets shared for cost effective purposes
4	Sharing only some productive assets	Willingness to involve PPP (public private partnership) model in several business ares
5	Modal superiority (competitiveness)	Model humbleness develops attitude towards inter-modality (complementarity's)
6	Strong political support for subsidization and social obligation	Flag carriers with profit motive
7	Service focus with aeronautical activities	Process focus coupled with aeronautical and non-aeronautical activites

4.3.1 Airport and Airline operations

The interaction between airports and airlines taking into account the evolution of air transport in recent decades and an approach to integrated quality of service has been addressed by *Rosario*. Her paper challenges the traditional model (airport management, legally binding agreements, sophisticated operations etc) and proposes a renewed business model for airports. It is observed that the evolution of air transport industry is shifting away from the traditionally looking at airport as a facility where aircraft operate and passengers and fright transit. This is giving a place for encompassing business model where parallel to the aeronautical activities; most airports incorporate other activities as listed here to increase the value of usage of the infrastructure (*Macário, 2008*):

- Retail mall concepts merged into passenger terminals
- Airport property beyond the terminal encompassing development of hotel, entertainment, conference, logistics and special economic zone (SEZ) facilities
- Complementary sets of facilities for airport and airline employees

India is a large country yet its annual per capita air trips amount to a lowly 0.02 (**Figure10**: air travel maturity), compared to 0.1 for China and as high as 2.2 trips for the USA. So, there is tremendous opportunity for air traffic growth in India. Additionally, population of India in million per aircraft is far too high at 2.89 as compares to China (1.14), Brazil (0.63), and USA (as low as 0.05) (*Economic Times, 2009*). This indicates that there is likely to be sustained momentum both for aircraft acquisition and air passenger traffic. That surely calls for renewed airline business models for airport and airline operations.

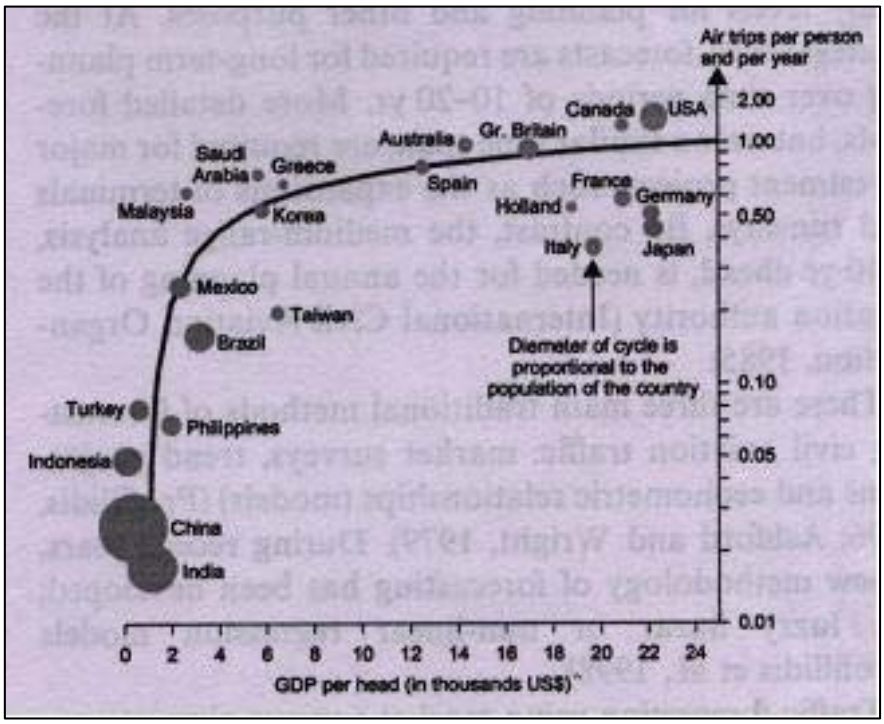

Figure 10. Air travel maturity: Gross domestic product (GDP) vs Air travel demand (*Source: Profillidis, 2000*)

4.3.2 Non-aeronautical revenue

There is a need to incorporate value addition of infrastructure to generate major non-aeronautical revenue to minimize local impacts of air transport etc. The earlier perception about whether an airport is a profitable or non-profitable business for a city is being addressed now because of Tech parks/ SEZs (special economic zones) planned proximity to the airports to enhance the economic activity of the cities. The international comparison (**Table 8**) at ten important airport hubs indicates that the non-aeronautical revenue constitutes about 50 to 80 percent on an average of the total income (*Iyengar et al, 2007*). The issues related to public private partnership (PPP) in airport infrastructure including airport connectivity under build-operate-transfer (BOT) needs to be addressed in the future. Revenue streams and beneficiaries in Indian Airports system is highlighted in **Table 9**. Indian airports currently get bulk of their revenues from aeronautical revenue streams. In the non-aeronautical segment, metro airports are the highest contributors amounting to approximately 20 per cent (*Iyengar et al, 2007*).

The city side development of 24 airports in India will be undertaken with private sector participation under PPP model. The scope of the city side development, through this model, would comprise commercial development of property, car park and cargo operation. This will further enhance the scope for generation of non-aeronautical revenue and minimize the local

impact of air transport. *Kasarda* presents a list of activities that can be developed within the operational perimeter of the airport and outer perimeter adding value to the aeronautical activities and generating additional demand for the airport and airlines activities (**Figure 11**).

Table 8. International comparison of aero and non-aero revenue (*source: Iyengar et al, 2007)*

Airports	Aeronautical Revenues	Non-Aeronautical Revenues
British Airports Authority	28%	72%
Toronto	38%	62%
Sydney	29%	71%
Houston	19%	81%
Heathrow	47%	53%
Kuala Lumpur	46%	54%
Los Angeles	57%	43%
Changi, Singapore	42%	58%
Paris	51%	49%
Zurich	49%	51%

Source:Annual Reports of Airports

Table 9. Indian Airports: Revenue streams and beneficiaries (*source: Iyengar et al, 2007*)

Revenue Stream	Components	Beneficiaries in AAI owned airports	Beneficiaries in proposed private airports
Aeronautical revenue	▪Route Navigation Facilitation charges(RNFC) ▪Landing, Housing and Parking Charges ▪Terminal Navigation Landing Charges(TNLC) ▪X-Ray Baggage charges	AAI	RNFC would remain with AAI Other charges to airport developer
Non-aeronautical revenue	▪Duty Free Shopping ▪Catering and restaurants ▪Car Parking & Car Rental ▪News, Shops, Banks etc ▪Airline terminal rents & Real Estate ▪Other (Hotel, Travel services)	AAI	Private airport developer

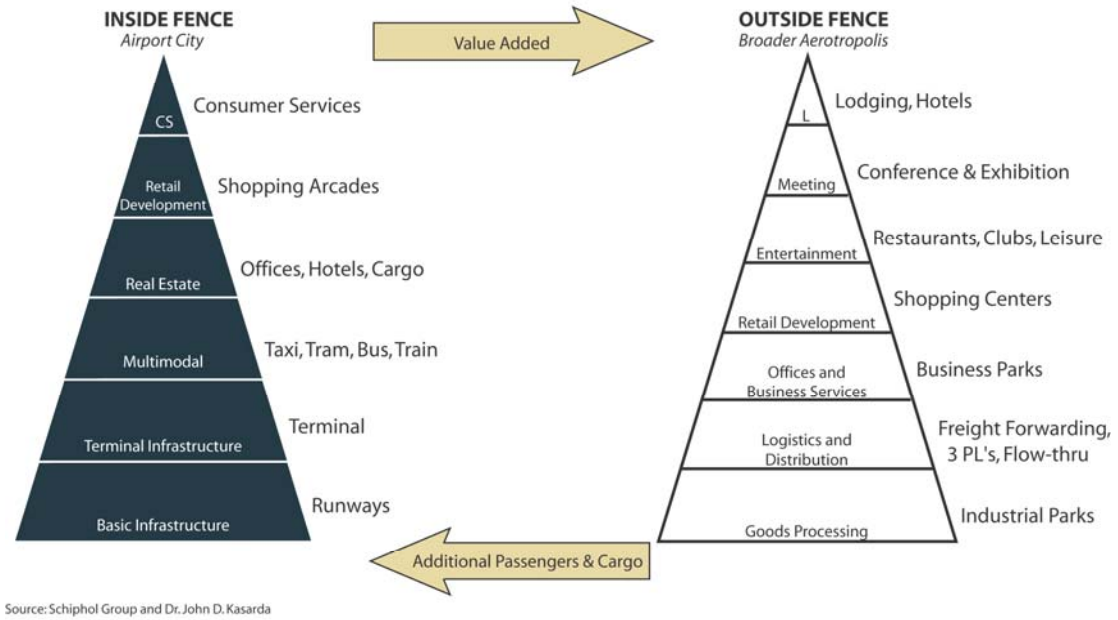

Figure 11. Aerotropolis synergies: Added value activities in a wider airport concept (*Source: Kasarda, 2006*)

4.4 Some thoughts for future

- India has tremendous potential for air transport. Future growth in air traffic will be fuelled by feeder sector, as the hinterland opens up industry, service and tourism.
- The advancements in technology of regional aircraft are not at par with the larger aircraft (**Figure 12**).
- There is will an incremental demand for fossil fuel due to ever increasing air traffic. As the biofuel for jets has made slow progress, there is an urgent need to focus research on alternative jet fuels for carbon-neutral air transportation system. For example viability of liquid hydrogen as an aviation fuel is to be explored (*Janić, 2008*). British Airways is planning to establish Europe's first green jet fuel plant that will turn land fill waste into carbon-neutral aviation fuel (*Times of India, 2010*).
- Emerging transport concepts like multi-modal airports, multi-modal vertiports (for Tiltrotor services) (*Reber, 1995)*, and intra-urban mobility mission VTOL air taxies or PAVs (personalized air vehicles) (*Moore, 2003*).
- New conceptual and technological facets for reduced operating costs.
- The future studies should address the role of regulatory, operating agencies like DGCA, AAI and local government in sustainability issues in civil aviation in India.
- Consideration to be given for development of auxiliary requirements.

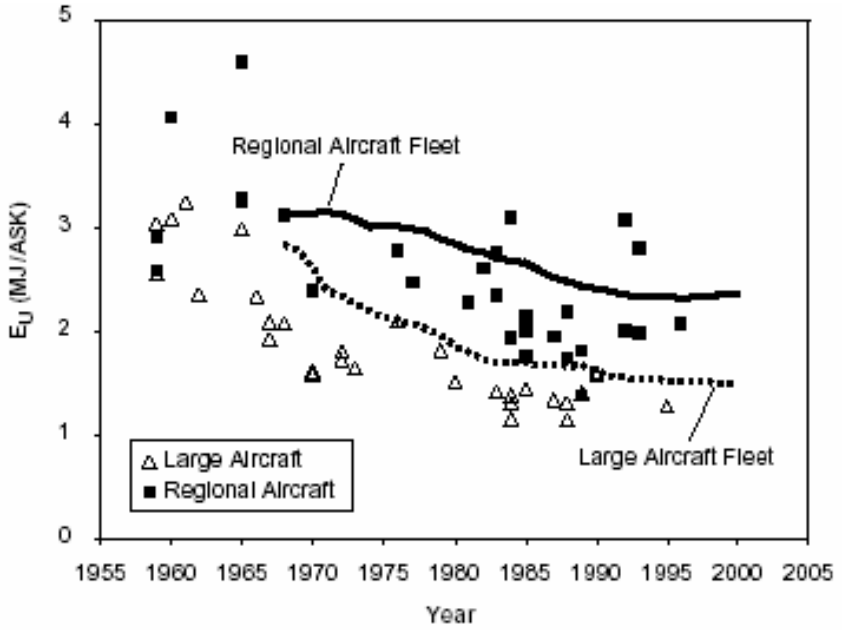

Figure 12. Energy Usage (Eu) of regional jet aircraft compared to larger aircraft (*Source: Rabikian et al, 2002*)

5. CONCLUSIONS

Key issues and perspectives that value to air transport industry and on sustainability of short-haul regional air transportation in the Indian context were discussed in this paper based on the past experiences of feeder and short-haul air services in India and elsewhere. Various ways to think about the future of air transport industry concerning the various facets of short-haul regional air travel in India have been briefly outlined with a focus on the contemporary overview of short-haul air transport systems. It will be prudent if airlines/ air transport industry aligns market shifts with products/ attributes (network, aircraft size, and frequency), cost

structure, financial resources etc. The strategy to match these attributes can produce profits that are sustainable over a long period of time. Future perspectives calls for decisions and judicious plans by the leadership members in government, airports, airline operators, aircraft design, development and production agencies, surface transport authorities etc. The literature review indicates that there have been efforts to address these issues but attempted each aspect separately. This paper generates an argument for the need for a comprehensive approach to examine all facets from the perspective of service providers (supply) and users (demand), which can contribute to understand the complexities of feeder and short-haul air transport systems under regional economies, multi-modal, social dimension (positive effects or benefits) and environmental concerns (negative impacts or costs), which can have multiplier effects on overall economic prosperity of India. The establishment of such a system will be of immense help for attaining consolidation and growth of civil aviation industry.

Considering the air passenger traffic increase during 2003-08 and the future growth potential of tier III (class C) and tier IV (class D) cities, there is need for sustainable feeder and short-haul regional air services in India. The advent of low cost carriers (LCCs) has moved passenger traffic from upper class rail to air transport. It is expected that the future growth will be led by feeder sector thereby creating tremendous opportunities for economically viable operations. To sustain the traffic growth, the rational selection of route, passenger friendly frequency with a mix of aircraft size viz., 10-20, 30-50, and 70-100 seating capacity are to be taken into account. The aircraft type is likely to be turbo prop due to its better specific fuel consumption (SFC), as prices of aviation turbine fuel (ATF) will continue to fluctuate upwards. A simplified approach and macroscopic aggregate measure was presented for quick assessment of alternative fleet scenarios and possibly reflect a quick method of estimating passenger traffic, aircraft and fleet size for serving short-haul air network in India.

The rationalization of network configuration (degree of connectivity) and development of profitability index curves will serve as a renewed operating/ business model to look at the extent to which a trade-off can be made to achieve the twin objectives of regional air connectivity (from policy/ social obligation point of view) and retain the interests of air carriers. With the ever-increasing number of airlines, desirous of operating from India, it was considered appropriate that the emphasis should be on ‘sustainable‘. Finally, some thoughts for future like alternative ‘carbon-neutral’/ green aviation fuels for air transport are put forward. It is expected that this paper can contribute to understand the complexities of short-haul regional air transport systems and complement the academic pursuit and research efforts in this field.

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Note:
The observations and results expressed/ presented in this paper are entirely of author's own and need not necessarily reflect the views of National Aerospace Laboratories (CSIR).

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