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A review of domestic air transportation in India

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Abstract

There were 7 private airlines operated in 1952 in India. After nationalization of airlines in India, exclusive public sector operations were performed from 1953 to 1991. The open sky policy in 1991 again allowed private airlines. India's vast unutilized air transport network has attracted several investments in the past few years. The paper draws inspiration in providing accessibility to regional economies and remote areas considering the continuing economic growth, increase in mobility levels, shift of premium rail passengers to air transport. There are changes in economic and business aspects (mergers and alliances), in addition to the evolution of air transport networks (spatial and time configuration of routes) over the years. This paper will focus on these developments and analyses the status of air transport by highlighting the promising areas of interest in civil aviation Industry in general and domestic air passenger transport system in particular in the Indian context.

Keywords: domestic air transport, passenger traffic, airline network, load factors, modal split, access and egress time, aircraft fleet composition, fuel consumption.

1. Introduction

Air Transport is the newest of the major modes of transportation and has grown rapidly since the world war II. Although its share of the total passenger traffic in comparison to other modes is very less, air transportation handles a significant volume of traffic on long sectors connecting metropolitan cities. Air transport has a distant advantage over surface transport due to its superiority in speed and substantial saving in time over long distance. Thus, domestic

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air transport plays an important role in overall transport services of a country. In India, air transport contribution is even more significant as many areas are located in difficult geographical terrain which are linked by slow means of surface transportation. In view of this air transportation provides socio-economic linkage of these places to the rest of the country [1, Ravi Shankar, 1991].

The existing network for domestic air travel needs analysis of demand and supply. With the influence of increasing population and other related economic growth factors, the air travel is going to be used more frequently creating higher demands. Since operational and infrastructure decisions involve significant capital investments compared other modes, scientific assessment is necessary. In this context, rationalization of the air network in relation to demand and fleet planning considering available technology will definitely fetches added benefits. While systematic planning can guide fleet composition, their deployment in a network for alternative operational strategies. Thus satisfying the national and regional integration of social and economic objectives.

Technology innovation has great importance in air transportation. Advancement in technology has led to improvements in passenger comfort and also other aspects of airlines productivity such as punctuality/ reliability. However, its most important effect was on operating costs. The change over from piston to turbo-prop and jet propulsion has led to a reduction in fuel consumption. The fuel price constitutes a greater significance in aviation industry.

India witnessed the highest ever air traffic growth of 45% during 2006-07. The number of airports in India are 449 and out of these 199 airports are classified as operational for civilian purpose. Presently, 83 airports are being served by 9 scheduled airlines. Majority of low-cost carriers (LCCs) have entered the Indian aviation market from 2004 onwards. An analysis of air traffic indicates that the embarked load factors vary 20 to 70 percent in majority of class-II to IV cities. This strongly indicates that there is a need to rationalize and use right type of aircraft because majority of the fleet presently operated are with seating capacity ranging from 119 to 168. The presently connected cities in short-haul air sectors may not justify the use of bigger aircraft. Hence, domestic airline operations in India need a re-look in terms of fleet composition and size, route network, frequencies.

There were seven private airlines operated in 1952 in India. After nationalization of airlines in India, exclusive public sector operations were performed during 1953-1991. Liberalisation in 1991 again allowed private sector airlines. India witnessed air traffic growth of 45% in 2006-07. An attempt has been made in this paper to review the domestic airline operations with respect to the hierarchy of air network in India. The number of airports in India is 449 and out of these 211 has ICAO/IATA ID, 199 are classified as operational for civilian purpose, and 65 are being used by scheduled flights. These includes, half a dozen low-cost carriers (LCCs) entered the Indian market during 2004-2009. Number of aircraft in India increased from 125 to 400 in the last three years and likely to touch 1000 by end of this decade. Most of the fleet presently operated are with B-737 (119-168 seats), A-320 (146 seats), and ATR (48-62 seats). The services in Northeast India are based on route dispersal guidelines and are not purely governed by local requirement or economics. Sometimes these obligations are traded between airlines.

Nomenclature

ELF	Embarked Load Factors
LCC	Low Cost Carriers
ICAO	International Civil Aviation Organisation
IATA	International Air Transport Association
DGCA	Director General Civil Aviation
CAGR	Compound Annual Growth Rate
AAI	Airports Authority of India
NH	National Highways
BT	Block Time

2. Air transport structure

Categorization of Air transportation

Air transportation is generally categorized as commuter/feeder, short, medium and long haul based on the range and seating capacity (Table 1).

Table 1. 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

Commuter/Feeder category usually consists of un-pressurised turboprop aircraft (such as Fairchild, Dornier D-228 and Jetstream 31) which are mainly employed either on routes with very low travel demand, or as feeders to the hubs from the spokes. Short Haul category covers turboprop or turbofan engined aircraft with slightly larger range and capacity (such as ATR-72, SAAB 2000 or Avro RJ-100) which are used on regional routes or for providing point-to-point service (hub-bypassing) on busy routes. Medium haul covers aircraft such as Airbus 330 or Boeing 757, which are deployed on national or international routes, whereas Long Haul represents aircraft such as Boeing 747 and Airbus 340, are operated on intercontinental or high-density routes.

2.1 Heirarchy of Airline network in India

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

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

The feeder routes are generally classified in the range of 100 to 500 km (this is only an indicative for the sake of convenient classification in the Indian context with exceptions like Bangalore-Chennai sector etc). As per the 2004 estimates based on DGCA data (Director General of Civil Aviation, India), **Table 1** show the number of routes and the passengers carried and **Table 2 represents** the share of each route over the total passengers carried. **Figure 1** shows the time-series trend in growth of passengers carried during 2000-2004 [2, DGCA website]**.**

Table 1. Hierarchy of airline network in India (year 2004)

Route	Trunk Route	Major Route	Feeder Route	Total
Number of routes (per direction)	6	78	76	160
Passengers carried (per week per direction)	42,001	2,35,471	29,462	3,06,934
Percent of total traffic carried	13.7	76.7	9.6	100

The compound annual growth rate (CAGR) over this period for trunk, major and feeder routes are 10, 4, and 2 percent respectively.

Table 2. Share of passengers carried by three categories of routes

S.No	Year	TRUNK	MAJOR	FEEDER	share (Trunk routes)	share (Major routes)	share (Feeder routes)
1	1999-00	28,738	202,946	27,758	11.1%	78.2%	10.7%
2	2000-01	30,704	220,094	29,718	10.9%	78.5%	10.6%
3	2001-02	28,206	195,236	27,262	11.3%	77.9%	10.9%
4	2002-03	34,590	215,092	28,246	12.4%	77.4%	10.2%
5	2003-04	42,001	235,471	29,462	13.7%	76.7%	9.6%

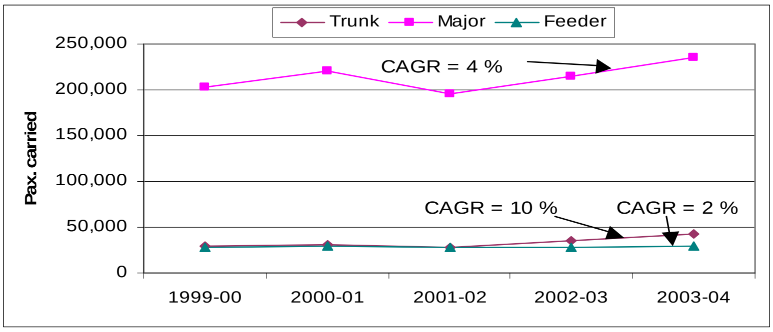


Figure 1. Trends in growth of passengers carried

The share of feeder routes over the last five years has marginally declined from 11 to 10 percent, whereas the trunk routes share has increased from 11 percent in 1999 to 14 percent in 2004.

2.2 Airport Statistics in India

The number of airports / aerodromes in India is 449 and out of these only 211 has ICAO/IATA ID [2 DGCA website, 3 Bhargava Kapil 2005]. The number of airports classified as operational for civilian purpose are 199 (44 percent of total). Out of these operational airports, 84 are managed by Airports Authority of India (AAI), 87 are under state/ private ownership and 28 are civil enclaves in defence airports. But it is surprising to note that only 65 airports (one third of total operational) are being used by scheduled flights in 2008. Presently, 83 airports are being served by 9 scheduled airlines.

2.3 Air passenger traffic in India

Based on the preliminary examination of published schedules of three airlines (Indian Airlines, Jet Airways, and erstwhile Air Sahara) in India and the DGCA airport statistics, around 65 cities are connected by air. The population of each city, its classification as major city (classified as A class /tier-I city in India: Table 3) and the total passengers handled along with embarked load factors are presented in Figure 2 to 6 [4, 5]. Classification of cities merely allows the pattern to be viewed in one more dimension.

Table 3. Classification of cities

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	

Analysis of the data clearly shows that all State headquarters are connected. There is air connectivity due to economic activity, tourism or if a destination has religious importance, in addition to DGCA route dispersal guidelines. Population of the cities by themselves is not a criterion for them to be connected. Historically, the airlines have commenced operations [4, 5], where airports are available and infrastructure has been provided. Analysis of the data indicates that there are 14 cities in the North, 17 in the South, 7 in East, 16 in the West and 11 in the North East region that have air connectivity.

Figure 2 to 6 shows the measure of total passengers embarking and disembarking by the aircraft movements from a city and this information can provide indicative system load factor of each of the metro/city/town. It is clear from figures that certain cities like Chandigarh, Port Blair, Bhopal, Rajkot, Jodhpur, Raipur, Aijwal, Jorhat, Dimapur, Diu show higher CAGR (10 percent and above during 1996-2004), 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. Table 5 presents ELF of 2014 study in comparison to analysis of 2014 data as shown in Figures 2 to 6.

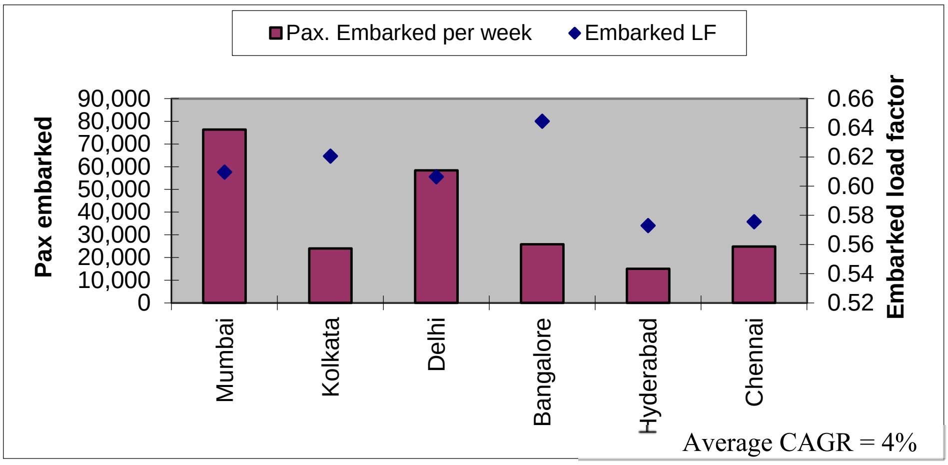


Figure 2. Passengers embarked and ELF for major metro (class A) cities

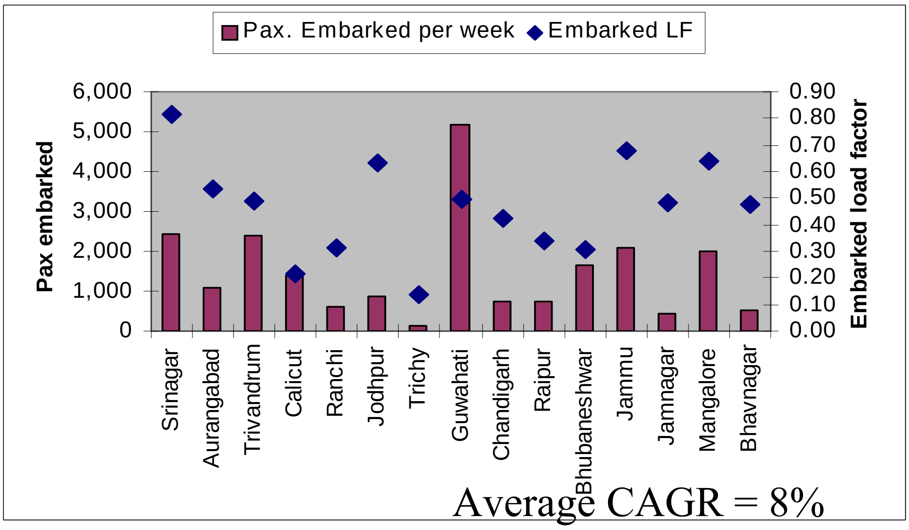


Figure 3. Passengers embarked and ELF for Metro (class A) cities

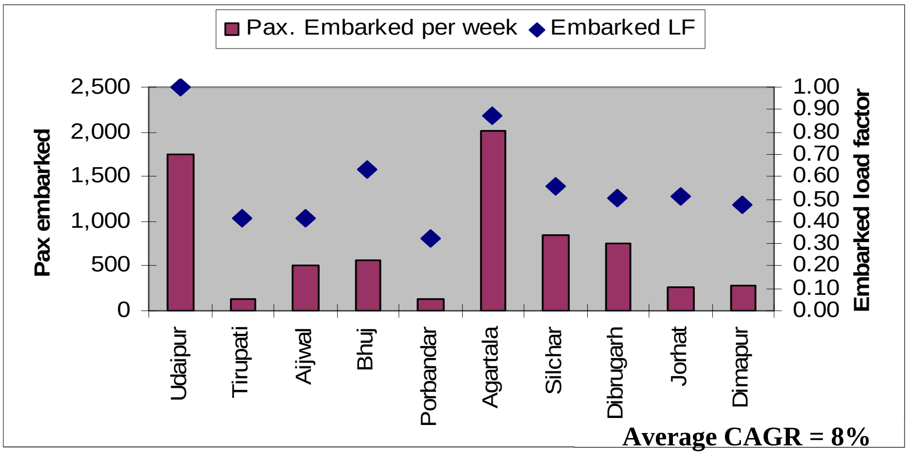


Figure 4. Passengers embarked and ELF for Class B cities

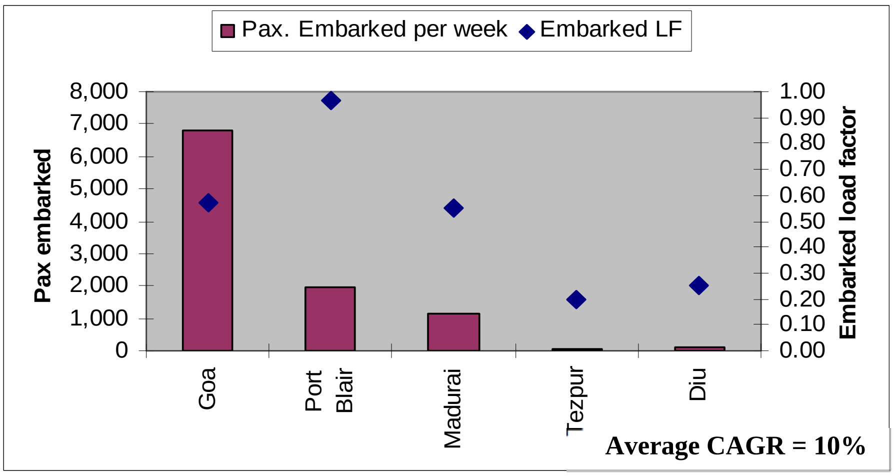


Figure 5. Passengers embarked and ELF for class C cities

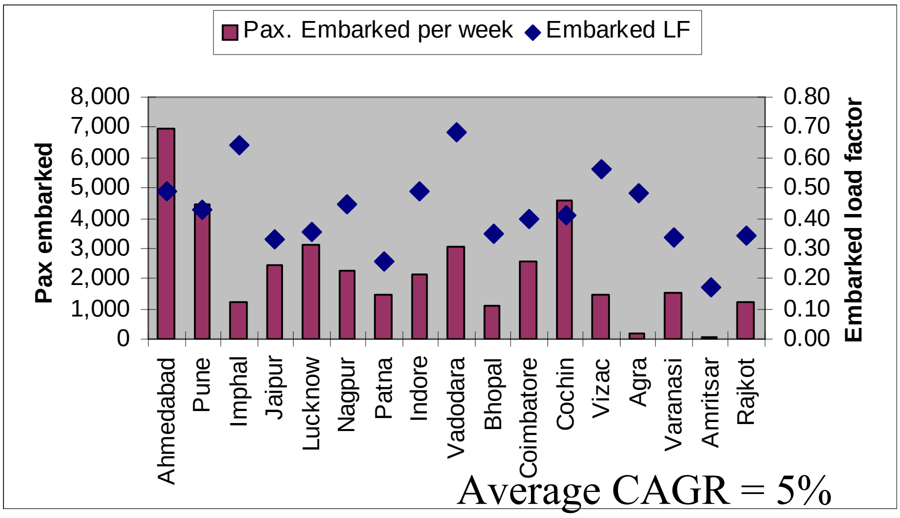


Figure 6. Passengers embarked and ELF for class D cities

It is clear from these figures that these gross embarked load factors (ELFs) indicate that there is a need to rationalize and introduce the right type of aircraft from an origin city to other destinations. An analysis of embarked load factors clearly indicates that there are a number of cities where the ELFs vary from 20 percent on some routes to more than 70 percent on other routes. 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 use small aircraft, because most of the fleet presently operated are with B-737, A-320, ATR aircraft. A similar study has been conducted to in 2014 to analyse the ELF pattern. **Table 4** enumerates the fleet composition presently being deployed on feeder routes. **Table 5** represents the comparative numbers pertaining to 2004 and 2014. The feeder services in North East 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, domestic air transport operations in India need a re-look in terms of fleet composition and size, route network, frequencies and fare structure.

Table 4. Present aircraft fleet composition on feeder routes

Aircraft Type	Seating capacity
ATR - 42	48 seats
ATR - 72	62 seats
B - 737	119 to 168 seats
AB - 320	146 seats
CRJ - 200	50 seats
ERJ - 145	50 seats

Table 5. Present aircraft fleet composition on feeder routes

S.N	Airport	Pax/dy 2011-12	Aircraft Type										AS/day 2011-12	ELF	
			Turboprops				Jets				Total				
			AS/dy	%	AM/dy	%	AS/dy	%	AM/dy	%	AS/dy	AM/dy		2012	2004
							Class - A cities								
1	Mumbai	28901	273	1%	4	2%	38162	99%	227	98%	38435	231	45738	63%	61%
2	Kolkata	12047	746	4%	13	11%	17827	96%	104	89%	18573	117	22102	55%	62%
3	Delhi	34478	1335	3%	19	7%	42793	97%	254	93%	44128	273	52512	66%	60%
4	Bangalore	14203	1257	7%	17	14%	17305	93%	101	86%	18562	118	22089	64%	64%
5	Hyderabad	9203	2301	15%	32	30%	12546	85%	74	70%	14847	106	17668	52%	57%
6	Chennai	11844	1952	11%	27	23%	15848	89%	92	77%	17800	119	21182	56%	57%
7	Ahmedabad	5456	65	1%	1	3%	6430	99%	37	97%	6495	38	7729	71%	50%
8	Pune	4375	208	3%	3	8%	6027	97%	35	92%	6235	38	7420	59%	43%
9	Imphal	1021	148	11%	3	30%	1142	89%	7	70%	1290	10	1535	67%	65%
10	Jaipur	2135	0	0%	0	0%	3474	100%	20	100%	3474	20	4134	52%	33%
11	Lucknow	2306	130	4%	2	9%	3354	96%	20	91%	3484	22	4146	56%	45%
12	Nagpur	1929	65	2%	1	6%	2957	98%	17	94%	3022	18	3596	54%	44%
13	Patna	1432	0	0%	0	0%	2049	100%	13	100%	2049	13	2438	59%	25%
14	Indore	1512	286	11%	4	21%	2383	89%	15	79%	2669	19	3176	48%	50%
15	Vadodara	898	65	4%	1	9%	1569	96%	10	91%	1634	11	1944	46%	70%
16	Bhopal	534	468	45%	7	64%	578	55%	4	36%	1046	11	1245	43%	35%
17	Coimbatore	1735	178	6%	3	15%	2968	94%	17	85%	3146	20	3744	46%	40%
18	Cochin	2940	433	10%	7	24%	3843	90%	22	76%	4276	29	5088	58%	40%
19	Vizag	1262	221	10%	3	20%	2049	90%	12	80%	2270	15	2701	47%	56%
20	Agra	0	1	100%	1	100%	0	0%	0	0%	1	1	1	0%	49%
21	Varanasi	864	65	4%	1	11%	1397	96%	8	89%	1462	9	1740	50%	34%
22	Amritsar	687	315	31%	6	60%	690	69%	4	40%	1005	10	1196	57%	35%
23	Rajkot	338	0	0%	0	0%	566	100%	4	100%	566	4	674	50%	35%
							Class - B cities								
24	Srinagar	2261	0	0%	0	0%	2934	100%	17	100%	2934	17	3491	65%	82%
25	Aurangabad	533	78	9%	1	17%	800	91%	5	83%	878	6	1045	51%	52%
26	Trivandrum	1328	221	12%	3	23%	1689	88%	10	77%	1910	13	2273	58%	50%
27	Calicut	311	212	28%	3	50%	547	72%	3	50%	759	6	903	34%	22%
28	Ranchi	657	65	6%	1	14%	941	94%	6	86%	1006	7	1197	55%	31%
29	Jodhpur	270	0	0%	0	0%	596	100%	4	100%	596	4	709	38%	64%
30	Trichy	151	197	100%	3	100%	0	0%	0	0%	197	3	234	64%	15%
31	Guwahati	3115	418	8%	8	22%	4774	92%	28	78%	5192	36	6178	50%	50%
32	Chandigarh	1106	259	12%	5	33%	1830	88%	10	67%	2089	15	2486	44%	42%
33	Raipur	1082	130	7%	2	17%	1622	93%	10	83%	1752	12	2085	52%	34%
34	Bhuvaneswar	1711	0	0%	0	0%	3084	100%	19	100%	3084	19	3670	47%	30%
35	Jammu	1191	19	1%	1	6%	2583	99%	15	94%	2602	16	3096	38%	69%
36	Jamnagar	0	0	0%	0	0%	128	100%	1	100%	128	1	152	0%	48%
37	Mangalore	839	212	16%	3	30%	1103	84%	7	70%	1315	10	1565	54%	64%
38	Bhavnagar	0	0	0%	0	0%	146	100%	1	100%	146	1	174	0%	47%
							Class - C cities								
39	Udaipur	448	130	20%	2	33%	530	80%	4	67%	660	6	785	57%	100%
40	Tirupati	298	156	32%	2	50%	339	68%	2	50%	495	4	589	51%	40%
41	Aijwal	0	178	55%	3	75%	146	45%	1	25%	324	4	386	0%	40%
42	Bhuj	0	65	28%	1	50%	170	72%	1	50%	235	2	280	0%	62%
43	Porbander	0	65	100%	1	100%	0	0%	0	0%	65	1	77	0%	32%
44	Agartala	1203	182	10%	3	25%	1637	90%	9	75%	1819	12	2165	56%	90%
45	Silchar	286	380	80%	7	88%	94	20%	1	13%	474	8	564	51%	55%
46	Dibrugarh	314	0	0%	0	0%	613	100%	4	100%	613	4	729	43%	50%
47	Jorhat	0	71	35%	1	50%	133	65%	1	50%	204	2	243	0%	50%
48	Dimapur	0	147	60%	3	75%	98	40%	1	25%	245	4	292	0%	46%
							Class - D cities								
49	Goa	3856	230	5%	3	10%	4839	95%	27	90%	5069	30	6032	64%	60%
50	Portblair	788	0	0%	0	0%	1441	100%	9	100%	1441	9	1715	46%	95%
51	Madurai	700	448	41%	7	64%	641	59%	4	36%	1089	11	1296	54%	60%
52	Tejpur	0	41	100%	1	100%	0	0%	0	0%	41	1	49	0%	20%
53	Diu	0	65	100%	1	100%	0	0%	0	0%	65	1	77	0%	25%
55	Khajuraho	0	0	0%	0	0%	158	100%	1	100%	158	1	188	0%	20%
56	Baghdogra	1004	0	0%	0	0%	1357	100%	8	100%	1357	8	1615	62%	40%
57	Agatti	0	41	100%	1	100%	0	0%	0	0%	41	1	49	0%	94%
	AS/dy = Available seats/day, AM/dy = Aircraft movements/day, ELF = Embarked Load Factor														

3. Modal split in intercity transportation in India

The extent of transport network reflects a multiplier effect in the economic development of any country and India is no exception to this. Railways, Roadways, and Airlines are the main mode of passenger transport in India.

Roadways are generally preferred for short travel, while for long distance travel (range of 500 km and more), the preferred modes nowadays are railways and airlines. As per the available data in public domain, 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 premium rail travel, especially for short haul travel. Though NHs constitutes only 2 percent of total road length, but it carries around 40 percent of total road traffic. This indirectly indicates that the NH network is not developing at par with the growth of traffic expected on it. With respect to rail (track) density, Northern region, West Bengal, and Tamil Nadu accounts for higher proportion [6].

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 7), the airlines and railways grew by 7 and 5 percent (CAGR) respectively, while the roadways experienced a negative growth (-2%). The share of intercity traffic among modes for the same period indicates the share of railways has increased to 61 percent from 48 percent, wheras the airline's share has marginally increased from 1.2 percent in 1996 to 1.7 percent in 2004.

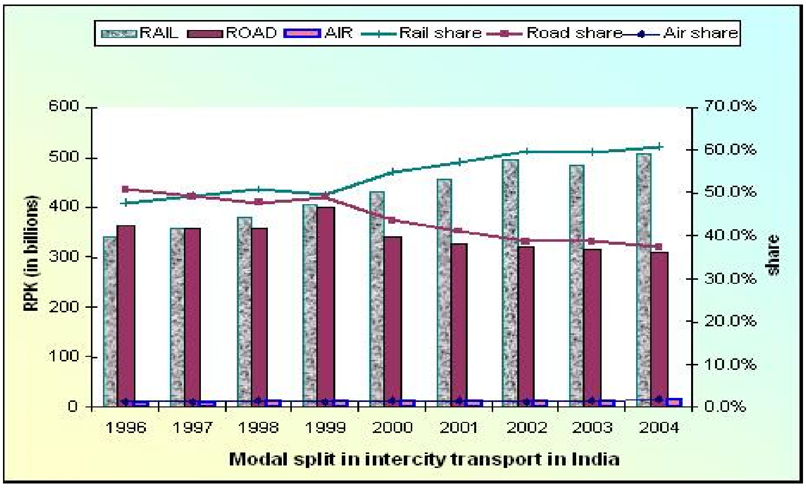


Figure 7. Long-term trends in growth of intercity transport (pax-km in mn)

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

The time series data on the growth trends in intercity rail (upper class) and air transport shown in **Figure 8** clearly indicates that the introduction of Shatabti and Rajdhani 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.

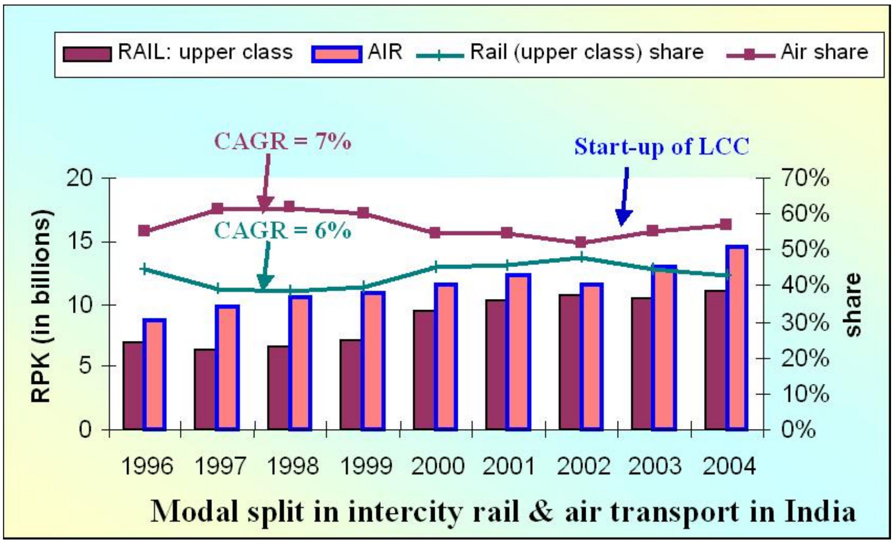


Figure 8. Passenger traffic carried by upper class rail and air transport

4. Air travel time

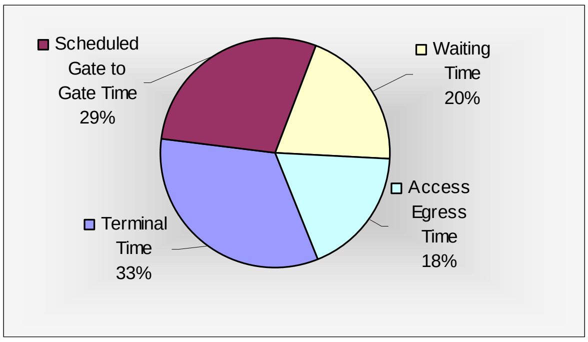
Comparison of travel time and fuel consumption: Turboprop Vs Turbofan

Difference in travel time

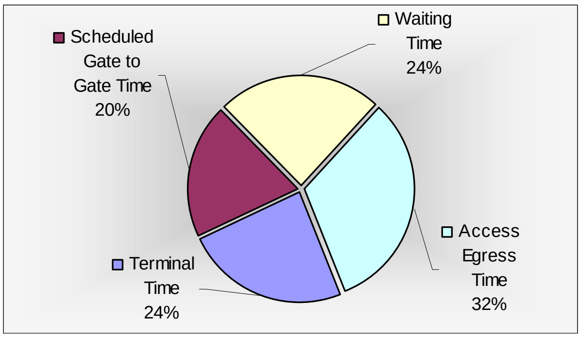
The total door-to-door time consists of
- (i) Access time (home to airport)
- (ii) Airport time
- **(iii) Actual airborne time**
- (iv) Egress time (airport to home/ destination)

4.1 Access and egress time

Studies showed that for distances of 300 km by air, the air travel speed is 250 kmph and average journey speed (door-to-door) is 100 kmph and constituting approximately 60% of the total travel time as access and egress time. The international experience indicates that for 300-400 km distances there is only little difference in door-to-door speed for fast rail and air transport. Similarly for distances of 1000 km by air, the air travel speed is 700 kmph and door-to-door speed is 300 kmph and approximately 33% is access and egress time [7]. A study conducted by Volpe in cooperation with NASA shows that 29% of total door-to-door trip time is the actual gate to-gate time for the airliner for trips under 500 miles [**Figure 9**(**a**)]. Similar observations in India shows that gate to-gate time and access-egress time accounts approximately 20% and 32% of total trip time respectively for a typical 800 km distance [**Figure 9**(**b**)].



9(a). for Volpe commercial airline (Source: Moore 2003)



9(b). for a typical Indian city pair

Figure 9. Typical breakdown of door-to-door trip time

The airport travellers often cannot afford to depend on the average access time and risk involved in missing a flight. The bottlenecks associated with traffic congestion result in increased access time in the access routes to most of the Indian airports. Improved access time on corridors leading to airports is not only beneficial to air passengers, visitors to the airport, airport and service staff but also to domestic traffic proximity to access corridors and traffic to Tech Parks/Special Economic Zones (SEZ's) located close to airports

Irrespective of aircraft type, the time related to (i), (ii), and (iv) are the same. Therefore, only air time (block time) is considered here for the travel time comparison purpose.

The following block distances are considered keeping in view the regional airline sectors:
(i). 250 km, (ii). 550 km, (iii). 750 km

Aircraft seat capacity:

50 seat capacity turboprop aircraft: ATR-42, D-8/ Q-300
50 seat capacity turbofan aircraft: E-145
70 seat capacity turboprop aircraft: ATR-72, D-8/ Q-400
70-100 seat capacity turbofan aircraft: CRJ-700/900, A-319-100, B-737-200

From **Table 5**, it is evident that for block distance of 250 km, there is not much significant difference in travel time. But, there is a difference of 30-45 minutes in the case of ATR-72 Vs other turbofans for block distances of 550 km and 750 km. For block distances of 550 km and 750 km, the travel times of high performance turboprop like Q-400 are comparable with turbofan aircraft like A319-100 and B-737-200.

Table 5. Difference in Travel Time: Turboprop Vs Turbofan

Details	**Block Time (BT): ATR-42 Vs E-145**				
	ATR-42		Embraer-145		
Seat capacity	48-50 (50)		50		
Normal Speed (kmh)	463		587		
Block Distance (km)	BT (Minutes)	Hour Minutes	BT (Minutes)	Hour Minutes	Time saving (minutes)
250	47	0 hr 47 min	41	0 hr 41 min	7
550	86	1 hr 26 min	71	1 hr 11 min	15
750	112	1 hr 52 min	92	1 hr 32 min	21
Details	**Block Time (BT): Dash-8 (Q-300) Vs E-145**				
	Dash-8 (Q-300)		Embraer-145		
Seat capacity	50-56 (50)		50		
Normal Speed (kmh)	528		587		
Block Distance (km)	BT (Minutes)	Hour Minutes	BT (Minutes)	Hour Minutes	Time saving (minutes)
250	43	0 hr 43 min	41	0 hr 41 min	3
550	78	1 hr 18 min	71	1 hr 11 min	6
750	100	1 hr 40 min	92	1 hr 32 min	9
Details	**Block Time (BT): ATR-72 Vs CRJ-700**				
	ATR-72		CRJ-700		
Seat capacity	64-74 (70)		66-78 (70)		
Normal Speed (kmh)	457		817		
Block Distance (km)	BT (Minutes)	Hour Minutes	BT (Minutes)	Hour Minutes	Time saving (minutes)
250	48	0 hr 48 min	33	0 hr 33 min	14
550	87	1 hr 27 min	55	0 hr 55 min	32
750	113	1 hr 53 min	70	1 hr 10 min	43
Details	**Block Time (BT): Dash-8 (Q-400) Vs CRJ-700**				
	Dash-8 (Q-400)		CRJ-700		
Seat capacity	68-80 (70)		66-78 (70)		
Normal Speed (kmh)	667		817		
Block Distance (km)	BT (Minutes)	Hour Minutes	BT (Minutes)	Hour Minutes	Time saving (minutes)
250	37	0 hr 43 min	33	0 hr 41 min	4
550	64	1 hr 18 min	55	1 hr 11 min	9
750	82	1 hr 40 min	70	1 hr 32 min	12

Table 5. Difference in Travel Time: Turboprop Vs Turbofan Contd…………

Details	**Block Time (BT): ATR-72 Vs A-319-100**				
	ATR-72		A-319-100		
Seat capacity	64-74 (70)		124-134-156 (100)		
Normal Speed (kmh)	457		713		
Block Distance (km)	BT (Minutes)	Hour Minutes	BT (Minutes)	Hour Minutes	Time saving (minutes)
250	48	0 hr 48 min	36	0 hr 36 min	12
550	87	1 hr 27 min	61	1 hr 1 min	26
750	113	1 hr 53 min	78	1 hr 18 min	35
Details	**Block Time (BT): Dash-8 (Q-400) Vs A-319-100**				
	Dash-8 (Q-400)		A-319-100		
Seat capacity	68-80 (70)		124-134-156 (100)		
Normal Speed (kmh)	667		713		
Block Distance (km)	BT (Minutes)	Hour Minutes	BT (Minutes)	Hour Minutes	Time saving (minutes)
250	37	0 hr 37 min	36	0 hr 36 min	1
550	64	1 hr 4 min	61	0 hr 1 min	3
750	82	1 hr 22 min	78	1 hr 18 min	4

Details	**Block Time (BT): ATR-72 Vs B-737-200**				
	ATR-72		B-737-200		
Seat capacity	64-74 (70)		97-115-136 (100)		
Normal Speed (kmh)	457		672		
Block Distance (km)	BT (Minutes)	Hour Minutes	BT (Minutes)	Hour Minutes	Time saving (minutes)
250	48	0 hr 38 min	37	0 hr 36 min	11
550	87	1 hr 27 min	64	1 hr 1 min	23
750	113	1 hr 53 min	82	1 hr 18 min	32
Details	**Block Time (BT): Dash-8 (Q-400) Vs B-737-200**				
	Dash-8 (Q-400)		B-737-200		
Seat capacity	68-80 (70)		97-115-136 (100)		
Normal Speed (kmh)	667		672		
Block Distance (km)	BT (Minutes)	Hour Minutes	BT (Minutes)	Hour Minutes	Time saving (minutes)
250	37	0 hr 37 min	37	0 hr 37 min	0
550	64	1 hr 4 min	64	1 hr 4 min	0
750	82	1 hr 22 min	82	1 hr 22 min	1

4.2 Fuel Consumption with respect to block distance

Table 6 shows that significant amount of fuel saving if turboprop aircraft are operated to serve regional or short-haul airline sectors.

Table 6. Difference in Fuel Consumption: Turboprop Vs Turbofan

Details	**Fuel Consumption: ATR-72 Vs A-319-100**							
	ATR-72			A-319-100				
Seat capacity	64-74 (70)		FC (kg/hr)	124-134-156 (100)		FC (kg/hr)		ATF (Rs/L)
Economy Cruise Speed (kmh)	457		720	713		1980		75
Block Distance (km)	Block Time (Minutes)	Block Time (hrs)	Fuel (kg)	Block Time (Minutes)	Block Time (hrs)	Fuel (kg)	Fuel saving (kgs)	Fuel saving (Rs.)
250	48	0.80	574	36	0.60	1189	615	46,153
550	87	1.45	1047	61	1.02	2022	976	73,187
750	113	1.89	1362	78	1.30	2578	1216	91,210
Details	**Fuel Consumption: Dash-8 (Q-400) Vs A-319-100**							
	Dash-8 (Q-400)			A-319-100				
Seat capacity	68-80 (70)		FC (kg/hr)	124-134-156 (100)		FC (kg/hr)		ATF (Rs/L)
Economy Cruise Speed (kmh)	667		1160	713		1980		75
Block Distance (km)	Block Time (Minutes)	Block Time (hrs)	Fuel (kg)	Block Time (Minutes)	Block Time (hrs)	Fuel (kg)	Fuel saving (kgs)	Fuel saving (Rs.)
250	37	0.62	725	36	0.60	1189	464	34,835
550	64	1.07	1247	61	1.02	2022	776	58,187
750	82	1.37	1594	78	1.30	2578	983	73,755
Details	**Fuel Consumption: ATR-72 Vs B-737-200**							
	ATR-72			B-737-200				
Seat capacity	64-74 (70)		FC (kg/hr)	97-115-136 (100)		FC (kg/hr)		ATF (Rs/L)
Economy Cruise Speed (kmh)	457		720	672		2827		75
Block Distance (km)	Block Time (Minutes)	Block Time (hrs)	Fuel (kg)	Block Time (Minutes)	Block Time (hrs)	Fuel (kg)	Fuel saving (kgs)	Fuel saving (Rs.)
250	48	0.80	574	37	0.62	1758	1185	88,844
550	87	1.45	1047	64	1.07	3021	1974	148,050
750	113	1.89	1362	82	1.37	3862	2500	187,520
Details	**Fuel Consumption: Dash-8 (Q-400) Vs B-737-200**							
	Dash-8 (Q-400)			B-737-200				
Seat capacity	68-80 (70)		FC (kg/hr)	97-115-136 (100)		FC (kg/hr)		ATF (Rs/L)
Economy Cruise Speed (kmh)	667		1160	672		2827		75
Block Distance (km)	Block Time (Minutes)	Block Time (hrs)	Fuel (kg)	Block Time (Minutes)	Block Time (hrs)	Fuel (kg)	Fuel saving (kgs)	Fuel saving (Rs.)
250	37	0.62	725	37	0.62	1758	1034	77,526
550	64	1.07	1247	64	1.07	3021	1774	133,049
750	82	1.37	1594	82	1.37	3862	2268	170,065

Travel times of high performance turboprop (eg. D-8/ Q-400) are comparable with 100 seat class of turbofan aircraft. But significant fuel savings can be achieved with most economical turboprops like ATR-72.

5. Conclusions

The paper focuses on review of domestic air transport system in India. The world experience shows that thin routes are generally served with small aircraft. Air transport provides employment and enables certain economic activities which are dependent on the availability of air transport services. The regional economy, in turn, drives the demand for air transport services. This type of review studies can help to guide development efforts, invest and policy decisions related to air transport in fast developing economies like India. It is expected that this paper can complement the research efforts in that direction.

References

1. Ravi Shankar A.U., 1991. Capacity Planning of Domestic Airline Passenger Services. Ph.D. thesis, University of Roorkee (Now IIT Roorkee), January 1991.
2. http://www.dgca.nic.in
3. Bhargava Kapil., "Status of India's Airports. Aerodrome India 2005: International Exhibition & Seminar on Airport Security & Infrastructure", Daily Show special publication by Indian Aviation, December 7, 2005.
4. Narayan Yegna K., Kodanda B., 2005. Feeder airline operations in India: Present and Future. Proceedings of the Aerodrome India 2005: International exhibition & seminar on airport security & infrastructure, 7-10 December 2005, Bangalore.
5. Chandra Satish, Kodanda B, Sridhar B C., "Air Traffic Stratification in India: Pointers for Fleet Ratioanlisation and Yield Management". TM CA0301, Dec 2003.
6. CMIE report: Infrastructure; Dec 1999, Jan 2001, March 2004, and October 2005.
7. Rallis Tom and Peen Jens. (1990) 'The traffic connection between airports and city centers', Journal of Advanced Transportation, **24**(3), pp 241-260.

Bibliography

1. Census of India 2001, 2011 (www.censusindia.net)
2. http://www.thehindubusinessline.com/2005/11/28/stories/2005112800460600.htm
3. John F, O' Connell., George Williams., 2006. Transformation of India's domestic Airlines: A case study of Indian Airlines, Jet Airways, Air Sahara and Air Deccan. Journal of Air Transport Management, Vol. 12, 2006, pp 358-374.
4. Ministry of Civil Aviation (MoCA)., 2001, 2016. Civil Aviation Policy (www.civilaviation.nic.in/moca); Ministry of Civil Aviation, Government of India
5. Rengaraju, V.R., Thamizh Arasan, V., 1992. "Modeling for Air Travel Demand". Journal of Transportation Engg. (ASCE), Vol.118/3, May/June 1992, pp 371-380.
6. Zhang Anming, 1998. Industrial reform and air transport development in China. Journal of Air Transportation Management, Vol. 4, No. 3, pp 155-164.
7. Hansman, R. John., Ishutkina Maria., 2009. "Analysis of the Interaction between Air Transportation and Economic Activity: A Worldwide Perspective". Massachusetts Institute of Technology (MIT) Research Report No. ICAT-2009-2, International Centre for Air Transportation, (ICAT-MIT), USA.
8. Janić Milan., 2002. `Air Transport System Analysis and Modeling: capacity, quality of services and economics'. Transportation Studies Volume 16, Gordon and Breach Science Publishers, Amsterdam, The Netherlands.
9. Raj Mahindra., 1988. 'Some Thoughts Towards the Establishment of a Civil Aviation industry in India'. CSIR-NAL, Project Document 8805, October 1988.
10. Roddam Narasimha., 2003. 'Can it be Boom - Time for Indian Aerospace? NIAS (National Institute of Advanced Studies) working paper WPI-2003.