ENHANCED REGIONAL AIR TRANSPORTATION IN INDIA- NEEDS, ISSUES AND CHALLENGES

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Abstract

The Indian economy has been growing between 7-9% per annum in the last few years. However much of this growth has taken place in the metros and other major cities. To sustain this growth, it is essential that growth spreads beyond the metros to interior regions of the country. For sustained economic growth, one of the key requirements is connectivity. Air transportation has been acknowledged world over as an important facilitator for economic growth. In particular, affordable air connectivity has proved vital for the smaller towns and cities to attract investment from high technology business. Also to sustain adequate traffic, it is important for the ticket prices to be affordable to the local population and this can only be achieved by the aircraft, right sized incorporating advanced technologies leading to reduced acquisition and operating cost and such an aircraft should have capability to operate from ill equipped airfields in all weather conditions. The key requirements are defined and main technologies that would enable development of such an aircraft are also defined.

Introduction

The Indian economy is growing at 7-9% per annum in the last few years. However most of this growth has taken place in the metros and other major cities. To sustain this growth rate, it is essential that growth spreads beyond the metros to interior regions of the country. One of the key requirements for sustained economic growth is connectivity.

Air transportation has been acknowledged world over as an important facilitator for economic activity and growth. In many of the developed economies, there is evidence that investments in the industry and services sectors have occurred with connectivity being established by air, rail and road infrastructure. In particular, affordable air connectivity has proved vital for the smaller towns and cities to attract investment from high technology industries. For example, when South West Airlines in the US introduced flights to a certain city, it was directly correlated to higher economic activity. Cities like Hubli and Belgaum in India have seen higher industrial growth after the introduction of flights. In an emerging economy like India, where the population is spread evenly across the country which has major metros located nearly 1000 kms apart (Delhi, Mumbai, Chennai, Kolkata) and each state has population more than that of major countries in Europe, air connectivity is important. India has a large services sector catering for the developed countries (like, IT, BPO, KPO etc) and these Companies are now shifting/ready to shift to Tier II and Tier III cities like Mysore, Coimbatore, Indore, Jaipur etc to reduce costs, but however they lay emphasis on air connectivity. While metro-metro load factors could justify a narrow body (Boeing 737, Airbus 320) type of aircraft, the metro to Tier I, Tier II or inter Tier I, Tier II connectivity can only be sustained with smaller regional aircraft, especially if appropriate frequencies and schedules need to be maintained. It is known that such connectivity creates conditions for enhanced economic activity. Apart from these sectors, the Industry, Tourism and Government need access to fast transportation. In times of crises, natural or political, access to these towns and cities are also vital. However, using large capacity aircraft like the narrow bodies on these sectors is not viable. As a result, some airlines in India have used ATR 72s, CRJ 200 and EMB 170 for route rationalization on metro-metro routes and also connecting a hub/metro with a smaller town or city using these aircraft. Ticket pricing on these routes are generally higher on a per km basis and there have been constraints with regard to the cost of the aircraft, fuel burn and maintenance. To enable higher levels of economic activity, it is very important for the ticket prices to be affordable to the local population and this can only be achieved by an

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aircraft right sized and having an operating cost performance that will make it viable.

**Ground Infrastructure**

India has around 450 airfields and these are evenly spread all over the interior regions of the Country. However, only 60 are upgraded enough for current operating environment. These unused airport/airfields are part of the initial endowment that makes the case of developing non-urban air link potentially feasible. However most of these airfields do not have any significant ground facilities. Also some of them are in mountainous regions where weather changes are routine and visibility changes could be quite rapid. The present generation aircraft (A320/Boeing 737/ATR 42/72, Embraer 145/170) can land on all weather conditions only if these airfields are equipped with instrument landing systems (ILS). ILS systems are very expensive to procure and also need extensive and stringent maintenance effort to be kept operational. If we would like to use these airfields and thereby connect the interior and hilly regions of the country, we need aircraft that are equipped with precession approach navigation systems thereby making the aircraft landing and takeoff operation feasible in all weather conditions independent of expensive ground infrastructure [1].

An examination of the existing airfield infrastructure shows two interesting facts (Fig.1[2]). Around 250 out of 450 airfields have runways longer than 5000 feet and 50% of India’s population is within 90 kms of an existing airfield of length greater than 5000 feet of on board and 2/3rd population is within 90 km distance of a 3000 feet runway as described by Bonnefoy in [2]. It would mean that even with existing airfield infrastructure, we could reach almost 2/3rd of the population provided, we have aircraft that could take off and land from a 900m (300 feet) runway and these aircraft are equipped with instrumentation that enable them to land in all weather conditions.

**Emerging Environmental Concerns**

Apart from these issues, a very critical issue related to civil aviation that is gaining increasing importance is emissions. Global civil aircraft emissions have now become a cause of major concern. It was found that if technologies that would reduce emissions could be supported, there would be a need for a new generation aircraft that would be friendly to the environment while serving its purpose of enhancing air transportation. The parameters that determine the pollution are the efficiency of burning fuel in a combustion system and the quantity of fuel that is required to sustain the flight which is a function of efficiency of propulsion system and the drag produced by the airframe to sustain the flight. This would need new generation propulsion and airframe combination that would need less fuel to burn and produce less pollution compared to present generation aircraft. Apart from Propulsion, Aerodynamic Technologies include enabling laminar flow over much of the aircraft, use of super-hydrophobic coatings that will ensure a clean surface and hence laminar flow, use of low cost composites for lower weight and better maintenance, integrated vehicle health monitoring and specifically structural health monitoring for higher reliability and higher maintenance intervals would be required.

**Structure of Air Transportation in India**

India’s demography and economic geography is interesting when mapped against its transportation networks (Fig.2). While, there are pockets of sparse populations, the rest of the country has more or less even distribution of population. Major metros that are nearly 1000 kms apart are magnets for economic activity and spawn connectivity with regions that are typically about 400-600 kms. Added to this, connectivity of State Capitals to major Metros, the National Capital, pilgrimage centers, Tourist destinations all contribute to the transport map. We also see that affluence pockets are more or less evenly distributed. These provide a case for a long range plan for connecting the country by air networks using appropriate aircraft. The road and rail transport networks have provided fair amount of connectivity but these networks have disadvantage of needing large time slots to cover a particular distance and also becoming totally dysfunctional during natural calamities such as floods/earth quakes or in times of conflict.

The disadvantage of air transportation is its prohibitive cost structure. With the introduction of the low cost airlines, the cost of travel came down substantially leading to India becoming one of the fastest growing aviation sectors in the world.

Air India and Private Sector Carriers like Kingfisher, Jet, Indigo, Spice Jet, Paramount etc. operate narrow bodies like Boeing 737 and the A320, a smaller number of wide body aircraft (Boeing 777, Boeing 747, Airbus 340) for International operations and the ATR 42/72, CRJ 200, EMB 170 for regional routes. Typical narrow body and regional aircraft routes are shown in Fig.3 and 4.
The present fleet in the country is as shown in the Table-1.

<table>
<thead>
<tr>
<th>Aircraft Type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wide bodies</td>
<td>62</td>
</tr>
<tr>
<td>Narrow bodies</td>
<td>260</td>
</tr>
<tr>
<td>Regional Aircraft</td>
<td></td>
</tr>
<tr>
<td>Turbo prop</td>
<td>72</td>
</tr>
<tr>
<td>Turbo fan</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>15</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>394</strong></td>
</tr>
</tbody>
</table>

The Indian Civil Aviation Sector is presently passing through a difficult phase with the traffic dropping due to the global economic conditions, very high operating costs driven by high fuel costs which were a reality till recently, high ownership costs and maintenance costs. Thus, it is vital for the survival of the industry, that new aircraft are considered that will reduce the financial pressures on this sector, are suited to India, will connect smaller cities and towns of the industry, operate with greater efficiency, reduce fuel consumption, significantly reduce emissions and with greater capability to operate from ill equipped short airstrips.

Thus it is imperative that we address the technologies that are needed for the efficient connectivity in India. It would mean that there is a need for an aircraft whose acquisition and operating costs are low and should be capable of being operated from airports with minimal infrastructure and instrumentation facility. It may be pertinent to point out that the infrastructure cost for providing air connectivity between city pairs is lower than that for either road or rail connectivity.

### Requirements for a New Generation Regional Aircraft

As shown in the Fig.5 [3], regional aircraft traditionally have been less energy efficient than larger aircraft. This has, as a result, translated into higher ticket prices for passengers. Also the emissions issue which has become quite important is also to be considered for regional aircraft. Here, based on work done by engine companies, turbo-prop aircraft have been known to have lower emissions than turbo-fan apart from lower fuel consumption for a typical stage length.

However, Turbo-fan Aircraft have been preferred aircraft due to higher speed, lower noise levels and comfort. However, Turbo-fan Aircraft have been about 30%-40% more expensive to own, apart from higher fuel costs. Turbofan regional aircraft have also a requirement of a longer field length. Nonetheless, Turbofan regional Aircraft have been used on ‘long-thin’ routes to replace narrow bodies where load factors have been lower. It is clear that both turbo-prop and turbo-fan models have a role in regional air transportation. It is thus important to find a common platform to enable the manufacture of versions of a regional aircraft with either propulsion systems. Fig.6 shows the balance that is required for design of such an aircraft.

### Interaction with Airline Operators and Requirements Definition

We had discussions with the airlines in India: Deccan, Kingfisher, Jet Airways, Air India etc and based on these discussions, following broad requirements has emerged to form the basis for development of a new generation regional aircraft.

- Acquisition costs : 25% lower
- Operating cost : 25% lower
- Fuel consumption : 25% lower
- Speed > 550 Kmph
- Maintenance : 25% lower
- Emissions : 25% lower
- T.O and landing field length : 900 m
- Ability to operate from ill equipped airfields

### Passenger Capacity

The aircraft should be so designed that with only change in fuselage length, the passenger capacity could be varied. With a nominal size of 70 passengers, the variation could be pegged at 70 (-20 / +20). It should be possible to keep the wing, empennage, cockpit, and systems common with only variation in fuselage length. A common airframe with alternate power plants (Turbo prop/ Turbo fan) (Fig.7) will provide great operational flexibility, supply chain commonality, maintenance standardization and maximization of commonality of training infrastructure and training requirements.
Technology Requirements

The requirements projected in the previous section, demand deployment of very advanced technologies. Let us examine each of the key requirements and identify the technologies that could help in achieving the performance targets.

The key requirement is reduction of fuel consumption by 20 to 25% compared to present generation aircraft. From the Breguet equation (Fig.8). It could be seen that range is maximized, when specific fuel consumption (SFC) is minimized, lift/drag ratio is maximized and empty weight is minimized. While SFC is a function of power plant efficiency, L/D is a function of aerodynamic efficiency, the empty weight is a function of structure and system weight.

Power Plant

The key component that contributes to fuel consumption is the specific fuel consumption of the power plant. It is evident that Turboprops have almost 20% lower SFC compared to Turbo fan engines. However the efficiency of Turbo prop comes down with increase in speed. The present generation Turbo props that are deployed in India, ATR 72 use P&WC 127F engines. The need is for at least 20% reduction in SFC for the new generation power plant. The engineering studies done so far shows that significant improvements are required in combustor design, compressor and Turbine technologies and it is feasible to achieve the efficiencies demanded. There is a requirement to develop a next generation Turbo prop engine along with an advanced propeller system. These technologies when incorporated not only improve the specific fuel consumption but also reduce the emission by 60 to 70%. From the point of view of fuel consumption and achieving the new emission requirements, development of a new power plant by engine design houses is imperative.

Aerodynamics

The key requirements are a new generation lifting surfaces with laminar and supercritical characteristics with optimized winglets to achieve cruise efficiencies. To reduce skin friction drag, there is a need to maximize laminar flow on the fuselage, nacelle, vertical tail and horizontal tail as well. To achieve STOL characteristics, there is a need for efficient high lift systems.

Surface Coatings

One of the key problems of laminar flow is that it is sensitive to the surface imperfections and ice/dust/insects trigger the flow to become turbulent. The present day composite manufacturing technology enables production of smooth surfaces. To prevent formation of ice and collection of dust/insects, there is need to develop anti icing coatings and super hydrophobic coatings. Nano technology enables development of such coatings.

Structural Technologies

The technology required to achieve weight and maintenance man hours reduction and part count reduction is advanced composites. Thanks to the LCA project and SARAS project, this technology has been developed within India. Design, analysis and manufacturing technologies are available at National Aerospace Laboratories (NAL), Aeronautical Development Agency (ADA), Hindustan Aeronautics Limited (HAL) and a number of private companies. As part of SARAS civil aircraft program, a new composite wing program based on non-autoclave technologies suitable for transport aircraft have been developed. ALH uses extensively wet lay-up technology, which is available within the country. There appears to be a need to deploy better topologies that take into account the unique properties of composite materials, apart from using MDO technologies to optimize the structure.

At present there is no health monitoring of airframe structures leading to heavy cost of maintenance. This is an area where considerable development work needs to be done. The aim is to develop a smart airframe which incorporates composites, aero elastic tailoring, passive and active vibration and noise control, Laminar flow control by deployment of Smart material technologies and MEMS along with Health Monitoring Technologies. These technologies would help in reducing structural weight, reduce maintenance effort leading to reduced fuel consumption and operating cost.
Avionics

Avionics systems contribute as much as 40% of the cost of aircraft. Reduction of cost of avionics is essential to bring down the cost of acquisition of the aircraft. While, well proven systems are available from established players in order to achieve significant cost reductions, we do believe an open system architecture with COTS components should be adopted (Fig.9). The challenge is development of applications.

The avionics system should incorporate following attributes to meet the specified goals:

• Use of Open System Architecture with COTS open standards like PCI, UME, CPCI and PCI express.
• Use of rugged zed commercial off the shelf (COTS1 components and sensor).
• Use of open standards for RTOS, networking (Bus1 and programming language).
• Provide scalability/growth potential by building in modularity.
• Provide reusability of Hardware and Software modules.
• Build in extensive BIT for all systems at LRV and system level (End to End).
• Provide real time on line and offline Health Monitoring system of all systems (IVHM).
• Provide extensive Diagnostics and prognostics for all the systems.
• Provision for Low Cost HUD, Synthetic and Enhanced Vision and Highway in the sky (HITS) to enable landing in Unequipped and non-towered Airports.
• Provision of ADS-B data to enable "Free Flight" operations.

ADS-B, weather link from ground, WAAS, Synthetic Vision and Enhanced Vision (SVS/EVS) are emerging technologies which need to be addressed to achieve the functionalities specified.

GAGAN is the Wide Area Augmentation System (WAAS) being developed by ISRO in collaboration with Airport Authority of India. Discussions with the ISRO team confirmed that CATI landing capability can be achieved with GAGAN in the Indian sub Continent. SVS/EVS technologies when embedded on the aircraft would be able to provide CAT II landing capability. This would enable near all weather landing capability for most of the airfields in India.

Flight Control Systems

While the present generation regional aircraft such as ATR- 42/72, Bombardier Q-400, Embraer 170 deploy conventional flight control system, we do believe that fly by wire systems should be adopted for the following reason:

• Enhanced safety.
• Enables to optimize fuel consumption.
• Provides Ride Comfort and Gust load elevation.
• Provides uniform handling qualities across the variants.
• Reduces maintenance effort.
• Facilitates vehicle health managed.
• Enables precision approach and Landing in Unequipped airfields.

While the cost of the system is apparently is higher by appropriate use of COTS technology the cost could be reduced substantially. The light combat aircraft project has provided significant experience in the development of fly by wire system albeit for a fighter aircraft. Based on this solid foundation, the fly by wire system for the new generation regional aircraft could be developed.

Integrated Vehicle Health Monitoring (IVHM)

It is expected that with IVHM, the monitoring of all vehicle utility systems over the entire fleet to reduce maintenance costs is possible. Based on the development of prognostic and diagnostic tools, sensors, communication systems and integration to avionics, it is expected that IVHM will play a major role in enhancing dispatch reliability of regional transport aircraft apart from lowering costs by increasing maintenance intervals and more condition based monitoring.

More Electric Architecture (MEA)

Conventional system architectures use engine bleed air. It is proposed that lowering of engine bleed will increase fuel efficiency. A more electric architecture that will drive the ECS, flight controls, etc likely to help to
reduce maintenance effort, increase reliability and enhance system efficiency. Some of these technologies have already been incorporated in aircraft such as Boeing 787. These technologies need to be tailored for regional aircraft.

**Air Traffic Management (ATM)**

More than 70% of India’s air traffic is concentrated at six metros leading to heavy traffic congestion resulting in time delays and additional fuel consumption. The ATM system functional architecture is given in Fig. 10.

Traffic flow management in congested air space requires tools and technologies to simulate traffic and develop policies that utilize Airport and airspace efficiently while maintaining safety.

The current planning procedures are based on limited automation and could be significantly improved with introduction of “What if procedures” and optimized planning. ATM decisions are interactive and integrated across time horizons (Fig. 11).

The requirements are:

- Collaborative ATM
- Modernized surface Operations
- Weather impacted Operations
- Trajectory based Operations
- Trajectory based separation Management
- Dynamic resonance and Aerospace Management

We need to pay attention to future ATM and work out policies, procedures, deploy technologies and techniques applicable to towered and non-towered stations that enable growth, efficiency and safety.

**Way Forward and Concluding Remarks**

To achieve 7-9% of growth of economy it is essential that air connectivity is expanded to interior regions of the country. This can only be achieved by a Regional Transportation System. Study of existing regional aircraft shows that they are costly to acquire, costly to operate and are based on much older technologies. It is also recognized that unless cost of air travel is reduced, the Regional Air Transportation will not be sustainable. The demand pattern shows there would be need for Turbo prop for short distance travel and Turbo fans for long thin routes. It is suggested that a common platform be developed which could be tailored either as a turboprop or a turbo fan with maximum of commonality embodying advanced airframe technologies and propulsion technologies identified. Such a new generation regional aircraft would not only meet the requirement of Indian sub continent but also needs of many developed and developing countries.

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Fig. 1 Characteristics of airports and access to Air Transportation in India

Fig. 3 Typical route structures for short haul by a regional turbo-prop

Fig. 2

Fig. 4 A combined trunk and short haul by a narrow body aircraft
Fig. 5

Fig. 6

Fig. 7
Fig. 8 Breguet Range Equation

Fig. 9
Fig. 10 Air Traffic Management: NextGen framework (across time scales) [4]

Fig. 11 ATM Structure [4]