Air Transportation Infrastructure Systems Worldwide; Opportunities for Infrastructure and Technology Improvements

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MIT Global Airline Industry Program - Industry Advisory Board Meeting
Massachusetts Institute of Technology
Nov. 6th 2008
Motivation & Research Objectives

- Increasing demand for air transportation
- Key air transportation infrastructure constraints (i.e. capacity)

Implications:
- congestion,
- degradation of the passengers’ quality of travel experience,
- economic impacts.

- Air transportation system is a vital underlying infrastructure of a country’s economy

- Analyze the characteristics and capabilities of national airport networks worldwide.

- Evaluate the opportunities and the implications of next generation air transportation technologies to improve the access to these airport systems.

Historical Evolution of Passenger Traffic
(Revenue Passenger Kilometers - RPKs)
from 1971 to 2007

Passenger Transport Activity (Revenue Passenger Kilometer per capita) vs. GDP per capita

Data sources: ICAO (2005), CIA (2005)
Approach

- Analyzed of the current characteristics and the capabilities of the national airport networks of 190 countries worldwide,
  - Data sources:
    - Worldwide airport database; Digital Aeronautical Flight Information File (DAFIF 2005),

- Performed a detailed multiple case study analysis of the national airport networks from 8 countries
  - Countries selected based on their characteristics and potential for improvement (identified in phase 1 of the approach),
  - Cases illustrate and contrast the opportunities and the implications of these technologies and capabilities across different types of air transportation systems,
  - Wide array of detailed population distribution databases,
  - Country specific information was used in each case study.

- Reviewed and analyzed next generation air transportation system technologies and capabilities
  - Literature review,
  - Discussion of the implications for potential improvements identified in phase 1 and 2.
## Research Approach & Methodology

### Framework for Analyzing Airport Infrastructure Capabilities and Potential for Improvements

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World airport network in numbers:

- 45,813 airports,
- 14,000 airports with at least one paved runway,
- 6,750 airports with at least one paved runway longer than 5,000 ft,
- 950 airports with at least one paved runway longer than 10,000 ft.

Data source: DAFIF (2005)
Analyses of the Characteristics and Capabilities of National Airport Systems

Analysis of Airport Network Density

- Computed ratio of population over the total number of existing airports for each country.
  - Metric that better reflects the adequacy between potential supply of air transportation services and potential demand.

- Great diversity in this ratio, indicative of the ability of different countries to accommodate future demand.

- All else being equal, countries with high ratio of population to number of existing airports are more likely to need the construction of new airports.
  - e.g. China and India will require significant future development of airport infrastructure as their GDP per capita increases.
  - United States and Europe generally have airport networks that are large enough compared to their population basins that they can rely on existing airports to accommodate future growth.

Data source: CIA (2007)
Analysis of Airport Runway Capabilities

- Analysis based on data from the Central Intelligence Agency (CIA) World Fact Book database,

- Results aggregated into 17 world sub-regions.
  - On average worldwide, 30% of all airports have paved runways and 15% have at least one runway longer than 5,000 ft.
  - Low end, Melanesia (6% of its airport equipped with paved runway and 3% with runways longer than 5,000 ft). Followed closely by Eastern Africa and Central America.
  - Opposite end, in Eastern Asia (despite having high potential for new airports) 76% of all airports have paved runways and 56% have runways longer than 5,000 ft.

Data source: CIA (2007)
Safe and reliable airside access (i.e. approach) to airports can be achieved using a set of technology based capabilities,

Analysis of airport approach capabilities for 190 countries using world airport database (DAFIF 2005).

Of the set of airports with paved runways and at least one runway longer than 5000 ft,
- 85% have runway lights that allow night operations.
- 82% of the airports with broadcasting weather and airport status services,
- 50% have a tower
- 29% have at least one ILS or precision approach system.

Data source: DAFIF (2005)
Potential Improvements of National Airport Network Capabilities

- Comparative analysis of capabilities and potential improvement across national airport networks based on the analyses of:
  - (1) the density of the airport network with regard to population in each country,
  - (2) the airport runway capabilities of existing airports,
  - (3) the airport approach capabilities,

- Used a Potential Improvement Index (PII)

\[
PII_c = \frac{\sum_{i=1}^{n}(1 - P_{i,c})}{n}
\]

- where \( P_{i,c} \) is the percentage of airports equipped with capability \( i \) in the set \( c \),
- \( n \) is the number of capabilities in this set \( c \)
- Index ranges from 0 to 1.
  - 0 = no potential improvement (airports in the airport network are fully equipped),
  - 1 = full potential for improvement (exhibit none of the capabilities)
Airport System in the United States

- **Density of the airport network:**
  - 14,800 airports,
  - Very low ratio of population over number of airports (i.e. 20,300),

- **Airport runway capabilities:**
  - 5100 with paved runways,
  - 1800 with a runway longer than 5,000 ft.

- **Airport approach capabilities:**
  - 96% have runway lights making them accessible by night VFR operations,
  - 95% have airport information services,
  - 33% have a tower,
  - 28% have at least one ILS or precision approach.

- **Generally, there is very good access to airports in the United States**
- **Limited potential improvement of airport access**

*Data sources: DAFIF (2005), U.S. Census (2000)*
Airport System in Brazil

- **Density of the airport network:**
  - 4200 airports,
  - Low to medium ratio of population over number of airports (i.e. 42,000),

- **Airport runway capabilities:**
  - 700 with paved runways,
  - 200 with a runway longer than 5,000 ft.

- **Airport approach capabilities:**
  - 54 have a tower,
  - 26 have at least one ILS or precision approach.

- **High potential for improvements on the runway and approach fronts.**
  - Without building any new airport, technology driven improvements of the airside access could almost double the coverage of population living within 50 miles of suitable airports (from 42% to 80%).

**Legend**
- Airport (unpaved runway and/or runway shorter than 5000 ft)
- Airport with paved runway and longer than 5000 ft
- Airport with paved runway >5000 ft, tower, ILS/Precision approach

**Data sources:** DAFIF (2005), Ministero da Agricultura (2008).
Airport System in France

- **Density of the airport network:**
  - 470 airports,
  - Low to medium ratio of population over number of airports (i.e. 128,000),

- **Airport runway capabilities:**
  - 61% with paved runways,
  - 30% with a runway longer than 5,000 ft.

- **Airport approach capabilities:**
  - 78% have at least one ILS or precision approach.

- **Very good access to equipped airports in France:**
  - 99.8% of the population living within 50 miles of an airport,
  - 99.5% within 50 miles of a “fully” equipped airport.

- **Very limited potential for improving access to airports.**
Airport System in Poland

- **Density of the airport network:**
  - 122 airports,
  - Medium ratio of population over number of airports (i.e. 312,000),

- **Airport runway capabilities:**
  - 68% with paved runways,
  - 60% with a runway longer than 5,000 ft.

- **Airport approach capabilities:**
  - 43% have a tower,
  - 33% have at least one ILS or precision approach.

- Next generation air transportation system technologies have potential to improve access to airports.

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**Case Study Analysis**

**Legend**
- Airport (unpaved runway and/or runway shorter than 5000 ft)
- Airport with paved runway and longer than 5000 ft
- Airport with paved runway >5000 ft, tower, ILS/Precision approach
- Airport (unpaved runway and/or runway shorter than 5000 ft)

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Airport System in India

- **Density of the airport network:**
  - 341 airports,
  - Very high ratio of population over number of airports (i.e. 3.3 million),

- **Airport runway capabilities:**
  - 240 with paved runways,
  - 140 with a runway longer than 5,000 ft.

- **Airport approach capabilities:**
  - 26 have at least one ILS or precision approach.

- **Significant potential for technology driven improvement of the airport airside access.**
  - 60% of the Indian population lives within 50 miles of an airport.
  - Equipping current airports with airside access technologies would significantly improve access to airports (fully equipped airports) from 25% to 50%.

Airport System in China

- **Density of the airport network:**
  - 480 airports (140 open to civil operations),
  - High ratio of population over number of airports (i.e. 2.7 million),

- **Airport runway capabilities:**
  - 66% with a paved runway longer than 5,000 ft.

- **Airport approach capabilities:**
  - 16% have at least one ILS or precision approach.

- **Significant improvements are feasible in all three categories;**

- **Initial efforts to address these needs are underway in China.**
  - Plan to increase the density of the national airport network (i.e. 97 new airports by 2020),
  - Development of RNP approaches into several regional airports (e.g. Lhasa, Linzhi, Jiuzhaigou)
Airport System in Nepal

- **National airport network**
  - 48 airports,
  - 10 with paved runways,
  - 1 with a runway longer than 5000ft,
  - 0 airport with ILS.

- **Due to difficult terrain conditions** (i.e. hilly and mountainous terrain in the northern two-thirds of the country) the ground transportation network is limited and expensive to build.

- Nepal relies heavily on air transportation for regional transport and tourism.

- Next generation technologies could be used to improve access to existing airports and provide reliable and safe approaches in Nepal’s airports.

Airport System in Ethiopia

- **National airport network**
  - 84 airports,
  - 13 have runways longer than 5,000 ft,
  - 1 airport is fully equipped.

- **Population: 83 million (in 2007)**
  - second most populous country in Africa after Nigeria

- **Country characterized by an inadequate road transport network.**
  - Fifth lowest road network length per capita in the world,
  - Poor conditions with only 4300 miles of paved roads.

- **Air transportation is an important part of the Ethiopian transportation network.**

- **Improvements in the air transportation network and infrastructure would lead to positive economic impact in Ethiopia.**

## Opportunities for Infrastructure and Technological Improvements

### Airport Network Characteristics

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<td>Paved runway</td>
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<tr>
<td>Sensors &amp; Info. Broadcast</td>
<td>Runway lights</td>
<td>IFR Operations</td>
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<td>Virtual Tower/ Self Separation</td>
<td>Runway lights</td>
<td>Sequencing &amp; High Capacity</td>
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<td>SBAS/GBAS &amp; RNP</td>
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<td>Info. Broadcast /ADS-B</td>
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### Airport Runway Capabilities

- Next Gen. Aircraft (STOL)
- Runway Pavement
- Runway Extension
- Paved runway
- Runway length
- Runway lights
- Airport Weather & Status information (ASOS/ATIS)
- Tower
- ILS / Precision App.
- Radar Coverage
- Sequencing & High Capacity
- Jet Operations
- Regional Jet & Narrow Bodies Operations
- Day & Night Operations
- Airport Weather Awareness
- Separation & Conflict Avoidance
- IFR Operations
- Overall Airport Network
- Nb. airports
Conclusions

- **Analyzed**
  - current characteristics and capabilities of 190 national airport systems worldwide,
    - (1) the density of the airport network with regard to population in each country,
    - (2) the airport runway capabilities (of existing airports),
    - (3) the airport approach capabilities (of existing airports).
  - investigated the opportunities for infrastructure improvements including using next generation air transportation system technologies.

- **Analyses showed significant differences between the nature and the capabilities of airport infrastructure across world regions.**
  - North American and the European systems exhibit good access to air transportation due to high density of airports.
  - In other regions such as Asia (e.g. China, India), a latent need for the construction of new airports was identified.

- **Potential from new technologies and capabilities;**
  - improve the efficiency of operations in regions with more mature air transportation infrastructure systems but marginal improvements for enhanced access.
  - in developing and emerging regions that these technologies and capabilities are more likely to have the greatest impact on improved access to air transportation by opening up the set of non-utilized and under-equipped airports.
Questions & Comments

Thank you!