International Civil Aviation Organization

Fourth Meeting of the ICAO Asia/Pacific Seamless ATM Planning Group (APSAPG/4)

Hong Kong, China, 3 – 7 June 2013

Agenda Item 3: Drivers for a Seamless ATM Environment

SEAMLESS ATM ECONOMIC STUDY

(Presented by IATA)

SUMMARY

This paper presents the initial economic analysis of transition to Seamless ATM.

This paper relates to –

Strategic Objectives:

C: ***Environmental Protection and Sustainable Development of Air Transport*** *– Foster harmonized and economically viable development of international civil aviation that does not unduly harm the environment*

1. INTRODUCTION

1.1 At APSAPG2, IATA offered to develop a "Cost Benefit Analysis" of transition to Seamless ATM.

1.2 This study entitled, "economic analysis of Seamless air traffic management", is discussed in this paper.

1.3 This report is predicated on the assumption that all ASBU Block 0 critical elements will be implemented and extrapolates the impact on Regional GDP should there be State or Regional differences or delays.

1.4 This study highlights the economic gain achieved in the long term by implementing Seamless Asian Skies while upgrading the present infrastructure.

1.5 In addition to the economic benefits, the study predicts losses which will accrue due to the failure to implement ASBU Block 0 in a timely manner.

1.6 Should this occur, Asia Pacific based airlines will suffer economic penalties as the technologies required to obtain the benefits from seamless air traffic management will be deployed in other parts of the world. This will require investment by our Region's airlines without the requisite operational benefits in the "home" Region.

2. DISCUSSION

2.1 A copy of the analysis is attached as **Attachment A** to this paper.

2.2 The attached report was tabled at APSAPG3 and very limited feedback has been received. The feedback received has not questioned the validity of the conclusion.

2.3 Additionally, we have referred this report for independent review both within IATA and externally. Both reviews have supported the conclusions noting the assumptions which drive the outcome of the report.

2.4 The key outcomes of this initial study are:

a) Aviation currently contributes 2.22% to Asia Pacific States Gross Domestic Product (GDP);

b) With ASBU Block 0 improvement, overall aviation contribution is forecasted to reach 4% to the Regional GDP by the year 2030;

c) This represents an overall aviation contribution of US$2358.76 billion to the Regional GDP in the year 2030;

d) Without ASBU Block 0 improvements, overall aviation's contribution to Regional GDP will fall to 0.8% by the year 2030.

2.5 Whilst traditionally ATM improvements are implemented on a State by State basis, and funded from either State revenues or Users, the critical elements of ASBU Block 0 will rely on a REGIONAL capability providing services to all States across the Region.

2.6 Therefore, the development of a cost benefit analysis will need to determine the cost of providing Regional services, such as ATFM and AIS, and then distribute these costs to each State on the basis of benefit derived in the State.

2.7 APSAPG is asked to consider the process necessary to complete the "cost" element of the cost/benefit equation.

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) notes the economic analysis and the economic cost to the Region if ATM efficiency is not improved;

b) consider a mechanism to develop a Region wide 'cost' of implementation to obtain the benefits of Seamless ATM; and

c) discuss any relevant matters as appropriate.

…………………………….

Seamless Asian Skies: Initial Economic Analysis of Benefits

International Air Transport Association (IATA),

Asia Pacific Office

Seamless Asian Skies: Initial Economic Analysis of Benefits

Executive Summary

This report is the first stage of IATA's commitment to work with States and other agencies to quantify the Seamless Asian Skies (SAS) initiative's likely benefits.

SAS will improve the efficiency of Asia Pacific's air traffic management and deliver the system capacity to meet the projected future demand.

This initial analysis suggests that if Asian Nations implement the critical ICAO Aviation System Block Upgrade (ASBU) elements of the Seamless ATM Draft Plan, aviation's contribution to Regional GDP will increase from 2.2% in 2011 to 4% in 2030. This would represent an Overall Aviation contribution of USD 2358.76 billion to the regional GDP for the year 2030.

However if Asian Nations do not implement ICAO Aviation System Block Upgrade (ASBU), aviation's contribution to the Regional GDP will fall to 0.8% in the year 2030.

Clearly, the figures indicate a demand for a sustainable and mutual development of aviation infrastructure in the Asia Pacific Region.

The next stage of IATA's commitment to SAS is to quantify the investment required to implement 'Block 0' upgrades across Asia Pacific.

Today, most airport and air traffic management upgrades are funded by airport or by the State (whether by airline revenue or consolidated funds) and implemented within that State.

Future air traffic management upgrades, as recommended in ASBU, will require a Regional solution implemented across a number of States and managed cooperatively between the participating Nations.

> If aviation is to continue to drive global economic prosperity and social development to the extent our community and the world have grown accustomed, especially in the face of dramatic regional traffic growth projections and the pressing need for more determined and effective climate related stewardship, States must fully embrace the new Block Upgrade process and follow a unified path to the future global Air Navigation system.
>
> ICAO Global Air Navigation Capacity & Efficiency Plan, 2013-2028, p24

Introduction

A finding of the second meeting of the ICAO Asia/Pacific Seamless ATM Planning Group (APSAPG/2) held in Tokyo 6-10 August 2012 was the need to develop a method to assess the economic implications of operational performance as a result of the implementation of the seamless operational concept (such as how to set the value of time to quantify passenger time savings) within a framework of business cases and cost-benefit analysis (CBA).

In accordance with APSAPG/2 agenda Item 3: 'Drivers for a seamless ATM Environment', IATA made a commitment to work with States and other organizations to define and quantify the likely benefits of Seamless ATM across the Asia Pacific region.

This report provides updated information from the first report which defined and quantified the economic benefits/costs of seamless skies in the Asia Pacific region. This is a "high level" study defining the overall costs and benefits of implementing ICAO's ASBUs as a framework for the harmonization of ATM.

This updated report illustrates extended economic benefits of upgrading current aviation infrastructure in the Asia Pacific region.

It is also a scoping study because it recognizes from the outset that the required information to conduct a detailed, step-by-step, analysis of the costs and benefits of the ASBU program is not readily available in this region. However, with the continued support of Asia Pacific leaders, airlines and ANSPs, it will be possible to collect the data needed to complete a detailed CBA of the seamless skies program from the perspective of individual airlines, ANSP's and Airports in the near future.

> As CANSO (2012)[1] commented, "At the economic and financial level, we may understand the costs but do not fully understand the benefits of ATM modernisation. Yet, billions are expected to be invested. ATM modernisation needs to be supported by a solid business case. ……. "

The study's methodology has been developed in accordance with the principles described in ICAO Doc 9161; ICAO Circular 257-AT/106; Eurocontrol (2000) Guidelines for the economic appraisal of EATMP projects; FAA (1998) Economic Analysis of Investment and Regulatory Decisions; SESAR (2006) Cost Benefit Modeling, and; Boeing C/ATF's (2000) Economic Evaluation of CNS/ATM Transition.

A detailed analysis of seamless skies should utilize the taxonomy of phase-offlight efficiency indicators which have been jointly developed over many years by Eurocontrol and the FAA[2] and which are now being recommended to ICAO's 12th Air Navigation Conference to become the common air navigation services (ANS) performance metrics

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[1] AN-Conf/12-WP/ /12, Addressing the Impediments to ATM Modernisation.

[2] US/Europe Comparison of ATM-related Operational Performance (2009, updated in 2012).
See http://www.eurocontrol.int/documents/useurope-comparison-atm-related-operationalperformance-2010

and indicators[3]. The benefits and costs, such as increased capacity, notional cost of delay per passenger are subsequently monetized to enable financial analysis. This methodology provides greater transparency and helps users align the cost of services with the benefits provided.

Limitations of the Study

As this initial study has been carried out over a relatively short time frame it therefore uses information that is readily available. Where there is an absence of data, the study makes assumptions, which are stated in the text. Any assumptions are conservative by design and the main results robust.

The first part of the study represents an aggregation of aviation activity across all the Asia Pacific countries. It should be noted there are wide variations in service levels and capacity between the States and often even within a single States.

The second section of the report represents an analysis of ASBU Block 0 Implementation into Manila, which is the gateway to the Philippines and a major traffic constraint point. To obtain more detailed and widespread CBA analysis requires the submission of historical flight data, schedules and demand forecasts from airlines, and projections of project costing for ASBU module implementation by ANSPs throughout the region.

Economic Analysis

When air navigation services projects are publicly funded, a methodology that reflects both the public and private benefits and costs of the project should be considered. Accordingly, this analysis identifies the benefits of aviation activity to the broader national economies. The analysis forecasts the overall contribution of aviation to the regions GDP by 2030 based on the expected growth in passenger and cargo movement.

There are also potential productivity gains for the providers of services, which must be taken into consideration. For example, an investment in modern ATS technology may reduce the number of air traffic controllers required in the future thereby reducing future operating costs. Transportation efficiency benefits may also accrue to operators (e.g. airlines) and would include savings arising from the more efficient operation of aircraft, and greater service reliability and predictability.

At a project level, once the benefits and costs have been identified and forecast, in order to determine if a project is cost-beneficial, or to assess which option yields the greatest net benefits; the net cash stream of benefits and costs is discounted to today's value to produce a single net present value (NPV)[4]. The preferred option, from an economic perspective, would be the one with the highest NPV.

The need for discounting stems from the fact that the value placed on income and expenditures depends on when they occur. One unit of currency to be received a year from now is worth less than the value of one unit of currency in one's pocket today, because of opportunities foregone during the year.

[3] AN-Conf/12-WP/35

[4] The discounted value of benefits from the investment less the discounted value of expected costs. A positive NPV indicates that an investment is worthwhile.

Steps in Cost and Benefit Methodology

Step 1 - Define the objective
Step 2 - Specify assumptions
Step 3 - Identify alternatives
Step 4 Estimate benefits and costs
Step 5 - Compare the alternatives
Step 6 - Evaluate the outcome

STEP 1 – Define the objective

The purpose of a cost benefit analysis is to identify, measure and aggregate the incremental costs and benefits associated with the replacement of existing technologies and procedures with ASBU Block upgrades to implement Seamless Asian Skies and how to use this information to draw conclusions about the expected economic impact on governments, ANSPs and users. The objective here is to compare the implementation of relevant Block 0 upgrades with a base case[5].

STEP 2 – Specify assumptions

Access to the full potential operational benefits of Block 0 upgrades is conditional on a broad range of aviation, economic and social policies, primarily national but also, in many cases, regional.

The overall model is generated based on the assumption that all benefits are accumulated based on the implementation of all relevant ASBU modules.

Certain assumption must be made in the calculation of projected benefits such as national and regional growth expectations, traffic forecasts, airline fleet configurations, discount rate for net present value calculations, etc.

To compare the implementation of relevant Block 0 upgrades, the base model assumes that there will not be any investment made in the region to upgrade current infrastructure, and overall aviation contribution will remain constant till the year 2030.

STEP 3 – Identify Alternatives

The alternatives available to governments, ANSPs and airlines with regard to the improvement of ATM performance through the implementation of ASBU modules as a framework for Seamless Asian Skies are:

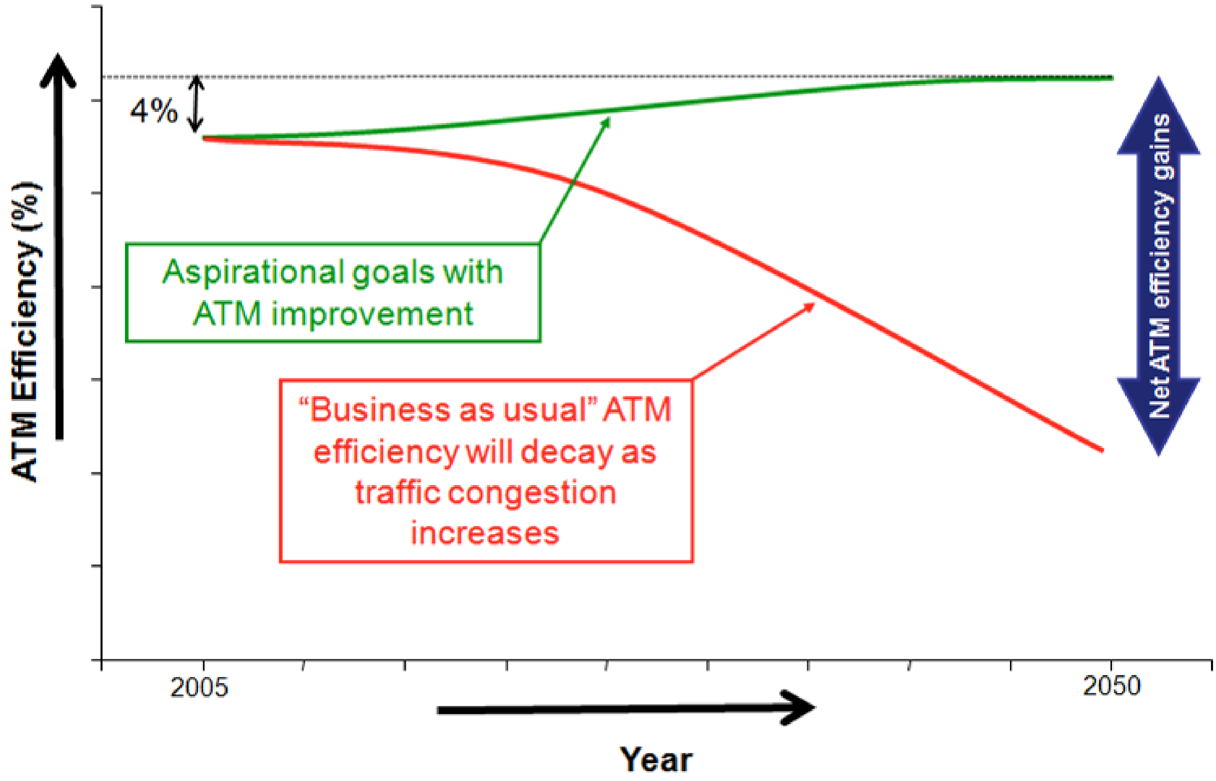
1. **Do nothing (base case)**

In this scenario, the state in the Asia Pacific region maintains the status quo in the face of increasing demand on the system. The current infrastructure, which is already insufficient to accommodate existing demand, is assumed to remain the same.

[5] Base Case: Maintaining the level of service available in the base year, with no change to equipment other than direct replacement at the end of service life.

> CANSO (2008, p. 7) reported that if the industry was to continue with the existing operational environment (business as usual) then the level of global ATM efficiency will decrease as additional traffic increases congestion.

Furthermore, in addition to the increased costs attributable to delays brought about by increased congestion, there will also be a negative impact on the nation’s economy from lost aviation activity (refer table page 19). These lost aviation activities will reduce catalytic affect (tourism).



Effect of increases congestion on ATM efficiency, Stollery (2008, p. 4)

2. Implement Aviation System Block Upgrades

This scenario considers the implementation of modules of the ICAO ASBUs in accordance with regional plans to enhance the performance of the ATM System. The preferential basis for the development of the modules relies on the applications being adjustable to fit many regional needs as an alternative to being made mandated as one-size fits- all application.

The ASBUs describe a way to apply the concepts defined in the ICAO Global Air Navigation Plan (Doc 9750) with the goal of implementing regional performance improvements. They include the development of technology roadmaps, to ensure that standards are mature and to facilitate synchronized implementation between air and ground systems and between regions. The ultimate goal is to achieve global interoperability. Safety demands this level of interoperability and harmonization. Safety must be achieved at a reasonable cost with commensurate benefits.

Each block and its underlying components are intended to interoperate seamlessly and independently of how they are implemented in neighboring States.

The modules in each block are grouped to provide operational and performance objectives in relation to the environment in which they apply.

The four performance improvement areas are (refer Appendix D),

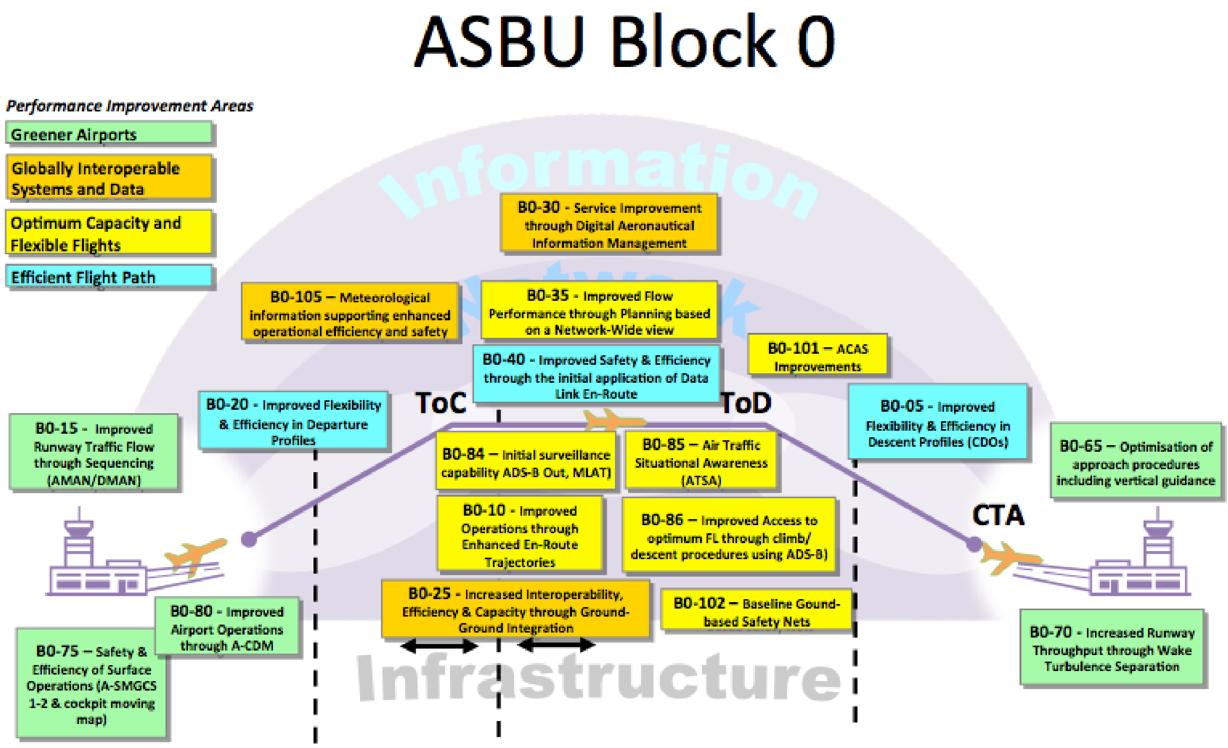
1. Greener airports
2. Globally Interoperable Systems and Data – through Globally Interoperable System-Wide Information Management
3. Optimum Capacity and Flexible Flights – through Global Collaborative ATM
4. Efficient Flight Path – through Trajectory Based Operations

The Aviation System Global Block Upgrade initiative constitutes the framework for a regional agenda towards ATM system modernization. Offering a structure based on expected operational benefits, it should support investment and implementation processes, making a clear relation between the needed technology and operational improvement.

Implement ASBU Block 0 (available now) – Note: IATA is seeking the region wide implementation of ASBU Block 0 by 2018.

For Block 0, no new airborne technologies are required, although modules may imply the deployment of existing technologies to a larger aircraft population depending on chosen modules respectively paired with tied benefits. It is therefore critical for all stakeholders to:

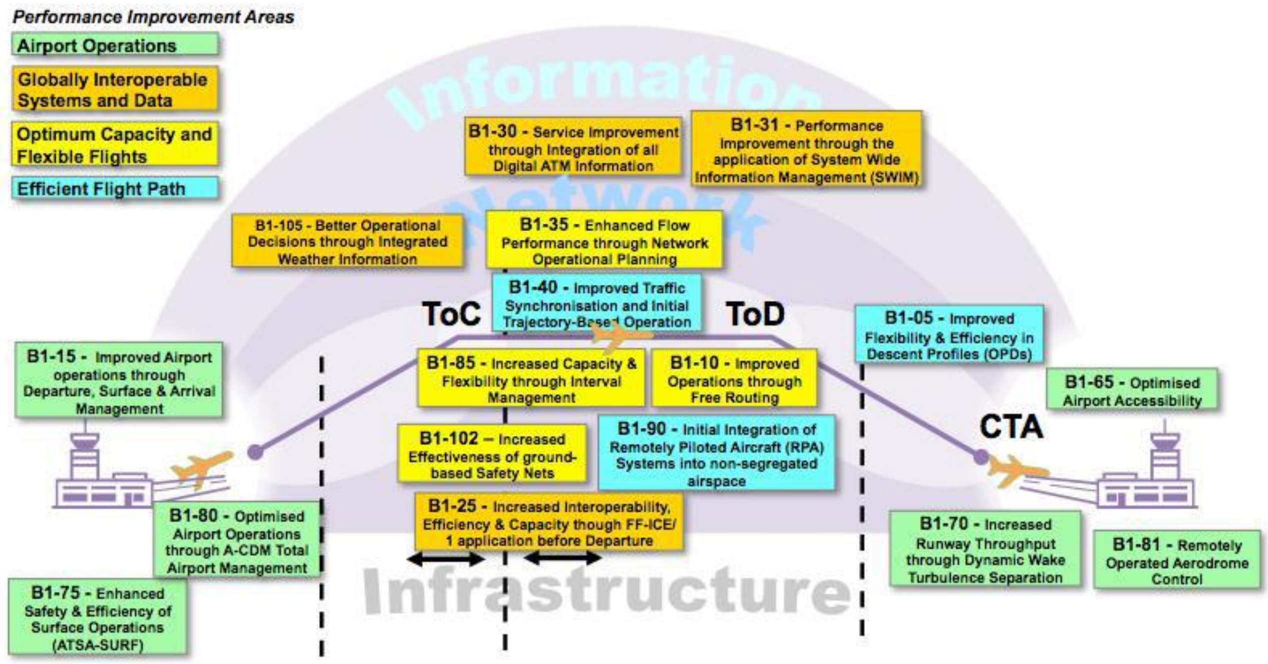
- Fully realizes the benefits and experience of current technology
- Determine and define future requirements (Blocks 1 and above) based on this experience.



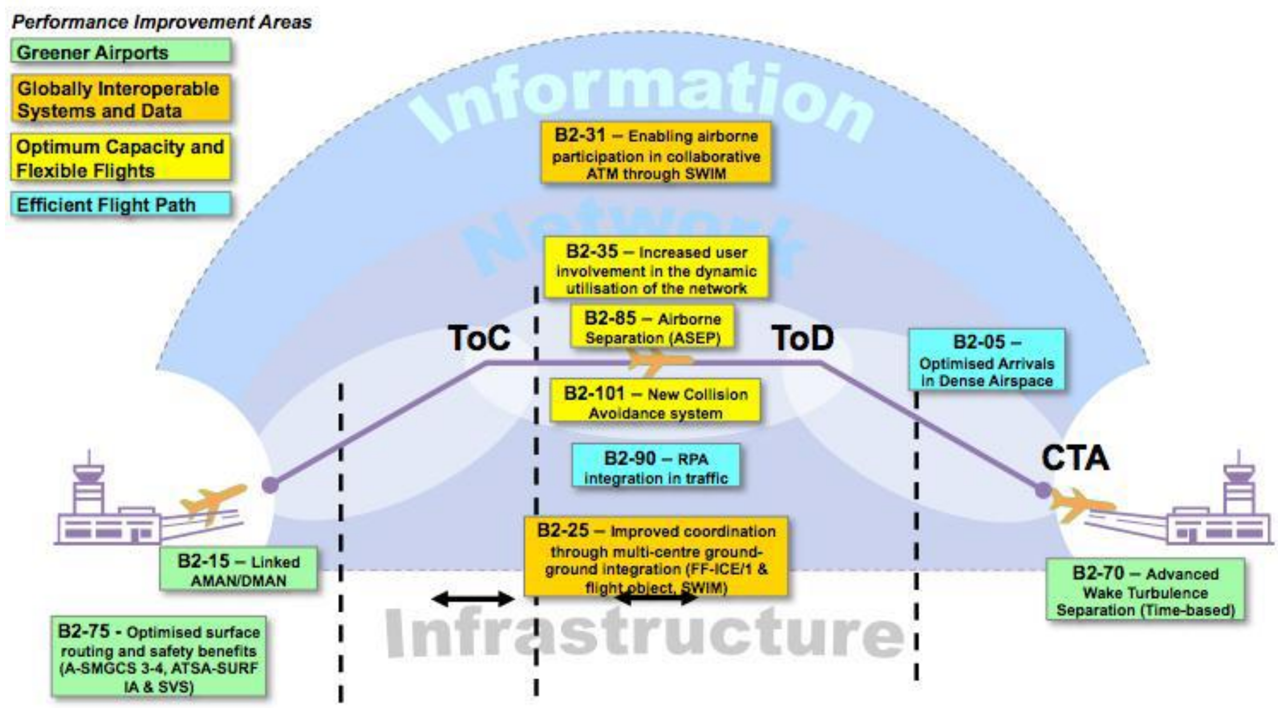
It must be recognized by stakeholders that if Block 0 is not implemented as a foundation, there is a risk certain functionalities may not be available as enablers for future blocks.

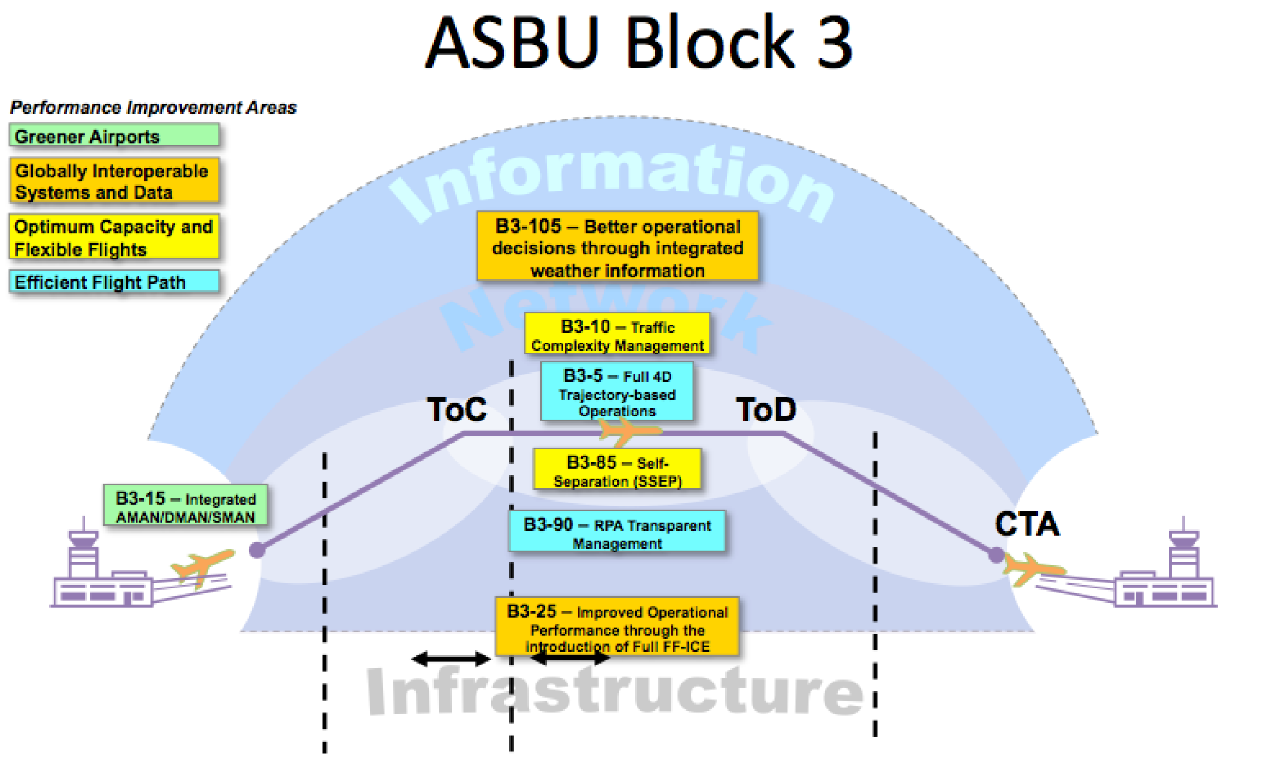
Implement ASBU Stage 1 (from 2018)

ASBU Block 1



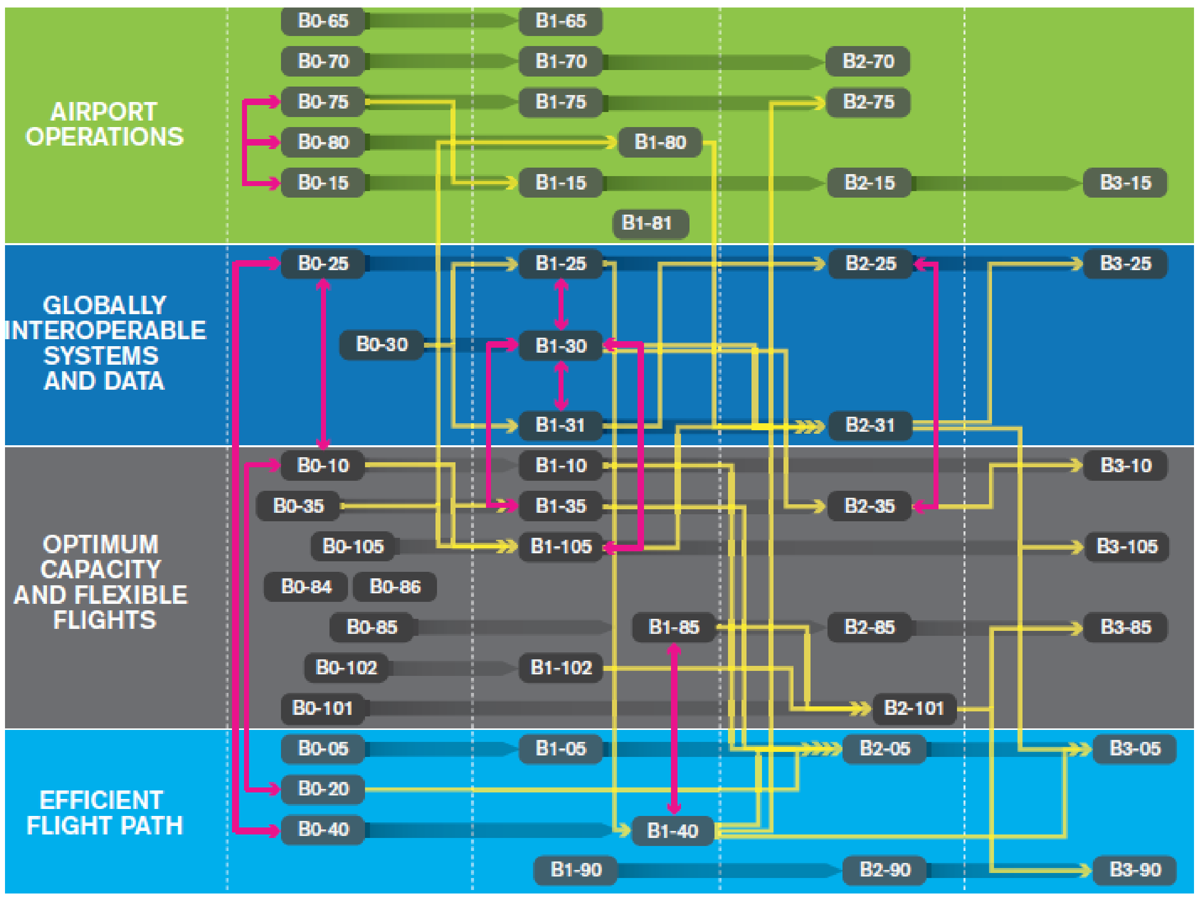
ASBU Block 2





In addition, ICAO's Global Air Navigation Capacity & Efficiency Plan 2013-2028 (in draft) reinforce the dependencies between modules stating that they are:

- Essentially Dependent, and
- The benefits of each module are mutually reinforcing, i.e. implementation of one module enhances the benefits achievable with the other modules.



Module Dependencies
Source: ICAO (2012) Global Air Navigation Capacity & Efficiency Plan 2013-2028, p 129 (in draft).

As the implementation of Blocks 1, 2 & 3 are dependent on the successful implementation of Block 0 modules this analysis will focus on a comparison between the costs and benefits of implementing the Block 0 modules up until 2018 to achieve seamless skies, with their non-implementation or the businesses-as-usual case.

STEP 4 - Estimate of Benefits and Costs

Air Transportation growth drivers

Growing delays threaten the competitiveness of national economies, by limiting the ability of the air transport system to serve the needs of the nation's economy. The growth in gross domestic product (GDP) and air travel demand are closely linked (Oxford Economics, 2009). A recent study that examined the interdependency of air transportation and economic activity in 139 countries (Ishutkina, 2009) revealed a correlation coefficient of 0.99 between air transportation passengers and GDP using world aggregate time-series data during the 1970-2005 time period.

However underpinning this strong correlation are many factors that can either stimulate or suppress the development of a nation's air transportation system in the shorter term. These factors are categorized as either Supply Side or Demand Side.

Air transport Supply Side Factors	**Air transport Supply Side Factors**
Regulatory Framework • Ownership Restrictions • Safety and Environmental Restrictions • Geopolitical and Security Restrictions Infrastructure Capability • Airport infrastructure Capacity • Air Navigation Services Capability • ATM Shortage of personnel Airlines • Airline Business Factors • Perceived airline/fleet safety • Insufficient fleet capacity (due to lack of finance, external factors)	Direct Factors • Exogenous Demand Shocks • Economic downturn (domestic or non-domestic) • Political/Economic sanctions • Competition of other transportation modes • Civil Unrest or War Indirect Factors • Political or Macroeconomic factors • Exchange rate Fluctuations

Air Transport System Change Factors. Adapted from (Ishutkina, 2009)

While each (or a combination) of the above factors, will at various times, effect the growth of a nation's aviation activity, from a long-term perspective Air Transportation growth is closely aligned to GDP growth.

However, the scope of this study is to evaluate the costs and benefits of the seamless skies initiative through ASBUs to improve Airport Capacity & Air Navigation Services Capability

Infrastructure Capability

Estimate of Benefits and Costs of Seamless Skies

Introduction

Increasing the overall capacity and efficiency of the aviation system in order to accommodate forecast growth in traffic is the principle driver of the Seamless Asian Sky (SAS) initiative. SAS is helping to define the way forward by harmonizing procedures and interoperable technology between states, bearing in mind it needs to be cost efficient at the same time.

"Aviation is a vital part of Asia's economy, supporting 24 million jobs and nearly half-a-trillion dollars of GDP. Connectivity, facilitated by aviation, is a critical link to markets and a generator of wealth—both material and of the human spirit. Ensuring the timely development of sufficient and cost-efficient infrastructure capacity is a priority for the continued successful growth of air transport in Asia- Pacific…We must not repeat the mistakes made in Europe where efforts to implement a Single European Sky are stalled because states are not delivering…. Asia –Pacific is not immune to air traffic congestion issues and these will continue to grow if they are not well managed with a regional perspective." said Tony Tyler, IATA's Director General and CEO.

In an endeavor not to repeat the mistakes of Single European Skies, which continues to suffer from fragmentation of airspace that caused 17.9 million minutes of delays in air traffic flow management in 2011[6], an analysis to identify the primary areas of capacity constraint and inefficiency in the system is required.

In 1999 the Intergovernmental Panel on Climate Change (IPCC) estimated global ATM inefficiency to be between 6-12%, with large variations by region and by airport. Since then efficiency has improved by 4% with the introduction of procedures such as RVSM. CANSO (2012) estimate worldwide ATM system fuel inefficiencies are currently between 6 and 8%.

There continues to be intense pressures on governments to further improve ATM systems around the world and recover the remaining inefficiencies.
Pressure on ATM system performance comes from:

- Airlines need for increased efficiency and capacity in the system;
- Some ATM systems that are becoming antiquated and costly to maintain;
- Multiple parties actively advocating individual technology 'solutions'

To increase ATM performance CANSO (2012, p10) believes stakeholder collaboration is required to plan a phased approach to implement,

- ANSP enhancements that safely increase ATM efficiency and global interoperability
- ANSPs to provide enhanced services to 'better equipped' aircraft as a means of capacity and efficiency improvement

[6] CAPA, http://centreforaviation.com/analysis/europe-to-take-a-third-attempt-at-sorting-outthe-single-european-sky-86383

- Better management of fuel efficient delay absorption into congested terminal areas
- Fuel efficient flight tracks while maintaining noise consequences near airports
- Regional solutions across major traffic flows (MTF)

ICAO's ASBU initiative is such a programme framework that develops a set of ATM solutions or upgrades that exploits current equipage, establishes a transition plan and enables global interoperability. The ASBUs comprise a suite of modules organised into flexible and scalable building blocks, where each module represents specific, well bounded improvements that enable capacity related and/or efficiency related benefits.

Benefits

The quantification of economic benefits is based on capacity and efficiency considerations. Examples of benefits are,

- Capacity Related
  - Capacity of en-route airspace and airports
  - Reduction in Separation Standards
  - Decision Aids
- Efficiency Related
  - Direct Routing
  - Optimum trajectory

Implementing ASBU will bring in aforementioned benefits to the region's aviation capacity and efficiency.

The Cost Benefit Study shows that upgrading the current aviation infrastructure to raise system's capacity to meet the future demand will increase overall aviation contribution to regional GDP from USD 470 billion in 2010 to USD 2358.76 billion by the year 2030.

> ***Implementing ASBU will increase overall aviation contribution to regional GDP at USD 2358.76 billion by the year 2030.***

Furthermore, increasing system capacity to accommodate future demand will also increase overall aviation contribution to the regions GDP from present 2.2% to 4% by the year 2030.

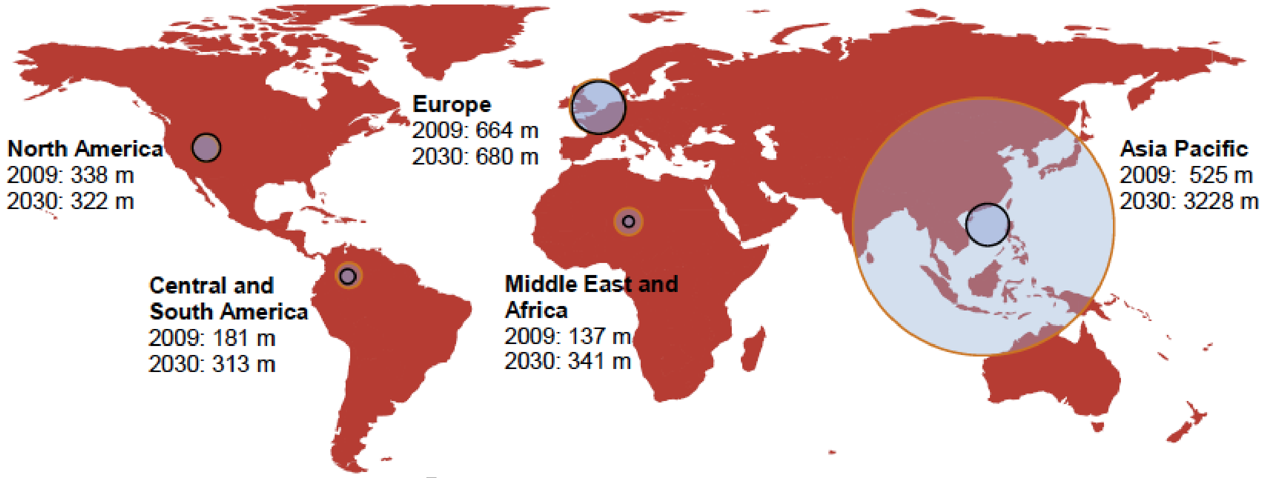
> ***Successful investment in ASBU will raise overall aviation contribution to 4% of the regional GDP by the year 2030.***

Capacity

Capacity is defined as the maximum number of aircraft that can be accommodated in a given time period by the system or one of its components (throughput). The term capacity can be used to refer to a number of factors, any of which could be the limiting factor that might place a constraint on the amount of air traffic that can be handled, e.g. airspace capacity, airport capacity, controller capacity or equipment capacity.

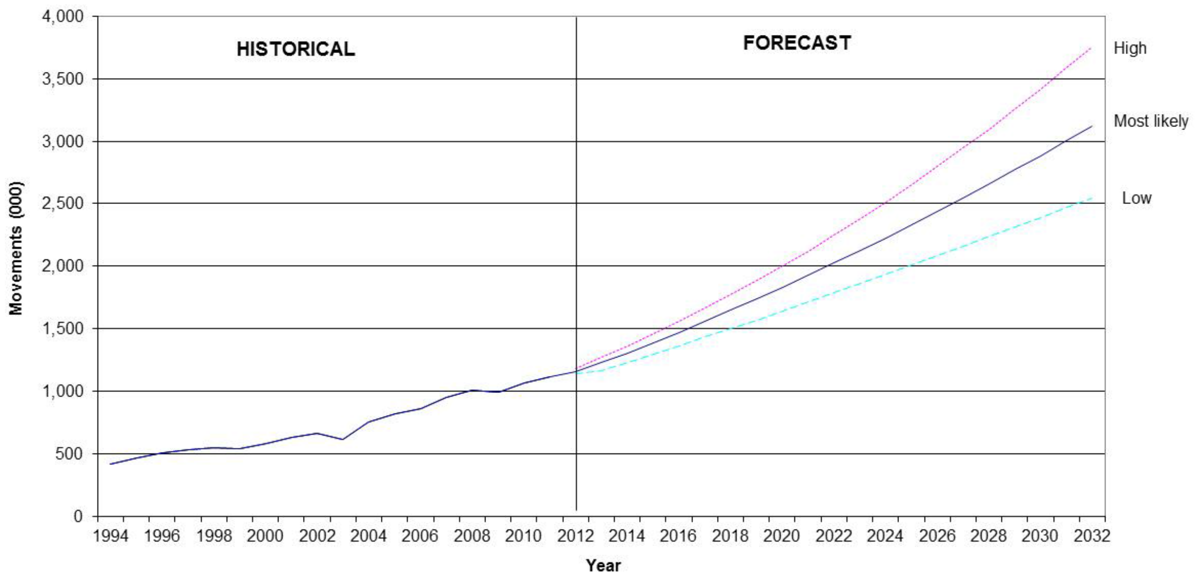
Demand

The Asia Pacific region is expected to be the fastest growing region in the world for air transport over the next 20 years with demand increasing by over 6% per annum. The number of passengers per inhabitant is expected to increase by 170%, from 0.16 to 0.44 (trips/person/year), in the next 15 years (Oxford Economics, 2008:46). The magnitude of the shift towards the region can be seen in the growth of middle-class consumers. An expanding middle class can use its increasing purchasing power to buy high-value products and services, be increasingly mobile, and help drive growth.



Growth of the 'Middle Class'[7] in Asia Pacific region

According to ICAO's Asia Pacific Area Traffic Forecasting Group (APA TFG) Report (Sept, 2012:27), Intra-Asia/Pacific passenger aircraft movements are expected to increase from some 1,114.9 thousand in 2011 to about 3,119.7 thousand movements by the year 2032, at an average annual growth rate of 5.0 per cent. The growth rates for the intermediate periods of 2011-2022 and 2022- 2032 are 5.6 and 4.4 per cent, respectively.



Intra-Asia Pacific aircraft movement forecast, Source: ICAO

However, it is unlikely these forecasts will eventuate due to the "bottlenecks" or constrained demand that already exist throughout the region.

Eurocontrol (1996:40) define three types of constrained demand as,

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[7] 'Middle class' is defined as those households with daily expenditures of between US$10 and US$100 per person. The black border circles and orange border circles depict the size of the middle-class population in 2009 and 2030 respectively. Source: Kharas & Gertz (2010).

- **demand generally less than capacity, but exceeding it during peak periods:** Excess demand may be accommodated by allowing delays to build up during the peak period then recovering during the subsequent “quiet” period;
- **demand approaching/exceeding capacity:** If capacity is, on a regular basis, insufficient to meet demand at certain times of the day, airlines may be forced to operate services at less busy times (demand spreading) or to fly non-optimum routings;
- **unaccommodated demand:** Demand may exceed capacity to the extent that there are simply no available slots for further traffic, and therefore demand spreading and re-routing are not possible. In this case airlines would be unable to satisfy any additional demand from passengers for further services.

Constrained Demand

Un-accommodated demand across the Asia Pacific region can be seen in an examination of the busiest city-pairs. As an example, the top 50 city-pairs that transited the Hong Kong FIR during a sample week 1-7 July 2012 (as per Table 15 of the aforementioned APA TFG report) show that every airport on the list is classified as an IATA Level III airport[8], with the exceptions of Macao, Osaka & Kaohsiung Level II, and Ching Chuan Kang (Military), Anchorage and Busan. A similar picture is painted in the report for aircraft transiting Bangkok, Fukuoka and Kolkata FIRs.

Without airport capacity enhancement through the construction of additional runways or the implementation of ICAO ASBU upgrades such Airport Collaborative Decision Making (A-CDM) and Arrivals Management (AMAN/DMAN), increases to one operator’s schedules can only be made at the expense of another’s.

Traffic Growth is possible only if there is sufficient aviation infrastructure present in the form of:

- Airport capacity
- Air Navigation System Capability

Many airports in the Asia Pacific Region are currently operating at nearly full capacity due to a long history of traffic growth, while land availability and environmental constraints have hindered expansion. IATA lists 42 Level III and 20 Level II airports in the region[9]. The infrastructure at these airports is not able to accommodate all of the demand and slot availability is subject to coordination and allocation.

The region also suffers from a high degree of variance in Air Navigation Services capability. The lack of sufficient communications, navigation and surveillance and air traffic management (CNS/ATM) capability at various locations affects the system’s

[8] A Level 3 airport is one where:

a) Demand for airport infrastructure significantly exceeds the airport’s capacity during the relevant period;
b) Expansion of airport infrastructure to meet demand is not possible in the short term;
c) Attempts to resolve the problem through voluntary schedule adjustments have failed or are ineffective; and
d) As a result, a process of slot allocation is required whereby it is necessary for all airlines and other aircraft operators to have a slot allocated by a coordinator in order to arrive or depart at the airport during the periods when slot allocation occurs.

[9] refer to http://www.wwacg.org/FTableList.aspx?list=62 for list of Airports

throughput, thus causing increased delays and adds to airline costs. Inadequate aviation infrastructure is also detrimental to the overall air transport system safety and its perception by the flying public. In particular air travel advisories are typically based on the country's total level of safety.

As Ball et al (2010:1) noted, "It is widely recognized that delay increases nonlinearly as demand approaches the capacity in the system (figure below). If current demand in the system is D1 with delay at delay1 level, it is likely that, without substantial upgrades to aviation infrastructure, such growth (for example, to D2) would result in flight delays far in excess of any we have hitherto experienced (delay2)".

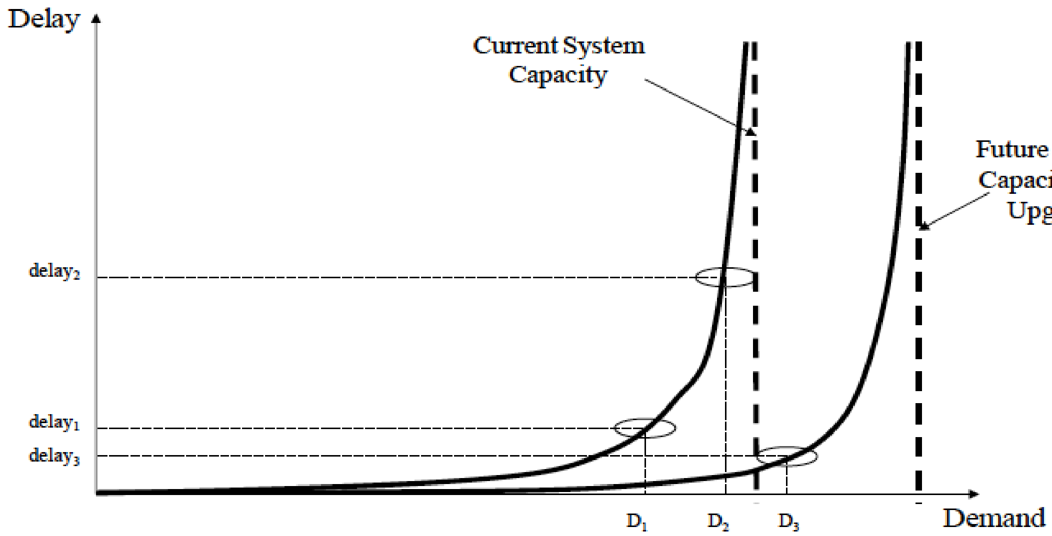


Illustration of the relationship between Demand, Delay and System Capacity Source: Ball et al 2010

The figure above could also be illustrative of a major traffic flow route who's capacity has been increased from point D2 to D3 through a reduction in enroute separation standards associated with the implementation of full surveillance coverage e.g. ADS-B, or RNP routes with ADS-C & CPDLC capability. Airlines then have the ability to increase existing schedules with a commensurate reduction in delay until the future system's capacity is reached.

It is this exponentially increasing delay that leads to a serious concern among users that system capacity must keep up with demand. Thus, capacity constraints in the system take on a level of urgency considerably higher than efficiency constraints, which grow linearly with traffic demands. (Allen, Haraldsdottir, Lawler, Pirotte, & Schwab, 1997) p. 7.

> *It is important to distinguish between operating costs caused by lack of capacity from cost due to procedural inefficiencies. Allen, et al (1997) p5.*

To accommodate capacity limitations at an airport or through airspace, aircraft may be required to wait (hold) on the ground prior to departure (at gate or on taxiways); deviate en route, or complete holding procedures prior to arrival. When traffic demand approaches available capacity, there is some necessary increase in congestion and fuel inefficient delays to maximize use of available capacity. This congestion reduces efficiency and increases CO_2 emissions.

Cost of Constrained Demand

As the number of flights increases per year, a number of capacity constraints are affecting the efficiency of the air transportation system, as well as its ability to expand further. The two main constraints are airport runway capacity (the number of takeoffs and landings that can be performed per hour), as well as terminal area and enroute capacity. Research into the identification of these capacity constraints, as well as potential ways of removing bottlenecks from the air transportation system, require the improvement of infrastructure and technology, and/or the adoption of new procedures.

As mentioned earlier, the Asia Pacific region boasts 62 level III or II airports, which indicated demand is beyond capacity in many countries. In addition many major traffic flows (MTF) are subjected to lengthy delays (e.g. Bay of Bengal) due to capacity limitations. Unless capacity constraints are identified and their performance elevated, national economies will suffer significant losses due to aviation activity stagnation.

Prudently and in accordance with Ishutkina's (2009) long-term findings, conservative national GDP growth rates have been used as opposed to aviation industry forecasts of aviation growth (e.g. Boeing & Airbus). In addition Oxford Economics' average Aviation Contributions to GDP have been used as proxies, where none exist.

The net overall opportunity loss caused by stagnated aviation infrastructure facility to the economic benefits to Asia Pacific countries is valued at USD 1888.76 billion for the year 2030.

If no action is taken, the lack of aviation capacity will cost Asia Pacific economies an opportunity loss of USD 1888.76 billion.

Aviation's overall contribution to Asia Pacific regional GDP will reduce from current 2.2% to 0.8% by 2030 if investment to increase aviation capacity and efficiency in infrastructure is not made.

Failure to invest in aviation capacity will reduce overall aviation contribution to 0.8% of regional GDP by the year 2030.

A consequence of reduced GDP growth is that the emerging economies of the last two decades risk becoming ensnared in 'the middle-income trap', in which middle-income[10] countries don't quite push through to high-income status.

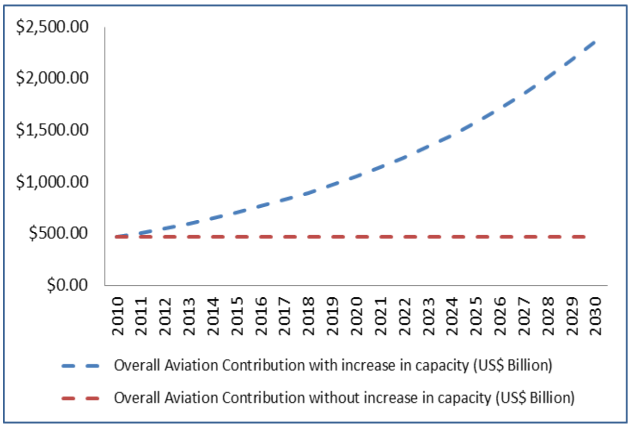
Unfortunately many middle-income countries[11] have seen infrastructure gaps develop and widen. While the existing aviation infrastructure of many countries is inadequate to accommodate the increased passenger and freight transportation, the middle-income trap is avoidable[12] if governments act early and decisively to improve access to infrastructure.

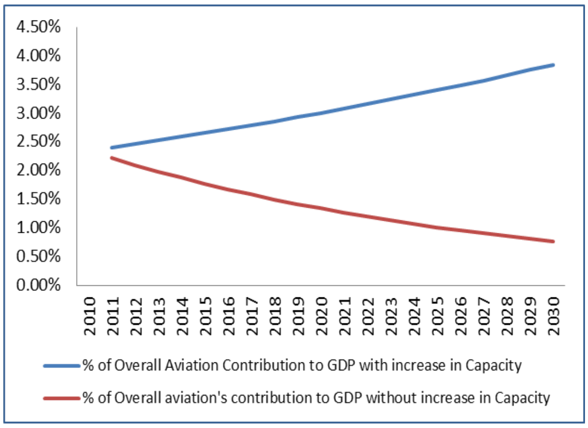
[10] Income Thresholds (GNI per capita) used by the World Bank in 2011 USD. The thresholds are; low income, $1025 or below; lower middle income, $1026-$4035; upper middle income, $4036- $12475; and high income, $12476 or above.

[11] Asia is different from the other developing regions, for some economies (four plus Japan) are already high-income, and five have been low-income since 1950. In Asia there are three (the Philippines and Sri Lanka in the lower middle-income trap, although the latter should get out of it soon; Malaysia in the upper middle-income trap, although it should also get out of it soon; and Indonesia and Pakistan will most likely fall into the lower middle-income trap soon).

[12] Avoiding the middle-income trap is a question of how to grow fast enough so as to cross the lower middle-income segment in at most 28 years (which requires a growth rate of at least 4.7% per annum); and the upper

The 'trap' can be mitigated to some degree with continued investment in infrastructure to improve regional connectivity (Agénor, et al, 2012).





Comparison of overall aviation contribution with and without investing in ICAO ASBU

Efficiency

While simply increasing public investment in infrastructure has often been advocated as a strategy for development, research shows that the effect of such investment critically depends on the efficiency of the existing infrastructure network (Riojas, 2003). The seamless skies initiative is designed to improve the efficiency of air navigation services through increased harmonization and interoperability and flight path optimization.

A cornerstone of seamless skies is that ATM service delivery management will operate seamlessly from gate-to-gate for all phases of flight and across all service providers (ICAO, 2008). In order to measure the success of seamless skies ANSPs and Airlines need to have quantifiable targets for efficiency and costs in order to develop a sound cost benefit analysis.

The Single European Sky (SES) program for example has set aspirational targets for efficiency as a threefold increase in capacity and significant reduction in delays, while the USA's NextGen program is expecting a 35% reduction in delays by 2018 whilst increasing capacity. SES and NextGen also expect to cut costs through delay reduction by EUR 250 Million and USD 23 Billion respectively.

From the perspective of a cost-benefit analysis, ATM Efficiency (Economic, Operational, Technical and Airspace) is of prime importance in order to:

- Improve cost-effectiveness;
- Optimize capacity & minimize delays;
- Reduce flight inefficiency and minimize environmental impact;
- Improve predictability of operations;

The quantification of ATM efficiency is most readily addressed through the single-flight perspective. Its value rests in reducing direct operating costs (DOC) by optimizing flight path trajectory and by eliminating excess flight time, route distance, and fuel usage at non-optimum speeds and altitudes. Because airlines fly millions of single operations per

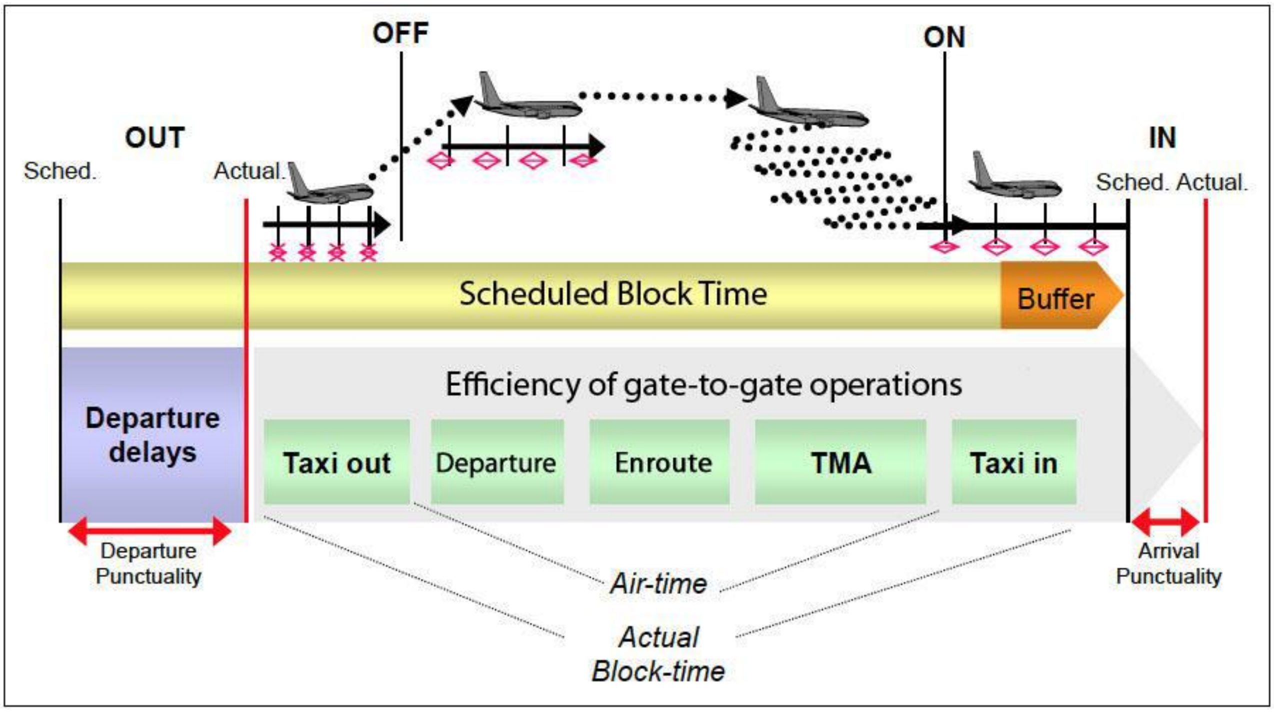
middle-income segment in at most 14 years (which requires a growth rate of at least 3.5% per annum). Only 13 countries were able to transition from middle to high-income status since the 1960s. Of these countries, five were from East Asia – Hong Kong SAR (China), Japan, Korea, Taiwan, China, and Singapore.

year, small incremental DOC savings on every flight can add up to significantly improved financial performance (C/AFT, 1999).

Therefore the unit of measure used to define ATM efficiency from gate-to-gate, is a single 'optimal' or 'ideal' flight that is not subjected to any delays and allowed to fly via the most direct path with continuous climb and descent profiles.

ATM efficiency is defined as the ratio between actual flight time and an 'ideal[13]' or 'optimum' flight time. The 'ideal' flight can then be disaggregated into different phases of flight, which follows the work of Boeing's CNS/ATM Focused Team (C/ATF) in the late nineties, Eurocontrol & FAA (2012), and Boeing & CANSO (2012)

Phases of Flight



Conceptual framework to measure ATM performance (Adapted from Eurocontrol & FAA (2012, p. 24), p.24

ATM system inefficiencies can be analysed gate-to-gate within the following phases of flight,

1. Planning, pre-flight and gate departure
2. Taxi-out
3. Departure
4. Enroute (including Oceanic)
5. TMA (descent and arrival)
6. Taxi in

[13] Ideal flight - Minimum cost travel between origin and destination, assuming still air conditions and no traffic or procedural constraints.

According to Boeing & CANSO (2012) p12, the inefficiencies for each phase of flight are defined as the difference between actual travel time, travel distance, or fuel use against an unimpeded or benchmark travel time, travel distance, or fuel use. The difference between actual travel time and benchmark travel time is delay.[14]

Inefficiencies in the different flight phases have different impacts on aircraft operators and the environment. Whereas ATFM related holdings result in departure delays mainly experienced at the stands, inefficiencies in the gate-togate phases generate additional fuel burn, which also has an environmental impact through gaseous emissions (mainly CO_2),

Gate Departure Delays (1)

Reducing gate/surface delays (by releasing too many aircraft) at the origin airport when the destination airport's capacity is constrained potentially increases airborne delay (i.e. holding or extended final approaches). On the other hand, applying excessive gate/surface delays risks under utilization of capacity and thus, increases overall delay. The aim is to keep aircraft at the gate in order to minimise fuel burn due to departure holdings at the runway.

Taxi out phase (2)

The impact of ANSPs on taxi times is marginal when runway capacities are constraining departures. However, data on taxi delays is useful in developing policies and procedures geared towards keeping aircraft at the gate longer, in readiness for the implementation of Airport Collaborative Decision Making (ACDM). A-CDM initiatives try to optimise the departure queue while minimizing costs to aircraft operators.

Departure (3) & Taxi In (5) phases

The results of the combined Eurocontrol & FAA (2012) study on ATM performance found the taxi-in and the TMA departure phases (40 NM ring around departure airport) generally not considered to be large contributors to ATM related inefficiencies.

Vertical Flight Inefficiencies in phases 3,4&5

In addition to time delays and horizontal inefficiencies are vertical inefficiencies, which comprise of two components.

1. Flight level capping: the flight can't reach its optimum cruising level during the flight
2. Interrupted climb/descent: during the climb or descent phase, the flight is kept at a suboptimal flight level (Intra-flight vertical inefficiencies)

A Eurocontrol, PRC (2008) study found vertical flight inefficiencies increased fuel burn by less than 0.6% (Average 23kg/flight). However it should be noted that study was conducted in airspace with full surveillance and VHF communication coverage –a similar study conducted across Asia Pacific airspace with limited surveillance and communication coverage would be expected to result in much higher fuel burn figures. Nevertheless, while vertical flight inefficiencies do generate some negative impacts they remain relatively small when compared to other types of inefficiencies (horizontal, taxi time, airborne delays).

While vertical flight inefficiencies will not be analyzed in this study, there is scope for improvement, and more work on vertical flight inefficiencies and the potential benefits of

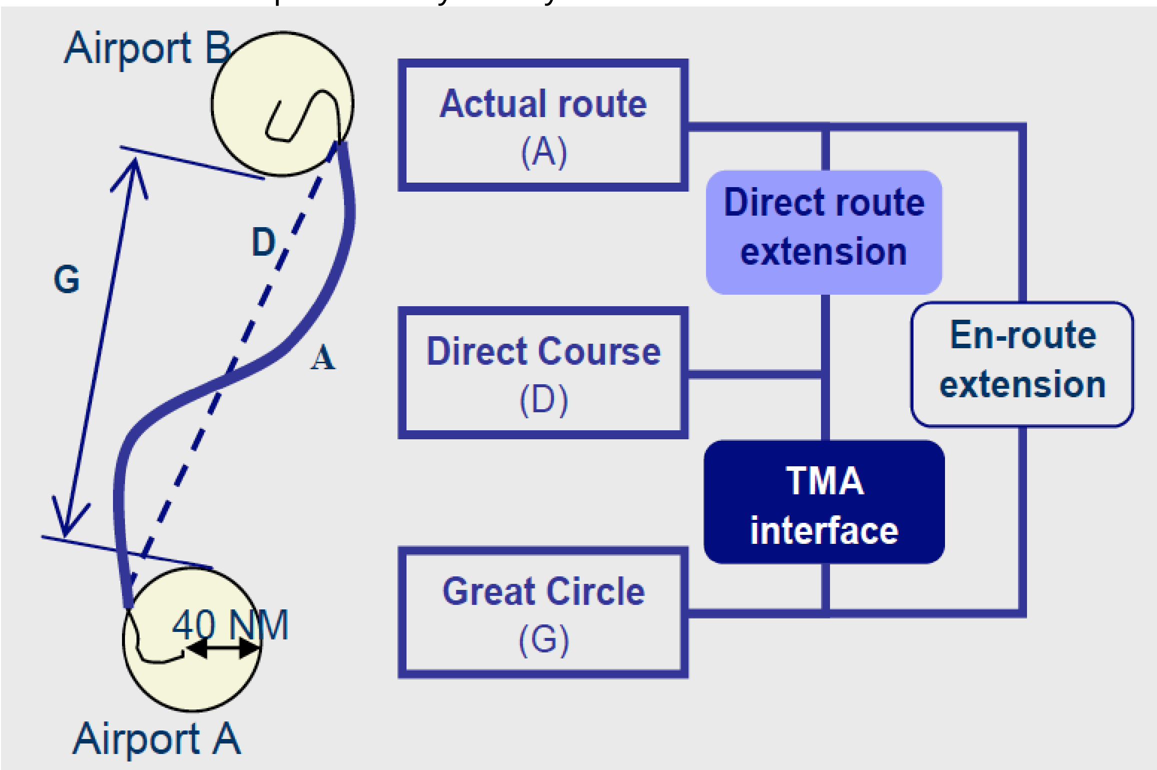
[14] Refer to Boeing & CANSO (2012) p 15-25, and Eurocontrol & FAA (2012) Chapter 6 for extensive discussion of Air Traffic Management efficiencies according to flight phase.

implementing Continuous Climb Operations (CCO)[15] and Continuous Descent Operations (CDO), as per ASBU B0-20 and B0-05 respectively, would form a more complete picture.

Enroute Inefficiency (Horizontal) phase 4
The objective of analyzing Enroute flight inefficiency is to:

- Calculate performance indicators that measure flight inefficiency,
- Identify areas in the Asia Pacific region where ATM system performance
- could be improved,
- Assess economic impact of flight extension on airlines and environment.

Optimum trajectories
The horizontal component of optimum trajectories has been defined by previous studies (E.g. Kettunen, et al. 2005; Boeing & CANSO, 2012; Eurocontrol & FAA, 2012) as the great circle distance. In a simplified view of aircraft flight management, this direct route is considered as the cheapest option, as it minimizes fuel costs. In reality, aircraft often do not follow this direct route since airlines have to make tradeoffs between several factors, such as meteorological conditions, which may lead to definitions of optimum, which differ, from great circle distance. However, great circle distance provides the advantage of being a constant benchmark (independent of individual strategies) against which actual trajectories can be compared from year to year.



The KPI used for horizontal en route flight efficiency is enroute extension. Enroute extension is defined as the difference between the length of the actual trajectory (A) and the Great Circle Distance (G) between the departure and arrival terminal areas (radius of 40 NM around airports) (Eurocontrol & FAA, 2012:47).

[15] It is important to consider that CCO and CDO benefits are heavily dependent on each specific ATM environment. Nevertheless, if implemented within the ICAO CCO / CDO manual framework, it is envisaged that the benefit/cost ratio (BCR) will be positive

Fragmentation of airspace and military restricted airspace play significant roles in increasing enroute inefficiencies and limits the ability of the enroute facilities to support airport throughput.

TMA (descent and arrival) phase 5.
TMA inefficiencies are defined by the average “additional” time beyond the unimpeded transit time for each airport within the last 100Nm of flight.

The additional time is used as a proxy to measure the tactical management initiatives (TMI) used at an airport irrespective of local ATM strategies (sequencing, flow integration, speed control, mile-in-trail, holding) (refer Annex IV, Eurocontrol & FAA, 2012 for detailed EU methodology). The fragmentation of Asia Pacific airspace is expected to be a significant contributor to TMA inefficiencies as the support of the en route function is limited and rarely extends beyond the national boundaries. Hence, most of the sequencing is done at lower altitudes around the airport.

Conclusion
This conceptual framework enables operational performance to be measured in a consistent way and ATM best practices to be better understood.

While the estimated total ATM inefficiency pool and associated fuel burn in more developed aviation systems such as the US and Europe are similar (estimated to be 6-8% of the total fuel burn), it is expected to be higher across the Asia Pacific region due to the diverse levels of CNS/ATM infrastructure and institutional fragmentation.

The analysis of aircraft operations, broken down by phase of flight (i.e. pre-departure delay, taxi-out, en route, terminal arrival, taxi-in, and arrival delay), will reveal the strengths and weaknesses or bottlenecks of the ATM system at various locations in the Asia Pacific region.

The subsequent implementation of associated ASBU Block 0 modules, which utilize today’s best practices, existing technology and operational concepts, should elevate the performance of ATM across Asia Pacific in the relative short term in a standardized, harmonized manner to achieve seamless operations.

Costs

As previously mentioned, delays and their subsequent costs increase exponentially as demand approaches the capacity limits of the system. As these levels are approached, aircraft must wait to use the system, or various parts of it, until they can be accommodated. These delays impose costs both in terms of aircraft operating expenses and the value of wasted passengers' time.

Estimation of the delay benefits of new infrastructure projects or procedures requires measurement of the aggregate annual aircraft operating time and passenger time which the new proposal will save.

The saving is the difference between the delays currently experienced and those, which would be experienced with the proposed new project or procedures. Once determined, the value of this saved time can be valued in dollars using standardized values (FAA, 1998).

Airline Costs

Cost of Delay to airline

A recent study by the University of Westminster (2011)[16] evaluated the costs of delay by four flight phases: at gate, taxi, Enroute extension, and TMA.
These costs are dominated primarily by passenger costs, and then fuel burn differences. Only tactical costs (marginal costs) incurred on the day of operations are considered in this study – network effects and strategic effects have been omitted.

Fuel

Fuel Cost

As of 2 Nov 2012 (IATA & Platts)

- USD $124.7/ barrel or
- USD $0.9827/kg

Rate of fuel burn

The cost of fuel burned per minute is calculated for the three off-gate phases. The at-gate calculations assume the engines and APU are off. As a proxy for fuel burn rates for individual aircraft types at varying weights and altitudes this analysis will use average fuel burn rates representing a 'standard' aircraft in the system as established by Eurocontrol & FAA (2012), p52.

Standard aircraft fuel burn

- Taxi = 15kg/min
- Enroute = 46 kg/min
- TMA holding = 41kg/min

Direct Aircraft Operating Costs (DOC)

Flight and ground cost per block hour[17] that are linked to the operation of an aircraft, such as fuel, aircraft parking, air bridges and maintenance costs (refer Appendix B for more detail)

Cost of Distance Flown

Marginal Cost (Tactical) USD $11.8 /Nm (for track extension calculation)

Passenger Value of Time

The passenger value of time is an opportunity cost, which corresponds to the monetary value associated with a traveler during a journey. This value of time is approximately equal to 70 per cent of the wage rate (Peterson, et al, 2013)

According to the Air Transport Association of America, the passenger value of time is USD$ 33[18]/ passenger /hour. Eurocontrol value the opportunity cost of passengers similarly at €24.20 (USD$ 32/passenger/hour) baseline case, and €3.90 (USD $5.13) low scenario.

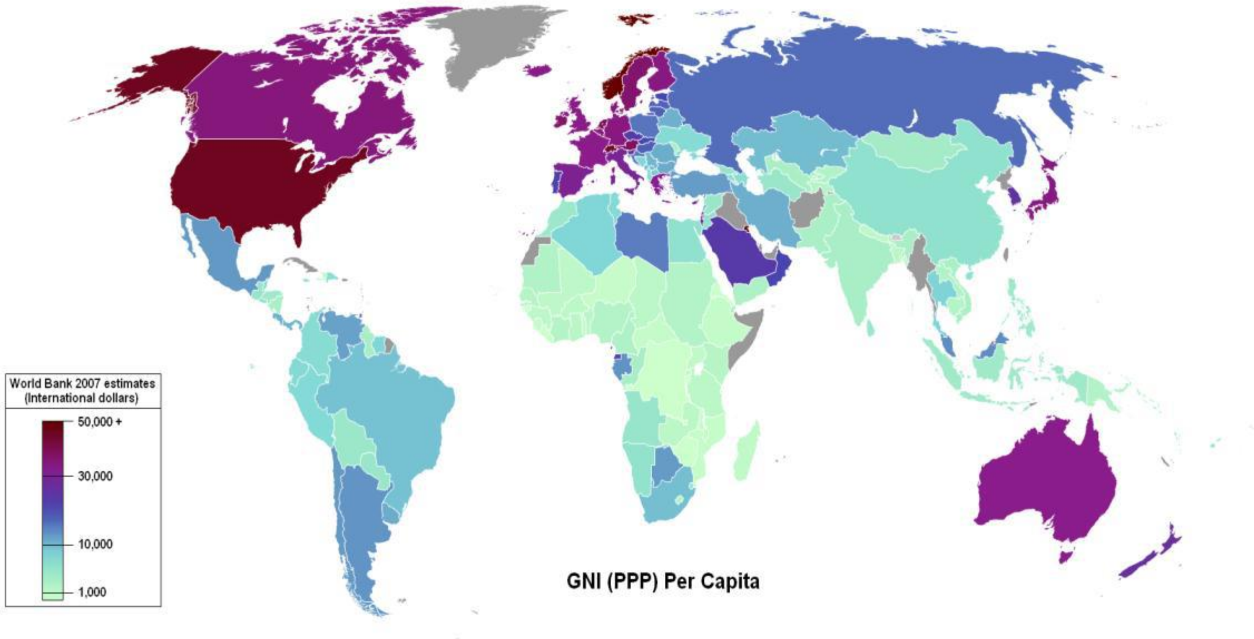
The diagram below provides an overview of Gross National Income (PPP) per capita. A valid argument could be raised for more similar average incomes for airline passengers

[16] European airline delay cost reference values. Final Report March 2011(Version 3.2)

[17] A block hour is the time an aircraft is utilised from the moment the aircraft door closes at departure of a revenue flight until the moment the aircraft door opens at the arrival gate following its landing.

[18] The time values are derived from the Air Travel Survey last conducted by the Air Transport Association of America in 1998 and adjusted to 2011 prices.

across all regions, however due to a lack of research on air passenger incomes outside of the USA and EU, Eurocontrol's low scenario amount USD $ 5.13/passenger/hour will be used for prudence (Note this figure is expected to produce a result on the extreme low side – a more appropriate figure is being sought).



Average Aircraft Capacity

	1989	1999	2009
Passenger Load Factor	68%	69%	76%
Aircraft Utilization (hours/aircraft/year)	2,193	2,770	3,502
Average aircraft Capacity	181	171	166

Source ICAO: 2009

Load Factors

- Passenger - Average approx. 77% (International and Domestic)
- Cargo - approx. 61% Available Freight Tonne kilometers (ATFK)

Source: IATA, Asia Pacific 2011-2012

Therefore the average passenger cost per aircraft with an average of 166 passengers, a load factor of 77% and USD $ 5.13 per hour = (166*0.77*5.13)=USD $655 per hour = USD$ 10.93/aircraft/minute.

ANSP Costs

The implementation of ABSU Block upgrades will require investment decision to be made by ANSPs. Cost categorisations include,

- R&D Costs
- Implementation Costs (refer Appendix C for indicative list of CNS/ATM costs)
- Operational Costs
- Overheads

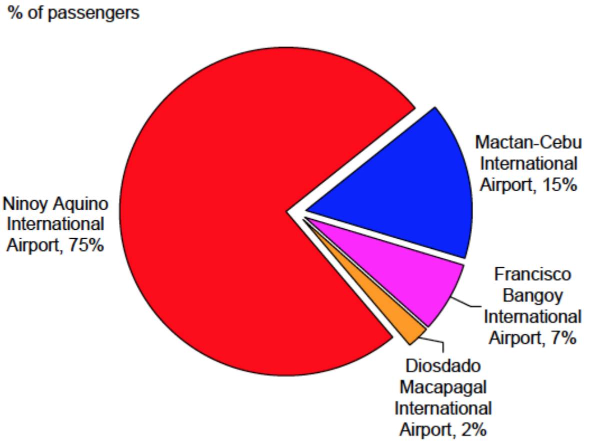
As these costs are context and environmental specific, an accurate CBA requires detailed data from each country.

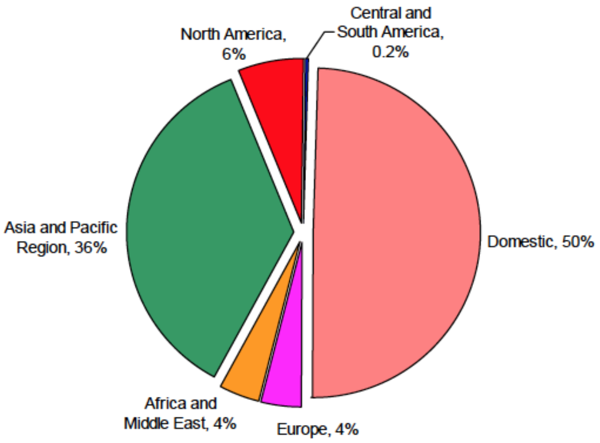
STEP 5 - Compare the Alternatives

Philippines FIR Business Case

A comparison of the benefits achieved between the 'business as usual' case and the implementation of Block 0 ASBU across in the Philippines provides an illustration of the net benefits of the ICAO model.

Current Situation:
The four busiest airports in the Philippines – Ninoy Aquino International (NAIA)(Manila), Mactan-Cebu International, Francisco Bangoy (Davao) and Diosdado Macapagal (Clark) – handle nearly 28 million passengers per year.90% of these passengers pass through NAIA (75%) and Mactan-Cebu (15%) airports, with 50% of the total domestic passengers.





Source: IATA

Accordingly, the continued growth of aviation activity at these airports is vital to the Philippines economy. As indicated in Oxford Economics' (2011) report, the aviation sector contributes PHP 35.5 billion (0.4%) to Philippine GDP, and with the addition of 'catalytic' benefits through tourism the overall contribution is raised to PHP 195.2 billion or 2.4% of GDP.
This analysis has been completed but has yet to be shared with relevant stakeholders to verify the assumptions and accuracy of the output.

STEP 6 - Evaluate the Outcome

Benefit of ASBU Block 0 to NAIA
Fuel savings achieved by implementing ASBU Block 0 into NAIA airport are:

	Taxi out Phase SBU	TMA Phase
Without implementing A	26,017,000 kg	59,261,400 kg
With implementing ASBU	6,504,300 kg	17,778,420 kg
Fuel Savings	19,512,700 kg	41,482,980 kg

Total Fuel savings: 609,956,680kg

Fuel Cost: USD $0.9827/kg

Total savings on Fuel: $ 59,940,454

CO_2 emission: 3.149 kg per kg of fuel

Total CO_2 reduced: 192,075 Tonne

Opportunity cost of delay to passengers (based on low scenario)

- Taxi Out phase: 18 Aircraft per hour * (24-6) min * $10.93/aircraft /min = $3,541/hour *11 Hours = 38,954 per day = USD $14,218,210 per year
- TMA Arrival: 18 Aircraft per hour* (20-6) min* $10.93/aircraft/min = $2,754/hour *11 Hours = $30,298 per day = USD $11,058,755 per year

Annual Passenger Opportunity Costs: USD $ 25,276,965 per annum.

Total Benefit of Implementing ASBU Block 0 to the users of NAIA is USD$ 85,217,419 per annum.

The cost of not implementing ASBU Block 0 to the users of NAIA is USD$ 85.2 million per year

Appendix A
Air Traffic Statistics

IFR Flights 2010 (Source ICAO GIS, 2012)				
Member State	FIR	Number of Flights	Total flight time in FIR (Hours)	Average Fight Time in FIR (Hours)
Afghanistan	Kabul	154684	67096	2.31
Australia	Brisbane Melbourne	449152 594383	495925 539255	1.01
Bangladesh	Dhaka	160779	35157	4.57
Bhutan				
Brunei Darussalam				
Cambodia	Phnom Penh	154618	38940	3.97
China	Hong Kong, Sanya, Guangzhou, Kunming Shanghai Wuhan, Lanzhou Beijing Shenyang Urumqui	558493 294,754 1348761 691992 1689318 591438 368355 760757 441305 153821	99448 94628 592660 364751 1150795 280118 229129 356517 227406 127650	1.96
Cook Islands				
Democratic People's Republic of Korea	Pyonngyang	178087	56101	3.17
Fiji	Nadi	62085	51569	1.20
India	Mumbai, Chennai, Delhi	521208 449267 395665	503565 311038 240904	1.29
Indonesia	Jakarta Ujung Panang Kota Kinabalu	502768 373258 202562	336942 300173 63784	1.54
Japan	Fukuoka	1084469	1027206	1.06
Kiribati				
Lao People's Democratic Republic	Vientiane	187894	37705	4.98
Malaysia	Kuala Lumpur	586760	183955	3.19
Maldives	Male	36240	21493	1.69
Marshall Islands				
Micronesia				
Mongolia	Ulan Bator	116635	95518	1.22
Myanmar	Yangon	220439	131179	1.68
Nauru	Nauru	1005	1214	0.83
Nepal	Kathmanu	170031	38050	4.47
New Zealand	New Zealand, Auckland Oceanic	246958 266598	19672 134446	3.33
Pakistan	Karachi, Lahore,	226444 150385	132528 54942	2.01
Palau				
Papua New Guinea	Port Morseby	48592	29021	1.67
Philippines	Manila	315681	258290	1.22
Republic of Korea (Sth)	Incheon	533119	213352	2.50
Samoa				
Singapore	Singapore	359938	174680	2.06
Solomon Islands	Honiara	7520	4928	1.53
Sri Lanka	Colombo	61234	44389	1.38
Thailand	Bangkok	459813	217153	2.12
Timor Leste				
Tonga				
Vanuatu				
Viet Nam	Ho Chi Minh, Hanoi	332981 194592	164826 55634	2.39
(Taipei)	Taipei	303731	94583	3.21
TOTAL	45	17008569	9698315	1.75

Appendix B

Direct Aircraft Operating Costs (DOC)

Flight and ground cost per block hour[19] that are linked to the operation of an aircraft, such as fuel, aircraft parking, air bridges and maintenance costs.

Value:

Aircraft	Fuel con-sumption	Other costs	Cost of Fuel	Total operating costs
A300-600	7,071	1,853	5,671	7,524
A319	3,108	1,349	2,492	3,842
A320	3,354	1,407	2,690	4,096
A321	3,505	1,607	2,811	4,418
A330-200	6,670	2,039	5,349	7,388
A330-300	7,083	2,048	5,680	7,728
A340-300	8,230	2,059	6,600	8,659
A340-600	9,782	2,456	7,844	10,301
A380-800	n/a	n/a	n/a	n/a
ATR-42	757	931	607	1,538
ATR-72	810	1,252	650	1,902
B-727-200	4,028	1,734	3,230	4,964
B-737-200	3,013	1,323	2,416	3,740
B-737-200C	4,300	1,833	3,449	5,282
B-737-300/700	2,612	1,397	2,095	3,492
B-737-400	3,051	1,560	2,447	4,007
B-737-500	3,044	1,400	2,441	3,841
B-737-800	2,135	1,099	1,712	2,812
B747-100	15,176	4,581	12,170	16,751
B-747-200	15,229	5,190	12,213	17,403
B-747-400	14,169	3,832	11,363	15,195
B-757-200	3,407	1,902	2,732	4,634
B-767-200	4,607	2,189	3,695	5,883
B-767-300	4,910	2,304	3,937	6,242
B-777-200	7,301	2,590	5,855	8,446
BAE 146-300	3,240	1,838	2,599	4,437
CRJ-100	1,832	1,027	1,469	2,497
CRJ-200	2,018	701	1,618	2,320
DC-9-10	3,153	1,331	2,529	3,860
DC-9-30	3,422	1,410	2,744	4,155
DC-9-40	3,661	888	2,936	3,824
DC-9-50	2,930	1,117	2,350	3,467
DC-10-10	6,787	3,675	5,443	9,118
DC-10-30	9,467	3,902	7,592	11,494
DC-10-40	8,464	3,576	6,788	10,364
DHC 8-100	931	839	747	1,586
EMB-120	591	868	474	1,342

Aircraft	Fuel con-sumption	Other costs	Cost of Fuel	Total OPS costs
ERJ-135	1,287	607	1,032	1,639
ERJ-145	1,321	710	1,059	1,769
MD-11	8,237	2,862	6,606	9,467
MD-80	3,025	1,597	2,426	4,023
MD-87	2,805	1,204	2,250	3,454
MD-90	2,351	2,129	1,885	4,015
L-1011-500	0	2,846	0	2,846
A300-600	7,071	1,853	5,671	7,524

(Adjusted from 2000 US $ values with 2011 jet fuel prices)

Source: ICAO Base-line Aircraft Operating Costs, Summer 2000
http://legacy.icao.int/icao/en/ro/allpirg/allpirg4/wp28app.pdf

[19] A block hour is the time an aircraft is utilised from the moment the aircraft door closes at departure of a revenue flight until the moment the aircraft door opens at the arrival gate following its landing.

Appendix C
CNS/ATM Base-line costs (USD)

Systems	Costs				
	Purchase	Upgrade/ retrofit Kit	Installation (same site)	Maintenance	Inspection/ commissioning
Communications aircraft					
AMSS Package (See notes)	$650,000				
HF data upgrade		$20,000			
FMS Retrofit (See Note)		$300,000			
FANS-1 retrofit (see note)		$134,000			
Communications ground					
VHF	$170,000	$51,000	$20,000	$17,000	
HF	$160,000	$48,000	$20,000	$16,000	
AMSS ground Station	$15,000,000		(included)	$1,500,000	
ATN Router	$120,000		(included)	$12,000	
ATN gateway	$100,000		(included)	$10,000	
Navigation aircraft					
GPS for FANS-1 PACKAGE (DUAL)	$58,000				
FMS retrofit (MD-11)	$300,000				
FMS retrofit (b-747-400)	$100,000				
MMR for GBAS (DIGITAL)	$30,000				
MMR for GBAS (ANALOG)	$40,000				
Navigation Ground					
VOR	$135,000	$45,000	$50,000	$9,700	$5000/$50000
DME	$125,000	$38,000	$50,000	$8,000	$5000/$50000
VOR/DME	$17,429	$80,000	$90,000	$12,200	$125000/$50000
DVOR/DME	$525,000	$160,000	$100,000		
NDB (100 WATTS)	$30,000	$10,000	$15,000	$3,000	$5,000
TACAN	$525,000	$240,000			
GNSS Master Station	$8,000,000				
GNSS Uplink	22,000,000/year				
GNSS reference Station	$1,000,000				
GBAS	$850,000				
Landing Aids					
ILS Cat I	$500,000	$290,000	$200,000	$17,100	$50,000
ILS Cat II	$1,100,000	$540,000	$225,000	$17,100	$50,000
ILS Cat III	$1,250,000	$540,000	$225,000	$17,100	$50,000
Control Center					
Work Station (CPDLC)	$350,000		(included)		$35,000.00
FANS-1 Work Station (see Note)	$540,000		(included)		$54,000.00
ATM FDPS	$950,000		(included)		$95,000.00
CNS/ATM Syst. (2 seats)	$2,000,000		(included)		$200,000.00
Additional seats	$650,000		(included)		$65,000.00

Note: 2000 figures require updating to 2012 (Source: ALLPIRG/4-WP/28)

Appendix D
ICAO Aviation System Block 0 & 1 Upgrades by Performance Improvement Area (PIA)

PIA 1. Greener Airports

Block 0	Block 1
B0-65 **Improved Airport Accessibility** This is the first step toward universal implementation of GNSS-based approaches	B1-65 **Optimized Airport Accessibility** This is the next step in the universal implementation of GNSS-based approaches
B0-70 **Increased Runway Throughput through Wake Turbulence Separation** Improved throughput on departure and arrival runways through the revision of current ICAO wake turbulence separation minima and procedures .	B1-70 **Increased Runway Throughput through Dynamic Wake Turbulence Separation** Improved throughput on departure and arrival runways through the dynamic management of wake turbulence separation minima based on the real-time identification of wake turbulence hazards
B0-15 **Improved RunwayTraffic Flow through Sequencing (AMAN/DMAN)** Time-based metering to sequence departing and arriving flights	B1-15 **Improved Airport operations through Departure, Surface and Arrival Management** Extended arrival metering, Integration of surface management with departure sequencing bring robustness to runways management and increase airport performances and flight efficiency
B0-75 **Improved Runway Safety (A-SMGCS Level 1-2)** Airport surface surveillance for ANSP	B1-75 **Enhanced Safety and Efficiency of Surface Operations (A-SMGCS/SURF IA) and EVS** Airport surface surveillance for ANSP and flight crews with safety logic, cockpit moving map displays and visual systems for taxi operations
B0-80 **Improved Airport Operations through Airport-CDM** Airport operational improvements through the way operational partners at airports work together	B1-80 **Optimized Airport Operations through Airport-CDM** Airport operational improvements through the way operational partners at airports work together
	B1-81 **Remote Operated Aerodrome Control Tower** Remotely operated Aerodrome Control Tower contingency and remote provision of ATS to aerodromes through visualisation systems and tools

PIA 2. Globally Interoperable Systems and Data – Through Globally Interoperable, SWIM

Block 0	Block 1
B0-25 **Increased Interoperability, Efficiency and Capacity through Ground-Ground Integration** Supports the coordination of ground-ground data communication between ATSU based on ATS Inter-facility Data Communication (AIDC) defined by ICAO Document 9694	B1-25 **Increased Interoperability, Efficiency and Capacity though FF-ICE/1 application before Departure** Introduction of FF-ICE step 1, to implement ground-ground exchanges using common flight information reference model, FIXM, XML and the flight object used before departure
B0-30 **Service Improvement through Digital Aeronautical Information Management** Initial introduction of digital processing and management of information, by the implementation of AIS/AIM making use of AIXM, moving to electronic AIP and better quality and availability of data	B1-30 **Service Improvement through Integration of all Digital ATM Information** Implementation of the ATM information reference model integrating all ATM information using UML and enabling XML data representations and data exchange based on internet protocols with WXXM for meteorological information
	B1-31 **Performance Improvement through the application of System Wide Information Management (SWIM)** Implementation of SWIM services (applications and infrastructure) creating the aviation intranet based on standard data models, and internet-based protocols to maximize interoperability
B0-105 **Meteorological Forecasts, Warnings and Alerts**. Global, regional and local meteorological information: • Aerodrome warnings to give concise information of meteorological conditions that could adversely affect all aircraft at an aerodrome including windshear. • Forecasts provided by world area forecast centres (WAFC), volcanic ash advisory centres (VAAC) and tropical cyclone advisory centres (TCAC) This information will support flexible airspace management, improved situational awareness and collaborative decision making, and dynamically-optimized flight trajectory planning.	B1-105 **Better Operational Decisions through Integrated Weather Information (Strategic >40 Minutes)** Weather information supporting automated decision process or aids involving: weather information, weather translation, ATM impact conversion and ATM decision support

PIA 3. Optimum Capacity and Flexible Flights – Through Global Collaborative ATM

Block 0	Block 1
B0-10 **Improved Operations through Enhanced En-Route Trajectories** To allow the use of airspace which would otherwise be segregated (i.e. military airspace) along with flexible routing adjusted for specific traffic patterns. This will allow greater routing possibilities, reducing potential congestion on trunk routes and busy crossing points, resulting in reduced flight length and fuel burn.	**B1-10** **Operations through Free Routing** Introduction of free routing in defined airspace, where the flight plan is not defined as segments of a published route network or track system to facilitate adherence to the user-preferred profile
B0-35 **Improved Flow Performance through Planning based on a Network-Wide view** Collaborative ATFM measure to regulate peak flows involving departure slots, managed rate of entry into a given piece of airspace for traffic along a certain axis, requested time at a way-point or an FIR/sector boundary along the flight, use of miles-in-trail to smooth flows along a certain traffic axis and re-routing of traffic to avoid saturated areas	**B1-35** **Enhanced Flow Performance through Network Operational Planning** ATFM techniques that integrate the management of airspace, traffic flows including initial user driven prioritisation processes for collaboratively defining ATFM solutions based on commercial/operational priorities

B0-84 Initial Capability for Ground-Based Cooperative Surveillance Ground surveillance supported by ADS-B OUT and/or wide area multilateration systems will improve safety, especially search and rescue and capacity through separation reductions. This capability will be expressed in various ATM services, e.g. traffic information, search and rescue and separation provision.	
B0-85 **Air Traffic Situational Awareness (ATSA)** Two *ATSA (Air Traffic Situational Awareness)* applications which will enhance safety and efficiency by providing pilots with the means to achieve quicker visual acquisition of targets: • AIRB (Enhanced Traffic Situational Awareness during Flight Operations). • VSA (Enhanced Visual Separation on Approach).	**B1-85** **Increased Capacity and Flexibility through Interval Management** Interval Management (IM) improves the management of traffic flows and aircraft spacing. Precise management of intervals between aircraft with common or merging trajectories maximizes airspace throughput while reducing ATC workload along with more efficient aircraft fuel burn..
B0-86 **Improved access to Optimum Flight Levels through Climb/Descent Procedures using ADS-B** This prevents an aircraft being trapped at an unsatisfactory altitude and thus incurring non-optimal fuel burn for prolonged periods. The main benefit of ITP is significant fuel savings and the uplift of greater payloads	
B0-101 **ACAS Improvements** To provide short term improvements to existing airborne collision avoidance systems (ACAS) to reduce nuisance alerts while maintaining existing levels of safety. This will reduce trajectory perturbation and increase safety in cases where there is a breakdown of separation.	
B0-102: Increased Effectiveness of Ground-based Safety Nets This module provides improvements to the effectiveness of the ground-based safety nets assisting the Air Traffic Controller and generating, in a timely manner, alerts of an increased risk to flight safety (such as short terms conflict alert, area proximity warning and minimum safe altitude warning).	**B1-102: Ground-based Safety Nets on Approach** This module enhances the safety provide by the previous module by reducing the risk of controlled flight into terrain accidents on final approach through the use of Approach Path Monitor (APM).

PIA 4. Efficient Flight Path – Through Trajectory-based Operations

Block 0	Block 1
B0-05 **Improved Flexibility and Efficiency in Descent Profiles (CDOs)** Deployment of performance-based airspace and arrival procedures that allow the aircraft to fly their optimum aircraft profile taking account of airspace and traffic complexity with continuous descent operations (CDOs)	B1-05 **Improved Flexibility and Efficiency in Descent Profiles (OPDs)** Deployment of performance-based airspace and arrival procedures that allow the aircraft to fly their optimum aircraft profile taking account of airspace and traffic complexity with Optimized Profile Descents (OPDs)
B0-40 **Improved Safety and Efficiency through the initial application of Data Link En-Route** Implementation of an initial set of data link applications for surveillance and communications in ATC	B1-40 **Improved Traffic Synchronization and Initial Trajectory-Based Operation.** Improve the synchronization of traffic flows at en-route merging points and to optimize the approach sequence through the use of 4DTRAD capability and airport applications, e.g.; D-TAXI, via the air ground exchange of aircraft derived data related to a single controlled time of arrival (CTA).
B0-20 **Improved Flexibility and Efficiency in Departure Profiles** Deployment of departure procedures that allow the aircraft to fly their optimum aircraft profile taking account of airspace and traffic complexity with continuous climb operations (CCOs)	
	B1-90 **Initial Integration of Remotely Piloted Aircraft (RPA) Systems into non-segregated airspace** Implementation of basic procedures for operating RPAs in non-segregated airspace including detect and avoid

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