A Discussion of the Capacity Supply - Demand Balance within the Global Commercial Air Transport Industry

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Executive Summary

There is a continuing discussion that has intensified recently, on the question of whether the air transport industry is in a state of overcapacity and, if so, to which stakeholder(s) the state of overcapacity should be ascribed. This debate has appeared frequently in the media and industry reports in recent months. The authors of this paper have observed that most reports do not attempt to genuinely define the various potential states of the industry before asserting their diagnoses that the industry is in a state of persistent structural overcapacity.

"A problem well-stated is a problem half-solved."

- Charles Kettering (1876-1958), American inventor, engineer, businessman and holder of 186 patents

In this paper we identify **three** states of the industry: **(1) balance**; **(2) overcapacity**; and **(3) under-capacity**. The air transport industry is always in one these states, as momentum builds for change in response to signals originating from inside and outside the air transport system.

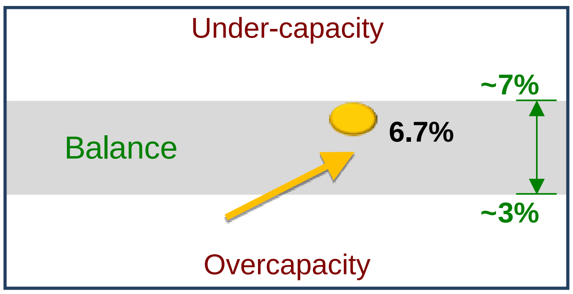
We discuss a broad set of considerations, measures and various indicators that are relevant and appropriate for assessing the supply-and-demand balance across the air transport industry. The key indicators are:

- **Available Seats Kilometers (ASK)*** **growth rate**, which measures the rate of change in supply of airline network capacity. [*or Available Seat Miles (ASM)]
- **Passenger Load Factor (PLF),** which measures the proportion of the network capacity filled by ticket-buying passengers (demand) versus the supplied capacity ASK.
- **Aircraft Utilization**, which assesses the active (revenue-generating) time of aircraft asset use across the fleet and is primarily measured in average flight hours per day.
- **Net Commercial Fleet growth rate**, which measures the rate of change or net growth of the commercial fleet size, the combined effect of new airplane deliveries, churn of the parked fleet, and retirement of aging and/or inefficient airplanes.

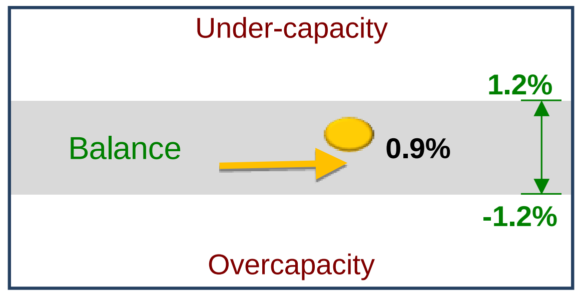
Capacity supply and demand is deemed in balance as long as most of the above indicators are within their nominal ranges (defined as 25^{th} to 75^{th} percentile of year-over-year variations, see Exhibit 1) around their underlying long-term trend or mean values. Only when most or all of the indicators have fallen out of their nominal ranges for a definite period of time (three years[1]), can capacity supply and demand be declared out of balance, that is, in a state of overcapacity or a state of under-capacity. Patterns in which indicators move at different paces or in divergent directions, imply that, whereas the system is in balance, it could be building potential for a change to another state.

Exhibit 1 (below) uses the above definition of the status of the industry and the indicator matrix to assess the current state of the air transport industry. **We find that all indicators are currently within their nominal ranges; there is no evidence of a persistent systemic overcapacity; and the industry capacity supply and demand is in balance.**

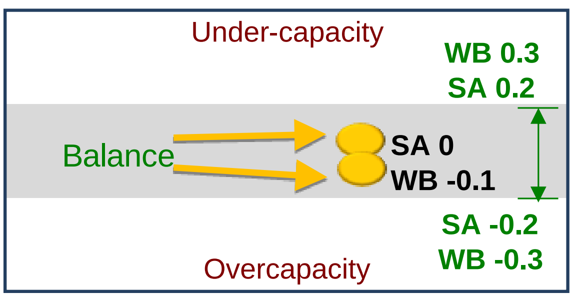
Exhibit 1 *The current state of capacity supply and demand balance in the air transport system (yellow dot represents current state with respect to nominal balance range, gray area, and yellow arrow shows momentum of status)*



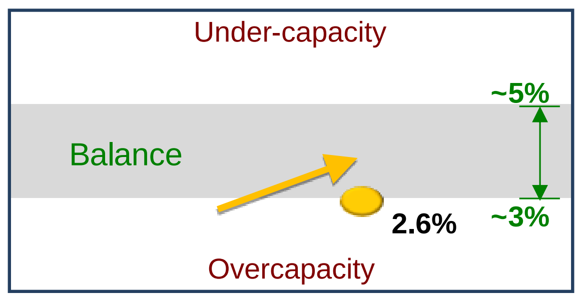
ASK growth is in balance based on growth recorded by ICAO, moving-average momentum moving from previous overcapacity to current balance state



PLF is in balance with delta from trend, based on ICAO data, moving-average momentum remaining relatively flat and in balance



Utilization Flight hours /day trend delta is in balance for single-aisle (SA) and wide-body (WB) aircraft at 0 and -0.1 respectively with momentum relatively flat and in balance



Year over year net fleet growth is in balance, since the moving average momentum is moving from previous state of overcapacity to current balance status

[1] *We suggest a three-year time window as the industry has been and will always be in continuous correction – the capacity supply constantly attempts to adapt to the ever-changing demand via a variety of means, from demand stimulation, revenue management, and network optimization, to fleet management. Three years is sufficient to observe correcting behavior with annual data; a shorter period could be considered with higher frequency data available.*

1. Introduction

1.1 Background and objective

A perennial debate exists in the air transport industry regarding the balance between the supply and demand of capacity, referred to, by some, as *overcapacity*. However, this term itself is prejudicial to any assessment and in this document a holistic viewpoint is provided. To understand this issue one must first define the scope and measurements necessary to assess capacity. Often a too narrowly defined perspective will over simplify the more complex and nuanced issues and thus bound the discussion to a limited field of considerations when a wider view can more appropriately place any assessment of the state of capacity balance in the context of the global commercial aviation system.

It is commonly understood that any industry that contributes and is subject to the macro economy will experience the ebb and flow of the economic environment. As an indispensable part of the global economy, the air transport industry is subject to the ups and downs of the exogenous macro environment and therefore assumes various states over time in response to changes in the economic environment.

The commercial aviation industry is a multifaceted system that consists of, and is influenced by, multiple sectors, stakeholders and systems, e.g.; airlines, governments, regulators, passengers, aircraft original equipment manufacturers (OEMs), aerospace supply manufacturing, airports, air traffic management (ATM) providers, aircraft leasing companies, financiers and investors, other services and suppliers, etc… To get the most informed read on the state of the industry, one should examine a matrix consisting of a series of indicators simultaneously.

Herein we attempt to lay out a broad set of considerations and appropriate measures for assessing the supply-demand balance across the industry. It is hoped that by providing an inclusive perspective and suggesting key system metrics, industry observers and analysts will be equipped with additional information and tools to consider with which to make their interpretation of the state of the industry.

1.2 Perspective

This paper discusses and attempts to draw some distinction between how different stakeholders in the global commercial aviation community view the industry capacity supply and demand balance. One of the key points of understanding the overall picture of the capacity balance is to consider the perspective of the stakeholder and the influence of the lens through which any assessment is viewed. In addition, time scale and market are also factors that can alter one's perspective on the assessment of capacity balance; and thus, consideration of time and geographic market elements are important.

1.3 Status metrics

In measuring status, thought has been given to variables, influencers and potential causal factors. However, to identify the status of capacity supply-demand balance, isolating the critical metrics that indicate status has been the guiding principle used to determine relevance. Also of value to understanding status is being able to detect when or where status change occurs in conjunction with measuring the points or bounds at which that state occurs in contrast to a counter-state.

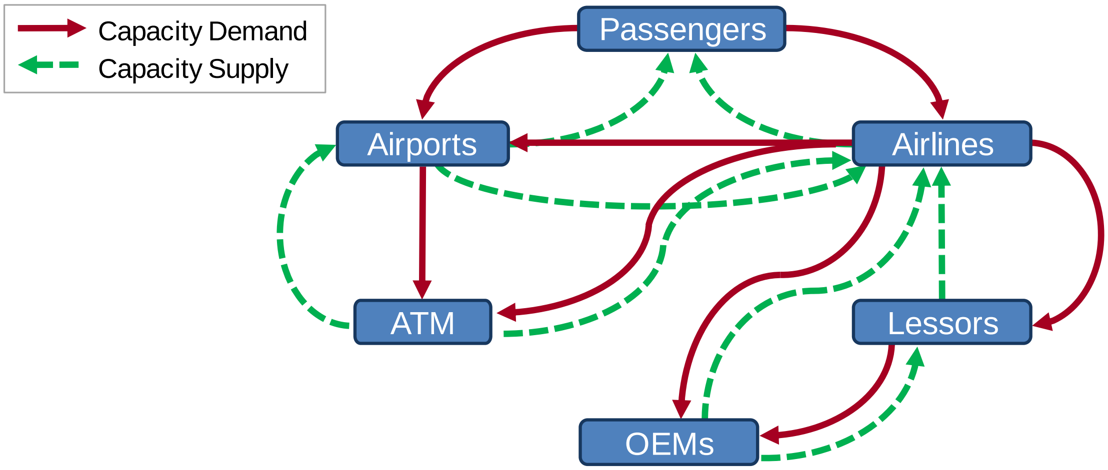
2. The Commercial Aviation Product

2.1 Definition of the commercial aviation product

It is important to define the product we are considering, as this will determine what we are measuring in the assessment of capacity balance status. Stakeholder perspective may be important in defining the commercial aviation product. For example, OEMs consider airplane production capacity and volume, airports consider terminal passenger and apron capacity or runway movement capacity, air traffic management (ATM) considers airways and control area capacity and flow management, while airlines may consider their routes or network in terms of lift capacity; i.e., how many passengers and how much cargo can be carried. The diagram in Exhibit 2 below illustrates sector interactions. In fact, in these examples each stakeholder accounts for a piece of the global capacity. For practical purposes, capacity is most simply defined in terms of the airline network metric for passenger operations: system-wide available seat kilometers (ASK) or available seat miles (ASM). In this paper we will concentrate on the global air passenger operation capacity, but one should recognize that there are typically equivalent air cargo capacity considerations and that interaction between passenger and cargo operations exist. Furthermore, there can be merit in looking at the industry as a series of connected, overlapping regional markets. However, the complex interactions between regional markets and the nature of airline partnerships, alliances, fleet movements and transactions are such that the global perspective is the most appropriate way to view the overall commercial aviation product.

Whichever stakeholder one considers there is a fundamental product. For example, aircraft OEMs provide seats (in the form of aircraft), both to replace obsolete equipment and to grow their markets. Airports provide terminal and runway capacity; this, however, translates to seats available for originating and connecting passengers on specific routes from or through their location. Airlines provide a network of seats, offering passengers service options across geographical destinations and time dimensions. Overall, the key commercial aviation product for the industry is ASK capacity. This has appeal on multiple levels because data are readily available and broadly applicable, from passenger network capacity to airplane demand.

Exhibit 2 *Significant flows of capacity supply and demand by key aviation sector stakeholders*



2.2 Capacity planning complexity

Changes in global ASK capacity may be positive (additions of capacity) or negative (reductions of capacity). At any point in time, multiple positive and negative capacity changes occur. For example, just as a new aircraft is delivered to one airline, another airline is reducing flight frequency on a route or pulling out of a city pair, reducing utilization of its fleet. At the same time, somewhere else in the network, an aircraft is being leased to add capacity, another is being temporarily parked, and still somewhere else an aircraft is being retired from commercial service. Airlines' capacity planning also involves multi-level assessments of individual city pair routes, while potentially considering route interactions and network connectivity both on-line (within their own network) and inter-line (with their partners' networks), and in relation to competitors' networks. This is especially true of the traditional network airlines. The low-cost carrier (LCC) airline business model has grown in popularity, especially in the short-haul markets, and has made inroads into the traditional network airline markets by increasing point-to-point services and reducing costs and fares. The LCC model, by its point-to-point nature, is easier to manage from a capacity stand-point because any capacity imbalance is more apparent, so capacity requirements can be tuned with minimal impact compared to traditional network carriers, where system-wide impacts maybe more complex. It is the integration of thousands of actions across the entire commercial aviation industry, like those described above and the seemingly small capacity adjustments made by multiple stakeholders across the industry in aggregate that are perhaps the largest contributor to system self-regulation and ability to achieve nominal capacity balance. Those actions are ultimately what determine the actual capacity at any given time. In effect, this is the net number of seats in the market at the time.

Actions like those described above are usually planned in advance and typically reflected in the published airline schedule. However, in addition, on any given day there are unplanned events such as weather, natural events, geopolitical, technical or system issues, etc., that impact capacity available at that time. In some local markets, there are constraints limiting capacity. For example, certain airports and air traffic management areas have limits on their ability to expand or contract capacity in terms of slot availability and usage, at least in the near term or at certain periods, seasonally or at specific times of day. Furthermore, some policy issues such as bilateral air services agreements specify limitations or policy related to environmental concerns for emissions. Noise regulations may also have some limiting influence on capacity across local, regional or pan-regional markets.

So far, the discussion in this section only describes an overview of the supply of capacity; the other side of the equation is the demand for capacity which also has variable and volatile aspects. Some are related to the supply-based issues discussed and some are not. Rather, they are driven by numerous influences such as socioeconomic, geographic, demographic, geopolitical, seasonal, periodicity, choice, competition, etc., in addition to event-driven issues that may impact demand for air transportation services. A further debatable question is the degree to which capacity demand is met by supply, compared to how much the capacity supply determines and/or stimulates demand – a chicken or egg debate for a different paper perhaps! Nonetheless, most commercial aviation observers will concede that there is an element of latent demand that is stimulated by supply availability, at least for some markets at certain times. Suffice to say, that planning capacity requirements is complex and imprecise, even before one considers the competitive market dimensions, interactions and connectivity, or commercial and/or political imperatives of the various stakeholders. The fundamental aim of capacity planning is to ensure that capacity supply is not disconnected from the demand. Provided there is no significant decoupling of the supply with demand, a balance can be achieved.

Airlines' ability to measure, predict and manage capacity has become increasingly sophisticated as the science, technology and operations research has evolved with complex algorithms built into operational management tools. Revenue management in the airline industry refers to the strategic management of capacity and seat pricing for controlling the sale of seats according to passenger demand in order to maximize profitability of routes in a given network. The advances made in these areas have significantly aided the overall growth in passenger load factor across the industry. Airlines strive to ensure that they exceed their minimum break-even load factor to maintain profitability. Initially, revenue management techniques utilized linear programming models based on typical demand experienced over time. More recently, optimization techniques have been favored, due to the stochastic nature of the passenger demand and the increased capability of computer processing that is required to accommodate the optimization routines. However, even with the benefits of such assistance, an overall industry-wide, precisely matched supply and demand balance cannot be ensured. The continuously changing and competitive nature of the business environment in the airline industry can harbor surprises, meaning at least that the management tools require time to adapt.

Capacity planning in the air transport industry falls into planning periods that cover current, near-term and long-term requirements. Making judgments about future capacity needs can be influenced by competitors' actions (to the extent they can be known or inferred) or by their own capacity plans; over- or under-estimating the future capacity requirement in a dynamic competitive environment can have near-term and long-term consequences on any given stakeholder's business. Furthermore, depending on the business, business model and strategy of the stakeholder, the planning of capacity depends on differing lead times, from setting objectives through implementation and execution of a given plan, with every step subject to potential need for refinement in response to multiple variations in cause and effect, and supply and demand.

2.3 Measuring commercial aviation status

For more than four decades, global airline industry growth has been resilient in face of several structural changes. From an industry centered on North America and Europe, it transformed to a more geographically diversified industry; from the dominance of network carriers it transformed with the boom of low-cost and alternative-business-model carriers; from a regulated air services environment, it adapted to an increasingly liberalized environment; and from less efficient, less capable technologies, it progressed to safer, highly efficient, more capable aircraft and systems. This poses a challenge to those attempting to measure the industry, as it increasingly requires one to examine the state of the airline industry with a systemic view. The challenge originates in the continuous changes that result from a background of global growth and structural, technical, regulatory and policy shifts with varying impact for the near- and long-term, creating a dynamic baseline against which one must measure.

Furthermore, the term 'balance' could imply that there is a single point of perfection at which supply and demand are equal. Rather the air transport industry is in a constant state of adjustment, so defining such a point would be ill-advised. It would be more meaningful to define balance as a situation in which the relevant metrics vary within bounds that allow for a dynamic harmony between supply and demand - a zone of balance. Conceptually, this is nominally balanced supply and demand, and thus inevitably can leave room for some subjectivity in assessments. This is acceptable as statistical analyses of systems with stochastic elements in their behavior are intrinsically probabilistic.

In considering potential indicators of supply-demand status, the typical accepted approach is to choose a reference from the most current data and compare it to a nominal value. The nominal value may also be expressed as a range or zone. Assessments can be made such that a value outside of the range will define the potential for an imbalance. Instantaneous current or future plan data are often of limited availability or subject to significant time lags, depending on the nature of the indicators and the stakeholder's ability to access timely data or predict future values. The nominal range is therefore typically derived from historical or broad industry data and data sources.

3. Primary Influencers and Indicators of Capacity Balance

3.1 Broad influence considerations

We have discussed the importance of the stakeholder perspectives and the complexity of planning capacity. We will next focus on the key elements considered to impact capacity. Fundamentally, if there is a significant imbalance between capacity supply and demand, a change in capacity would be required to achieve a nominally balanced state. Typically this would involve a capacity supply change, as this is the most manageable and controllable element for a stakeholder to affect. Knowing when and where surplus or deficient capacity exists is crucial to understanding whether a change in capacity is likely required.

At the highest level, economic activity is a significant driver of air transport demand, so economic metrics, especially GDP, should be considered as a causal factor in commercial aviation capacity. However, GDP or GDP growth are not indicators of capacity balance. They are nonetheless useful influencers that help in the interpretation and potential direction of the future state. There are other socioeconomic and geopolitical influencers, such as consumer spending power, demographics, income elasticity, consumer sentiment, etc. These, however, are often causal influences related to demand, but not specifically indicators of a capacity balance status.

Similarly, the relative openness of air services and the degree of liberalization or regulation over time is an influencer and a potential causal factor. In some cases, the degree of liberalization is a limiting factor for capacity balance, albeit with diminishing impact as liberalization expands globally. Nonetheless, liberalization should not be considered as an indicator.

Availability of sectorial investment capital also plays a role in influencing the availability of capacity, because the ability to invest in future capacity enhancements, such as airport, ATM or OEM infrastructure or airline fleet acquisition, could be considered as a potentially limiting and causal factor, but is not an indicator of capacity balance itself.

3.2 Aircraft asset-related influences

No discussion of the air transport industry supply-demand balance could be considered complete without specifically addressing the key instrument of capacity in the industry: the aircraft. Aircraft are inherently moveable and transferrable assets. Airlines routinely adjust their networks by reassigning aircraft into markets with increased demand, and/or away from markets with reduced demand. They can switch an aircraft of greater capacity with an aircraft of lesser capacity in response to demand, time of day, seasonally, etc. They may reconfigure the cabin layout and seating types or quantity. They may also rebalance fleet assignments in response to competition or for strategic reasons. Fleet adjustments of this nature can be made as required and often quite rapidly, up to and sometimes on the day of operation. Furthermore, airplanes often move from one airline to another during their lifetime. Flexibility of asset deployment is an important characteristic of commercial airplanes and one reason they are often viewed as desirable investments in the financial sector.

Asset utilization is determined by the degree to which the fleet is active, which also has a bearing on scheduled and unscheduled maintenance requirements, which in turn affect capacity availability.

The various aircraft types represent different levels of risk for investors and operators. The most popular and flexible types typically represent the least risk. The relative degree of risk of a given airplane type at a particular time is one result of the capacity supply-demand balance at that time. Further, the value of a discreet asset at a point in time is associated with the asset risk and therefore reflects an outcome in the status of capacity balance, though it is not itself an indicator.

A more useful and indicative measure related to the aircraft asset is the lease rate. Leasing data are often lacking on a comprehensive global basis; such data are considered commercially sensitive. To date, no effective and reliable surrogate for lease rate exists, so lease rate is discounted here as a viable indicator. It is recognized, however, that for some stakeholders in some markets, such data are available, though only internally.

Similarly, data for airplane residual or market values are equally difficult to acquire with any degree of confidence or on a comprehensive and comparative basis, although airplane retirements and retirement behaviors provide a useful surrogate for this indicator. (*See Boeing whitepaper, 'Key Findings on Airplane Economic Life' – Jiang, H., 2013*)

3.3 Defining nominal values for indicators

As described in 2.3 above, indicators are assessed against a nominal range to establish the status of each indicator. Generally the range is established based on historical data in terms of a distribution about a trend or a distribution around the mean of historical levels or current industry-wide norms, depending on data type and availability. The historical period over which the nominal range is developed, especially in the case of indicators that have trend characteristics, should extend over sufficient time as to capture behavior throughout at least a typical business cycle. This will ensure that the range of values fully captures trends in the nominal levels and helps define upper and lower bounds for a nominal range.

Often the actual or collected data available requires a conversion, such as an amalgamation of similar or component data, a transformation or derivation before it is useful as a measure for indicating status. For example, in some cases the measure required is the growth of a variable over time, compared to the range of typical nominal growth established from history. This ratio of the current, recent, expected or snapshot value to the nominal range is the indicator used as input into the overall assessment of capacity balance status at that time.

Ultimately it is the use of the appropriately converted value of an indicator, compared to its nominal levels that enable one to incorporate it in the overall assessment of status. The overall assessment considers the magnitude of indicator movement with respect to the nominal range and requires review of direction of movement of the indicator and, potentially, the rate of change in the indicator value. The following section discusses the relevant indicator variables.

3.4 Key and ancillary indicators

As discussed previously, complex systems require the use of several indicators in order to make the most informed assessments of status. Further, the combination of multiple indicators provides the holistic perspective sought and is generally considered as best practice. It is possible occasionally that key indicators alone may not provide sufficient clarity on status. For example, if indicators display conflicting assessment results, it may help to review some ancillary indicators to provide additional clarity for the overall assessment.

Next we identify the most relevant indicators. In addition, several ancillary indicators for consideration will be presented in a table of recommended indicators in section 3.5.

System available seats, measured in ***ASK***, are probably the most essential measure of capacity, representing the network seats airlines supply to the system to meet expected demand. The ASK capacity metric requires conversion into to the growth of ASK per unit time (typically year-over-year annually or quarterly) and may be compared to the nominal range from historical ASK growth observed over multiple historic time periods. In this form, ASK data prove the most useful indicator.

Crucially, a rise in ASK is typically associated with a nearly simultaneous rise in revenue passenger kilometer (RPK) demand (sometimes a slight lag or lead may occur). Thus any significant variation of ASK growth outside of the nominal range is only a relevant indicator of a potential imbalance if it significantly decouples from the RPK demand growth.

Associated with ASK capacity and RPK demand is the passenger ***Load Factor*** (PLF) which determines the portion of filled or demanded capacity. This component of key indicators is usable in its raw form as a percentage value. Again the data for PLF are compared to a nominal range. Because PLF has developed along a growing trend over time, the nominal range must be defined around that trend. Further details of the development of the nominal ranges and the measurement of individual indicators metrics is covered in the Appendix.

Additional key indicators include:

Aircraft Utilization which is an indicator necessary to understand how hard the fleet is being worked. Comparison to the nominal range established by historical values and industry levels can also provide insight into likelihood that the system can flex utilization to balance capacity.

In addition, overall ***Commercial Aircraft Fleet net growth*** indicators include over time:

- the number of expected new ***aircraft deliveries***;
- the number of viable modern technology aircraft (typically, in-production types) that are not being utilized; that is, the ***parked fleet***, and
- the number of expected ***retirements*** of obsolete aircraft to be removed from use.

A matrix of the aforementioned measures will provide the most important indicators of capacity status and, together, will provide data for near-term capacity availability and growth.

3.5 Table of indicators

The table below completes the recommended matrix of relevant and generally available indicators for consideration in making capacity balance assessments.

Reading the table:

The shaded portion represents those indicators considered ancillary; Ancillary indicators may be regarded as such due to merit and/or general data availability issues.

The left-most column: **Indicator**, names the common raw form of the data behind the indicator. Where applicable, the converted form of the data used for the given indicator is named in square brackets.

The center column: ***Description*** is a brief explanation of the indicator in the form used.

The right-most column: **Indicator Information** provides a brief overview of why the indicator has value or merit in the assessment matrix and/or the use of the indicator. Unless otherwise stated, the indicator is referenced to the nominal range established for the indicator, as defined in the Appendix.

Indicator raw [*used*] form	***Description***	**Indicator Information**
Available Seat Kilometers **[*ASK year-over-year growth*]**	*The rate of change in supply of network capacity ASK expressed as annual growth rate*	Directly relates to capacity supply, near-term planned scheduled capacity is published in advance. Reasonable forecasts are possible. Recent changes in direction and magnitude point to potential for imbalance. Importantly, rises in ASK are closely associated with simultaneous RPK demand. Thus any abnormal ASK growth that could otherwise create a capacity imbalance is only relevant if it significantly decouples from RPK growth.
Passenger Load Factor **[PLF % = *Revenue Seat Km/Available Seat Km*]**	*A measure of the average proportion of filled network capacity (used capacity) expressed as a percentage*	Directly relates to capacity use and indicates ability for capacity management tools to fill available capacity. Typically, data availability lags, but slowing or acceleration of the trend is indicative.
Aircraft Utilization **[*Hours/day*]**	*The active time of aircraft assets use per unit time. An average for in-service fleet, but could also include selected parked fleet expressed in flight hours per day*	Observing relative shifts provides insight into the likely direction of capacity changes. Significant shifts may limit system ability to employ utilization flexibility to mitigate capacity change requirements.
Commercial Aircraft Fleet **[*net fleet year-over-year growth rate = fleet net of base in-service + parked + deliveries - retirements*]**	*The combination of components summed and measured year-over-year as growth in Net Fleet = In-service (t0) + Parked (t0) + Deliveries (t1) – Retirements (t1) – Parked (t1); expressed in aircraft units.* ***Note****: retirements = scrapped, (t0)= previous or current, (t1)=expected or future*	Each component has a meaningful relationship to overall capacity. Together, they directly relate to capacity supply. Near-term plans for each component can be reasonably forecasted. Current/recent changes in direction and magnitude point to potential imbalance. Moreover, the ratio of fleet growth to ASK growth is an indicator of relative balance.
Airline Yield **[*rate of change in average yield year-over-year*]**	*A measurement trend of airline ability to extract value for its services over time, year-over-year, (Passenger Revenue $/RPK per year)*	Insightful to assess airlines' management of the trade-off between average passenger fare paid and capacity utilization. Useful compared to historical norms over time. Data are difficult to obtain and clarity is poor on revenue sources.[2]

[2] Reported yield is an average and declines with longer stage lengths and discounted fares. Airline yield represents a potentially rich and useful indicator. However, even in the United States, where data for yield is collected under mandate, there is a lack of transparency on the components of the data with respect to revenue sources and air fares, etc.

Indicator raw [*used*] form	***Description***	**Indicator Information**
Aircraft Order Backlog **(Units or $ Values)** **[*rate of change in the number of years to clear aircraft backlog at known or forecast production rates*]**	*The quantity and rate of change of backlog units*	Relates to capacity demand and supply and can have implications for potential balance. Increasing rate of change, however, does not imply imbalance. Caution must be exercised, as backlogs can shift with production rates, new product introductions, delays, order deferrals, accelerations or cancellations.
Book-to-Build Ratio	*A measurement of the market appeal trend for new aircraft. A ratio >1 = expanding market; i.e., growth in new delivery capacity*	Indicates potential capacity expansion or contraction trend. Rate of acceleration/deceleration in indicator provides insight on industry sentiment and likely future capacity implications.
Average Fleet Age **[*rate of change in average age year-over-year*]**	*A measurement of change in relative age expressed in years per year*	When measured over time, gives a trend that can indicate likely direction of future capacity changes, but is a lagging indicator.
Stakeholder/Sector Profit **[*rate of change in profit year–over-year*]**	The rate of change in profitability across a given commercial aviation sector	Can indicate sector ability to invest in capacity additions. Requires knowledge of influences affecting profitability and/or return on invested capital. Care is necessary to ensure meaningful trends extracted are influenced by commercial aviation activities only -- can be misleading.

4. System Dynamics of Commercial Aviation Capacity

4.1 Responding to system capacity requirements

Capacity requirements are planned against a background of imperfect information about the future (see section 2.2). Each stakeholder in the commercial aviation industry makes decisions with a given lead-time, defined by the capability of the stakeholder and/or its suppliers, partners or customers to respond to a request or necessity to change capacity. As a whole, the industry has been on a global growth trend throughout the ‘jet age’ and there is little indication that growth is abating in the aggregate. Continued aggregate growth in demand for air travel requires an ongoing need to adjust capacity supply to meet demand. Generally, plans are focused on capacity additions and are strategic and/or preemptive, whereas capacity reductions are more often reactive. Additions can be more measured and, at a system-wide level, are relatively gradual, due in part to the inherent lead times. Capacity withdrawal can be a rapid response, especially if it is a reaction to an unexpected event. Similarly, following a capacity reduction, the ability to respond to a need to return unused or under-used capacity can be swift, at least to the point of, or marginally beyond, pre-reduction level.

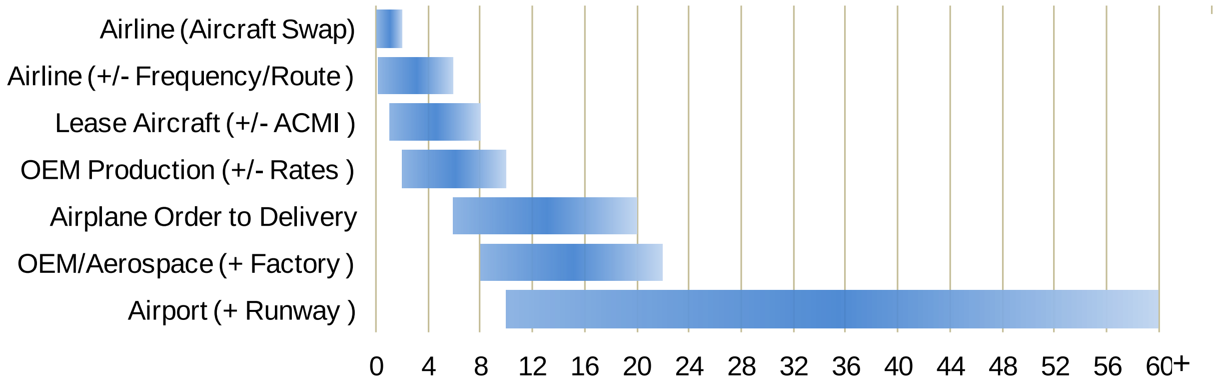
For argument's sake, assume that each stakeholder expects to grow with the market and that the right strategy and/or more advantages will help them grow at a faster rate, which theoretically would force competitors to grow more slowly. Rarely, however, does a stakeholder expect or plan to grow more slowly than its competitors over the long-term. Constraints to growth may exist in some local markets at certain times or, in extreme cases, for the period extending across typical business planning horizons. Consequently, some stakeholders may have to adapt their growth plans to such local constraints. Generally, growth plans appear to be rational, driven by market forces. However, they may also be driven, in part or in whole, by commercial or noncommercial imperatives that are not related to market forces. For example, some stakeholders may be supported by a government or government-owned corporation in order to satisfy a national imperative, such as to boost employment, trade, socioeconomic or geopolitical benefits, or simply for national pride. Such issues, although apparently declining in use, have persistent legacies, creating inefficiency in the system and further complicating the judgments and decisions stakeholders make about future capacity needs.

There can be multiple interim steps before capacity changes are made. For example, in the case of a potential capacity reduction, airlines may opt to: operate with lower load factors; attempt to stimulate demand to mitigate the need for a capacity reduction; or accept reduced revenue and/or lower airfares. Similarly, airlines may do the opposite in response to capacity shortages. The constant adjustment based on tradeoffs is part of the management toolset and decision-making process that is required to ensure that balance is achievable. Too much capacity, overcapacity, or too little, under-capacity are both states that the system cannot sustain indefinitely and corrections are required when either state is approached or is recognized to exist.

4.2 Timing is important

Lead time varies for each capacity-change decision and for each stakeholder in the commercial aviation system, depending on sector business model, the relative size of the change and the period over which the change is required. The gamut of potential capacity changes across the commercial aviation industry differs not only in terms of typical lead times, but also capacity adjustment times, which are rarely in harmony across sectors. (See Exhibit 3). In addition, the reason the stakeholder is implementing the capacity change also affects the timing and relative scope of the decision, hence the lead time.

Exhibit 3 *Examples of stakeholder capacity adjustments and typical lead times (quarters)*



The management tools used, plan maneuverability and degrees of freedom also vary depending on whether the capacity change requirement is near-term (e.g., within the day of operation and through the ticket-selling period), or long term (e.g., from order of a new airplane to delivery). Fluctuations in the competitive landscape and in market forces present risk and opportunities. Exogenous events that impact demand can present challenges in how or when to respond. Often there are operational limitations in the management of capacity adjustments and in the tools employed. The freedom to fully account for necessary changes, therefore, may not exist within the realm of any given sector or stakeholder. Recognition of these limitations among other sectors and stakeholders in association with appropriate and timely action can assist the industry in mitigating forced capacity changes and the ability to achieve an industry-wide capacity balance.

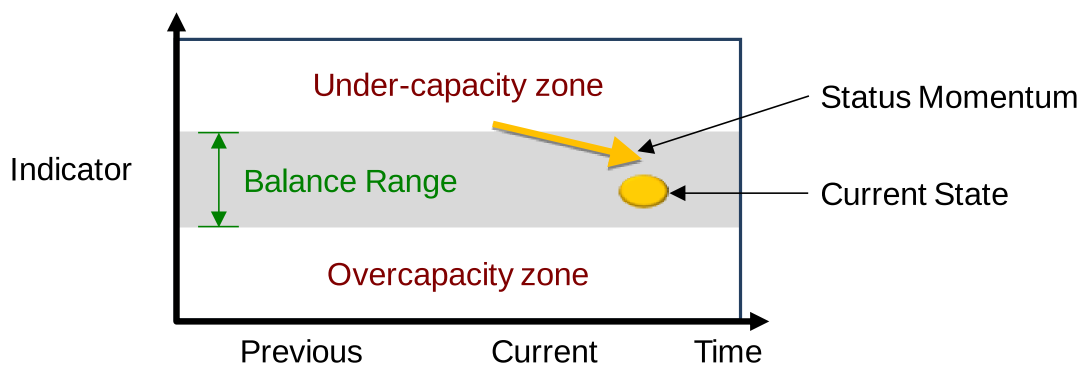
Since capacity change decisions are forward looking and are typically based on a plan that must rely on imperfect information, subject to simplifying assumptions and unforeseen circumstances, the planned changes will ultimately also need to be adjusted. The adjustment attempts to correct the plan to the required capacity at a point in time in order to account for new information or circumstances. The various lead times inevitably result in lags: between the time at which circumstances change to the time at which the change is recognized; and between the time the decision is made and the time when the capacity adjustment can be implemented. The longer the lag period, the greater the opportunity for a change in the circumstances and assumptions on which the planned change was based! The required change may be small or significant and adjusting the plan may be limited in terms of practical ability or degrees of freedom to adjust. Typically, adjustments introduce a further lag. Correcting the new plan may require additional adjustment, because there is a tendency to over-correct and the adjustment lag allows circumstances to change in the interim.

5. Defining System Overcapacity

System overcapacity will be apparent when capacity indicators or the significant majority of them are collectively registering imbalance beyond limits - outside the nominal range and directionally aligned. Furthermore, the ability or desire to correct the imbalance through the application of capacity management tools inherent in the system is insufficient to substantially mitigate the perceived imbalance. The inability to arrive at a balance often manifests itself in the length of time that capacity indicators remain outside the nominal range, as well as how much they deviate from the mean. The longer the capacity indicators remain outside of the nominal range and/or the greater the deviation, the stronger the correction must be to bring the industry capacity back into balance.

Three basic states of capacity can exist (see Exhibit 4). It is established that for any system for which it is possible to define a state, a counter state will exist. It should be noted that capacity imbalance can exist in either the state of overcapacity or the counter state, under-capacity. Recognition of status change requires multiple assessments of a given indicator over time and the comparison of current to the previous state. The system corrects the state of overcapacity through capacity reduction, whereas in the state of under-capacity the system corrects the imbalance with positive adjustments to add capacity. Similarly, there are lags in the system that make an instantaneous response to return balance unlikely. The lags, however, can be shorter for an under-capacity situation, because this state typically exists directly after the counter state, so capacity that was furloughed or underutilized during a capacity surplus can readily be brought back on-line to mitigate a capacity shortfall. The reaction of the industry to the recovery from a downturn has been observed to be relatively decisive, especially when demand proves robust.

Exhibit 4 *Air transport system states, with yellow arrow illustrating an example change in state and directional momentum from previous to current state*

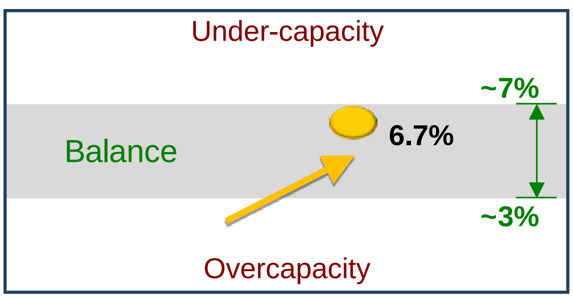


6. Assessment of Current Capacity Status

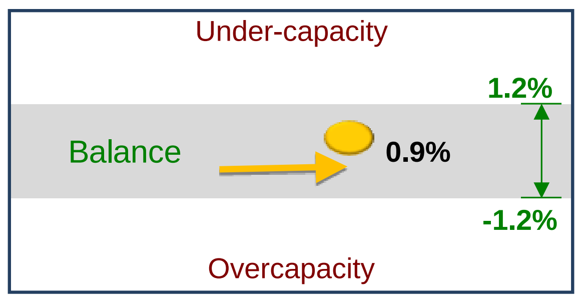
Using the recommended indicators of the global air transport industry and the analysis of historical data, we have defined the boundary conditions of nominal capacity balance (presented in the Appendix) as summarized below and shown in Exhibit 5.

- ASK growth rate has averaged 5.2% per year historically with a nominal range of year-over-year variations about plus or minus 2% per year;
- Passenger load factor has globally increased from mid-50% in the 1970s to today's nearly 80%, approximating 0.9% improvement per year and a nominal range of year-over-year variations of plus or minus 1.2% per year;
- Utilization of single-aisle passenger airplanes, measured in average flight hours per day, has increased by four minutes each year over the past three decades, with a nominal range of variations of plus or minus 0.2 flight hours per day. Utilization of wide-body passenger airplanes has improved at a pace of five additional minutes each year, with a nominal range of variations of plus or minus 0.3 flight hours per day;
- Net fleet growth rate of all western-built commercial jets has averaged 4% per year since 1980, with a nominal range of plus or minus 1% around the mean.

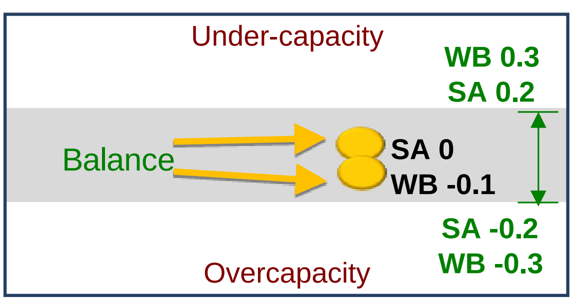
Exhibit 5 *The current state of capacity supply and demand balance in the air transport system (yellow dot represents current state with respect to nominal balance range, gray area, and yellow arrow shows momentum of status)*



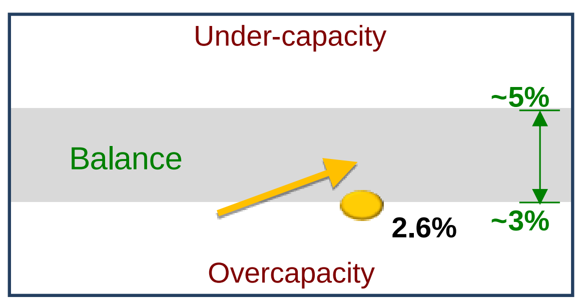
ASK growth is in balance based on growth recorded by ICAO, moving-average momentum moving from previous overcapacity to current balance state



PLF is in balance with delta from trend, based on ICAO data, moving-average momentum remaining relatively flat and in balance



Utilization Flight hours /day trend delta is in balance for single-aisle (SA) and wide-body (WB) aircraft at 0 and -0.1 respectively with momentum relatively flat and in balance



Year over year net fleet growth is in balance, since the moving average momentum is moving from previous state of overcapacity to current balance status

As shown in the charts of the Appendix, all, or the significant majority, of these indicators were below the lower boundaries during the 2001-2003 downturn and the recent 2008-2009 recession, suggesting a state of overcapacity. Between the two downturns, all or most indicators moved upward, approaching or exceeding the upper boundaries during 2006 to early 2008, indicating a state of under-capacity.

Applying the same principle to the present, all capacity indicators are either within or near the nominal boundaries. Therefore, our assessment of the latest information for the matrix of indicators informs us that the aviation system is currently in balance.

7. Conclusions

Assessing the capacity balance in the global air transportation system requires an understanding of the complexities of the system and the interactions among the many entities that comprise the system. A comprehensive assessment of a number of relevant system metrics is required. Use of anecdotal data, local perceptions, a single metric or a single-state definition to assess or describe the capacity balance in the aviation system is fundamentally flawed and can be misleading at best.

As the industry continues to evolve, one needs to stay aware of emerging alternatives, improved data or new indicators that may provide additional insight and improved analysis, while watching for ancillary indicators that may aid assessments. The authors recommend vigilant tracking and monitoring of the suggested indicators, and continued research of industry status and the factors impacting it.

Based on a current assessment of the system using the collection of industry-relevant indicators, we find that all indicators are within their nominal ranges; there is no evidence of a persistent systemic overcapacity; and the industry capacity supply and demand is in balance at this time.

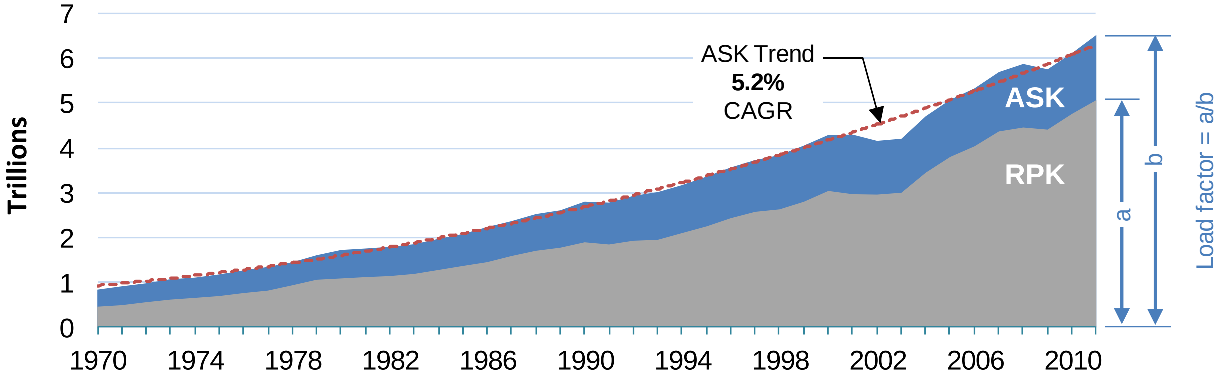
Appendix

This appendix presents the data used to assess each of the indicators recommended within this paper in terms of the boundaries for nominal balance. In this appendix, the data concentrates on global-level passenger indicators. However, the principles and methodologies employed can be generally applied across various regional markets using data appropriate to the market(s) in question. The charts in the exhibits indicate the nominal balance range by a shaded area and the label "balance" in green text, the labels "overcapacity" and "under-capacity", both in red text, are also indicated. This labeling is intended to show the status at the current or then-current period; it is not intended as predicative of future state. The interpretation of the balance charts is best achieved by noting how the moving average lines compare to the shaded zones representing the range of nominal balance.

1. Available Seat Kilometers (ASK)

ASK capacity growth, illustrated in Exhibit 6, shows the absolute levels for ASK and RPK and the ASK growth trend. Importantly, rises in ASK are closely associated with simultaneous RPK demand growth, thus any abnormal capacity growth that would otherwise lead to potential overcapacity is only relevant if it significantly decouples from demand growth.

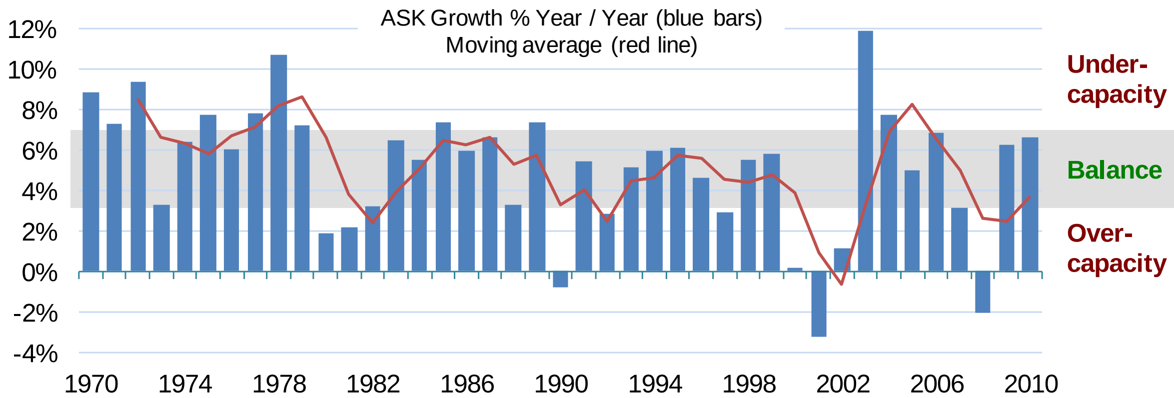
Exhibit 6 *Annual ASK growth trend and global ASK and RPK industry-wide since 1970*



Source: ICAO, BCA analysis

ASK growth has averaged 5.2% per year. Exhibit 7 shows the year-over-year annual growth in ASK. The gray band represents a range between the 25^{th} and 75^{th} percentile that defines the recommended nominal range for ASK growth, as this accounts for 50% of the variation in the range of the historical growth. The band extends from approximately 3.2% to 7.2%. The period over which growth is outside of the nominal range is another consideration for which one should account in making assessments. A three-year moving average, illustrated by the red-line, is a useful way to cross check the ASK indicator status and potential future direction.

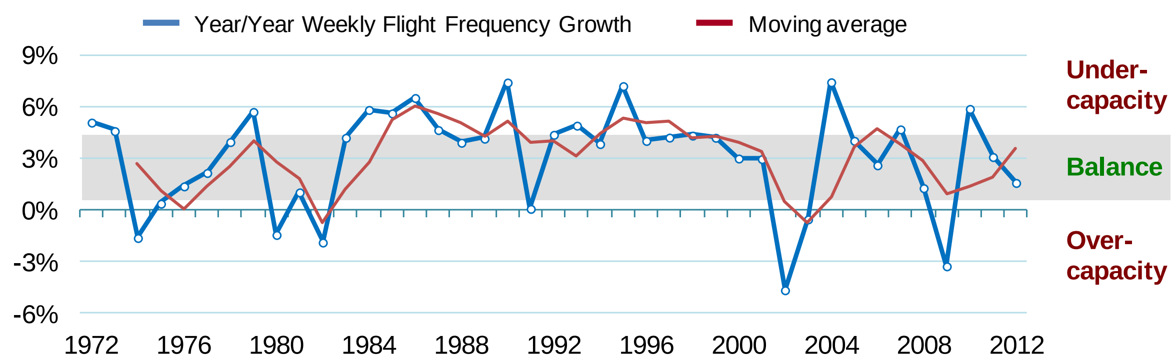
Exhibit 7 *Annual ASK growth*



Source: ICAO, BCA analysis

Additional perspective can be gained from observation of a subcomponent of the ASK growth: the year-over-year weekly flight frequency growth, as depicted by the blue line in Exhibit 8. This can also be an indicator of balance status. The average flight frequency growth is approximately 3.1% per year. The gray band around the frequency growth represents the 25th and 75th percentile range of historical growth rates, defining a nominal range of between 1.4% and 4.7%.

Exhibit 8 *Flight frequency growth*

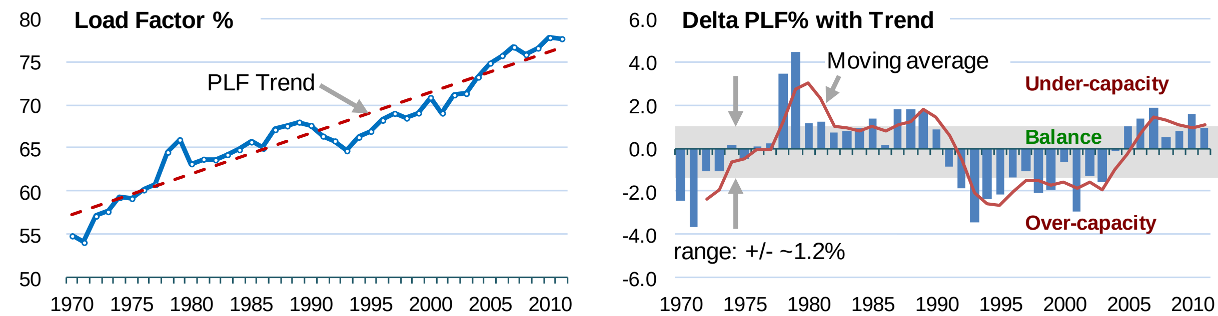


Source: OAG, BCA Analysis

2. Load Factor (PLF %)

Global passenger load factor has been on an increasing trend, the PLF is defined by the proportion of capacity filled and can be calculated as RPK/ASK. Exhibit 6 illustrates the PLF based on the comparison of the ASK and RPK for a given year. It is also shown more directly as a percentage in the left chart of Exhibit 9. On average, annual growth in PLF% has been approximately 0.9% per year. A definitive PLF limit of 100% exists and there is much discussion in the industry about the practical limit for PLF. No conclusive practical limit has been defined recently, as previous postulated values have since been exceeded. The difference in growth around the trend is shown in the right chart of Exhibit 9. The nominal range for PLF % growth per year is plus or minus 1.2%.

Exhibit 9 *Load Factor (PLF %) trend (left), PLF% delta trend and nominal range (right)*

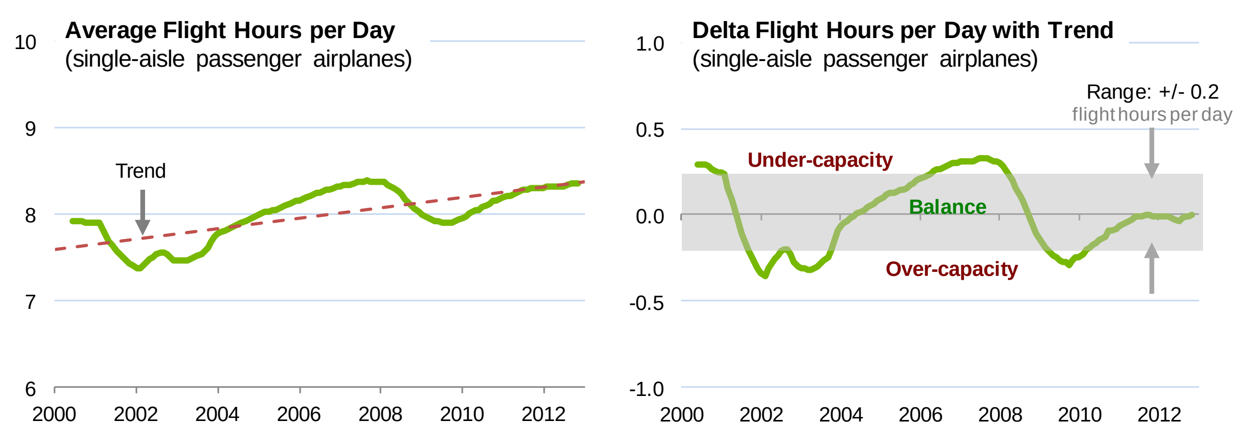


Source: ICAO, BCA analysis

3. Aircraft Utilization

Single-aisle passenger airplane utilization, measured in average flight hours per day, has increased in the past decade, as evidenced by the upward trend line in the left chart of Exhibit 10. On average, a single-aisle passenger airplane flies about four minutes more each year. Notice the trough in 2009 is about the same level as the peak in 2000. Average daily flight hours fluctuate up and down – demonstrating airlines' constant effort to match capacity supply with ever-changing demand. Such effort is depicted in detail as variations of the actuals from the trend (Exhibit 10, right chart). The nominal range (25^{th} to 75^{th} percentile) of delta is plus or minus 0.2 flight hours per day. Another observation is that the actuals have been close to the trend since 2011, indicating nominal balance between capacity supply and demand.

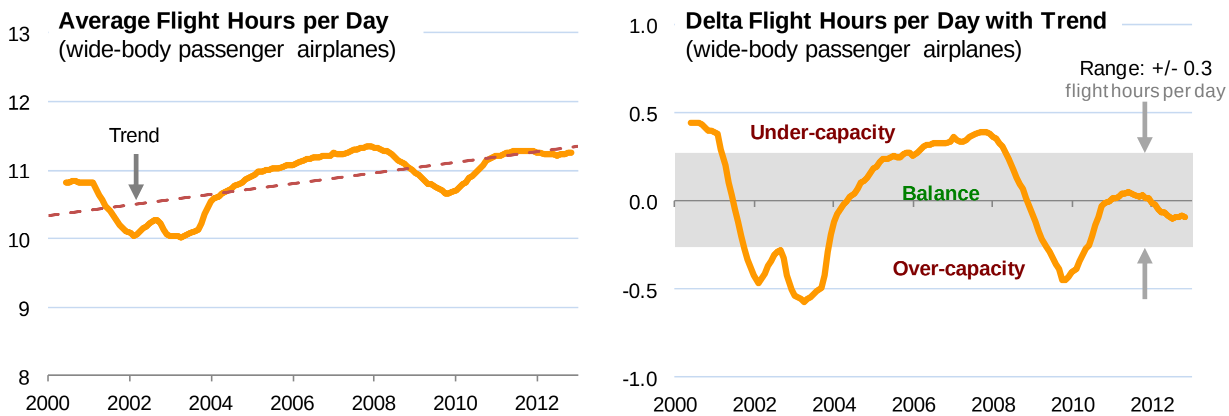
Exhibit 10 *Single-aisle passenger airplane utilization trend (left) and delta nominal range (right)*



Source: Boeing, BCA Analysis

Similarly, Exhibit 11 shows that wide-body passenger airplane utilization has increased through ups and downs in the past decade, averaging about five more minutes each year (left chart). The nominal range of variations from the trend for wide-body passenger airplane is plus or minus 0.3 flight hours per day (right chart).

Exhibit 11 *Wide-body passenger airplane utilization trend (left) and delta nominal range (right)*



Source: Boeing, BCA Analysis

4. Commercial Aircraft Fleet

The commercial fleet is, no doubt, a central piece in balancing capacity supply and demand. Its dynamics involve multiple elements. Exhibit 12(a) illustrates that the in-service single-aisle fleet has nearly tripled between 1980 and 2012, averaging 3.4% CAGR (compound annual growth rate). This is the net result of:

- Taking new deliveries to add capacity. The delivery as a percentage of in-service and parked fleet (solid line in Exhibit 12(b), right axis) has oscillated over time. The magnitude of oscillation has declined with the long-term trend, approximately 6% (dashed line).

- Changes in the parked fleet. This, along with airplane utilization, is among the most powerful levers that airlines use to adjust capacity with short lead time, great flexibility and relatively low cost. Depending on the magnitude of change, radical increase or decrease in the parked fleet could result in a net reduction or addition to the fleet size respectively. Over time, the parked fleet has followed a cyclical path (Exhibit 12(c)) in terms of units (bars, left axis) and percentage of in-service and parked fleet (solid line, right axis), with recent trend hovering around 10% and the net change averaging 0.2% increase in parked fleet per year.

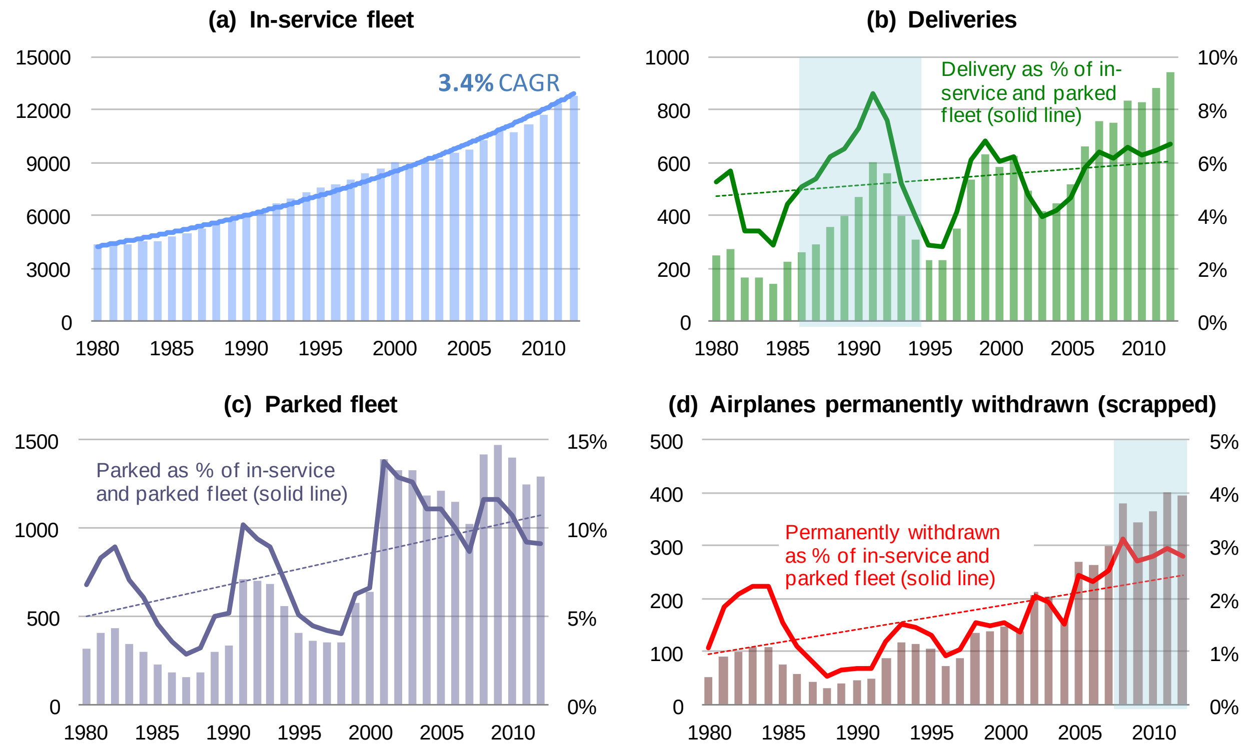
- Retirement of aging and inefficient airplanes for capacity reduction as shown in Exhibit 12(d). The level of airplane retirements has increased since 2005 (shaded area), representing between 2% and 3% of in-service and parked fleet. While many analyses attribute the phenomenon to the rapid rise of fuel price, the fact that majority of those airplanes retired since 2005 were built in the late 1980 delivery cycle (shaded area in Exhibit 12(b)) suggests that the delivery cycle two decades ago is influencing airplane retirements today and its influence will be felt until the entire wave passes through the system.

Adding new airplane deliveries (6%), subtracting the net increase in parked fleet (0.2%), and subtracting airplane retirements (2% to 3%), gives the net growth rate of the commercial single-aisle fleet (3.4%).

+ New airplane deliveries	~6%
– Net increase in parked fleet	~0.2%
– Airplane retirements	~2-3%
Net Single-Aisle Jet Fleet =	~3.4%

Given the dynamics discussed above, it is no surprise that the year-over-year net fleet growth rate in reality has rarely fallen exactly on the trend, as evidenced by the bars in Exhibit 12(a) (left axis).

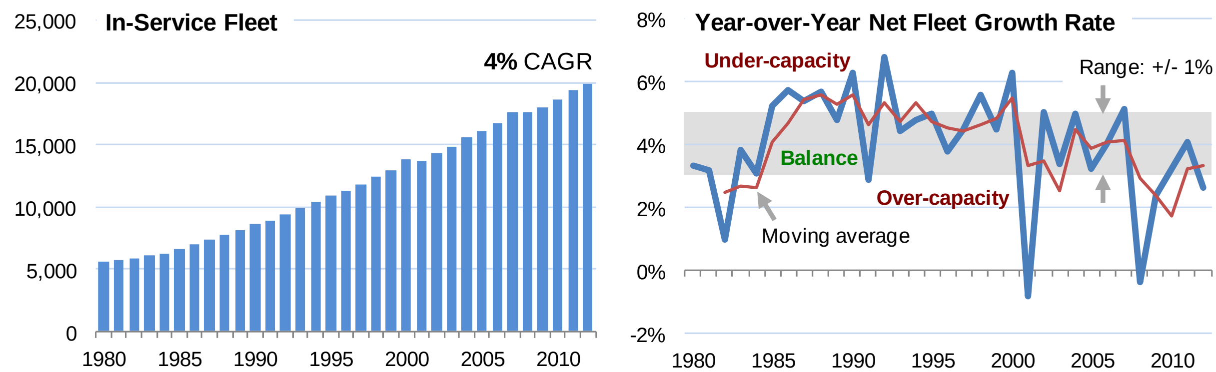
Exhibit 12 *Western-built single-aisle commercial fleet overview*



Source: Flightglobal Ascend database, BCA Analysis

Extending above measures to a broader scope, the in-service fleet of all western-built commercial jets has grown from 5,600 units in 1980 to nearly 19,900 units in 2012, averaging net fleet growth of 4% per year (left chart of Exhibit 13). The year-over-year net fleet growth rate (right chart of Exhibit 13) bounces around 4%, with the nominal range (25^{th} to 75^{th} percentile) of plus or minus 1%.

Exhibit 13 *Western-built commercial jet fleet*



Source: Flightglobal Ascend database, BCA Analysis

5. Ancillary Indicators

This section presents an overview the pros and cons of several potential ancillary indicators that, provided the assessment requires additional perspective, can be used to aid a conclusion about status.

5.1 Airline Yield

Airline yield is a potentially rich and useful indicator. It can, however, be a misleading concept, requiring an understanding airlines ability to obtain value for their flying services. It is, nonetheless, insightful to assess airlines' management of the trade-off between average passenger fare and capacity utilization. It is the most useful ancillary indicator when compared to historical norms over time. For most stakeholders, however, the data is difficult to obtain and the clarity on components within the data is poor. In many ways, yield may also be regarded as an outcome of airline efforts to arrive at a balance for capacity supply and demand. Airlines, of course, have data regarding their own yield, but this is not broadly available across the air transport industry on a comprehensive and comparable basis. Reported yield data is typically an average that declines over time, due to the trend toward increasing stage length and discounted fares. Even in the United States, where yield data are collected under mandate, data regarding fares, leg proration, class of travel, ancillary revenue, handling of reward flights and upgrades, etc., lack transparency.

5.2 Aircraft Order Backlog

Aircraft orders address only a portion of the potential future capacity. The quantity of aircraft on order and estimates of how many aircraft can be delivered over time provide some insight into potential additional capacity. No explicit information about the use of the aircraft and precise timing of deliveries can be implied. The backlog cannot precisely indicate capacity that is additional for growth as opposed to that used to replace existing capacity. However, estimation of expected and forecast retirements can assist in distinguishing the future growth from replacement capacity. Variability in backlog associated with delivery schedule movements, delivery options, new product introductions, delays, production rate changes, etc., makes the backlog an unreliable source for capacity estimation beyond production delivery lead times.

5.3 Book-to-Build Ratio

Since the book-to-build ratio relates to the orders placed for future capacity, some of the same issues related to backlog apply equally to the book-to-build ratio. In a general sense, the behavior reflected in the book-to-build ratio can nonetheless be used as an indication of the industry sentiment towards the desire to grow and replace existing capacity. When the ratio exceeds the value of one (that is, when order growth is occurring), market expansion is expected in the industry. Conversely, a ratio well below one indicates the opposite.

5.4 Average Fleet Age

The changes in average fleet age expressed as a year-over-year growth rate can provide some indication of likely direction of future changes in required capacity. It is, however, a lagging indicator.

5.5 Sector Profitability

Profitability should indicate a sector's ability to invest in capacity; however, it requires knowledge of influences affecting profitability, typically on a case-by-case basis. Care is necessary to ensure that meaningful trends can be extracted and that the data are influenced by commercial aviation activities only, inasmuch as some multi-sector or broad-based companies may only provide visibility of profit across their total or group businesses. In the air transport industry, the sectors can be affected by a small number of large stakeholders, such that overall profitability may be negative in aggregate even when the majority numbers of stakeholders are positive individually. Similarly, return on invested capital which assesses a company's efficiency in allocating the capital under its control suffers from the downside that return on capital tells one nothing about where the return is being generated. Profitability or return on capital are second-order indicators, in a systems dynamic sense, and are lagging indicators, that can be misleading.

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Ricky Mack is currently a Senior Analyst and Director of Aviation System Analysis with Boeing Commercial Airplanes. Ricky was born and educated in the UK and holds a degree in aeronautical engineering. Additionally, he has studied air transport management and business, including market forecasting, operations planning and airline marketing at the post-graduate level. He also studied at Oxford Air Training College where he gained his commercial pilot's license and went on to fly Fokker F27s at Air UK. Ricky has almost 30 years of aviation experience. He has worked for OAG as Manager of Market Analysis and at IATA as Assistant Director Statistics, Economics and Forecasting. Ricky is a recognized expert in air transport forecasting and market analysis. He is a regular contributor and steering committee member for various industry forums including serving as the current President of the Air Transportation Research International Forum. He also speaks on the air travel market and forecasting.

Helen Jiang

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