The advent of a variety of ultra long-range large and ultra-large aircraft has allowed airlines to pursue more flexible fleet planning strategies. Airlines' needs for different aircraft sizes, and the operating cost performance of the types on offer are examined.

Ultra large aircraft: fleet planning strategies & economics

Long-haul fleet planning has become more flexible with the advent of 250- to 550-seat aircraft with ultra-long-range capability. This is a change from the domination of the major long-haul routes by the 747-400 prior to 2002. These new types allow airlines to match supply more closely with passenger demand. Moreover, many 747-400s have already been replaced, and others are due to be.

The seat configurations of 747-400s vary by operator, but average about 365. The types closest in capacity are: the A340-600, with an average seat count of 307; the 777-300ER, with an average of 316 seats; and the A380, with an average of 484. The 747-8I, due to enter service with Lufthansa in 2012 and Korean Air in 2013, is expected to be configured with 380-430 seats. No replacement for the 747-400 has equal seat capacity.

Airlines can therefore choose types that are smaller or larger than the 747-400. Selection criteria will depend on which types suit an airline's capacity requirements and the relative operating economics of the choices available.

Capacity & fleet

The active passenger fleet of 747s used for long-haul operations by 24 of the world's major 747 operators has declined from 506 units in 2002 to 300. The number of 777-300ERs and A340-600s has increased by 215, and 40 A380s have also entered service.

The long-haul fleet development of these operators has also included the retirement of MD-11s and the entry into service of 777-200s, A340-500s and other A330 and A340 models since 2002.

The period since 2002 is significant because the 777-300ER entered service in 2004, and there were only four A340-600s in operation at the end of 2002. The first A380s entered service in 2007 with Singapore Airlines (SIA). Before 2002, therefore, airlines had little choice of types close in size to the 747.

In many cases, the decline in the number of 747s since 2002 has led either to: their replacement with smaller types and service frequencies being maintained; or, in a smaller number of cases, their replacement with the A380, and service frequencies being maintained or reduced. Six airlines with a need for high-capacity aircraft, including Air France, SIA, Korean Air and Qantas, have introduced the A380 and reduced their 747-400 fleets in parallel.

Many other 747-400 operators have reduced their 747-400 fleets since 2002, and increased their 777-300ER and A340-600 fleets over the same period.

747 phase-out

Large fleet reductions

Airlines that have retired or phased out large numbers of 747s in their fleets are Air France, United Airlines, Northwest Airlines (Delta since 2008), EVA Air, All Nippon Airways (ANA), South African Airways (SAA), Korean Air, Asiana, Malaysia Airlines and Air New Zealand. These carriers have collectively reduced their 747-400 fleet by 96 aircraft since 2002. The largest reductions, however, have been by SIA and Japan Airlines (JAL), which have phased out 36 and 45 units.

United, Northwest/Delta and Malaysian airlines have collectively removed 40 747s since 2002, and have not replaced any of these with large widebody types. They have, however, replaced the 747 with smaller widebodies such as A330s and 767s on many routes.

United has phased out 15 747-400s since 2002 and has replaced some of this lost capacity on its long-haul network with 767s and 777-200s. It underwent a rationalisation of its route network after it entered Chapter 11 in 2002, and dropped a large number of long-haul routes, but it now has 25 A350s on order.

In 2008, Delta Airlines acquired Northwest, which had a fleet of 33 747s in 2002, and operated mainly to Amsterdam, Bombay, Tokyo, Osaka, Nagoya, Beijing and elsewhere in Europe and the Asia Pacific. Since 2002 it has substituted its 747 capacity with 777s and A330s, having removed a lot of capacity from its Japanese routes and opened several new destinations in the Asia Pacific.

Malaysian Airlines' operation has grown only by a modest 9% since 2002. The capacity provided by the seven 747-400s it has removed from operation has been replaced by 777-200s, and growth in its network provided by A330s.

Among airlines that have phased out large numbers of 747-400s, JAL, SIA, Air France, EVA Air, Korean Air, ANA and Air New Zealand have added many 777-300ERs over the same period.

JAL's 747 fleet reduction of 45 reflects the fact that Tokyo, which had been used as a trans-Pacific connection hub, has been undermined by the introduction of a large number of non-stop trans-Pacific services. The annual one-way capacity provided by JAL's 747 fleet on its long-haul route network from Tokyo has declined by 2.9 million seats and 6,500 flights since 2002. This capacity has mainly been replaced by 767s and 777-300s, with the airline adding 13 777-300ERs.

SIA's operation from Singapore has reduced annual one-way seat capacity

Most 747-400 operators have selected the 777-300ER to supplement or replace their 747-400 fleets. The 777-300ER has been configured with a 10-abreast economy cabin, which means its seat capacity can come close to the 747-400's.

provided by 747-400s by 1.5 million. SIA has reduced its 747-400 fleet by 36, and had a net increase in long-haul capacity of about 1 million seats since 2002, achieved with a mix of A380s, 777-200s, 777-300s and A340-500s.

SIA's 747-400 fleet has almost been phased out. It has five A380s, eight 777-300ERs, 15 A330-300s and 20 A350s on firm order.

Air France, EVA Air, Korean Air, ANA and Air New Zealand have collectively retired 48 747-400s, and added 81 777-300ERs and 10 A380s to their fleets over the same period.

Like JAL, ANA's route network, which included mainly trans-Pacific operations, has been undermined by the steady growth in non-stop routes that have bypassed Japan over the past decade. ANA has therefore had no net increase in long-haul capacity, and has replaced all of its 747 capacity with 767 and 777 operations.

Air France has phased out 16 747s since 2002, but has more than replaced its lost capacity with 34 777-300ERs. By the end of 2011 it was operating six A380s, and has another six due for delivery, as well as eight 777-300ERs. These aircraft would be sufficient to replace its remaining 747-400s.

Korean Air has had one of the largest increases in its long-haul operations of all major airlines. Capacity has increased by more than 70% since 2002. It has reduced its 747-400 fleet by 10 to 17, but has also put four A380s and nine 777-300ERs into service over the same period. It has another five A380s, five 747-8Is and five 777-300ERs on order, so enough aircraft to replace all of its 747-400s. If Korean continues to experience high rates of growth it will require further capacity.

Smaller Korean airline Asiana has increased its long-haul operation by more than 80%. It has halved its 747-400 fleet, and replaced it with 777-300ERs. It has six A380s and 30 A350s on order, which suggests it expects to continue to experience high rates of growth.

EVA Air has only had a modest increase in capacity, but has replaced most of its 747s with 777-300ERs. It has also opened some new routes with the 777-300ER.

Air New Zealand has replaced all its 747 capacity with the 777-200 and 777-300ER. It will completely replace its 747-400 fleet with 777-300ERs.

SAA is the only airline to have completely phased out its 747 fleet and replaced it almost entirely with A340-600s. It has maintained a similar level of capacity to 2002 by increasing service frequencies.

Small fleet reductions

British Airways (BA), KLM, Lufthansa, Air China and Qantas have made relatively small reductions in their 747 fleets since 2002; with a collective reduction of 27 aircraft. They have also added 17 A380s, 24 A340-600s and 12 777-300ERs over the same period, indicating a strong development in their long-haul operations.

BA, with the world's largest 747-400 fleet since 2002, has added four 777-300ERs, with another two on order. It also has 12 A380s on order. BA operates to about 20 long-haul destinations from London at two or three daily frequencies with either 747s or a mix of 747s and 777s. This makes it one of the world's few international carriers to operate at high frequencies on a large number of long-haul routes.

BA has also increased its long-haul capacity by about 30% since 2002, and is therefore more likely to replace most of its 747-400s with larger types, than smaller aircraft such as the 777-300ER.

KLM has had a net increase of 1.5 million seats, virtually all provided by 777-300ERs. It has phased out six 747s, and most of its remaining fleet are 280-seat, Combi-configured aircraft. KLM has replaced a lot of 747 capacity with 777-200ERs and 777-300ERs configured with larger seat counts of 327 and 425.

Lufthansa has had a small reduction in its 747 fleet, but has had a large overall rise in the size of its long-haul operation, as a result of increasing its flights at Frankfurt and Munich. It has used A340-600s and A330-300s to provide this capacity growth. It still has 30 747-400s in operation but has nine A380s, 20 747-8Is, and four A330-300s on order.

Air China, with its main operation based at Beijing, has had a small reduction in its 747-400 fleet of six aircraft. The capacity of its long-haul operation has trebled since 2002, and most capacity is now provided by A330/340s and 777s.

Qantas is the only major 747 operator to have used just the A380 as a large widebody to replace capacity provided by 747s. Qantas has also used the A330-300 to provide additional capacity, and its overall long-haul operation has grown. It still operates 26 747-400s, and has nine A380s on order.

747 fleet additions

Airlines that have had no 747 fleet reduction or even an increase are Virgin Atlantic, Thai International, China Airlines and Cathay Pacific. These four carriers have collectively had a 747 fleet increase of four units. Virgin, Thai and Cathay have also had increases in long-haul network seat capacity since 2002.

Cathay Pacific has seen seat capacities from Hong Kong grow by more than 100%, using a mix of A330s, 777-200s and 777-300s. Its 747 operation has also seen a small growth. It still operates 21 747-400s, but it has 26 777-300ERs and 30 A350s on order, which will be used partly to replace the 747-400 fleet.

Thai International has increased its

Qantas has maintained most of its 747-400 fleet, and replaced a small number with the A380. The A380 is utilised in its busiest routes. The airline also has a low-cost subsidiary Jetstar, which it uses to carry low yield traffic on routes in the Asia Pacific.

long-haul operation by 64% since 2002. It has seen large capacity increases on most of its routes, and has also opened six new destinations. Thai has increased its 747-400 fleet to 18, by acquiring some from United. It has a large number of aircraft on order, including six A380s, 14 777-300ERs, and 10 A350s.

Virgin Atlantic has had a modest increase in its long-haul operation since 2002, and has used the A340-600 mainly to replace the smaller -300s. It also has six A380s on order (although it has delayed taking delivery of these) and five A330-300s.

Non 747 operators

Four major airlines that are now major international operators, but have never utilised the 747, are China Eastern, Emirates, Etihad and Qatar Airways.

Since 2002, China Eastern has more than trebled the size of its operation from Shanghai Pudong, and has opened routes to Rome, Frankfurt, London, Honolulu, New York, Los Angeles, Vancouver and Melbourne. China Eastern has built up its long-haul operation entirely with A330s and A340s, the A340-600 being its most numerous type. In terms of annual seat capacity, China Eastern's international operation has increased by a factor of about three. The airline operated just three long-haul routes from Pudong in 2002, and has since opened new routes to Rome, Frankfurt, London, Moscow, New York, Vancouver and Melbourne.

Emirates now has the largest long-haul operation in the world, with one-way seat capacity exceeding 6 million, compared to less than a million in 2002. In addition to A330s and 777-200s, Emirates has added 18 A380s and 61 777-300ERs to its fleet since 2002. It will continue to grow, and has a large number of A350s, 777-300ERs and A380s on order.

Emirates, which operates a long-haul connecting operation at its Dubai hub, can only offer service frequencies of one flight per day, or less than even seven per week on many of its routes.

Etihad has grown at a similar rate, and its long-haul operation is about a third the size of Emirates'. Etihad has added 777-300ERs and A340-600s since 2002. Qatar Airways has also seen a fast rate of development of its long-haul operation, and has also added A340-600s and 777-300ERs. It has A380s on order.

Capacity & demand

Many of the major 747-400 operators have swapped some or all of their 747-400 capacity with smaller types on a large number of their routes. The A380 has been used on services where an airline experiences a high level of demand, but the increase in capacity that results is then offset by downsizing from a 747 to a smaller type on the other services during the day. The change by SIA from three daily services with a 747 to two per day with an A380 and one per day with a 777-300ER on its Singapore-London service is an example. This pattern has been repeated on a large number of long-haul routes operated by the world's major 747-400 operators since 2002.

The change either to smaller types or to the larger A380 raises the issue of what strategies airlines are following to match seat supply more closely to passenger demand. There is also the 747-8I, sized halfway between the 747-400 and A380.

Major 747-400 operators still use it to provide most of the long-haul capacity on their networks. The 747-400 is ageing, however, and there are still another 290 777-300ERs and 186 A380s on order. The passenger-configured 747-8I could be used to provide the right levels of supply, but few airlines have ordered it, perhaps because it has, or is perceived to have, poorer operating economics than the A380. Are the 747-8I's technological standards such that its operating performance, fuel burn and maintenance cost will result in a seat-mile cost that is competitive with the A380? Is the 747-8I maligned, or is it the wrong size to meet most airlines' requirements?

Aircraft characteristics

The prime contenders in the large and ultra-large category are the A380, 747-8I and 777-300ER. The A340-600 would have been considered at one stage, but has not received a firm order since 2008. The 350-seat (Airbus standard tri-class) A350-1000 series has, however, won orders from several major 747-400 operators, including Asiana, Emirates, Etihad and Qatar Airways.

Airlines that have experienced, or are due to gain from, continuous growth on their current routes may use larger types while maintaining frequencies, or increase services to a level that may be more attractive to business passengers. Emirates, in particular, cannot increase frequencies to much more than a daily service on most of its long-haul routes. Sustained traffic growth has thus fuelled its demand for a large number of A380s.

Airlines that have experienced only low rates of growth or none at all, and that have downsized their operations and capacity, clearly need to rationalise their fleets. For example, the 747-400 is too large to meet JAL's needs. The 777-300ER is the largest it needs. Air New Zealand will swap its entire 747-400 fleet for 777-300ERs, and SAA has similarly wholly replaced its 747s with A340-600s.

A third approach to gauging aircraft requirements is illustrated by Qantas. It has segregated low-yield traffic into its low-cost subsidiary Jetstar on its Asia Pacific routes. Aircraft gauge has therefore become less important.

Overall, the issue of aircraft gauge is

AIRCRAFT CHARACTERISTICS

Aircraft type	A380	747-8I	747-400ER	747-400	777-300ER
MTOW-lbs	1,235,000	987,000	910,000	870,000	775,000
MZFW-lbs	796,000	651,000	555,000	542,500	524,000
OEW-lbs	596,000	470,000	406,900	394,000	370,000
Structural payload-lbs	200,000	181,000	148,100	148,500	154,000
Tri-class seats (OEM)	525	515	416	400	370
Tr-class seats-airline range	407-547	N/A	287-464	287-464	246-364
Airline average	484	440*	363	363	316
Passenger payload-lbs	106,480	96,800	79,860	79,860	69,520
Fuel capacity-USG	84,600	63,034	63,024	57,065	47,890
Range with average airline seats-nm	8,250	7,900	8,050	7,200	8,000
Long-range cruise speed-Mach	0.85	0.855	0.85	0.85	0.84
Belly freight					
ULD type	LD-3	LD-1	LD-1	LD-1	LD-3
ULD number	38	36	26	32	44

**** Estimated expected airline average***

now less straightforward than it was in the past, and has become a more varied issue. Airlines now follow individual rather than broadly similar strategies. Operators of the 747-400 cannot replace them with aircraft of the same size, and can only select smaller or larger types. As well as desired capacity and service frequency, airlines also have to consider operating costs in terms of costs per trip and per available seat-mile (ASM).

Fuel and maintenance are the main issues for each type under consideration, but the newer types' additional technologies also have direct and indirect benefits. Electronic flightbags (EFBs), electronic technical logs (ETLs), and satellite connectivity can deliver reduced cost and increased revenue generation.

The fuel burn and likely total aircraft maintenance costs of each type are the main concern for airlines. The other two key issues are actual seating configuration and associated range performance.

Although the 747-400 has a standard tri-class configuration of 400 or 416, airline layouts vary from 287 to 464 seats and average 363. The aircraft can operate up to about 7,200nm with this load. Los Angeles-Sydney, which has a great circle distance of 6,500nm, with headwinds causing a longer still-air distance, is one of the longest routes on which it is operated. This explains Qantas's need for the 747-400ER, which has a 800nm longer range.

The three main options of the A380, 747-8I and 777-300ER have standard tri-class seat capacities of 525, 515 and 370 seats. The A380 and 777-300ER have actual average airline configurations of 484 and 316 seats *(see table, this page)*: 121 seats more, and 47 fewer, than the 747-400. The 747-8I has yet to enter service, and although actual airline configurations are not known, they may be 400-440 seats.

The 777-300ER is interesting in terms of its tri-class seat capacity. As standard, its economy cabin is configured with nine-abreast seating; while the 747 has a 10-abreast economy class. Five of the 777-300ER's operators, however, have a 10-abreast layout. These are Air France, Air New Zealand, KLM, Emirates and Qatar Airways. This makes it possible for the 777-300ER to have seat numbers similar to, or higher than, the 747-400 when first- and business-class cabins are configured similarly. The 777-300ER can gain from seat numbers to achieve a lower unit cost per ASM.

The 747-400's fuel burn and maintenance costs are established *(see Owner's & operator's guide: 747-400 series, Aircraft Commerce, April/May 2007, page 3)*.

On typical missions, the 747-400 burns 0.020-0.0213 US Gallons (USG) per ASM *(see 777-300ER, A340-600 & 747-400 fuel burn performance, Aircraft Commerce, August/September 2010, page 26)*. At current fuel prices this is equal to 6.0-6.5 cents per ASM, illustrating the effect of high fuel prices on total cost per ASM (CASM) for long-haul operations.

To put this in perspective, a monthly lease rental of $1.2-1.5 million for a 747-400 with 365 seats and completing about 4,800FH and 550FC per year is equal to a cost per seat of 1.7-2.1 cents per ASM.

While the fuel burn efficiency of any new type cannot completely overcome all of the rise in fuel trip costs caused by higher crude oil prices, any reduction in fuel burn cost will help to lower costs. The fuel burn and operating performance of the A380 and 747-8I are expected to be 0.018USG per ASM. The 777-300ER has a similar fuel burn performance. These fuel burn rates are equal to costs per ASM of about 5.8 cents.

The absence of a significant difference between the two large types and the 777-300ER may be because the A380 and 747-8I benefit from their large seat counts, but suffer from their relatively inefficient four-engine designs. The 777-300ER clearly gains from its twin-engine design, but suffers relative to larger types because of its smaller seat count.

With typical airline seating configurations, range performances are 8,250nm for the A380, 7,900nm for the 747-8I, 8,000nm for the 777-300ER, and 8,400nm for the A350-1000. These are relatively close, so all aircraft should be able to operate on most of an operator's long-haul network without many limitations in passenger numbers.

The A350 is interesting in terms of its probable or likely fuel burn performance. It has almost the same seat capacity as the 777-300ER, but the A350-100 has a range of up to 8,400nm with 35 more passengers. Moreover, the A350-1000's maximum take-off weight (MTOW) is 96,000lbs lower, and its fuel capacity 6,690USG smaller, than the 777-300ER's. This indicates that the A350-1000's fuel burn per ASM may be 15% lower than the 777-300ER's, equal to a saving of 0.9 cents per ASM.

Maintenance costs

Maintenance costs are the other area where new types could potentially realise

One of the 777-300-ER's biggest advantages are its low engine-related maintenance costs on account of its twin-engine configuration.

savings for 747-400 operators. The total maintenance costs for the 747-400 are $1,850-2,000 per FH, depending on engine type, aircraft age, style of operation, and maintenance man-hour (MH) labour rate *(see 747-400 maintenance analysis & budget, Aircraft Commerce, April/May 2007, page 14).*

This total cost is equal to a unit cost of 1.2 cents per ASM. It comprises six elements: line and ramp checks, A checks, C and heavy checks, heavy components, rotable components, and engines. Line and ramp checks could provide a saving in the new types through technology.

Line, A and base checks in new types have lower MH, and parts and materials requirements. First, the component and system architecture, and the sophistication of on-board maintenance computers should all lead to fewer component and system failures, and a faster rectification of technical failures that result in non-routine line maintenance. The labour needed for non-routine maintenance should fall, as should the cost of materials and parts.

The maintenance programmes and technical documentation of new types are evolving so that they have fewer routine tasks, which are easier to perform and have longer intervals.

The difference between the 747-400, 747-8I and A380 is shown by the number of routine tasks in its base checks. The original equipment manufacturer (OEM) generally recommends the highest number of tasks for the 747-400. Its MPD intervals are for a C check every 24 months and now a D check every six years; or every third C check. The number of routine tasks are 199 for the 1C check at 24 months, 129 for the 2C at 48 months and 181 for the 3C or D check at 72 months. The full D check will therefore include 509 tasks. The 747-400 has another 119 heavy inspections tasks in its supplemental structural inspection document (SSID), which are performed every second D check. The aircraft has another 365 additional tasks, which will be treated as out-of-phase (OOP) tasks.

In contrast, the 747-8I has a similar number of tasks for its 1C and 2C and D check groups of tasks, which all have the same interval as the -400, but the 747-8I has no SSID and has fewer additional tasks at 235. The 747-8I will thus have 540 routine, MPD tasks to perform in its first D check, and this number will only increase by nine in its second D check.

The A380 also has the same C check intervals. Like all other Airbus types, it has an MPD with two groups of structural tasks and therefore heavy checks in its base check cycle. Its 1C group of tasks has 168 items, the 2C group has 75 tasks and the first structural check has 308 tasks. The first heavy check, with a six-year interval, will have a total of 551 routine MPD tasks. The second group of structural tasks, with an interval of 12 years, has 189 tasks. This means the second heavy check will total 740 MPD tasks, similar to the number of tasks in the 747-400's second D check.

The A380 has another 545 additional or OOP tasks.

The newer types therefore generally have fewer MPD routine tasks than the 747-400. Additional factors reduce the airframe maintenance burden of newer types. The greater use of materials such as carbon fibre is intended to reduce the incidence of findings and corrosion, and so reduce the MH for non-routine rectifications. Overall MH consumption and the cost of parts and materials should therefore be lower for the base checks of newer types; and ultimately give lower reserves per FH for base checks.

This leaves the elements relating to heavy components, rotables and engines. There are unlikely to be large or significant differences in the costs for tyres, wheels, brakes, landing gears, APU and thrust reversers between the four main types. The A380 and 777-300ER, however, can offer a small advantage here because they have two thrust reverser sets compared the 747-400's and -8I's four.

Engine-related maintenance accounts for the largest portion of total maintenance costs. Engine reserves for the 747-400 are $215-250 per engine flight hour (EFH) *(see 747-400 maintenance analysis & budget, Aircraft Commerce, April/May 2007, page 14).* Total engine maintenance costs are therefore $860-1,000 per FH.

The potential for newer types to have lower, similar or higher engine maintenance reserves than the 747-400 is dependent on several issues. The Trent 900 and GR7200 powering the A380, the GEnx powering the 747-8I, and the GE90-115 powering the 777-300ER have all been designed to achieve longer removal intervals, but they will have higher costs for materials, parts and shop visits than the 747-400's powerplants.

Reserves for the Trent 900 are expected to be $250-300 per EFH; higher than engines on the 747-400.

The GE90-115's reserves are estimated to be $350-400 per EFH; so $700-800 per FH, and lower overall than the 747-400. These engine reserves are only approximate, however, and could be higher.

An overall total lower maintenance cost of $200 per FH would equate to a reduction of 0.1-0.14 cents per ASM, however, for the A380, 747-8I and 777-300ER. A reduction in maintenance costs is welcome, but makes only a small difference to total CASM. A reduction in fuel burn is the most important factor in contributing to a lower overall CASM. AC