While it is several years before the A350 & 787 enter service, estimations of how their fuel & maintenance costs compare to their predecessors can be made. When considered in addition to probable financing charges, their total operating costs can be assessed.

How do the 787 & A350 measure up?

The 787 and A350 were launched to improve revenue-generating capacity, passenger comfort and payload-range performance, and lower operating costs over current aircraft. Significant cost savings can now be realised in only three areas: fuel burn, maintenance and financing.

The designs of the two aircraft mean that there are fundamental differences between the two. These are analysed to examine what cost savings the 787 and A350 might provide over the current generation aircraft that they could replace.

787 basic features

The 787 has three variants, the 787-3, 787-8 and 787-9, with tri-class seat capacities of 224 and 259 *(see table, page 33)*, aimed principally at replacing the 757, 767, A300-600, A310 and A330.

In early 2006 Boeing announced that it is launching the 787-10, a stretched derivative of the -9, which is expected to be 8 metres (26 feet) longer than the -9 variant. This will allow 10 additional economy-class seat rows, and a tri-class configuration of up to 290 passengers. It will have a range of about 7,300nm with the current engines available. This compares to the 787-9's 8,300nm. The range could be increased to about 8,000nm if more powerful engines become available. If this were the case, the -10 will encroach on the 300-seat A350-900 and 305-seat 777-200ER.

The replacement potential of the 787 family ranges widely from the 757 to the 777-200ER.

The 787-3 and -8 variants share the same fuselage, and so can have equal equal seating capacities. The maximum take-off weight (MTOW), specification weights, fuel capacities, seat numbers, belly freight volume, structural payloads and range of the 787-3, 787-8 and 787-9 are summarised *(see table, page 33)*.

A350-800/-900

Since the launch of the 787 by Boeing, Airbus has launched the A350, which has two models: the 253-seat -800 and 300-seat A350-900, which are both derived from the A330-200 and -300. The A350-800 uses the same fuselage as the A330-200, and the A350-900 the same as the A330-300.

Although the A350 models are derivatives, they have several differences due to technological improvements, including aerodynamic changes, cabin enhancements, simplification of the structure and fuel system, use of carbon fibre, and a new underfloor flightcrew rest compartment (FCRC).

The A350-800's and -900's MTOW, specification weights, fuel capacities, seat numbers, available belly freight volume, structural payloads and range capability are summarised *(see table, page 33)*.

The A350-800's standard tri-class configuration of 253 seats makes it a direct competitor of the 787-9, while the A350-900's standard tri-class 300-seat capacity puts it in competition against the 777-200ER, and the 787-10 if launched.

Airbus has been marketing the A350 models with two-class configurations, now that the use of lie-flat seats is becoming more common on long-haul operations. A two-class A350-800 has 258 seats and the -900 has 316 seats.

The A350 variants have higher seat capacities than the A330 models, due partly to re-engineering of the cabin aft of the rear doors and to new optimised locations for crew rest facilities.

Weight & performance

The operating empty weights (OEWs) for the 787-3/-8 /-9 are 223,100lbs, 239,200lbs and 254,300lbs *(see table, page 33)*, giving the variants an OEW per seat of 754lbs, 1,068lbs and 982lbs.

When the A350-800 and -900 are equipped with GEnx engines, the OEWs are 273,590lbs and 288,361lbs, resulting in an OEW of 1,081lbs and 961lbs per seat with a tri-class configuration.

The A350-800's OEW is 19,300lbs higher than the 787-9's. This higher weight will affect the A350-800's fuel burn compared to the 787-9. The A350-900's OEW per seat is about 20lbs lower than the 787-9's, which is to be expected given the A350-900's larger size.

Cabin comfort

The A350 has an interior fuselage diameter of 222 inches. In an eight-abreast arrangement, its economy-class seats are 17.5 inches wide.

The 787 has an interior fuselage diameter of 226 inches, four inches longer than the A350. The 787 has the same eight-abreast arrangement as the A330/A350. The additional four inches in the 787's cabin allow a width of 18.5 inches for the economy-class seats, and 21.5 inches for the aisles. The wider seat provides passengers with more additional space.

While metal-made commercial aircraft are typically limited to cabin pressurisation altitudes of 7,000-8,000 feet to reduce cyclic fatigue on the structure, the 787's use of more robust composite allows for a 6,000-feet cabin altitude. Higher moisture levels will also be possible because of the use of carbon fibre. These two factors are expected to reduce the effects of jet lag.

Carbon fibre

Of the materials used in the 787's structure, 50% are carbon fibre composites, used in the fuselage, wing skin and empennage, and 20% is aluminium.

In contrast, the A350 uses 39% carbon-fibre reinforced plastic (CFRP) in its structure, in the wing and empennage, more than in previous Airbus widebodies.

Aluminium-lithium, used in fuselage panels, comprises 21% of the structure.

Current generation aircraft use up to 25% carbon fibre in their structures. Its key advantage is that it is strong and light, thereby reducing hull weight and OEW. This allows a relatively high structural payload, and contributes to the aircraft's reduced fuel burn compared to current generation types.

Another benefit of carbon fibre is its resistance to structural damage and corrosion. A conventional metal structure suffers from corrosion due to leakage in the lavatories and galleys. Resistance to corrosion leads to savings from reduced routine tasks in structural checks, as well as a lower incidence of, and rate of increase in, the non-routine work relating to corrosion, its prevention and treatment. Carbon fibre will influence the number of MH and cost of materials and consumables used in base checks.

Powerplants

The 787 and A350 are powered by variants of the same two main engine types: the Rolls-Royce Trent 1000/1700 and GEnx.

The Trent 1000 will power the 787, and the Trent 1700 the A350-800/-900. The Trent 1000 and 1700 are two variants of the same engine, derived from the Trent 900 which powers the A380. Two variants of the GEnx will power the 787 and A350 families.

A conventional jet engine bleeds high-pressure air from its compressor section for use in systems such as cabin pressurisation, air conditioning, and wing anti-icing protection. This reduces the engine's output power and fuel efficiency.

Instead, the 787 will use electrically-powered systems to perform most pneumatic functions of a conventional aircraft, leaving only the engine nacelle and cowl anti-ice systems to be powered pneumatically. The absence of air-bleed systems from the engine's compressor will improve engine efficiency, and contribute to lower specific fuel consumption (SFC), and so to lower fuel burn.

The A350 will use conventional air-bleed systems to power its pneumatic services. The operational weights and size of the aircraft are similar to the 787, so the A350 requires different variants of the same engine powering the 787.

The main feature to reach the 787's fuel burn and operating cost reduction targets is a high bypass ratio. The Trent 1000 and Trent 1700 will both have a bypass ratio of 11:1, partly due to a smaller fan hub.

The Trent 1000 provides seven thrust ratings ranging from 53,200lbs to 73,800lbs, while the Trent 1700 has four, ranging from 63,000lbs to 75,000lbs.

The Trent 1000 is started electrically and has no need for ducts. The Trent 1700 is similar to the Trent 1000, but still needs air-bleed ducts.

Overall, the Trent 1000 on the 787 is expected to have a 15% lower SFC than the 767-300ER powered by the CF6-80C2. The Trent 1700-powered A350-800/-900 is expected to have 12% lower fuel burn than the A330-200/-300.

The GEnx engine has five thrust ratings ranging from 53,200lbs to 72,000lbs, and bypass ratios varying from 8.0 to 9.6. The engine will have a 15% improved SFC over the CF6 engine.

The GEnx is designed to stay on wing 20% longer than the CF6-80C2, and to use 30% fewer parts so as to reduce parts and materials costs in shop visits.

The GEnx will be an intelligent engine with diagnostic capabilities down to the component level. It will have a built-in core water wash, so that operators can attach a hose and run the engine on idle, to help maintain exhaust gas temperature (EGT) margin. The engine will alert operators when this needs to be done.

Fuel burn

The A350-800 is expected to have 12% lower fuel burn per trip than the A330-200, and the A350-900 11% lower fuel burn per trip than the A330-300.

A route of 5,000nm is representative for both A350 variants, and the 787-8 and -9. Fuel burn for the A330-200 and -300 on this sector length is 19,300 US Gallons (USG) and 21,000 USG. There is a small difference in fuel burn between the two A330 variants.

Based on the expected fuel burn differences between the A330 variants, the A350-800 will burn 18,200 USG and the A350-900 18,700 USG.

At the current price of $2 per USG, the A350's fuel economy will save the -800 $2,200 for a 5,000nm trip. The A350-900 will save $2,600 over the A330-300 on the same stage length.

The 777-200ER has a fuel burn of 24,000 USG for the same stage length. The A350-900 will thus provide a saving of $2,600 over the 777-200ER.

The 787-8 is smaller than the A350-800, and closer in size to the 767-300ER, which is its prime replacement target. Initial estimates are that the 787-8 will burn 15-20% less fuel. The 767-300ER burns 17,300 USG on a 5,000nm sector, so the 787-8 will have a fuel burn of 14,700 USG, giving the 787-8 a saving of $5,200 over the 767-300ER.

The 787-9 is likely to have 15-20% lower fuel burn than the 767-400ER, which burns 18,800 USG on a 5,000nm trip, depending on operating conditions and MTOW. The 787-9 will therefore burn 16,000 USG, 2,300 USG less than the A330-800, thereby saving $4,600 at current fuel prices.

Maintenance cost savings

The 787 and A350 have been designed to reduce maintenance costs for line and ramp checks, C and base checks, and engines, and even costs related to rotable and heavy components.

A350 & 787 FAMILY CHARACTERISTICS

Aircraft type	A350-800	A350-900
MTOW lbs	540,100	540,100
MZFW lbs	374,800	397,900
OEW lbs	273,590	288,362
Structural payload lbs	101,210	109,538
Tri-class seats	253	300
Range nm	8,800	7,500
Belly freight volume cu ft	5,147	6,101
Aircraft type	**787-8**	**787-9**
MTOW lbs	476,000	508,500
MZFW lbs	340,000	376,000
OEW lbs	239,200	254,300
Structural payload lbs	100,800	121,700
Tri-class seats	224	259
Range nm	8,500	8,200
Belly freight volume cu ft	4,854	6,126

The 767-300ER is one of several replacement targets for the 787-8 and A350. Both aircraft are aiming to reduce fuel and maintenance trip costs compared to the 767 and other current-generation widebodies.

Line & ramp checks

The routine content of line and ramp checks has been shrinking as aircraft evolve. On-board maintenance computers have increased the monitoring of aircraft systems, thereby reducing the number of routine tasks in line and ramp checks.

The 787 will monitor three times the number of parameters monitored by current generation aircraft, because certain types of faults will be monitored electronically for the first time. With the 787 Boeing aims to eliminate the routine tasks normally seen in pre-flight, transit and daily checks.

While it is possible to reduce the size of these checks, and even completely to eliminate some, technical faults will still arise during operation. Their analysis, troubleshooting and rectification have been simplified by the development of increasingly sophisticated on-board maintenance systems.

It is difficult to estimate how the number of man-hours (MH) used in line and ramp checks for the 787 and A350 will compare to the 767 and A330, but it can be assumed that the new types will be at an advantage.

An important consideration is how the pattern of operation affects the type and number of line and ramp checks performed each year. Aircraft operating an ultra-long-haul stage length of 5,000nm will only complete 420 flight cycles (FC) per year. A daily check will be performed on most operating days, either at the home base or an outstation, prior to operations, meaning that 350 daily checks will be performed annually. Only 65-70 pre-flight checks will therefore be required prior to the remaining flights.

Small savings in MH for these checks can result in a significant reduction in the number of MH used over a year's operation. The A330 and 777-200ER, for example, may use 12MH in a daily check, and the 767 15MH. The reduction in routine items and improved on-board maintenance systems might cut the 787's daily check requirement to 10MH, so saving up to 1,750MH annually per aircraft, or $122,000 at a labour rate of $70 per MH. The fall in MH will see a corresponding reduction in materials and consumables. The 767's daily check uses $500, and so the 787's might use $350.

The A350 is also expected to achieve the same level of savings as the 787. The A350's daily checks may use 10MH and $350 in materials and consumables, compared to 12-15MH and $500 for the A330-200/-300.

While transit checks are small, savings can also contribute to lower maintenance costs. A conservative estimate is that the 787 and A350 may only use 1.5MH compared to 2.0MH used by the 767 or A330. The 787 and A350 may use an even smaller number of MH.

The 787 will not have weekly checks, but the A350 is likely to retain the 7-day visits that are in the A330's and A340's maintenance programmes. A conservative estimate is that the A350 will use 5MH less and have $200 lower materials and consumables costs than the A330.

As described, the total cost of line and ramp checks will be $80 per FH for the 787, and $100 per FH for the A350, against $125-130 per FH for the 767 and A330, and $140 for the 777-200ER.

A checks are another aspect of maintenance costs where the 787 and A350 are likely to make savings. The 767 has a cycle of block A checks which completes after 12 checks, with a standard interval of 500FH. The 787's A check interval is expected to be 1,000FH.

While the extended interval may result in more inputs being required for the 787's A check, the increase will not be proportionate to the extended interval over the 767's interval. The cost of labour charged at $70 per MH, and materials and consumables, totals $305,000 for the complete A check cycle. Total inputs for the 787's A check cycle will be $375,000, but amortised over twice the interval. Considering actual intervals achieved by operators, this will equal $63 per FH for the 767, and $39 per FH for the 787.

The A330 has a cycle of eight A checks, and a standard interval of 600FH. The A350's target A check interval is 800FH. The 777-200 has a standard interval of 500FH. Assuming the inputs for A checks on the A330 and A350 will be about equal, the cost for all A checks will be $38 per FH for the A350 and $53 per FH for the A330. A check costs for the 777-200ER are $60 per FH.

Base & C checks

The 767 has a system of four C checks in its cycle, with a full interval of 24,000FH. About 45,000MH are consumed in the full C check cycle, with the heavy 4C check using 25,000MH. The total cost of materials and consumables is $715,000. These inputs are equal to a reserve rate of $140 per FH. As the aircraft ages, the increase in routine and non-routine requirements will raise this reserve.

Boeing's objective for the 787 is a basic C check interval of 36 months, and heavy check interval of 12 years. The use of carbon fibre in the 787 should reduce the number of MH for both routine and non-routine tasks, by eliminating or reducing the number of routine tasks for fatigue and corrosion inspections.

While it is difficult to predict exactly how many MH the 787 will consume in its C and base checks, Boeing estimates that its MH content will be 20% lower than current generation aircraft. Analysis shows there are fewer maintenance tasks by each ATA chapter when compared to other aircraft, such as the 777 and 767.

Non-routine MH ratios can be as high as 2.5:1 on current generation types in the first, second or third D check. The 787's non-routine ratio is expected to be closer to 1:1, due to the low level of

The 787's most notable feature is the high use of carbon fibre in its structure, which has many implications on its operating cost performance, as well as contributing to improved cabin comfort.

corrosion and fatigue. The non-routine ratio is also likely to increase more slowly with age because of the lower incidence or complete absence of corrosion due to the carbon fibre in the structure.

Even if the total expenditure of MH and materials, parts and consumables for the 787's four base checks is the same as that used by the 767 in its base check cycle, the 787's longer check intervals will mean it has lower reserve rates. The 767's maintenance expenditure is equal to a reserve of about $140 per FH, while the 787 has a reserve of about $60 per FH.

The A330's base check interval is 15 to 18 months, depending on operator. The base check cycle or eight C checks includes two heavy checks: the IL and D check. Total consumption in the base check cycle would be 80,000-85,000MH, with $1.6-1.8 million required for materials and consumables, resulting in a reserve of $120-125 per FH when actual intervals between checks are considered.

The intended C check interval for the A350 is 24 months, so actual achieved intervals may be 18 months. On this basis, the full C check cycle would be completed in 57,000FH.

The A350's structure has less carbon fibre than the 787's, so it is likely to have larger non-routine ratios in base checks and a higher rate of increase in the non-routine ratio as it ages. If it has the same labour and materials costs, the A350's longer check intervals will give it a lower base check reserve of $100-105 per FH.

The 777-200 has a flexible base check system in its maintenance planning document (MPD). Many operators perform annual generic C checks, with a heavy check every fourth check, equal to 17,000FH for an aircraft operating on the 5,000nm sector described. Analysis shows the 777-200ER will consume 36,000-40,000MH for a full base check cycle, including cabin refurbishment. With material and consumable consumption of $600,000, the reserve for base checks is $155 per FH.

Rotable components

Industry market rates for the supply, repair and management of rotable inventories are established for the 767 and A330. Complete packages are $230-250 per FH for the 767 and A330, and $280 per FH for the 777-200ER.

The 787 and A350 have been designed to increase the reliability of rotable items, and so reduce the amount of inventory required to maintain an operation. The 787 will also have a high number of electrical components, so leaks from hydraulic and pneumatic system components will be reduced.

The catalogue price of rotable items to support the 787 and A350 is expected to be higher than for the 767 and A330, however. The cost of supplying inventory for the 787 and A350 therefore must be assumed to be equal to the 767 and A330. Only several years of in-service experience with the 787 and A350 will reveal if they are achieving improved rotable reliability and overall lower costs.

Heavy components

Heavy components include the landing gear, wheels and brakes, auxiliary power unit and thrust reversers. Their maintenance intervals are either driven by flight cycles (FC) or are on an on-condition basis.

It is not expected that the maintenance intervals or repair costs for these four main component types will differ greatly between the 787 and A350 and 767 and A330. Costs for the four components combined are $570 per FC for the 767, $630 per FC for the A330, and $660 per FC for the 777-200ER. A rate of about $600 per FC can be expected for the 787 and A350.

Engine-related maintenance

Reserves per engine flight cycle (EFC) for life limited parts (LLPs) and per engine flight hour (EFH) for shop visit costs are the two main elements of engine maintenance costs.

Rolls-Royce and General Electric have tried to increase the on-wing life between maintenance visits and hold the cost of shop visits constant to achieve lower reserves per EFH.

Shop visit reserves for engines powering the A330 are $155 per EFH, with shop visit costs of about $2 million being amortised over an interval of 13,000EFH. Reserves for 777-200ER engines are about $200 per EFH.

While longer intervals may be achievable with the Trent 1000/1700 and GEnx, their shop visit costs are not yet clear. Airline and independent engine shops comment that engine parts prices have increased at rates exceeding inflation for the past 10 years. It is therefore assumed that shop visit reserve rates for the Trent 1000/1700 and GEnx will be similar to those achieved by the engines powering the A330-200/-300.

List prices for LLP shipsets will be $3.3-5.0 million, depending on engine type. The long average cycle time for aircraft operating ultra-long-haul routes, means that LLPs are likely to be replaced with a short stub life after 18,000EFC. This will result in LLP reserves of $210-280 per EFC, equal to $35-50 per EFH if used exclusively on sectors of 5,000nm.

Aircraft financing

Aircraft financing charges account for the highest percentage of total operating costs. The cost of financing an aircraft is expressed in terms of monthly lease rate factor, which will partly be influenced by the amount of financing to be repaid, the financing term and interest rates.

All methods of financing require the repayment of debt. In most cases, not all the debt has to be repaid, and the aircraft

The A350-900 is a direct replacement candidate for the A330-300. With increased seat capacity and range, and lower fuel and maintenance costs, the A350-900 is a formidable competitor to the 777-200ER.

financier can negotiate a debt balloon, which is repaid at the end of the financing term from the re-sale proceeds of the aircraft. "The size of the debt balloon will depend on the expected residual value of the aircraft after a certain period," says Phil Seymour, managing director of the IBA Group. "A current generation aircraft, in a half-life maintenance condition, is expected to have a residual value of about 6% after 25 years. The projected residual value varies by aircraft and engine type, but debt balloons are usually 5-10% less than the projected residual value. The higher the debt balloon the smaller the amount of debt to be repaid, and so the smaller the monthly repayments required."

Market lease rates from most aircraft lessors for young, current generation aircraft are equal to a lease rate factor of 0.8% with current low interest rates. Lease rates must be considered in relation to aircraft prices and purchase discounts. Taking a 30% discount on the manufacturer's list price as standard will give some indication of the lease rentals payable for each aircraft type.

The 767-300ER has a list price of $133 million. A lease rate factor of 0.8% and 30% purchase price discount will give a monthly lease rental of $745,000.

The A330-200 and -300 have list prices of $155 million and $175 million. Applying the same purchase discount and lease rate factor of 0.8%, the two aircraft will have monthly lease rentals of $868,000 and $980,000. The 777-200ER's list price of $193 million equals a lease rental of $1.08 million per month.

The 787, however, is expected to have a stronger residual profile compared to current generation aircraft. "The use of carbon fibre means the aircraft's fuselage will be less prone to corrosion, and so is expected to have a longer economic life of 35 years," explains Seymour. "As a consequence, the 787 is expected to have a residual value of 25% after 25 years."

These advantages mean the financing terms for the 787 are likely to include higher debt balloons, allowing lessors and financiers to offer operators lower lease rentals. Seymour predicts a monthly lease rate factor of 0.5-0.6% for the aircraft.

The list prices for the 787-8 and -9 are $136 million and $150 million. The price discount of 30% and a conservative monthly lease rate factor of 0.7% result in lease rentals of $665,000 and $735,000, illustrating the effect of favourable financing terms.

The A350's financing terms are expected to be similar to those of current types. The list prices for the A350-800/-900 are $165 million and $183 million. With a purchase discount of 30% of the list price and a monthly lease rate factor of 0.8%, they will have lease rentals of $924,000 and $1.02 million respectively.

Direct operating costs

As discussed, maintenance and fuel burn are the main areas where the variants of the 787 and A350 can be more economical than current types such as the 767-300ER, A330-200/-300 and 777-200ER. Other operating costs, such as flightcrew and landing and navigation charges, vary little between new and current generation aircraft.

The differences between the three cost categories studied will show how effective the 787 and A350 are against their competitors. Grouped by seat capacity, the 767-300ER and 787-8 can be compared in one group, the A330-200, A350-800 and 787-9 compared in a second group, and the A330-300, A350-900 and 777-200ER compared in a third.

The 787-8's fuel, maintenance and financing costs are $11,000 lower than the 767-300ER's for a 5,000nm trip. This translates to a lower unit cost of 1.20 cents per available seat-mile (ASM). This is when the 767-300 is analysed as a new aircraft and has a lease rate higher than the 787-8's, since the 787 is likely to have more favourable financing terms. The 787 saves $2,600 in fuel and $1,700 in maintenance. The 767-300ER's monthly lease rate would have to be about $360,000 for the two aircraft to have equal trip costs. This illustrates the 787-8's operating cost advantage.

In the second group the 787-9 and A350-800 offer lower fuel, maintenance and financing trip and ASM costs than the A330-200.

The A350-800's monthly lease rental is $56,000 and $1,600 per trip higher than the A330-200's. The A350-800, however, is able to offset this with fuel burn and maintenance savings of $2,900. The A350-800 has $1,300 lower trip costs and 0.30 cents lower unit costs per ASM. The A350-800 also has 10 more seats and superior payload-range performance, however, and is more likely to operate on routes averaging 5,000nm.

The 787-9 has about $5,100 lower fuel and maintenance costs than the A350-800. The 787-9's main advantage is its lease rate, which here is $190,000 less than the A350-800's, in which case the 787-9's trip costs are $10,500 lower. This illustrates the impact of the 787's more favourable financing terms.

The A350-900 has $5,300 lower fuel and maintenance costs than the A330-300. This saving could be even larger if the A350 benefits from lower MH and materials consumption as well as extended maintenance intervals. This saving offsets the A350-900's $45,000 higher lease rental. Overall, the A350-900 has $4,000 lower trip costs than the A330-300. The A350-900 also has five more and a superior payload-range performance to the A330-300.

The A350-900's trip cost is $15,000 lower than the 777-200ER's, due to $13,100 lower fuel, maintenance and lease charges. This gives the A350-900 an advantage of about 0.90 cents per ASM over the 777-200ER. AC