The 767-300ER, A330-200, A330-300, 777-200 & 777-200ER are long-haul workhorses. Their operating and fuel burn performance is analysed across six Transatlantic routes varying from 4,750nm to 7,500nm. The 777-200ER has the strongest operating performance, and lowest burn per ton-mile.

767-300ER, A330-200/ -300 & 777-200/-200ER fuel burn performance

Despite the arrival of ultra-long-range aircraft, there is still a big demand for medium widebodies. Many traditional long-haul routes such as those between Europe and North America or the Middle East are trunk city-pairs for airline networks, with flight times ranging from six hours to more than 10.

Boeing and Airbus have a number of twin-engined widebodies that meet the needs of most long-haul operations. These aircraft vary in their range, payload, passenger capacity and technological advances. Both original equipment manufacturers (OEM) are due to start delivering the A350 and 787 over the next few years. These more advanced medium to large widebodies will eventually replace long-haul workhorses such as the relatively modern A330-200 and -300, and the 777-200/-200ER, and the slightly older-design 767-300ER.

This analysis will examine which of these aircraft perform most efficiently on various routes in terms of fuel burn per seat and total permitted payload. This may suggest which fleet is the most likely to be replaced by the A350 or 787.

All the aircraft are capable of carrying additional freight payload in addition to full passenger loads, but the amount and the fuel burn per seat and per lb of payload will differ by route and between types. The 777 and A330 may be expected to have better operating performance and fuel burn characteristics than the 767, whose smaller seating capacity means that its fuel burn per seat-mile is likely to be poorer than that of the larger A330 and 777-200 variants.

The operating and fuel burn performance of the five aircraft analysed here is examined on medium and long routes, taking into account the ambient temperature at the departing airport. Aircraft become challenged when they are operated at the edge of their payload-range envelopes or when they are departing from hot airports, which can lead to a deterioration in their performance, since permitted take-off weight and payload can be limited. Reduced payloads generate less revenue, often making the aircraft uneconomic to operate. As these aircraft are often used for both high-density, short- to medium-length routes, as well as long-haul ones, this analysis will show the mission lengths on which each type starts being limited.

It is important for an airline operating a number of routes of varying distances, and wishing to limit the number of aircraft types it operates, that the aircraft in its fleet are versatile and flexible.

Range performance

Few aircraft are operated to their full range performance and payload capacity in actual operations. The aircraft being analysed are often used on a variety of route lengths by their operators. Greater

The A330-200 has the lowest fuel burn per available ton-mile compared to the 767-300ER, A330-300 and 777-200. The 777-200ER, however, has the lowest burn per available ton-mile.

route length increases the likelihood that an aircraft will be unable to complete the journey without a fuel stop, or will suffer a payload limitation.

The distance to suitable diversion airports when in the air is also an issue, since this affects the total amount of fuel required, and therefore the remaining payload an aircraft can carry on the mission. The distance from an aircraft's flight path (track) to the most suitable diversion airport could affect the track taken, and may increase it. It is especially important for twin-engined aircraft to be within a certain flying time from a suitable diversion airport at all stages of a flight. The diversion flying time can be extended by certifying the aircraft for extended range twin-engine operations (ETOPs). ETOPs is important to all six aircraft in this analysis, especially on routes over large expanses of water, since it shortens the track, flight time, and fuel burn required to complete the mission, and can therefore increase permitted payload.

While a route may seem possible for an aircraft when the great circle distance is looked at, the flight's track will be different, and the tracked distance longer. Airlines follow certain paths via waypoints between departure and arrival routeings. This can mean a large increase in the distance flown with a 7,000nm route rising to 7,400nm quite easily. En-route winds also need to be considered. The general direction of upper winds blowing eastwards decreases the equivalent still air distance (ESAD) that an aircraft will have to fly when operating eastwards, due to tailwinds, while the ESAD of a westward-bound aircraft will increase because it is flying against headwinds.

If an aircraft takes off or or lands at an airport that is hot or high, its take-off and landing weights can often be restricted, which can negatively impact permitted payload.

Performance limitations such as increased ESADs, high departure airport temperatures or airfield elevations can all restrict the payload, and therefore the revenue-generating potential, of an aircraft on the longer routes. In particular, the longer the ESAD, the more challenging the route becomes for the aircraft and its payload.

Aircraft types

The 767-300ER, A330-200, A330-300, 777-200 and 777-200ER are all currently popular widebodies used on medium- and long-haul missions. Their ranges vary from 4,000nm to 7,725nm, while their maximum seating ranges from 269 to 375 seats. These factors, together with the structural weights and fuel burn rates, determine the payload that each aircraft is capable of carrying on each route.

All aircraft have been compared as evenly as possible using the same routes, weather, tracks, operating conditions and passenger weights, in order to identify the permitted take-off weight, actual take-off weight, total payload and the fuel used for each aircraft on each route. This will reveal which type is the most negatively affected by long mission lengths at the edge of their payload-range capabilities. The maximum take-off weight (MTOW) will define the upper limit of the take-off weight. The payload-range profile determines the maximum payload and range possible with different payloads.

For an aircraft to be able to make a trip within its capabilities, it will need full fuel tanks and a reduction in payload to reach destinations at the extreme of its payload-range profile, so that total weight is less than the MTOW. Take-off weights can be restricted to below MTOW, when the aircraft is operating at airports with high altitude, high temperatures or short runways. In this case an aircraft's payload would have to be reduced.

The MTOWs for the aircraft analysed are 407,000lbs for the 767-300ER, 511,000lbs for the A330-200, 507,000lbs for the A330-300, 535,000lbs for the 777-200, and 634,500lbs for the 777-200ER.

The operating empty weight (OEW) can vary between operators on the same aircraft type, because each one will have different seat and interior configurations (the number of galleys, toilets and crew rest areas), crew numbers, as well as items loaded for cabin service (meals, entertainment and drinks). An increased OEW will mean less available payload and a higher fuel burn. The OEWs used here fall into the realistic OEW range for each aircraft type. The OEWs are 195,500lbs for the 767-300ER, 261,000lbs for the A330-200, 270,000lbs for the A330-300, 294,000lbs for the 777-200 and 302,000lbs for the 777-200ER.

A two-class layout has been used in each case, because this is more common on these aircraft types than a three-class one. The OEM standard two-class layouts are shown in the table *(see table, page 22)*. Standard configurations are rarely used in reality, and for the analysis an average has been used, of current airlines operating that particular aircraft in a dual-class configuration. These averages are lower than the OEM figure, particularly in the case of the 777-200ER. The difference between OEM and average airline seating numbers is much closer on the A330, particularly on the A330-200. This could be because Airbus has been more realistic in its suggested layouts, or because the aircraft is generally used less on long-haul and more on high-density, medium-haul routes, which are particularly apt for low-weight A330-200s with low 4,000nm ranges. This would mean less need for flat beds and other large seating, plus a less generous seat pitch in the economy cabin compared to those aircraft used on long to ultra-long routes. This illustrates the compromise made between the number and weight of passengers and baggage, and the additional amount of belly freight that can be carried. A more spacious interior and a lower seat count improves comfort standards, especially on long routes, but it has the effect of reducing seat numbers and passenger payload and increasing potential belly-freight payload. OEWs may be similar, however, because of more generously proportioned seating in the larger, premium cabins.

The 777-200ER has by far the largest range, which is over 7,700nm with maximum payload, although it does not have the largest number of seats. The average airline passenger numbers are similar to those of the A330-200/-300s. The A330-200 has the second longest range at 6,400nm and similar average airline seat numbers to the A330-300 and 777-200ER. The 767-300ER, 777-200 and A330-300 all have similar ranges of 5,240-5,990nm, but different seating capacities. The largest average airline capacity is on the 777-200, although it has the smallest range.

The other major difference between the aircraft is their engine options. The 767-300ER aircraft has the choice of Pratt & Whitney PW4000-94 or General Electric CF6-80C2 engines, while Airbus gives the option of the PW4000-100, Rolls-Royce Trent 700 or GE CF6-80E1 on the A330-200/-300.

All three engine manufacturers offer an option for the 777: the PW4000-112, Trent 800 and GE90.

For the analysis, the PW4000 family has been used on all the aircraft types to maintain consistency.

The maximum zero fuel weight (MZFW) for each aircraft remains the same, and determines maximum structural payload. For the 767-300ER, the MZFW is 278,000-295,000lbs, and for the A330 it is 374,800-385,800lbs. For the 777-200/-200ER the MZFW is much higher at 420,000-595,000lbs.

Operating conditions

There are a number of operational situations that can affect the performance of an aircraft.

767-300ER, A330-200/-300 & 777-200/200ER CONFIGURATIONS

	767-300ER	A330-200	A330-300	777-200	777-200ER
Seats					
OEM 2-class	269	293	335	375-400	375-400
Av. Airline 2-class	228	285	298	326	291
Max. range (nm)	5,990	6,400	5,850	5,240	7,725
Engine options	PW4000 CF6-80C2	PW4000 Trent 700	PW4000 Trent 700 CF6-80E1	PW4000 Trent 800 GE90	PW4000 Trent 800 GE90
Thrust (lbs)	62,100 - 63,300	68,000 - 71,100	68,000 - 72,000	76,000 - 77,000	90,000 - 93,700
Max. structural payload (lbs)	84,000 - 96,600	108,100	101,200	120,450 - 126,600	125,550 - 131,000
Max. fuel capacity (USG)	24,140	36,750	25,765	31,000	45,220
Weights (lbs)					
MTOW	380,000 - 412,000	507,000 - 513,700	478,400 - 513,700	506,000 - 545,000	580,000 - 660,000
MZFW	278,000 - 295,000	374,800 - 381,400	381,400 - 385,800	420,000	430,000 - 595,000
OEW	193,840 - 198,440	257,400 - 265,700	265,185 - 274,500	293,400 - 297,250	299,000 - 353,800
Belly freight capacity					
Containers	30 LD-2	26 LD-3	32 LD-3	32 LD-3	32 LD-3
Volume (cu ft)	4,030	containers + 695 bulk	5,656	5,656	

SUMMARY OF APT PARAMETERS FOR THE PERFORMANCE ANALYSIS

	Runway	Runway length (ft)	Temperature - Av. Daily highs - June (deg.C)	Airport terminal elevation (ft)
Los Angeles Intl. (LAX/KLAX)	06L/24R 06R/24L 07L/25R 07R/25L	8,925 10,285 12,091 11,096	27	126
London Heathrow (LHR/EGLL)	09R/27L 09L/27R	12,001 12,802	19	83
Helsinki Vantaa (HEL/EFHK)	04R/22L 04L/22R 15/33	11,286 10,039 8,518	18	179
Rome Fiumicino FCO/LIRF)	07/25 16R/34L 16L/34R 16C/34C	10,856 12,795 12,795 11,811	26	15
Istanbul Ataturk (IST/LTBA)	18L/36R 18R/36L	9,842 9,842	25	163
Dubai Intl (DXB/OMDB)	12L/30R 12R/30L	13,124 13,124	38	62
Mumbai C. Shivaji Intl (BOM/VABB)	09/27 14/32	11,302 9,596	32	37

The winds and temperatures have an impact on performance at the departure and arrival airport. Standard rules have been followed for the flight plan analysis with long-range cruise (LRC), and average wind and temperature figures for the month of June. These affect the ESAD, which in turn provides an indication of the fuel burn per seat per mile.

The six routes used were selected for their gradually increasing great circle distance, so that all aircraft are tested at the edge of their payload-range capabilities when upper winds and the resulting ESADs are taken into consideration. The six routes have ESADs ranging from 4,551nm to 8,485nm, compared to great circle distances of 4,741-7,568nm, and tracked distances of 4,771-8,729nm *(see table, page 26)*. Los Angeles (LAX) is the departure point for all the flights, due to its high ambient temperature and because it is a departure point for routes of varying lengths operating in an easterly direction. London (LHR) is the shortest ESAD route at 4,551-4,568nm, followed by Helsinki (HEL) at 4,871-4,881nm, Rome (FCO) at 5,289-5,310nm, Istanbul (IST) at 5,857-5,874nm and Dubai (DXB) at 7,375-7,387nm. The longest route featured is to Mumbai (BOM), at 8,485nm, but only the 777-200ER can operate it.

Average daily temperatures for June mean that LAX is 27 degrees centigrade, while average temperatures at the six destinations vary from 18 to 38 degrees centigrade *(see table, page 23)*. The airport elevations vary from 15ft at FCO to 179ft at HEL.

All the routes are within the maximum ranges of the 777-200ER, with the shortest four being within the capabilities of all the aircraft. Payload (and therefore passenger numbers) may have to be reduced on longer routes for all the aircraft, but the 767-300ER and 777-200 are the aircraft capable of only operating the shortest routes.

Performance results

The performance results for each aircraft on each route provide a total available payload. This has been converted into passenger numbers by using 220lbs per passenger, including baggage, as a standard weight. The surplus available payload represents the possible belly freight weight that the aircraft could additionally carry on the flight. The only aircraft to have any MTOW restrictions imposed on it is the 777-200ER, and then only slightly on first two routes.

The two main factors in the results are the available payload and the fuel burn. The fuel burn is for both the flight and 30 minutes' worth of taxi time. The block time also includes 30 minutes of taxi time. Payload will be an airline's main concern on long routes, since this represents its revenue-generating potential. The real test is not just the payload restrictions, but by how much the payload is reduced.

The longest route is LAX-BOM with an ESAD of 8,485nm. It is only achieved by the 777-200ER, but with a large restriction in the number of passengers it can carry, thereby potentially halving its revenue. The 777-200ER manages to accommodate a full passenger load for all but the longest route, with additional

FUEL BURN & OPERATING PERFORMANCE FOR THE 767-300ER, A330-200/-300 & 777-200/-200ER

Route	Great circle distance (nm)	Tracked distance (nm)	ESAD (nm)	Wind (kts)	Block fuel burn (USG)	Block time (mins)	Payload (lbs)	Passenger numbers	Additional cargo (lbs)	Fuel burn (lbs) per ton-mile	Fuel burn (USG) per seat-mile
767-300ER											
LAX-LHR	4,741	4,786	4,551	24	17,467	624	78,689	228	28,529	0.732	0.017
LAX-HEL	4,879	4,991	4,876	11	18,375	662	70,936	228	20,776	0.797	0.017
LAX-FCO	5,522	5,596	5,289	27	19,682	718	64,243	228	14,083	0.869	0.016
LAX-IST	5,971	6,097	5,857	19	21,353	792	49,626	225	126	1.103	0.016
LAX-DXB	7,246	Not possible to reach destination									
LAX-BOM	7,568	Not possible to reach destination									
A330-200											
LAX-LHR	4,741	4,771	4,566	21	19,614	620	100,512	285	37,812	0.641	0.015
LAX-HEL	4,879	4,991	4,877	11	20,707	657	91,400	285	28,700	0.697	0.015
LAX-FCO	5,522	5,596	5,302	26	22,181	715	83,599	285	20,899	0.751	0.015
LAX-IST	5,971	6,097	5,872	18	24,079	784	67,004	285	4,304	0.918	0.014
LAX-DXB	7,246	7,610	7,376	15	29,014	974	35,832	162	192	1.648	0.024
LAX-BOM	7,568	Not possible to reach destination									
A330-300											
LAX-LHR	4,741	4,771	4,566	21	19,617	621	87,381	298	21,821	0.738	0.014
LAX-HEL	4,879	4,991	4,877	11	20,696	659	78,357	298	12,797	0.813	0.014
LAX-FCO	5,522	5,610	5,303	27	22,267	718	70,015	298	4,455	0.900	0.014
LAX-IST	5,971	6,097	5,872	18	24,069	786	54,158	246	38	1.136	0.017
LAX-DXB	7,246	7,610	7,375	15	28,847	977	23,360	106	40	2.513	0.037
LAX-BOM	7,568	Not possible to reach destination									
777-200											
LAX-LHR	4,741	4,786	4,568	23	20,673	603	83,075	326	11,355	0.818	0.014
LAX-HEL	4,879	4,991	4,881	11	21,821	638	73,540	326	1,820	0.912	0.014
LAX-FCO	5,522	5,596	5,310	26	23,393	695	65,276	296	156	1.013	0.015
LAX-IST	5,971	6,093	5,874	18	25,303	790	48,473	220	73	1.334	0.020
LAX-DXB	7,246	Not possible to reach destination									
LAX-BOM	7,568	Not possible to reach destination									
777-200ER											
LAX-LHR	4,741	4,771	4,563	22	23,362	602	128,000	291	63,980	0.600	0.018
LAX-HEL	4,879	4,991	4,871	12	25,245	638	128,000	291	63,980	0.608	0.018
LAX-FCO	5,522	5,596	5,301	27	27,468	692	124,674	291	60,654	0.624	0.018
LAX-IST	5,971	6,097	5,867	19	29,804	762	104,135	291	40,115	0.732	0.017
LAX-DXB	7,246	7,599	7,387	14	35,710	946	66,491	291	2,471	1.091	0.017
LAX-BOM	7,568	8,729	8,485	14	39,672	1,081	31,888	144	208	2.201	0.032

Source: Navtech Flight Planning

cargo also only slightly affected for the first three routes. It is on the last but one route, LAX-DXB, that the payload capabilities suddenly drop off, after having had a full payload (63,980lbs) on the shortest two routes.

The 767-300ER and the 777-200 were unable to complete the longest two routes. The 767-300ER succeeded in carrying a full passenger load for the first three routes, unlike the 777-200 which only managed this for the first two. The 777-200's payload was seriously affected by the longer routes, while the 767-300ER only had to reduce its passenger load by three, before being unable to complete a route. This is partly because of the much smaller average passenger numbers seen on the 767 compared to the 777.

Both the A330s perform well in that it is only the last route that they cannot complete. Having said that, their passenger numbers on the last possible route are down by more then half on the A330-300, with virtually no cargo, and more than a third on the A330-200. The A330-200 copes better with the longer routes than the -300 model, and has a full passenger load for all but the longest two routes. The A330-300 manages to carry a full load on the first three routes, but its ability to carry additional cargo is seriously affected on all routes, partly because the A330-200 has a slightly higher MTOW and slightly lower OEW than the A330-300.

The fuel burn performance of the five aircraft is considered in terms of the fuel burn (USG) per available seat-mile and fuel burn (lbs) per available ton-mile (fuel used per unit of payload per mile flown). In terms of fuel burn per ton-mile, the 777-200ER is the most efficient aircraft on all routes and the best fuel burn per ton-mile was found on the shortest routes for all aircraft.

The A330-200 is the next efficient aircraft on the routes that it is able to complete, because its payload-range envelope means that its payload is the least affected. It also has more modern technology than its competitors in this analysis, thereby making it more efficient. The 777's more modern technology produced quicker flight times by about 20 minutes, although the 777-200 struggled to stay ahead on the longer routes.

In terms of fuel burn per available seat-mile, the A330-300 and the 777-200, in particular, are the most efficient, due to their ability to carry more passengers than the other aircraft being analysed. The route length seemed to have no effect on the fuel burn per seat-mile. The figures remained roughly the same, although they did go up on the longest two routes. In terms of fuel burn, the economic stopping point for these aircraft could therefore be about 6,000nm. AC