Assessing operational performance of candidate aircraft is the first stage of aircraft selection. The operating & payload performance of several medium widebody freighters is analysed on sample routes which originate from some of the most challenging hot & high airfields.

Widebody freighter operating performance

When selecting freighter aircraft, an airline must examine the payload-carrying performance of all aircraft with similar payload capacities across its route network. This will allow it to identify the weaker performers before making further aircraft selection assessments.

The payload-carrying performance of widebody freighters on some of the most challenging routes and operating conditions is analysed here, including: the 767-200BDSF (Bedek conversion); the 767-300ERF (Boeing STC); the A300-600F (Airbus/EADS conversion); the A310-300F (Airbus/EADS conversion); the DC-10-30F (Aeronavali/Boeing conversion); and the DC8-73F (Aeronavali/Douglas conversion). The DC-8-73F is included here as a benchmark for comparing the performance of younger generation freighters.

New generation freighters

Younger generation freighter aircraft include recent conversions and factory-built Airbus and Boeing aircraft capable of extended-range twin-engined operations (ETOPS). Overall, younger generation aircraft can be a more economic option than older types, despite their relatively high capital costs, because they may have superior operating and payload performance and revenue-generating capacity, particularly on more challenging routes. Maximum available payload and range with payload cannot be taken for granted, especially when flying from hot-and-high airfields or in other situations where the operating performance of the aircraft is challenged or limited. Moreover, although the total operating costs of the oldest aircraft may be lower for freight operations, older types, as exemplified by the DC-8-73F here, tend to have poorer take-off or second-segment climb performance, particularly from hot-and-high airfields. This can limit payload carried and therefore the revenue generated for the amount of fuel burned and other cash operating costs that are incurred.

The particular aircraft types analysed here are: a high gross weight version of the 767-200F; the highest gross weight models of the 767-300ERF, A300-600RF, and A310-300F; the DC-10-30F; and the DC-8-73F.

Testing performance

This analysis examines the payload-carrying ability of these aircraft from two of Latin America's more prominent hot-and-high departure points, Mexico City (MEX) and Bogota (BOG), to three destinations. These are Miami (MIA), Los Angeles (LAX), and Santiago de Chile (SCL). MEX has an elevation of 7,316 feet above sea level and a runway length of 12,966 feet *(see table, page 60)*, while BOG has an elevation of 8,360 feet above sea level and a runway length of 12,467 feet. These airfields also experience high ambient temperatures. This analysis uses midday temperatures for July: 20ºC at BOG; and 22 ºC at MEX. These are relatively high compared to the international standard atmosphere (ISA)

Care should be taken to distinguish between certified maximum take-off weight, available take-off weight and actual take-off weight when assessing the operating performance of freighter aircraft. Available take-off weight is affected by airfield characteristics and operating conditions, which in turn affects available payload.

HOT-AND-HIGH AIRPORT CHARACTERISTICS

Airport	Mexico City	Bogota	Miami
Ambient temperature deg C	22	20	22
Elevation (feet)	7,316	8,360	8
Runway length (feet)	12,966	12,467	13,000

MEDIUM WIDEBODY FREIGHTER SPECIFICATIONS

Aircraft type	Engine	MTOW lbs	MZFW lbs	OEW lbs	Structural payload lbs	Fuel USG
767-200BDSF	CF6-80A	351,000	261,005	164,399	96,606	16,700
767-300ERF	CF6-80C2B7F	412,000	309,000	190,700	118,300	24,140
A300-600F	CF6-80C2	375,888	295,000	182,983	112,017	17,536
A310-300F	CF6-80C2A2	361,558	251,327	159,614	87,744	19,924
DC-10-30F	CF6-50C2	565,000	391,000	236,776	154,224	36,646
DC-8-73F	CFM56-2C1	355,000	262,000	151,000	111,000	24,243

PAYLOAD-RANGE CHARACTERISTICS OF WIDEBODY FREIGHTERS

Aircraft type	MTOW lbs	Structural payload lbs	Distance nm	Block fuel lbs	Block fuel USG
767-200SF	351,000	96,606	2,970	75,151	11,215
767-300ERF	412,000	118,300	3,175	87,698	13,087
A300-600F	375,888	112,017	2,415	70,001	10,446
A310-300F	361,558	87,744	3,870	98,617	14,717
DC-10-30F	565,000	154,224	3,950	157,683	23,531
DC-8-73F	355,000	111,000	2,700	81,306	12,133

temperatures for their elevations. The standard ISA temperature at BOG's elevation is minus 0.4ºC, so an ambient temperature of 20ºC is equivalent to ISA plus 20.4ºC. Meanwhile, the standard ISA temperature at MEX's elevation is minus 1.7ºC, so the ambient temperature of 22ºC is ISA plus 23.7ºC. In addition to these elevated airports, this analysis also includes, as a 'control', flight plans from MIA as the departure point. MIA has an elevation of eight feet and is virtually at sea level *(see table, this page)*. From here one can see how payload performance improves for a given aircraft type when high runway elevation is not a mission-constraining factor.

The high temperatures for their elevations at MEX and BOG further reduce air density, thereby placing severe limitations on engine thrust, wing lift, and therefore aircraft take-off and second-segment climb performance. For all aircraft analysed here, the maximum available take-off weight (MATOW) from these airfields is lower than their certified maximum take-off weights (MTOW) *(see tables, page 63 & 64)*.

The extent to which an aircraft's payload is reduced or limited on a particular route depends on its MATOW, and maximum zero-fuel weight (MZFW), as well as the fuel that the aircraft must carry in order to complete the trip and have the legal minimum for reserves.

Another factor to be aware of is actual take-off weight (ATOW), which is either equal to or lower than the MATOW. The MATOW is the take-off weight that is possible for the aircraft at the specific airfield in the prevailing conditions. If the actual take-off weight is less than the MATOW, then this is all that the aircraft requires to take-off and to complete its mission without any payload limitations. If the actual take-off weight equals the MATOW then this indicates that the aircraft requires more take-off weight, and is weight limited.

The analysis here uses a total taxi time of 25 minutes, enough reserve fuel for a 30-minute hold and 200nm diversion, plus 3% of sector fuel for navigational tolerance. The difference between the MATOW and the operating empty weight (OEW) determines the disposable load that can be split between payload and fuel, although payload is also limited by the difference between MZFW and OEW. There is a trade-off between payload and weight of fuel. The longer the trip and the more fuel required, the lower the payload that can be carried.

All aircraft types have to accept reduced payloads on long sectors at the edge of their maximum payload-range. The reduction in payload will be greater still when the MATOW is lower than the MTOW. This is the case with all the sectors, apart from MIA-SCL, where there is no take-off performance limitation.

Before commencing an operation, operators therefore have to calculate the MATOW, by taking into consideration the specific operating conditions at the airport: the runway length; the runway slope; the airfield pressure elevation; and the ambient temperature. Based on this, there are two limitations to take-off weight: the runway-limited take-off weight; and the second-segment climb-limited take-off weight. The permitted take-off weight to be used for payload calculations is the lower of these two weights. In actual operations the take-off wind component would also be used. In this study zero wind at take-off has been assumed. Rick Methven, director of Aerocom Aviation Software, points out that in this particular study, and from the two elevated airports chosen, the main limitation on all aircraft is the second-segment climb phase. This is from landing gear retraction to the point at which air speed is high enough for flaps to be retracted.

The first weight that must be considered for each type is the aircraft prepared for service (APS) weight, which comprises the OEW of the aircraft plus some allowance for crew, baggage, catering and other items. APS does not include tare weights of pallets or containers, however; these are included in each aircraft's available gross structural payload. Tare weights of a preferred container or pallet configuration should be deducted from the gross structural payload in each case to calculate the available net payload, which provides the revenue-generating payload. Other important aircraft specifications include engine type, MTOW variant and MZFW.

Aircraft specifications

The specifications of the six aircraft types analysed are summarised *(see table, this page)*. The 767-200BDSF is the 767-200 model converted by Bedek Aviation.

This aircraft has a high MTOW of 351,000lbs, which was upgraded during conversion. Fuel capacity remains the same for the basic -200 series. It should be noted that the -200ER could have been included in the analysis. The -200ER has several gross weights up to an MTOW of 395,000lbs and a fuel capacity of 24,140USG. The route analyses show that the MATOWs for the 767-200 are lower than the MTOW by 70,000lbs at BOG and 60,000lbs at MEX. The aircraft is therefore take-off climb-limited on the five sectors from these two airports. This means that the MATOW would not be higher even if the aircraft had a higher certified MTOW. The 767-200ER would therefore have no payload advantage over the 767-200 under these take-off conditions.

The 767-300ER is the highest gross weight version, and the A300-600RF and A310-300F models used are the highest gross weight and highest fuel-capacity variants available.

The DC-10-30F and DC-8-73F models used are standard variants operated in the largest numbers.

Results commentary

The aircraft take-off and en-route performance and flight plan data have been calculated and provided by Aerocom Aviation Software using its Payload and Costing System (PACS). All sectors are flight-planned tracked distances with zero en-route wind.

There are three sectors of successively greater tracked distances which use BOG as the departure point: the short-range BOG-MIA (1,531nm); the medium-range BOG-SCL (2,385nm); and the most demanding long-range BOG-LAX (3,088nm). In addition, there are two range-contrasting sectors that use MEX as the starting point: MEX-MIA (1,162nm); and MEX-LAX (1,443nm). The final sector, MIA-SCL (3,660nm) is a long-range route which demonstrates the payload capability on a route where no aircraft is runway- or climb-limited. Sectors starting from the three respective departure points are now discussed in turn.

From Bogota

Even on the first and shortest sector in this section, BOG-MIA with a sector distance of only 1,531nm, all aircraft, except for the A310-300F suffer payload limitations due to the runway elevation and ambient temperature conditions. The A310-300F, which is neither runway- nor climb-limited, is successfully able to depart with its maximum structural payload (MSP) of 87,744lbs which in turn is the maximum payload possible with the certified MZFW.

All the other aircraft on this sector are take-off climb-limited and hence suffer from varying degrees of payload reduction below their MSP. Of these, the best performing freighter, with the least amount of payload limitation, is the DC-10-30F whose available payload is 95% of the MSP. In absolute payload uplift, the DC-10 carries by far the greatest, with 146,737lbs, which is about twice the payload of the other aircraft. Next in the payload-limitation ranking, and very close together, are the 767-200BDSF and 767-300ERF both of which manage to uplift 68% and 67% of their MSPs, respectively. As discussed, the 767-200ER is unlikely to have a higher MATOW than the lower gross weight 767-200 model.

Close behind the 767s is the DC8-73F at 66%, which leaves the A300-600F trailing with only 59% of its MSP. It is interesting that from a sea-level departure, these aircraft are able to carry their MSPs over much greater distances *(see table, page 63)*.

Many aircraft types have limited performance at Quito due to the combination of its high elevation and short runway. As with Quito, many aircraft operating from airfields such as Bogota and Mexico City have available take-off weights that are significantly lower than their certified maximum take-off weights.

The other observation worth taking into consideration on the short BOG-MIA route is the fact that even at the airport's 8,360ft elevation, the A310-300F with an ATOW of 306,775lbs possesses sufficiently good runway performance margin to, in theory, uplift an additional 6,839lbs of payload, were it not MZFW-limited. This is illustrated by its MATOW of 313,614lbs, which is 6,839lbs higher than its actual take-off weight. All the other aircraft could have carried more structural payload, since they are limited not by their MZFW but by their respective take-off performance limitations.

On the subsequent sectors from BOG, the aircraft are ranked in a very similar descending order of structural payload percentage. For both BOG-SCL and BOG-LAX, all the aircraft, including the A310-300F, are take-off climb-limited as a result of the ambient conditions at departure, and not by MZFW or any other constraint *(see table, page 63)*. Regarding the A310-300F, the results show that this aircraft is still in the lead, being able to uplift 87% of its MSP. As before, the worst performing aircraft is the A300-600F, being able to carry only 42% of its MSP.

On the longest sector from BOG, the payload percentages slip even further. This time, the A310 is yet again in the lead and carries 70% of its MSP, while at the other end of the ranking, the large bodied, but small-winged A300 clearly struggles with only 27% MSP uplift.

"Looking at the most restricting sector, BOG-LAX, it is clear that this is not a route on which anybody would typically operate these aircraft without a refuelling stop, because of the restrictions. The DC-10 is the exception to this because it has three engines, so the take-off weight restrictions are not as great," says Methven.

"The DC-8-73 loses out because it was never designed for hot-and-high airfield performance. It was really designed for US domestic operations, like the other DC-8s before it," continues Methven. "Moreover, it is hampered aerodynamically because it does not have the lower flap setting (the lower the flap setting, the shorter the time and distance to get to a clean configuration). In contrast, the DC-10 has an infinitely variable flap setting between zero and 20 degrees which helps it. Meanwhile, the 767-200 has a one-degree flap setting, whereas the 767-300 and the Airbuses have a five-degree setting. The DC-8-73 has a higher, 15-degree setting, which makes it more limited, even though it has four smaller engines."

It is worth noting that in this analysis the 767-200 used is with the CF6-80A series turbofan rated at around 48,000lbs thrust. The vast majority, that is, 40 out of 53 767-200 freighters in service today, are powered by this engine. In addition to these CF6-80A-powered aircraft, most of which are operated by ABX Air, the 767-200 converted freighter fleet also includes about eight 767-200s with the more powerful CF6-80C2B2 engine rated at about 52,000lbs thrust. These are operated by Tampa (Colombia) and Star Air (Denmark). It is fair to say that this version would have better hot-and-high takeoff performance and would be able to carry slightly more payload than the CF6-80A-powered 767-200s. However, the underlying 767 design is inherently freighter-disadvantaged in terms of MATOW on hot-and-high missions relative to the A310-300, because the latter has a more advanced high-lift supercritical wing, high-lift leading-edge devices and flaps than the earlier 767 design. As well as this, however, the A310-300 has significantly lower OEW than the 767-200 (159,614lbs of the A310-300 versus 164,399lbs of the 767-200 freighter). To the 767's credit, however, when the CF6-80A powered 767 is operated from a sea-level airport (and is thus not take-off nor climb restricted) it can carry approximately 10,000lbs more total structural payload over shorter ranges than the CF6-80C2-powered A310-300.

In the passenger fleet of 767-200ERs, there are large fleets flying with even more powerful versions of the CF6-80C2. One of these is with Continental Airlines which operates 10 767-200EREM powered by CF6-80C2B4Fs rated at 57,200lbs thrust each. For the time being, however, these more capable aircraft are likely to remain more profitable as passenger aircraft than be converted to freighters.

From Mexico

From MEX, the same aircraft as above seem to fare better. Here the DC-10-30F is clearly the best overall freighter. Not only does it lose no payload whatsoever on both MEX-MIA and MEX-LAX, but its available payload also totals a colossal 154,224lbs.

In general, although the ambient temperature is two degrees hotter than at

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BOG-MIA: Sector distance 1,531nm, take-off temperature 20 deg C

Aircraft	MTOW lbs	MATOW lbs	Actual TOW lbs	Max payload lbs	Available payload lbs	Payload percent	Block fuel USG	USG fuel per ton-mile	Payload limitation
A310-300F	361,550	313,614	306,775	87,744	87,744	100	6,021	0.0987	MZFW
DC-10-30F	565,000	466,054	466,054	154,224	146,737	95	9,562	0.0921	Take-off climb
767-200BDSF	351,000	282,191	282,191	96,606	65,918	68	5,693	0.1250	Take-off climb
767-300ERF	412,000	325,016	325,016	118,300	79,609	67	6,096	0.1119	Take-off climb
DC-8-73F	355,000	281,770	281,770	111,000	73,407	66	6,438	0.1250	Take-off climb
A300-600F	375,890	303,208	303,208	112,017	66,304	59	5,922	0.1283	Take-off climb

BOG-SCL: Sector distance 2,385nm, take-off temperature 20 deg C

Aircraft	MTOW lbs	MATOW lbs	Actual TOW lbs	Max payload lbs	Available payload lbs	Payload percent	Block fuel USG	USG fuel per ton-mile	Payload limitation
A310-300F	361,550	313,614	313,614	87,744	76,366	87	8,781	0.1053	Take-off climb
DC-10-30F	565,000	466,054	466,054	154,224	118,205	77	13,696	0.1086	Take-off climb
767-300ERF	412,000	324,961	324,961	118,300	60,272	51	8,898	0.1382	Take-off climb
767-200BDSF	351,000	282,191	282,191	96,606	47,818	49	8,313	0.1612	Take-off climb
DC-8-73F	355,000	281,770	281,770	111,000	52,311	47	9,494	0.1678	Take-off climb
A300-600F	375,890	303,208	303,208	112,017	46,568	42	8,781	0.1744	Take-off climb

BOG-LAX: Sector distance 3,088nm, take-off temperature 20 deg C

Aircraft	MTOW lbs	MATOW lbs	Actual TOW lbs	Max payload lbs	Available payload lbs	Payload percent	Block fuel USG	USG fuel per ton-mile	Payload limitation
A310-300F	361,550	313,614	313,614	87,744	61,840	70	10,885	0.1250	Take-off climb
DC-10-30F	565,000	466,054	466,054	154,224	94,935	62	17,067	0.1283	Take-off climb
767-300ERF	412,000	324,961	324,961	118,300	44,778	38	11,143	0.1777	Take-off climb
767-200BDSF	351,000	282,191	282,191	96,606	33,358	35	10,411	0.2237	Take-off climb
DC-8-73F	355,000	281,770	281,770	111,000	35,382	32	11,947	0.2402	Take-off climb
A300-600F	375,890	303,208	303,208	112,017	30,765	27	11,070	0.2566	Take-off climb

BOG, MEX's reduced elevation (7,316ft versus 8,360ft) coupled with the shorter sector tracked distances and hence less block fuel required *(see table, page 64)* allows more payload to be loaded. That MEX is a less severe departure point is further illustrated by the higher MATOW numbers across the board, which are all closer to respective MTOWs. This compares with those at BOG where the greater shortfalls between aircraft MATOWs and corresponding MTOWs are all evident.

It is also worth noting that on both the MEX-MIA and MEX-LAX sectors, the take-off weight restrictions for the A310-300F and the DC-10-30F are small enough not to reduce their payload. Both aircraft can therefore still carry their MZFW-limited payload. In short, both aircraft are take-off-weight limited, but the short range of the sector does not result in a payload loss, because the DC-10 and A310 are designed as long-range aircraft.

While the 767-300ERF does lose a significant amount of payload, it still manages to carry well over 100,000lbs on both sectors from MEX. The smaller 767-200, meanwhile, does reasonably well by losing no more than 20% of its MSP.

From Miami

Removing any altitude-related take-off restrictions by flying to SCL out of MIA, a sea-level airport, still shows a payload reduction for all aircraft in the group except for the A310-300F. Also, the ranking order is the same as in the previous sector example, with the A310-300F losing the least payload, and the A300-600F losing the most as a fraction of MSP. This is because the A300-600 was not designed as a long-range aircraft. However, while the A310 does not lose any payload on this route, it nevertheless has a modest total load of 87,744lbs, compared with much higher available payloads for the DC-10 (146,755lbs) and 767-300 (106,496lbs).

In addition, the reduction evidenced this time around arises from the need for aircraft to load more fuel to fly the 3,660nm tracked distance *(see table, page 64)*. Although none of these respective increased fuel loads actually reach the maximum fuel capacity limits, when they are added to the OEW, they do result in a reduced available payload capability in order to stay within the MTOW limit.

Methven points out that all the aircraft on this sector except the A300-600RF can carry reasonable amounts of payload and with reasonable fuel efficiency, especially the 767-300. The A300-600 loses a considerable amount of payload because it does not have the range capability with a high payload.

Conclusions

Looking at aircraft performance across all sectors, this study shows that in terms of absolute payload uplift capability, the DC-10-30F is consistently the most capable hot-and-high freight

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MEX-MIA: Sector distance 1,162nm, take-off temperature 22 deg C

Aircraft	MTOW lbs	MATOW lbs	Actual TOW lbs	Max payload lbs	Available payload lbs	Payload percent	Block fuel USG	USG fuel per ton-mile	Payload limitation
A310-300F	361,550	320,029	297,965	87,744	87,744	100	4,745	0.1020	MZFW
DC-10-30F	565,000	483,290	460,841	154,224	154,224	100	7,592	0.0921	MZFW
767-300ERF	412,000	348,550	348,550	118,300	110,341	93	5,061	0.0855	Take-off climb
767-200BDSF	351,000	293,325	293,325	96,606	84,474	87	4,618	0.1053	Take-off climb
DC-8-73F	355,000	289,414	289,414	111,000	89,940	81	5,150	0.1086	Take-off climb
A300-600F	375,890	310,909	310,909	112,017	82,111	73	4,747	0.1086	Take-off climb

MEX-LAX: Sector distance 1,443nm, take-off temperature 22 deg C

Aircraft	MTOW lbs	MATOW lbs	Actual TOW lbs	Max payload lbs	Available payload lbs	Payload percent	Block fuel USG	USG fuel per ton-mile	Payload limitation
A310-300F	361,550	320,029	304,659	87,744	87,744	100	5,715	0.0987	MZFW
DC-10-30F	565,000	483,290	472,298	154,224	154,224	100	9,252	0.0921	MZFW
767-300ERF	412,000	348,550	348,550	118,300	103,595	88	6,039	0.0888	Take-off climb
767-200BDSF	351,000	292,325	293,325	96,606	78,275	81	5,516	0.1086	Take-off climb
DC-8-73F	355,000	289,414	289,414	111,000	82,761	75	6,190	0.1151	Take-off climb
A300-600F	375,890	310,909	310,909	112,017	75,466	67	5,710	0.1151	Take-off climb

MIA-SCL: Sector distance 3,660nm, take-off temperature 22 deg C

Aircraft	MTOW lbs	MATOW lbs	Actual TOW lbs	Max payload lbs	Available payload lbs	Payload percent	Block fuel USG	USG fuel per ton-mile	Payload limitation
A310-300F	361,550	361,550	361,550	87,744	87,744	100	14,061	0.0954	MZFW
DC-10-30F	565,000	565,000	565,000	154,224	146,755	95	23,895	0.0987	Fuel load
767-300ERF	412,000	412,000	412,000	118,300	106,496	90	14,811	0.0855	Fuel load
767-200BDSF	351,000	351,000	351,000	96,606	81,185	84	13,451	0.0987	Fuel load
DC-8-73F	355,000	355,000	355,000	111,000	82,347	74	15,753	0.1151	Fuel load
A300-600F	375,890	375,890	375,890	112,017	76,787	69	14,933	0.1184	Fuel load

platform, with available payload far exceeding any of the other types under any conditions. Indeed, the DC-10-30F's strengths have always been its high MZFW (391,000lbs), high-thrust multi-engined layout, and very high MTOW capability (565,000lbs).

Importantly, compared with the twin-engined 767s and A300/310s, the three-engined DC-10 is not as penalised by engine-out situations. In other words, if one engine fails on a DC-10, it still has two-thirds available thrust to continue climb-out, whereas the twin-engined aircraft only have half the power remaining for climb-out after an engine failure. Therefore, in order to maintain safety margins, especially in the second segment of hot-and-high departures, greater take-off-weight restrictions are placed on a twin-engined aircraft (as part of its certification) to ensure that climb-out following an engine-out situation can continue safely. This adversely affects the available payload that can be carried, which in turn damages the aircraft's operational economics.

In terms of fuel burn, it may be surprising to see results which show that the DC-10-30F, for all its antiquity compared with the much younger 767, still delivers a competitive fuel burn per ton-mile on payload-restricted missions *(see tables, page 63 and this page)*. This is because the DC-10's available payload, like the A310, is consistently high as a fraction of its MSP. The DC-10 is a much larger aircraft, however, which means that its higher payload will be harder for airlines to fill. All the other types are closer in payload capacity. The DC-10-30F will also have higher cash operating costs.

However, when the ambient take-off conditions are less restricting, the 767-300ERF returns the best fuel efficiency of all the aircraft in terms of fuel burn per payload ton-mile *(see tables, page 63 and this page)*. This is not surprising given that it is a more modern, twin-engined aircraft.

When the other aircraft studied here are payload-restricted due to ambient conditions, they suffer greatly from increased fuel burn per ton of payload carried, regardless of the fact that they may be powered by newer-generation engines.

While this analysis may not appear to put the A300-600F in a particularly good light, it should be remembered that this aircraft's strength as a high-volume, low-density regional freighter, becomes its 'weakness' when it is flown on these demanding hot-and-high general cargo missions - a role for which it was never really intended. The A300-600F and the A310-300F complement each other as 50-tonne, medium-range and 40-tonne, long-range aircraft. The A300-600's bigger fuselage gives it another 50 cubic metres of volume and 10 tons more payload compared to the smaller A310-300. AC