Freight airlines operating the DC-10-30F or MD-11F may need to consider fleet replacements. The A330-200F and 777F are the closest options. The payload specifications and capacities, payload accommodation and revenue generating capacities of the four freighters are examined.

Revenue capacity of the DC-10-30F, A330-200F, MD-11F & 777F

Freight airlines have several aircraft types to choose from. Their choice will depend on the route lengths, freight volumes and density, and type of freight across their route networks, including: overnight freight; express package freight; general freight of manufactured goods; and large or outsized items.

Airlines requiring medium and large widebody freighters can choose between factory-build freighters, or conversion of used passenger aircraft. Conversion is generally carried out on aircraft that have not accumulated excessive flight hours (FH) and flight cycles (FC), and whose values have declined to the economic zone of convertibility.

The A330-200F and 777F are factory-built freighters, while the DC-10-30 and MD-11 are passenger aircraft that are converted to freighters. There were a limited number of DC-10s and MD-11s built as freighters. These four types have gross structural payloads between 152,100lbs and 228,700lbs *(see table, this page)*.

The freighter market has developed over recent years with the modernisation of older fleets and capacity growth. This has been through the increasing availability of younger types for conversion, and of factory freighter versions of successful passenger aircraft; including the A330-200 and 777-200. Airlines with long-term contracts that can generate high freight volumes and yields, and achieve high rates of aircraft utilisation, can justify the use of factory-built freighters.

The DC-10-30CF, MD-11F, A330-200F and 777F are analysed for their payload and revenue-generating capacities. These play an important role in aircraft selection, in addition to the acquisition or lease cost and cash operating costs. Other factors can include commonality with an operator's current fleet, aircraft type availability on the market, an operator's need to grow capacity or just update its fleet and routes that an aircraft will be used on.

Freight aircraft carry their payload in two different forms: on pallets or in containers. Pallets come in a number of sizes, and are generally used for larger, bulky items with a net over the top to hold the items to the base and in place. Containers, known as unit load devices (ULDs), are enclosed containers of various shapes and sizes. They are contoured to closely fit the interior measurements and profiles of freighters as closely as possible.

ULDs are generally used for smaller packages and express freight, while pallets tend to be used for general freight. Since pallets have lower tare weights than ULDs, the use of pallets provides aircraft with higher net structural payloads (i.e. gross structural payloads less the tare weight.)

There is no way to completely use all of a cargo aircraft's available volume and space, but the aim is to design and use the pallets or ULDs that best fit the space. There are many combinations of pallets and ULDs that can be used on each type of freighter, depending an operator's needs, and the cargo carried.

SPECIFICATIONS FOR DC-10-30F, A330-200F, MD-11F & 777F

	DC-10-30F	A330-200F	MD-11F	777F
Engine	CF6-50C2	PW4000 Trent 700	PW4000 CF6-80C2	GE90
Engine thrust (lbs)	51,000	68,000 -71,000	60,000 -65,000	110,100 -115,300
Fuel capacity (USG)	36,650	25,770	38,615	47,890
Range with maximum payload (nm)	3,500	3,200	3,910	4,900
MTOW (lbs)	572,000	513,700	602500	766800
MZFW (lbs)	414,000	392,400	451300	547000
OEW (lbs)	236,000	240,300	248567	318300
Max structural payload (lbs)	178,000	152,100	202,733	228,700

Freighter roles

There are still 38 DC-10-30Fs in operation. There are just 37 777Fs and a single A330-200F in operation with 11 operators. Range capabilities vary from 3,200nm to 4,900nm, meaning that the aircraft can carry their loads on both medium and long-haul routes.

The available payload for an aircraft is determined by its payload-range profile, while the gross structural payload of each aircraft dictates the maximum weight it can carry. Gross structural payload is the maximum zero fuel weight (MZFW) minus the operating empty weight (OEW). Gross structural payload can therefore vary according to the aircraft's OEW.

Payload reduces on longer routes as the maximum take-off weight (MTOW) is reached, and also if the weather and airport temperature or elevation limit

The 777F has the highest structural payload compared to the DC-10-30, A330-200F and MD-11F. The 777F also has a similar containerised payload volume to the MD-11F, and as a consequence the 777F also has the highest packing density of the four freighters.

take-off weight.

The tare weight of pallets and ULDs needs to be considered, as this can be added to the OEW to get a proportionate reduction in payload to arrive at the net structural payload.

An aircraft's volumetric payload is a product of the aircraft's total available payload volume and the packing density of the freight being carried. The maximum packing density, which cannot be exceeded, is the net structural density divided by the total available volume. The total available volume varies depending on the combination of ULDs and pallets used. There are therefore several total available volumes for each aircraft, since there are many container and pallet configurations. Individual ULD measurements, volumes and tare weights can also vary slightly depending on the manufacturer and the ULD variant. Some can be lightweight versions, to reduce the tare weight, while others can be reinforced to increase the potential packing density. This latter option can increase the tare weight, as can the choice of materials used for the ULD, and the choice of doors or nets as an opening.

DC-10-30F

With just 38 examples of this aircraft left operating globally, the DC-10-30F is a fleet in decline. The youngest DC-10-30F is now over 30 years old, so the fleet realistically has only a few years of operation left. Many freight operators are changing to more modern fleets, instead of continuing with the DC-10, which is included in this analysis as a benchmark for an aircraft in the size category, and one that would be considered for replacement with the MD-11F, A330-200F and 777F.

The DC-10-30F has a similar range performance to the other three types, and is not the lowest when it comes to both gross structural payload and MTOW. Its gross structural payload is in fact 26,000lbs higher than the A330-200F's *(see table, page 54)*. The DC-10-30CF, however, has the oldest technology and the highest maintenance costs, as well as higher fuel burn performance that limits its future.

The DC-10-30CF has several MTOWs, but the highest is 572,000lbs. The MZFW is 414,000lbs while a typical OEW, not including tare weight of freight pallets or containers, is 236,000lbs. This results in a maximum structural payload of 178,000lbs *(see table, page 52)*. The range with maximum payload is about 3,500nm.

The DC-10-30F has many configurations for both containers and pallets. There are a number of maindeck (MD) configurations using pallets, such as the PBJ (88 X 108 inches), PAG (88 X 125 inches), PMC (96 X 125 inches) or a combination of PAG & PMC.

DHL uses an efficient system of 23 AAC containers, which provide a total volume of 9,660 cu.ft., and have a tare weight of 10,810lbs. The AAC is a dual-contoured container based on the AAA container and first introduced by Satco. The shape means that it can be used both laterally on narrowbodied aircraft and longitudinally on widebodied aircraft.

The configuration that maximises volume is the use 22 AMD containers; loaded in 11 pairs. AMDs have a tare weight of 672lbs and volume of 759 cu.ft. This provides a total volume of 16,698 cu.ft. on the MD, and an associated total tare weight of 14,784lbs *(see table, page 55)*.

On its lower deck (LD), the DC-10-30F can use combinations of LD-3/AKE, LD-11/ALP and LD-9/AAK containers. The option that provides the largest containerised volume uses 13 LD6s, also known as ALFs. These have a volume of 314 cu.ft. and tare weight of 355lbs. The total volume is therefore 4,082 cu.ft. and the total tare weight is 4,615lbs *(see table, page 55)*. The ALF container is specifically designed for LD use and is contoured at the bottom, occupying the same place as a pair of LD-3s. This means that 26 LD3s could be used as an alternative. The A330-200F's LD could accommodate the same number of LD-3s or LD-6s as the DC-10.

Adding together the MD and LD volumes and tare weights, the DC-10-30F has a total containerised volume of 20,780 cu.ft. and total tare weight of 19,399lbs *(see table, page 55)*. Deducting the tare weight and OEW from the MZFW leaves a net structural payload of 158,601lbs. This gives a maximum packing density of 7.63lbs/cu.ft, ranking the DC-10-30F third out of the aircraft being analysed *(see table, page 55)*.

The configurations using combinations of LD-3s, LD-9s and LD-11s do not have as much available volume. A typical express package operation would have a packing density of 6.5lbs/cu.ft, which, using the configuration shown in the table, would give the DC-10-30F a volumetric payload of 135,070lbs. Its range and capabilities are therefore unlikely to be limited. A higher packing density of 7.5lbs/cu.ft gives a volumetric payload of 155,850lbs, which comes very close to the DC-10-30F's net structural payload.

A330-200F

The A330-200F is the youngest of the four freighters being analysed, and is a factory-built freighter with two engine options. Just four are currently operated, by Etihad, Hong Kong Airlines and Airbus. It is likely that the A330-200F could replace some DC-10-30Fs as they are retired, since the two have a similar range and available volume capabilities. The A330-200F's maximum structural payload, however, is lower than the DC-10-30F's.

PAYLOAD CHARACTERISTICS DC-10-30F, A330-200F, MD-11F & 777F

	DC-10-30F	A330-200F	MD-11F	777F
Max. structural payload (lbs)	178,000	152,100	202,733	228,700
Maindeck				
Type of containers	AMD	AMJ	AMD	AMX
Type of pallets				
No. of containers and pallets	22	22	26	27
Unit volume of container (cu.ft.)	759	594	759	704
Unit tare weight of container / pallet (lbs)	672	680	672	667
Total volume MD (cu.ft.)	16,698	13,068	19,734	19,008
Total tare weight MD (lbs)	14,784	14,960	17,472	18,009
Lowerdeck				
Type of containers	LD-6/ALF	LD-6/ALF	LD-6/ALF	LD-6/ALF
Type of pallets				
No. of containers + pallets	13	13	16	16
Unit volume of container (cu.ft.)	314	314	314	314
Unit tare weight of container / pallet (lbs)	355	355	355	355
Total volume LD (cu.ft.)	4,082	4,082	5,024	5,024
Total tare weight LD (lbs)	4,615	4,615	5,680	5,680
Totals				
Volume of all containers (cu.ft.)	20,780	17,150	24,758	24,032
Tare weight of all containers (cu.ft.)	19,399	19,575	23,152	23,689
Net structural payload (lbs)	158,601	132,525	179,581	205,011
Maximum packing density (lbs/cu.ft.)	7.63	7.73	7.25	8.53
Volumetric payload at 6.5lbs/cu.ft.	135,070	111,475	160,927	156,208
Volumetric payload at 7.0lbs/cu.ft.	145,460	120,050	173,306	168,224
Volumetric payload at 7.5lbs/cu.ft.	155,850	128,625	N/A	180,240
Volumetric payload at 8lbs/cu.ft.	N/A	N/A	N/A	192,256
Volumetric payload at 8.5lbs/cu.ft.	N/A	N/A	N/A	204,272
Volumetric payload at 9lbs/cu.ft.	N/A	N/A	N/A	N/A

The A330F has a maximum payload range of 3,200nm, an MTOW of 513,700lbs, MZFW of 392,400lbs and OEW of 240,300lbs. This results in a maximum structural payload of 152,100lbs *(see table, page 52)*.

While there are two main configurations for the LD, there are at least five for the MD. On the LD 13 LD-6 /ALF containers (or 26 LD-3/AKE containers) can be used, again giving a total volume of 4,082 cu.ft. as in the case of the DC-10. Tare weight is also the same at 4,615lbs.

The MD can use a number of pallet options, including: a single type; a combination involving PAG, PMC and PRA pallets; and a combination involving four PMC pallets & nine AMA containers.

The configuration that gives the largest available volume, is 22 AMJ containers, loaded in 11 pairs. AMJs have a unit volume of 594 cu.ft. and a tare weight of 680lbs. This gives a total MD volume of 13,068 cu.ft. and a total tare weight of 14,960lbs *(see table, this page)*. This is a lower volume than the DC-10, because the AMJs are a few inches shorter than the AMDs used on the DC-10.

The total available volume from MD and LD containers for the A330-200F is then 17,150 cu.ft., with a total tare weight of 19,575lbs. The net structural payload is thus 132,525lbs, giving a maximum packing density of 7.73lbs/cu.ft.

With a packing density of 6.5lbs/cu.ft., the volumetric payload is 111,475lbs. While the A330F's maximum packing density is higher than that of the DC-10, its net structural payload and volumetric payloads at various packing densities are lower. The A330-200F therefore has the lowest payload characteristics of the four aircraft examined here.

MD-11

The MD-11F is the largest fleet of the four aircraft, with 166 still in operation. The fleet ranges roughly in age from 15 to 20 years. The aircraft remains popular, especially as a freighter and can expect another 15-20 years of operation.

The aircraft has two engine options and a range with maximum payload of 3,910nm; a superior performance over the previous two aircraft types. With an MTOW of 602,500lbs, MZFW of 451,300lbs and OEW of 248,567lbs, the resulting maximum structural payload is 202,733lbs.

Like the other aircraft, there are many MD combinations including the use of PMC, PBJ and/or PAG pallets. The use of 26 AMD containers loaded in 13 pairs generates a total available volume of 19,734 cu.ft. and a tare weight of 17,472lbs. An AMD is 96 x 125 inches at its base, and has an individual volume of 759 cu.ft. and a tare weight of 672lbs.

On the LD, LD-3s or LD-6/ALFs can be used, with the LD-3s being half the width of LD-6s. The latter uses the full width of the LD, and takes the place of two LD-3s, ensuring that maximum volume is used. However, when LD-3 containers are used, two fit across the cross-section, thereby doubling the number required. Although the utilisation of LD-3s gives a slightly reduced volume and increased tare weight, it simplifies the interlining of freight between aircraft. LD6 containers are contoured with base measurements of 60.4 x 125 inches. The top is 160 x 60.4 inches, while the height is 64 inches. With 16 LD-6/ALF containers, the LD has a total volume of 5,024 cu.ft. and a tare weight of 5,680lbs. Added together, the MD and LD result in available volume of 24,758 cu.ft. and tare weight of 23,152lbs *(see table, this page)*.

The total tare weight taken from the maximum structural payload results in a net structural payload of 179,581lbs. This in turn, when divided by the total available volume, means a maximum packing density of 7.25lbs/cu.ft. *(see table, this page)*, the lowest of all four aircraft. If the express packing density of 6.5lbs/cu.ft. is used, the MD-11F has a volumetric payload of 160,927lbs, which rises to 173,306lbs at density of 7.0lbs/cu.ft. *(see table, this page)*.

VOLUMETRIC PAYLOAD REVENUE DC-10-30F, A330-200F, MD-11F & 777F

	DC-10-30F	A330-200F	MD-11F	777F
Volumetric payload at 6.5lbs/cu.ft.	135,070	111,475	160,927	156,208
Volumetric payload at 6.5lbs/cu.ft. 90% load factor	121,563	100,328	144,834	140,587
Revenue generated at $1/lb	121,563	100,328	144,834	140,587
Volumetric payload at 7.olbs/cu.ft.	145,460	120,050	173,306	168,224
Volumetric payload at 7.olbs/cu.ft. 90% load factor	130,914	108,045	155,975	151,402
Revenue generated at $o.40/lb	52,366	43,218	62,390	60,561
Revenue generated at $o.8o/lb	104,731	86,436	124,780	121,121

777F

The second youngest freighter being analysed is the 777F. This entered service in 2009 with Air France, and there are now 33 in operation globally. As well as having the most powerful engine thrust, it also has the largest range, fuel capacity, operating weights and payload potential. It has a range of 4,900nm with maximum payload, so is less likely to be used on medium-length routes, compared to the other three aircraft being assessed.

The 777F's MTOW, MZFW & OEW weights are 766,800lbs, 547,000lbs and 318,300lbs resulting in a maximum structural payload of 228,700lbs. This is the largest of all four aircraft types, being 50% more than the A330-200F, 28% more than the DC-10-30F, and 13% more than the MD-11F.

There is only really one efficient configuration for the MD, which is the use of 27 PMC pallets or similar-sized ULDs, such as the AMX. The AMX has a volume of 704 cu.ft. and a tare weight of 667lbs. The total MD tare weight is 18,009lbs, while the volume provided by the 27 AMXs is 19,008 cu.ft.

DHL, through AeroLogic, uses a configuration with 125 x 96 inch (PMC) or 125 x 88inch (PAG) pallets. DHL also allows the use of AAJ, AAC, AAX, AMP, AML, AMX and AMH containers on the MD. The counters of the AML were specifically designed to allow it to be used on the 777F MD. Based on the AMX, the AML is two inches shorter and has a different side profile to increase the number of positions the container can be used in. The contoured AMX itself was also designed for the 777F and is slightly more square than the AML.

The LD can accommodate 32 half-width LD-3/AKE containers or 16 full-width LD-6/ALF containers. Alternatively 10 AAJ containers or PAG/PMC pallets can be used. The best LD volume is gained from 16 LD-6/ALF containers, providing a total volume and tare weight of 5,024 cu.ft. and 5,680lbs *(see table, page 55)*; the same as like the MD11F.

The total MD and LD containerised volume and resulting tare weight comes to 24,032 cu.ft. and 23,689lbs. This reduces the net structural payload to 205,011lbs. This in turn results in a maximum packing density of 8.53lbs/cu.ft., the highest of all four aircraft.

Volumetric payload is 156,780lbs at a packing density of 6.5lbs/cu.ft, which goes up to 180,240lbs for a packing density of 7.5lbs /cu.ft.

Payload summary

The net structural and volumetric payloads analysed are the highest possible, and assume that the aircraft does not have payload restrictions due to limited MTOWs, mission length, weather or airport characteristics.

The lowest net structural payload is on the A330-200F, although it still had the second highest maximum packing density. The highest net structural payload, of 205,011lbs, is on the 777F, even though is has the second largest available volume. This high payload also results in it having the highest packing density.

The MD-11F provides the largest volume at 24,758 cu.ft. The A330-200F has the smallest volume, which results in it having the second highest maximum packing density. Both the A330 and DC-10, when pallets are used throughout, appear to have potentially much higher maximum packing densities than the MD-11F and 777F. But this would depend on the pallets still using as much volume as possible.

Freight revenue

Ideally, all aircraft, both passenger and cargo, would operate with 100% load factors. In reality they often operate with moderate loads. The revenue-generating capacity of an aircraft is considered at relatively high load factors, but not full, so 90% is used here.

As already mentioned, express package operations typically pack freight with a density of 6.5lbs/cu.ft. The effect of various packing densities on the volumetric payload, has been assessed *(see table, this page)*. A net freight yield of $1 per lb of volumetric is used. This indicates the aircraft's approximate and relative revenue earning power, both of alternative configurations and against its competitors.

It makes sense that the aircraft with the largest capacity will have the highest revenue, and this is almost true for the 777F, with the MD-11F narrowly gaining a bit more revenue because of its overall higher containerised volume.

The A330F is the smallest revenue-generating freighter of the four analysed here, despite having a high potential packing density. It is followed by the DC-10-30F, as the second smallest revenue generator. The A330-200F has a smaller net structural payload than the DC-10, and this shows in the revenue potential.

The volumetric capacity at a packing density of 7.0lbs/cu.ft. and load factor of 90% for general freight is the next revenue aspect to look at. A typical net yield for general freight is $0.40/lb of volumetric payload, although in some markets it can be as high as $0.80/lb. The aircraft fall into the same order as before, with the MD-11F performing best and the A330-200F having the lowest revenue. These differences would grow if repeated daily.

The revenue figures cannot show the effect that the A330-200F and 777F, being new aircraft types, can have on final profit. Their advanced technology and materials mean that they will have reduced fuel burn, emissions, maintenance costs, and in some cases flightcrew costs. This makes them more efficient overall, which can increase profit by reducing the operating costs subtracted from the revenue. AC