Freight operating margins are thin and are sensitive to shifts in yields and load factors. Revenue generating capacity of freighter aircraft is a function of payload-range performance, containerised volume and packing density. The revenue capacity of large widebody freighters is analysed.

The revenue capacity of large widebody freighters

Following four to five years of stagnant growth, the freight market has seen rapid growth since 2004. More aircraft are being added to cater for this growth, and to replace ageing freighters. These new freighters are both factory-built aircraft and passenger-aircraft conversions. The widebody freighter fleet has expanded at a high rate, and freight carriers have many choices available to them. The appeal of any aircraft is its ability to generate more revenue and a higher gross profit than its competitors, which is strongly linked to an aircraft's payload capacity.

Widebody cargo aircraft vary in size from the smallest A310 and 767-200 to the largest 747-400F, 747-8F and A380F. The payload capacities and revenue-generating ability of the smaller widebodies have been evaluated *(see Revenue capacity of the A300-600RF, A310-300F, 767-200SF and 767-300SF, Aircraft Commerce, June/July 2004, page 43)*. The revenue-earning capacity of the larger widebodies, which are those aircraft with a cargo capacity of 80 tonnes or more, is evaluated here. In approximate order of aircraft size, this includes the MD-11F, 777F, 747-400SF, 747-400F, 747-8F and A380F. The net structural payload capacities of these aircraft range from 199,000lbs to 330,000lbs.

While some freight is carried in the belly space of long-haul passenger aircraft, growth in freight traffic is seeing a larger number of dedicated freighters being operated. Boeing predicts that dedicated freighters will eventually provide more than half the world's total air cargo capacity.

While the largest aircraft may immediately appear to have a clear advantage over the smallest, the economics of operating freight aircraft are dependent on narrow operating margins, and operating costs have to be considered with the revenue capacities. Even a small difference in the payload capacities of two similar-sized aircraft, such as the MD-11F and 777F, can give one a decisive advantage over the other. Moreover, if several aircraft have similar trip costs it is the aircraft that can generate the greatest revenue that will be the most profitable.

Revenue generation is a product of the structural payload capacity of each aircraft, which is the difference between the maximum zero fuel weight (MZFW) and the operating empty weight (OEW). OEW includes the empty aircraft weight, non-usable fuel, oil and hydraulic fluids, crew and related baggage. The aim of manufacturers and converters is to minimise OEW so as to ensure the highest possible payload.

MZFW is the maximum weight of the aircraft without any usable fuel being added. The lowest possible OEW combined with the highest possible MZFW consequently results in the highest possible structural payload.

The tare weight of containers and pallets should be deducted from the gross structural payload to provide the net structural payload. This is the weight of revenue-earning payload that the aircraft can carry.

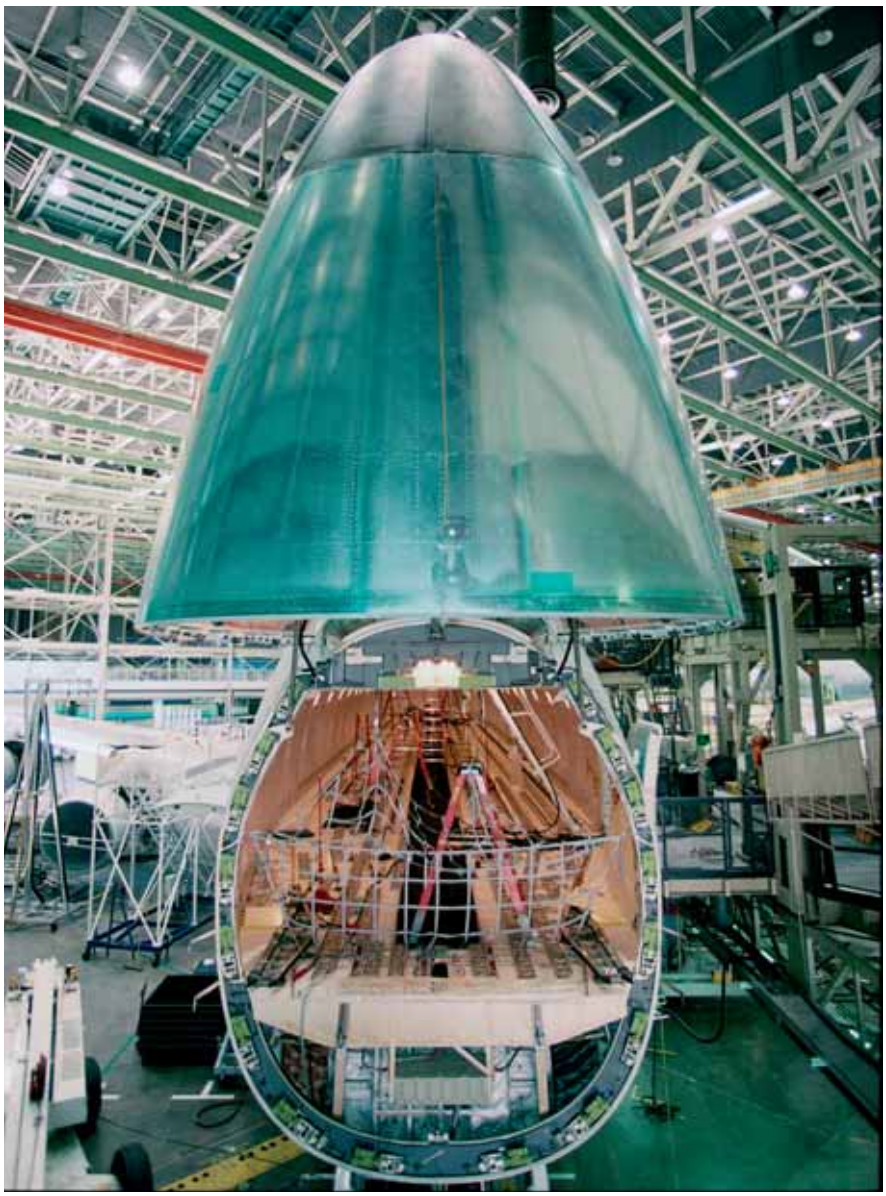
This weight capacity should be considered together with the volumetric capacity of the aircraft, which is determined by the volume (in cubic feet) of all the maindeck and belly containers or pallets that the aircraft can carry. The volume of these containers is then taken into consideration together with the average packing density of freight to arrive at a volumetric payload. As there are several different container and pallet configurations available for each aircraft, the volumetric payload can vary, depending on the container configuration used in a particular operation.

Freighter roles

Airbus and Boeing both forecast a requirement for about 650 freighters with a payload of more than 75 tons over the next 25 years. The majority are expected to be passenger-to-freighter conversions. The few remaining MD-11s in passenger service will be converted, but these will only provide about another 65 aircraft. The 747-400 is therefore likely to provide several hundred of the converted aircraft. Some older 777s may yet be converted, although it is likely to be another 10 years before a passenger-to-freighter conversion programme is developed. The MD-11F/SF and 747-400SF converted aircraft will compete with the 747-400F, 777F and A380F factory-built freighters.

The aircraft types being examined are the largest aircraft available, and will be deployed by established airlines either to add capacity to existing routes or to increase the capacity on routes served with medium-sized aircraft. They will not generally be used to launch new routes. They will also be used in a variety of roles: carrying low-density, small and express-package operations; and carrying higher-density general freight. Large freighters are required for the more established markets in the world: the transatlantic, trans-Pacific, Europe-Asia Pacific and intra-Asia Pacific markets. The MD-11F is already used in large numbers for both express and general freight, and the 777F and A380F have been ordered by several carriers for the same purpose. The 747-400F and -400SF have so far only been specified by airlines that carry general freight.

On some routes, mid-size widebodies will be replaced with the larger aircraft to allow more capacity or reduced frequencies. High rates of traffic growth are being experienced in many markets, and these larger freighters are likely to be required in parts of the intra-Asia Pacific.



The payload capacities of factory-built and converted 747-400s differ by about 900 cubic feet. Operating costs of the two types have to be considered, and projected rates of aircraft utilisation have a large influence in determining which is the most economic aircraft.

Boeing predicts that global freight capacity will see an average annual increase of 6.1% in aircraft tonne kilometres (ATKs). Growth rates of freight traffic, measured in revenue tonne kilometres (RTKs), are expected to remain constant with growth in world trade at about 7% per annum, which will fuel demand for large freighters. Another key factor in the economics of carrying freight is load factor. An increase will see improvement in revenues, and continued growth is likely to result in improved load factors.

Freighter routes

As already described, the margins between trip revenue and the cost of freight operations are thin, emphasising the need to maximise revenues. Freighters can only operate economically on routes with lengths that are up to the range where they can carry their maximum payload. Payload capacity drops sharply for distances longer than this, while trip costs also increase. The range at which different freighter aircraft can carry their maximum payloads is summarised *(see table, page 63)*, and is a crucial factor in an aircraft's economic performance. This requires each aircraft type's payload-range profile to be taken into consideration.

The routes on which large widebody freighters are likely to operate are another consideration when analysing their revenue generation potential. Yields also vary by market and by freight type. Some operators fly routes with one or several stops when they fill their aircraft by collecting and delivering cargo, as well as refuelling the aircraft. One example of a multi-stop route is Seoul-Hong Kong-Dubai-Frankfurt-London Stansted, which is operated by Korean Air. Lufthansa Cargo operates round-the-world routes and a number of Latin American carriers operate multi-stop routes via several Latin American countries and the US. Multi-stop routes often include legs that are within the maximum payload range capabilities of aircraft types, with traffic rights having been negotiated after considering aircraft performance.

Aircraft that have to make intermediate technical stops for refuelling, without loading any additional freight, have higher total trip costs than aircraft that can operate non-stop between the same origin and destination cities. Longer range capability can therefore play a crucial factor in an aircraft's selection.

Some of the routes on which large widebody freighters will be operated are already established. These are the high-capacity routes like transatlantic, Europe-Asia and US domestic routes. Other routes can now be flown without the need for technical stops, since they fall within the range of modern aircraft.

Transatlantic routes are generally the shortest. London, Brussels and Frankfurt are among Europe's main freight airports, while Memphis, Louisville, Miami, Chicago and Los Angeles are the major cargo hubs in the US. Routes between these cities have great circle distances of 3,000-5,000nm, and headwinds encountered en route will increase these distances by up to 500nm.

Europe-Asia Pacific routes have longer route lengths on average, with city-pairs from London Stansted and Amsterdam to Seoul, Hong Kong, Singapore, Beijing and Tokyo having a great circle distance of 4,400-5,900nm. These routes will also experience headwinds in a westerly direction to Europe, and the still air distance will exceed the range capability of all aircraft with a maximum payload. Routes in these markets are therefore likely to be operated with a technical stop, at cities such as Dubai. Routes from London and Amsterdam to Dubai are about 3,000nm, for example.

Trans-Pacific routes between major cities in the Asia Pacific and the west coast of the US are a similar length: 4,200-5,500nm. These are reduced by tailwinds when operating eastwards to the US, but are made longer by headwinds when operating to the Asia Pacific. Freight carriers therefore include a technical stop so that aircraft can utilise a full payload, and Anchorage is the favourite for this purpose. Great circle distances from Tokyo and Beijing to Anchorage are 3,000-3,500nm, and are shorter from Anchorage to the western US.

The MD-11 has proved popular and been a strong alternative to the 747-200F. Less than 100 MD-11s are left for conversion to freighter. The 777F, however, has 2,500 cubic feet more space and a 1,000nm longer range, and presents a strong alternative to the MD-11.

Aircraft requirements

The six aircraft analysed can be divided into three pairs of similar-sized types: the MD-11F and 777F, 747-400SF and -400F, and the 747-8F and A380F.

The MD-11F has the shortest range with a maximum payload of 3,500nm *(see table, page 63)*. This compares to 4,500nm for the 777F. The two have similar containerised volumes, but the 777F has a 30,000lbs higher net structural payload and 1,000nm longer range. The 777F therefore has a performance and revenue-capacity advantage over the MD-11, especially on longer routes. The MD-11's range of 3,500nm is shorter than most long-haul market route lengths, making it uncompetitive.

The cash operating costs of the two types also have to be considered. The 777F will have lower airframe- and engine-related maintenance costs than the MD-11, which suffers from a fuel burn disadvantage as a result of its three-engine configuration. The 777F, however, has a list price of $230-245 million, and with a purchase discount this will result in a monthly lease rate of $1.3-1.5 million. This compares to a lease rate of about $500,000 for an MD-11F. These factors have to be considered against the 777F's higher revenue-earning capacity, and its longer range, which make it more flexible on a larger number of routes.

The 747-400SF and -400F are close, and the passenger-to-freighter conversion programmes offered by Boeing Commercial Airplane Services and Bedek Aviation are intended to provide an aircraft with similar payload characteristics to the factory -400F. The -400F has about 900 cubic feet more capacity, but both aircraft have almost identical net structural payloads, with the -400F having a small range advantage of about 350nm. Both have ranges with a maximum payload of more than 4,000nm.

The -400SF and -400F are essentially the same aircraft, so the two will have the same crew costs and fuel consumption on the same routes. Since the converted aircraft are mature versions of the -400F, the -400SF will have higher maintenance costs. The -400F, however, has a list price of $220-240 million, which will result in a monthly lease rate of about $1.4 million with a typical purchase price. This compares to a market lease rate of about $600,000 for the -400SF. The -400F will have a longer operating life, but it can probably only be justified if its operator can achieve higher rates of utilisation than it could with the -400SF.

There are large cargo volume and structural payload differences between the 747-8F and A380F. The A380F has about 4,000 cubic feet more volume and about 35,000lbs higher volumetric payload *(see table, page 63)*. The A380F also has a range advantage of 300nm, and is the only aircraft that can carry its full payload on routes of 5,000nm.

All aircraft need a range of 5,000nm if they are to complete most city-pairs in the three important international markets non-stop and with a full payload. This means that freight carriers will have to consider the reductions in payload necessary for these aircraft to operate non-stop, or the use of technical stops for refuelling.

Volumetric payloads

Each aircraft also has to be assessed in terms of volumetric payload. This is the product of the aircraft's containerised volume and the average packing density of the freight it is carrying. An aircraft's maximum packing density is the net structural payload divided by the available volume. The maximum packing densities of the six aircraft are close, ranging from 9.3lbs to 10.0lbs per cubic foot *(see table, page 63)*.

The available volume for each aircraft varies, since it will have five or six different loading configurations. Several types of container and pallet can be used for the maindecks and bellies, each with their own tare weights and volumes. The configuration with the highest available volume for each aircraft has been used.

Volumetric payload cannot exceed net structural payload. A packing density of 8lbs per cubic foot is typical for general freight, and the volumetric payloads of the six aircraft range from 163,000lbs to 269,000lbs. This lessens the 777F's advantage over the MD-11F to about 20,000lbs, while the 747-400F has a 7,000lbs advantage over the -400SF. The A380F has a 31,000lbs higher payload than the 747-8F *(see table, page 63)*.

Payload capacities

Freighter aircraft carry cargo in the belly and the maindeck, with the A380 offering two maindecks. All the cargo, with the exception of that in the aft bulk hold, is containerised or palletised.

The lower hold or belly containers are the LD-1 or LD-3, depending on the aircraft. An LD-1 container has a capacity of 175 cubic feet, and is used on all 747 variants. The other widebodies use LD-3s, which have a volume of 146 cubic feet.

All aircraft can use several types of maindeck containers. The A380 employs a unit load device (ULD), with a rectangular cross-section for its maindeck.

Other types of container and ULDs are used on the maindecks of the other widebodies, and the ones that provide the highest volumes are those that are contoured to fit the profile of the aircraft's inner fuselage. The A380F is the

PAYLOAD CHARACTERISTICS OF MD-11F, 777F, 747-400F, 747-400SF, 747-8F & A380F

Aircraft type	MD-11F	777F	747-400F	747-400SF	747-8F	A380F
MTOW-lbs	633,000	766,000	875,000	870,000	970,000	1,300,000
MZFW-lbs	461,300	547,000	610,000	610,000	709,000	886,000
OEW-inc container tare-lbs	262,600	318,000	361,700	361,300	413,600	555,500
Net structural payload-lbs	198,700	229,000	248,300	248,700	295,400	330,500
Range with max payload-nm	3,592	4,540	4,450	4,100	4,675	5,000
Containerised volume-cu ft	20,454	22,973	26,597	25,714	29,824	33,681
Maximum packing density lbs/cu ft	9.7	10.0	9.3	9.7	9.9	9.8
Volumetric payload @ 8lbs/cu ft	163,632	183,784	212,776	205,712	238,592	269,448
Payload at 90% load factor-lbs	147,269	165,406	191,141	185,141	214,733	242,503
Revenue @ 25 cents/lb-$	36,817	41,351	47,875	46,285	53,683	60,626
Revenue @ 35 cents/lb-$	51,544	57,892	67,024	64,799	75,156	84,876
Revenue @ 40 cents/lb-$	58,908	66,162	76,599	74,056	85,893	97,001

only aircraft to have an additional upper deck, and uses contoured containers to make full use of the fuselage.

The net structural payloads, total containerised cubic capacity, maximum packing densities and volumetric payloads for the six aircraft are summarised *(see table, this page)*.

MD-11

There were 200 MD-11s produced from 1989 to 1998, with the majority of these aircraft already having been converted into freighters. About 65 passenger aircraft remain in operation, and some have already been purchased for conversion to freighter. There are only three main fleets left for possible conversion, including Finnair's and KLM's.

The MD-11 is a popular freighter because of its high MZFW and good volume characteristics and, until the launch of the 777F, was in a class of its own.

The MD-11 has a net structural payload of 198,700lbs and total containerised capacity of 20,454 cubic feet *(see table, this page)*. At a packing density of 8lbs per cubic foot, it has a volumetric payload of 163,000lbs. While it has a range of 3,500nm with a full payload, it will be able to operate longer distances with its volumetric load of 163,000lbs.

The MD-11F is the smallest aircraft in the large widebody category. Its range makes it more suitable for medium-haul markets, and as a small-package-carrying aircraft, where a high weight capability is not as important as it is for general freight. The MD-11 has, however, offered freight carriers an attractive alternative to the 747-200SF.

777F

The 777F was launched in late 2004. The aircraft is based on the 777-200 and it has the highest maximum take-off weight of all -200 variants, at 766,000lbs.

The aircraft has a net structural payload of 229,000lbs, putting it between the MD-11F and 747-400SF/F. The 777F's high gross weight also gives it a range of about 4,500nm with a maximum payload, and this is about 1,000nm longer than the MD-11F. The 777F has an appreciable payload-range advantage over the MD-11F.

The 777F has already been ordered by Air Canada, Air France, Avion Group and Emirates. The 777F received a further boost recently with FedEx ordering 10 after it cancelled its A380F order.

The 777F benefits from an efficient two-engine design and lower maintenance costs than the MD-11F, giving it further economic advantages.

The 777F has a containerised volume of 22,873 cubic feet, and a volumetric payload of 183,784lbs with freight packed at 8lbs per cubic foot. This is 20,000lbs more than the MD-11F, and 22,000lbs less than the 747-400SF.

The aircraft's range will be increased with this lower weight, so it will be able to operate on a large number of routes in the major long-haul markets.

747-400F

The 747-400F has been ordered in large numbers, with 92 already in service with 16 airlines, and a further 42 on order for Cargolux (2), Atlas (12), Emirates (10), LoadAir (2) and Nippon Cargo (2).

The 747-400F is the largest freighter aircraft currently available, and has been mainly ordered to accommodate the high growth of traffic from the Asia Pacific region.

The 747-400F has the same upper deck and fuselage as the 747-200F, but the -400F has had some revisions made to the upper-deck floor, which have created space for two additional 10-foot-high pallets on the maindeck. The 747-400F can accommodate 30 containers on the maindeck, which provide a total capacity of 21,347 cubic feet. In addition to the capacity provided by the 30 LD-1 belly containers, the aircraft has a total volume of 26,597 cubic feet *(see table, this page)*.

This is combined with a net structural payload of 248,300lbs, and gives the aircraft a maximum packing density of 9.34lbs per cubic foot.

A packing density of 8lbs per cubic foot gives the aircraft a volumetric payload of 212,776lbs *(see table, this page)*. With this payload the aircraft's range will be extended from its 4,500nm capability with a full load. This will allow the -400F to operate on many routes with a full volumetric payload.

Conversions of 747-400s to freighter have already started, but larger numbers of conversions are expected when A380s and 747-8Is have started to be delivered in large numbers.

747-400SF

There are more than 470 747-400s in operation, which were built in the period 1989-2005. There are no passenger-configured 747-400s on order, but it remains the long-haul workhorse of many major airlines.

Boeing and Bedek Aviation have both developed passenger-to-freighter programmes for the 747-400, both of which provide an aircraft with similar payload characteristics to the -400F. Conversions of 747-400s have already begun, but the numbers are expected to increase once the 747-8I has been in production for several years.

The 747-400SF accommodates most of the containers accommodated by the -400F, but the 400SF has a slightly lower total containerised volume of 25,714 cubic feet *(see table, page 63)*. The aircraft has a net structural payload of 248,700lbs, and a range of about 4,100nm with this weight.

With freight packed at 8lbs per cubic foot, the aircraft has a volumetric payload of 205,712lbs, about 7,000lbs less than the -400F. Like all other types, this reduction in payload carried from its maximum structural capability will extend its range.

The -400SF will be converted at a mature age, and so will have higher maintenance costs than the -400F. The -400SF's lower financing costs and lease rate can offset its higher maintenance costs and its small payload disadvantage.

747-8

The 747-8F programme has had a good start, with orders for 44 aircraft.

The 747-8F is a stretch of the -400F, which allows the -8F to carry two more LD-1 and four more maindeck containers. This gives the 747-8F a total containerised volume of 29,824 cubic feet *(see table, page 63)*, which is about 3,200 cubic feet more than the -400F.

The 747-8F has a net structural payload of 295,400lbs, and a range of 4,675nm with this payload. With freight packed at 8lbs per cubic foot, the aircraft has a volumetric payload of 238,592lbs, about 26,000lbs more than the -400F.

The aircraft will have a range of more than 5,000nm with this volumetric payload, allowing it to operate with few or no payload limitations on most long-haul city-pairs.

A380F

The A380F is clearly the largest freighter, and is in a unique size class.

The A380F has a net structural payload of 330,500lbs and corresponding range of 5,000nm. The aircraft accommodates payload in 36 LD-3 belly containers, 29 maindeck ULDs and 25 upper-deck contoured containers. These provide a total volume of 33,681 cubic feet, which allows a maximum packing density of 9.8lbs per cubic foot. With freight packed at 8lbs per cubic foot, the aircraft has a volumetric payload of 269,000lbs *(see table, page 63)*. This is 31,000lbs more than the 747-8F.

Revenue generation

The revenue generation of each aircraft type can be assessed by using typical freight yields. Yields change constantly in dynamic markets, and also vary between routes and different directions on a route. This makes accurate revenue projections difficult, but representative rates give an indication of how aircraft compare.

Yields will be strong where traffic and load factors are high, but will be weak when traffic volumes in the other direction on a route are lighter. Many freight routes only generate profits in the direction of stronger traffic, and these have to be used to offset losses made in the other direction.

Net yields for general freight are 25-40 cents per lb, and the revenue generated by each of the six aircraft types, with three different yield levels at a 90% load factor, is shown *(see table, page 63)*.

The revenue generation of each aircraft changes if yields go up or down. The relative position between the aircraft will remain constant, however, while freight packing densities also vary.

As described, the six aircraft fall into three broad categories. The yields are low, which minimises the differences in payload capacities between closely competing types. The MD-11F and 777F have a revenue difference of $6,000-7,000. This has to be considered against the operating costs of both types. The MD-11F may be more economic overall where both are able to carry full loads, since the 777F has higher finance charges. The 777F will benefit on longer routes, where the MD-11 has payload limitations. The 777F may also be able to operate at higher rates of utilisation, thereby diluting its finance charges.

There are small differences between the 747-400SF and -400F, and operating costs are the major difference between the types. The most important factor for both aircraft is the net difference between maintenance and financing costs.

The 747-8F and A380F have proportionate differences in revenues.

Trip costs must be considered for all aircraft types, and these increase as route length increases. Yields and revenues, however, change less with route length, so aircraft will achieve the best economic performance on routes where they do not suffer payload limitations. AC