The supply of used 747-400s that are suitable for conversion to freighter is likely to increase, and their market values fall. While various market factors influence demand for freighters, there are two conversion programmes for the 747-400. Their characteristics and economics are studied.

The economics of 747-400 freighter conversion

There has been limited availability of used passenger aircraft, such as the 747-400, of a suitable age and market value at the right time to make conversion to freighter economic in recent years. Until mid-2008, the shortage of passenger-configured widebodies coincided with high freight-traffic growth rates and a need to replace large numbers of ageing 747-100Fs/-200Fs. The resulting shortage of feedstock for conversions means that only 50 747-400s have been modified to freighter. The global economic downturn from mid-2008 and the large number of A380s and 777-300ERs placed by passenger operators to replace 747-400s means that the latter's availability is likely to increase again. This is likely to lead to lower aircraft values and a higher demand for conversion to freighter. It is therefore timely to consider the freighter conversions available, the payload characteristics of the converted aircraft and how they compare to the factory-built 747-400F, and the total cost of acquiring, converting and preparing a 747-400.

There are two freighter conversion modifications or supplemental type certificates (STCs) for the 747-400: Bedek Aviation's (following modification the aircraft is designated the 747-400BDSF); and Boeing Commercial Aviation Services' (following conversion the aircraft is designated the 747-400BCF).

Bedek conversion

Bedek Aviation is the commercial division of Israel Aircraft Industries (IAI), and provides freighter conversions and maintenance for airframes, engines and components for a wide range of aircraft types.

Bedek's 747-400 modification programme is a joint venture with PSF that is based in Cyprus. PSF negotiates contracts and markets the modification, while Bedek performs the conversion.

Specification weights

The payload-carrying performance of the converted 747-400 is ultimately dependent on the number, type and volume of the containers it can carry on its maindeck and underfloor space, and the main specification weights. Maximum take-off weight (MTOW) will be unaffected by the modification, although it is possible to increase it. While this does not increase payload capacity, it does increase aircraft range. The 747-400 has several MTOW options, ranging from 800,000lbs to the highest option of 870,000lbs for the passenger-configured aircraft.

Higher MTOWs are possible in both passenger and converted freighter aircraft, although the ability to upgrade MTOW depends on the aircraft's wing number. The highest certified MTOW for aircraft modified by Bedek Aviation's STC is 870,000lbs *(see table, page 62)*.

Bedek Aviation is planning two MTOW weight options for the -400BDSF. The first is a higher weight of 875,000lbs, while the second is a lower weight of 811,000lbs *(see table, page 62)*.

The maximum zero fuel weight (MZFW) is the second most important specification weight. The highest current certified limit for the -400BDSF is 630,000lbs, although this has only been available since July 2008. The -400BDSF's standard MZFW is 610,000lbs *(see table, page 62)*. The future MTOW option of 875,000lbs will have the standard MZFW of 610,000lbs. The lower MTOW of 811,000lbs will have a higher MZFW of 635,000lbs *(see table, page 62)*.

The aircraft's gross structural payload is the difference between the MZFW and operating empty weight (OEW). Actual OEW is the hull weight or basic empty weight (BEW) of the aircraft, including the cargo loading system, plus the weight of the crew and other items necessary for operation. It does not include the tare weight of containers or pallets for carrying the freight, or the weight of fuel.

OEW varies between individual converted aircraft. One factor affecting OEW is the engine type that the aircraft is equipped with, since engine models vary in weight. Aircraft powered by the Rolls-Royce (RR) RB211-524G/H are about 3,000lbs heavier than those equipped with General Electric (GE) CF6-80C2 engines. Demand for converting RB211-equipped aircraft is low as a result. OEW is also influenced by the original configuration of the aircraft. Combis undergo less interior configurational changes than passenger aircraft. The average OEW of the GE-equipped combi aircraft converted by Bedek is 356,383lbs. The average for passenger-converted aircraft is 357,321lbs. The OEWs of Pratt & Whitney PW4000-powered aircraft are higher than those of CF6-powered aircraft but lower than those of RB211-equipped aircraft. PW4000-powered passenger-converted aircraft at 358,725lbs are 1,400lbs heavier than their CF6-powered

BEDEK AVIATION 747-400BDSF & BOEING 747-400BCF SPECIFICATION WEIGHTS & PAYLOAD DATA

Weight configuration	Bedek Option 1	Bedek Option 2	Bedek Option 3	Bedek Option 4	Boeing
MTOW-lbs	870,000	870,000	875,000	811,000	870,000
MZFW-lbs	610,000	630,000	610,000	635,000	610,000
OEW-lbs	357,500	357,500	357,500	357,500	359,650
Gross structural payload-lbs	252,500	272,500	252,200	277,500	250,350
Main deck containers					
Number	30	30	30	30	30
Total volume-cu ft	20,674	20,674	20,674	20,674	20,674
Tare weight-lbs	7,950	7,950	7,950	7,950	7,950
Lower deck containers					
Number	30	30	30	30	30
Total volume-cu ft	5,250	5,250	5,250	5,250	5,250
Tare weight-lbs	4,650	4,650	4,650	4,650	4,650
Total volume-cu ft	25,924	25,924	25,924	25,924	25,924
Total tare weight-lbs	12,600	12,600	12,600	12,600	12,600
Net structural payload-lbs	239,900	259,900	239,900	264,900	237,750
Maximum packing density-lbs/cu ft	9.3	10.0	9.3	10.2	9.2

counterparts. PW4000-powered combi-converted aircraft at 358,980lbs are about 2,600lbs heavier than their GE counterparts.

The OEWs of the first converted aircraft are generally high, and tend to fall as experience with conversions is gained. The first three aircraft converted by Bedek were PW4000-powered, so it is likely that OEWs will reduce as more are modified. Overall, Bedek claims to have a lower OEW than the alternative Boeing conversion programme. This is because Bedek changes the original floorbeams for machined ones made from carbon fibre, which is the same technology that Boeing uses in the 777. As well as saving weight, carbon fibre also makes the floorbeams resistant to corrosion.

The three different MTOW options will have three different gross structural payloads as a result of different MZFW specifications. Taking an average OEW of 357,500lbs, the aircraft with the standard MTOW of 870,000lbs and standard MZFW of 610,000lbs will have a gross structural payload of 252,500lbs *(see table, this page)*.

Once the higher MZFW of 630,000lbs has been certified for this aircraft it will have a gross structural payload of 272,500lbs *(see table, this page)*.

The future option of the higher MTOW of 875,000lbs will have the same standard MZFW, and so the same standard gross structural payload of 252,500lbs *(see table, this page)*. The 5,000lbs higher MTOW, however, translates into additional fuel capacity, giving it longer range performance.

The second future option of 811,000lbs and MZFW of 635,000lbs provides the aircraft with a gross payload of 277,500lbs *(see table, this page)*; 25,000lbs more than the standard aircraft.

Payload carriage

The second main issue of payload capacity is the total volume of all lower deck and maindeck containers.

The lower deck has few options, and the most common configuration is the carriage of 15 pairs of LD-1 belly containers. Each container has an internal volume of 175 cubic feet and tare weight of 155lbs. These 30 containers therefore provide 5,250 cubic feet, and have a tare weight of 4,650lbs *(see table, this page)*.

Several configurations are possible for the maindeck. There are two main differences between converted -400Fs and factory-built versions. Factory freighters have a uniform height on the maindeck, and so can accommodate containers with a height of up to 118 inches (just under 10 feet) throughout. They also have a front nose freight door, as well as a side door.

Converted aircraft retain the original passenger upper deck, and its floorbeams protrude down into the converted aircraft's maindeck. The result is that the deck's height is lower at the forward section of the fuselage, up to station 903, than it is for the remainder of the deck. Containers at the front section can only be up to 96 inches (eight feet) tall, while those at the rear, aft of station 903, can have a height of up to 118 inches.

There are several main deck configurations for the -400BDSF. The most popular uses 30 LD-9 containers, which have base dimensions of 96 inches by 125 inches. Unit tare weight is 265lbs.

The forward section of the main deck accommodates nine containers. One has an internal volume of 532 cubic feet, while the other eight have a volume of 549 cubic feet each. These provide a total of 4,924 cubic feet.

The aft section carries 21 containers that are 118 inches high, each one with 750 cubic feet of capacity. These therefore provide 15,750 cubic feet.

Total maindeck volume provided by these 30 containers is therefore 20,674 cubic feet. The total tare weight is 7,950lbs.

The overall volume of this configuration is therefore 25,924 cubic feet, and tare weight is 12,600lbs. Net structural payload is gross payload less container and pallet tare weight.

Net structural payload of the four options is 239,900lbs for the aircraft with

The Bedek 747-400 freighter conversion programme has four main weight specification options. The highest will provide a gross structural payload of 277,000lbs.

the standard specification weights. This rises to 259,900lbs with the higher MZFW of 630,000lbs. The two future MTOW options have net structural payloads of 239,900lbs and 264,900lbs *(see table, page 62)*.

These different net structural payloads have a further implication for maximum packing density. These vary from 9.3 to 10.2 lbs per cubic foot. Most freight types do not, however, have packing densities as high as this, so the aircraft's volumetric payload can be as high as the net structural payload in most cases.

The purpose of the two new weight options, options 3 and 4, is to provide either longer range capability or higher payload where relatively short routes are operated.

Bedek's modification has a downtime of about 130 days, and customers have a choice between an Ancra or Telair cargo loading system. The price of conversion is $23-25 million. Modifications are currently undertaken at Bedek's facility in Tel Aviv, but it is also opening an additional facility in Bangkok in the expectation of a surge in feedstock resulting from the downturn in the passenger market.

Boeing conversion

The Boeing modification currently offers one weight option, with a standard MTOW of 870,000lbs and standard MZFW of 610,000lbs. The aircraft also has an OEW of 359,650lbs, which is about 2,150lbs more than the average for a Bedek-converted aircraft. This gives the 747-400BCF a gross structural payload of about 250,350lbs *(see table, page 62)*.

Like the Bedek-converted aircraft, this OEW is an average of PW- and GE-powered aircraft.

As with the Bedek-converted aircraft, aircraft modified under the Boeing programme only have a side cargo door. Moreover, the height of the forward main deck is lower than the aft maindeck. This has the same implications for maindeck container loading configurations as in the Bedek modification.

The aircraft can therefore have the same number and arrangement of containers and freight pallets. A standard configuration would be for the aircraft to carry 30 96-inch X 125-inch containers on its maindeck. The nine containers forward of station 903 would be eight feet high, while the 21 containers aft of station 903 would be 118 inches high.

The first nine containers would provide a total of 4,924 cubic feet, and the other 21 would provide 15,750 cubic feet. The 30 containers would have a total volume of 20,674 cubic feet. The total tare weight would be 7,950lbs.

The lower deck with 30 LD1-s would take total containerised volume to 25,924 cubic feet and tare weight to 12,600lbs, leaving the aircraft with a net structural payload of 237,750lbs. The container volume allows a maximum packing density of 9.2lbs per cubic foot *(see table, page 62)*. As with the Bedek-converted aircraft, volumetric payload will be the same as net structural payload in most cases because packing densities of most freight types are not as high as 9.2lbs per cubic foot.

The Boeing modification takes 100-110 days to complete. To date, Boeing has converted 36 aircraft, and operators include Cathay Pacific, Korean Air, Japan Airlines, Singapore Airlines, and United Parcel Service (UPS). There are a further 13 on firm order. The standard price is $28-30 million.

747-400F/-400ERF

The payload capacities of the -400BDSF and -400BCF should be considered against the factory-built freighters, the -400F and -400ERF.

The -400F has MTOW options up to 870,000lbs and 875,000lbs, and is accompanied at this weight by an MZFW of 635,000lbs. The OEW without tare weight is about 350,000lbs *(see 747-400 series specifications, Aircraft Commerce, April/May 2007, page 4)*. This gives the aircraft a gross structural payload of 285,000lbs, which equates to a 7,500-32,500lbs advantage over the converted aircraft. The -400ERF has an MTOW of 910,000lbs, MZFW of 611,000lbs and OEW of 350,400lbs. The gross structural payload is 260,600lbs, but the higher MTOW gives it additional range performance.

The -400F/-400ERF have the advantage of a nose cargo door, which allows faster loading and unloading that can contribute to higher levels of utilisation. The forward part of the -400F/-400ERF's maindeck is lower in height than the remainder. This restricted part is shorter than in converted aircraft, meaning that the -400F/-400ERF can carry two more 10-feet-high containers than converted examples. This gives the factory-built aircraft a few hundred more cubic feet in capacity.

Preparing for service

The economics of converting 747-400s depend on the total cost of acquiring used aircraft, converting them and performing maintenance to make them ready for service. This total cost then has to be financed. Aircraft might be converted by lessors when demand for passenger operations is reduced. In this case the total costs of preparation for service should be considered in relation to the market lease rate lessors can expect.

Aircraft can be converted directly by airlines and financed by themselves, or financed by lessors with specific customers committed to the aircraft.

The monthly market lease rental has to be at least 1.1-1.3% of total investment in the cost of preparing the aircraft for service to make the transaction economic for a lessor or

The Boeing 747-400 freighter modification has attracted the majority of orders. Although it has a $5 million higher price, Boeing has extensive support capabilities.

financier. The market lease rates that can be expected vary according to demand for aircraft. The 747-400BDSF and -400BCF compete with the 747-200SF, 747-400F and 747-8F. The 747-8F can only be justified where regular high loads and rates of utilisation can be expected. The 747-200SF fleet was vulnerable to higher oil and fuel prices, but this threat has now receded.

The global economic slowdown will generally reduce demand for freighters, so market lease rates are likely to soften. These have been $700,000 and higher, but will have reduced to $500,000-650,000 in recent months. This means that if a lease rate of $650,000 per month is achieved, total expenditure on preparation for service should be $55 million.

Aircraft acquisition

There was a large number of used 747-400s available in 2003 and 2004, but numbers fell from 2005 with the market's recovery. Aircraft will only come available for conversion if availability of parked aircraft increases again. This is possible, and market values of used 15-year-old aircraft have declined to $25-30 million from $40-45 million in late 2007. Aircraft should be at least 15 years old to justify conversion, and older aircraft will have lower market values and be available in higher numbers.

Maintenance

Several elements of maintenance will be required when converting used aircraft. These relate to airframe, engine and component maintenance.

Carrying out a heavy or D check is usually recommended during conversion to freighter, so that the aircraft has a maximum heavy check interval following its entry into service. A heavy check could not be justified, however, if the aircraft was up to halfway between heavy checks at the time of conversion. In this case a C check would be the more economic option. Moreover, the maintenance status and time since the last D check and the time remaining to the next D check would be reflected in the acquisition cost. Few 747-100s/-200s have been through more than five D checks. The D check interval on the 747-400 is 30,000 flight hours and six years in the case of most operators, so if the aircraft is to operate to its sixth D check before retirement, then its life is effectively capped at 36 years. This life limit and the acquisition cost and age of used aircraft being converted have to be considered.

Inputs for a D3 check for an aircraft that is to go through freighter conversion are 55,000-60,000 man-hours (MH) and $700,000-900,000 for materials. This will incur a cost of $3.6-4.0 million, and compares to 10,000MH and $225,000 for materials for a C check input.

In the case of CF6-80C2 and PW4000 engines, shop visit removals are 16,000-18,000 engine flight hours (EFH). This implies an engine shop visit is required on average once every 4,000-4,500EFH, about equal to the aircraft's annual utilisation. One engine shop visit is therefore likely to be required during conversion, and the remaining time to the next shop visit and the likely shop visit costs for the other three engines should be reflected in the aircraft's acquisition cost. Shop visit inputs for CF6-80C2 and PW4056/60 engines are $1.8-2.8 million, depending on workscope.

The remaining life of engine life limited parts and their cost of replacement should also be reflected in the aircraft's acquisition cost. A shipset of LLPs for a CF6-80C2 or PW4056/60 engine has a list price of $3.5 million, and full life of 15,000-20,000 engine flight cycles.

For components, landing gear, wheels and brakes, the auxiliary power unit (APU) and thrust reversers all have to be considered. The landing gear is overhauled once every 10 years, so this may not be required at conversion. Exchange and overhaul fees are $0.8-1.1 million. Overhauling the complete shipset of tyres, wheels and brakes will cost $500,000-800,000. A shop visit for the APU will cost $450,000, while a thrust reverser shop visit costs $300,000.

An allowance or budget of $300,000 should be made for the testing, repair and return to service of various rotable components.

The total cost for component maintenance can therefore total $2.0-2.6 million.

The total cost of maintenance if a C check and one engine shop visit are required will be $4.5-6.0 million.

Total preparation costs

An aircraft with an acquisition cost of about $25 million will require an additional $25-28 million for conversion to freighter at list prices. Another $4-5 million is likely for maintenance to prepare the aircraft for service, but the aircraft's maintenance condition and requirements will be taken into consideration when negotiating an acquisition price. Total investment in this case will be $54-58 million. Lease rentals of at least $650,000 will have to be possible to justify conversion. If market conditions push down lease rentals then only older aircraft at lower acquisition costs can justify the transaction.

Lessors and other owners converting aircraft already owned will have to take into consideration the book value, cost of conversion and maintenance, and probable lease rental. AC