**There are currently no conversion programmes available for the 777 family but there are indications that several might be under consideration. The potential demand for a converted 777 freighter is addressed here. The most likely conversion candidate is identified and its potential payload-range performance is compared to existing freighters.**

# Is there a market for 777 P-to-F conversions?

The potential for 777 passenger-to-freighter (P-to-F) conversions was first proposed a decade ago, but there are still few signs of an imminent programme launch.

*Aircraft Commerce* has examined the potential demand for converted 777 freighters. This analysis considers demand levels in the widebody freighter market, which 777 variant is most likely to be converted in the near-term, and who is likely to offer the modifications. The proposed payload-range performance of a converted 777 is compared to that of other widebody freighters, and potential acquisition and conversion costs, as well as operators are considered.

## Widebody freighters

The global financial crisis that began in 2008 resulted in reduced demand for air cargo. In addition to falling freight demand, there are suggestions that the dedicated widebody freighter market is coming under pressure from alternative modes of transport, and increased belly capacity in the newest passenger aircraft.

"Growth in traditional cargo will remain in low single digits in the foreseeable future," says retired air cargo executive Ram Menen. "Real growth will be driven by the e-commerce industry, and this may well be accommodated by the increase in available passenger aircraft belly capacity, which will put further pressure on cargo yields."

The latest generation of widebody passenger aircraft, such as the 777-300ER, 787, and A350, have more belly cargo capacity available than earlier generation types, such as the 747 *(see The belly freight capacity of widebody passenger aircraft, Aircraft Commerce, December 2014/January 2015, page 52).*

In its 2014 forecast, Airbus estimated that the combination of higher passenger growth rates and more capable long-haul aircraft would reduce the need for dedicated long-range freighters, with belly capacity capturing more freight demand. Airbus estimates that the percentage of air cargo carried as belly freight will increase from 51% to 57% from 2014 to 2034.

Martin P O'Hanrahan, International Society of Transport Aircraft Traders (ISTAT)-certified appraiser at AVITAS, notes that, in addition to increasing use of belly capacity, there has been a shift to cheaper transportation by sea. "Many older 777s are likely to be retired rather than converted to freighters." he adds

## New-build vs converted

Of the various challenges facing the widebody freighter segment, demand for converted aircraft seems to have suffered the most. 71 widebody aircraft were converted into freighters from July 2011 to July 2016, compared to 196 conversions in the preceding five-year period. New-build freighters have accounted for 78% of all widebody freighter deliveries since July 2011.

There has been a particular decline in the number of large widebody conversions. From July 2006 to July 2011 104 large widebody aircraft were converted, including 67 747-400s and 37 MD-11s. Since July 2011, only 12 large widebodies have been converted into freighters, including 11 747-400s and a single MD-11. Operators are preferring new-build variants of large widebody freighters and in particular the 777F and 747-8F, which together account for 145 deliveries since July 2011. This is equivalent to nearly two-thirds of all new-build freighter deliveries.

There are suggestions that the decline in widebody conversions is partly due to technical complications and costs.

"Today there is limited demand for widebody freighters," claims Cliff Duke, chief executive officer at Eolia Group and Low Cost Freighter (LCF) Conversions.

"The secondary market for third generation passenger widebodies, such as the 777, A330 and A340, has not materialised to the same extent that it did for previous generations, like the DC-10, MD-11, and A300," continues Duke. "These third generation widebodies are difficult to re-market into alternative passenger operations after they retire from tier-one operators. At the start of 2016, 45 777-200ERs were parked, and it is forecast that 115 more will be seeking new markets within five years."

Menen also hints at the potential technical considerations complicating the conversion of later generation widebody aircraft. "All widebodies designed and produced in the 1990s and beyond are going to face the same challenge," claims Menen. "Technology has enabled better optimisation of weight for passenger aircraft, but freighters need to be a lot more robust and rugged, so the modifications required to convert an already optimised passenger aircraft into a freighter are more extensive and expensive than they were for previous generations of aircraft."

## Dedicated freighters

Despite challenges, there is a conviction that demand for dedicated widebody freighters will continue.

It is likely that production freighters, including the 777F, will continue to account for a large part of the widebody freighter fleet. "More new generation aircraft will be needed, and they are likely to be production freighters," suggests Menen. "Demand for the 777F is likely to continue. In the longer term I can see airships and freighter drones dominating this space with far lower operating costs."

"Most experts in the field believe that the 777F is the best large freighter," claims Jacob Netz, senior analyst at Air Cargo Management Group, expressing


*There are currently no conventional P-to-F conversion programmes available for the 777 family, although Boeing and IAI Bedek have indicated that they are examining the market. The 777-200ER is the most likely variant to be converted in the near- to medium-term.*

his own opinion. "Its size, payload, volume, range, and operational economy are unmatched by other large freighters."

"Not everybody can afford the high acquisition costs of a new production freighter," says Menen. There are signs of growing momentum for medium widebody conversions with the rate of 767-300ER conversions increasing and the A330P2F programme now under way. There are also indications that 777 conversion programmes are being considered, but Menen believes the likely P-to-F conversion costs for a 777 would not be economic at this time.

## 777 developments

There are no conventional conversion programmes available for the 777 family. Boeing and IAI Bedek are the most likely candidates to provide 777 P-to-F conversions in the future, and both already offer widebody conversions for 767-300ERs and 747-400s.

"Boeing first promoted the concept for a 777 conversion in 2006/2007," says Duke. Boeing has indicated that it is still considering its options. "Product development studies are under way on the 777 Boeing Converted Freighter (BCF), and we are working to understand the changes necessary to convert 777 passenger airplanes into freighters that provide payload and range capabilities that meet market requirements. A decision to convert early 777s into freighters has not yet been made. We continue to explore the market demand, which would ultimately drive a programme launch."

IAI Bedek has indicated via recent marketing material that it is developing a supplemental type certificate (STC) for 777 P-to-F conversions. A spokesperson for IAI Bedek told *Aircraft Commerce* that it has accumulated technical data and is now ready to carry out detailed design work for a 777BDSF conversion. IAI Bedek is expected to make an announcement in the near future regarding this proposed development.

## 777 candidates

The passenger-configured 777 family consists of five separate variants: the 777-200, 777-200ER, 777-200LR, 777-300, and 777-300ER.

The 777-200 was the first member of the family to enter service in 1995. The 777-200ER and 777-200LR have the same fuselage dimensions as the -200, but offer longer range due to weight upgrades and higher-rated engines. The -200 has a range of up to 4,240nm with a full passenger payload compared to 7,065nm for the -200ER and 8,555nm for the -200LR.

The 777-300 and -300ER feature a 33-foot fuselage stretch over the -200 series variants. The 777-300 has a range of up to 5,045nm. The 777-300ER has higher certified weights and higher-thrust engines, providing it with a range of up to 7,370nm.

The current passenger-configured 777 fleet comprises 1,252 active and stored aircraft. This includes 658 777-300ERs, 403 777-200ERs, 78 777-200s, 57 777-300s, and 56 777-200LRs.

Most P-to-F conversions take place when feedstock aircraft are 15-to-20 years old, because aircraft of this vintage generally have the right balance between acquisition cost and remaining economic life to allow for an acceptable return on investment for freighter operators.

Three-quarters of the current 777 fleet comprises aircraft that are less than 15 years old. There are only 13 777s that are older than 20 years of age, and all of these are early-build 777-200s. There are currently 311 active and parked 777s in the typical feedstock age range, including 220 777-200ERs, 58 777-200s, and 33 777-300s. These types represent the most likely early conversion candidates.

If a 777 conversion programme is launched in the near future, the current age profile and comparative performance of the 777 fleet suggest that the 777-200ER variant is the most likely initial conversion candidate.

"Within the 777 family, most conversion candidates are likely to come from older units in the existing fleet of 777-200ERs," says O'Hanrahan. "The smaller in-service fleets of 777-200s and -300s limits the number of aircraft which could potentially be converted."

"Although feedstock for the original -200 variant will be cheaper, it is not a good conversion candidate due to its limited range and payload capability," claims Menen. "The 777-200LR might be a better candidate than the -200ER, based on payload/range performance, but the feedstock is still very expensive."

In addition to higher acquisition costs, the 777-200LR fleet is relatively small which could limit future conversion potential. It is also comparatively young, so the first 777-200LR will not reach the conversion age threshold for another four years. The 777-300ER is the most popular member of the family. It is unlikely to be a conversion candidate in the near to medium term, since it remains popular with passenger operators. While this remains the case, market values are unlikely to fall to levels that make P-to-F conversions economically viable. The oldest 777-300ER will not reach the conversion age threshold until 2018.

## Market positioning

The following analysis identifies how a converted 777-200ER might complement, or compete with, existing widebody freighters. It summarises the current widebody freighter fleet and identifies the available new-build and conversion options. Potential payload-

CURRENT WIDEBODY FREIGHTER AVAILABILITY

| Aircraft type | New-build | Conversion |
|---|---|---|
| **Medium-widebody** | | |
| 767-200ER | None | IAI Bedek |
| 767-300 | None | IAI Bedek |
| 767-300ER | Boeing | Boeing /IAI Bedek |
| A300-600 | None | EFW |
| A330-200 | Airbus | EFW, ST Aerospace, Airbus |
| A330-300 | None | EFW, ST Aerospace, Airbus |
| **Large-widebody** | | |
| 777-200F | Boeing | None |
| 747-400F | No longer in production | Boeing /IAI Bedek |
| 747-8F | Boeing | None |

range specifications for a converted 777-200ER freighter are compared to those for current widebody types.

The widebody freighter fleet comprises 1,014 active and 131 parked aircraft. In its World Air Cargo Forecast, Boeing splits the widebody freighter fleet into two categories: medium widebodies with a net structural payload of 40-80 tonnes, and large widebodies with a revenue payload of 80 tonnes or more. Under this classification system, the current fleet includes 532 medium widebody and 613 large widebody freighters.

The medium widebody freighter fleet includes 483 active and 49 parked aircraft. The in-service fleet includes 174 A300-600s, 146 767-300ERs, 58 767-200s, including some ER variants, 34 A330-200s, 31 DC-10-10s, 19 DC-10-30s, 12 A310s, and nine A300-B4s.

Some of these fleets, including those for the A300-600 and 767-300ER, are a mix of production and converted freighters. Others, such as the 767-200 fleet, are made up entirely of converted aircraft. The current A330-200 fleet consists entirely of production freighters.

There are two production freighters available in the medium widebody market, the A330-200F and 767-300F *(see table, this page)*. Conversion programmes are available for 767-200ERs, 767-300s 767-300ERs, A330-200s, A330-300s, and A300-600s. The A330 and 767-300ER programmes are expected to provide the most medium widebody conversions in the near to medium term.

Boeing and IAI Bedek both offer conversions for the 767-300ER. Converted aircraft are designated 767-300BCFs or 767-300BDSFs.

EFW and ST Aerospace offer a conversion programme for A330-200s and -300s. EgyptAir was announced as the launch customer for the A330P2F programme with an order for two A330-200 conversions. The first converted A330 freighter is yet to enter service.

The large widebody freighter fleet consists of 531 active and 82 parked aircraft. The in-service fleet includes 200 747-400s, 123 777Fs, 123 MD-11s, 64 747-8Fs, 17 747-200s, three 747-100s, and a single 747-300.

The 747-400 and MD-11 fleets are a mix of production and converted freighters. The 777F and 747-8F fleets consist entirely of new-build aircraft. These are the only production freighters available in the large widebody market. The only large widebody conversion programmes available are offered by Boeing and IAI Bedek for the 747-400. Converted aircraft are designated 747-400BCFs or 747-400BDSFs. Only 11 747-400s have been converted in the past five years, with the last modification taking place in 2012.

## Payload-range performance

*Aircraft Commerce* has seen proposed payload and range specifications for a potential 777-200ER BCF conversion. These are only speculative developmental numbers and have not been authenticated by Boeing, so actual specifications for a converted 777-200ER could vary if or when a conversion programme is finally launched. Nevertheless, the proposed figures provide an opportunity to assess the likely payload-range characteristics of a proposed 777-200ER freighter and to compare these to current aircraft.

### Assumptions

The following payload comparison is based on a number of assumptions. The estimated cargo volumes and tare weights assume the aircraft are loaded with pallets where possible, although some of the aircraft variants feature containers as part of lower-deck configurations.

The volume and tare weight assumptions used for the pallets and containers should be realistic. In practice the volume and tare weight of pallets and containers will vary by manufacturer. Volume and tare weight specifications of a pallet are influenced by the internal contour of the aircraft's fuselage and thickness of the pallet's base. Total cargo volume used for each aircraft in this analysis includes available bulk volume.

Gross structural payloads used in the analysis are based on estimated operating empty weights (OEWs). The OEW will vary with each aircraft. Many of the aircraft in this analysis come with multiple engine options. Different engine families can vary slightly in weight, leading to minor differences in OEW. Specifications for those aircraft with multiple engine options include assumptions related to the engine variant *(see table notes, page 78)*.

The analysis compares a potential 777-200ER freighter to other widebodies that have active conversion programmes or are available as new-build freighters. The DC-10-30F production freighter and MD-11F and MD-11BCF freighters are included to provide extra perspective on the 777-200ER's potential position in the market. Some of the aircraft covered in the analysis will have multiple weight specification options. Some of the most likely configurations are covered here.

Specifications used for converted 767-300ERs and 747-400s are based on Boeing's BCF conversion. IAI Bedek also converts these aircraft. Specifications used for the A330-300P2F are based on the high gross weight (HGW) option.

### Comparison

Proposed design specifications suggest that the 777-200ER BCF would have a maximum take-off weight (MTOW) of 650,000lbs, and a maximum zero fuel weight (MZFW) of 477,000lbs *(see table, page 78)*. The highest MTOW and MZFW specifications available for passenger-configured 777-200ERs are 656,000lbs and 442,000lbs respectively. This indicates that conversion could involve altering the feedstock aircraft's MTOW and upgrading its MZFW.

"With many P-to-F programmes, the performance of the converted freighter is almost equal or only slightly inferior to the equivalent production freighter," says Netz. "However, the performance of early converted models of the 777 will be considerably inferior to that of the 777F". This is because early conversion candidates are likely to be -200ERs, while the production freighter is based on the -200LR variant, which has higher weight specifications leading to greater payload and range capability.

The specifications estimate that a 777-200ER BCF would be able to operate up to a range of 3,925nm with a maximum structural payload of about 190,000lbs *(see table, page 78)*. The 777F can carry an additional 38,000lbs for a further 1,000nm *(see table, page 78)*.

The proposed 777-200ER would be positioned between a DC-10-30F and the MD-11 freighters in terms of maximum structural payload on offer.

It is assumed that a converted 777-200ER would provide the same potential loading configurations and, therefore, the same cargo volume as the 777F production freighter. This means it could accommodate up to 27 96-inch x 125-inch pallets on the main deck, and a further 10 on the lower deck. The lower deck containers would have a lower stacking height than those on the main deck. In this configuration, a converted 777-200ER BCF freighter would offer a cargo volume of 23,051 cubic feet (cu ft).

Some indicators of an aircraft's payload capability include net structural (revenue) payload, maximum packing density, and volumetric payload at different packing densities.

Net structural payload is the payload remaining for freight once the tare weight of containers or pallets has been accounted for. It is calculated by subtracting total tare weight from the aircraft's gross structural payload.

Maximum packing density indicates the maximum density at which freight can be packed to make full use of the available volume and payload. It is calculated by dividing net structural payload by available volume, and is expressed in lbs per cu ft.

Volumetric payload is the actual cargo payload that can be carried at a given packing density.

An aircraft's net structural payload, maximum packing density, and volumetric payload will vary according to whether it is configured for express package or general cargo operations.

Express package or integrator operations involve the carriage of small packages or parcels across hub-and-spoke networks. The freight is often loaded in containers or unit load devices (ULDs) with relatively low packing densities, beginning at about 6.5lbs per cu ft.

General freight operations tend to involve more point-to-point services and the carriage of heavier, bulkier items at higher packing densities of 7.0lbs per cu ft and up.

General freight is often carried on pallets. Express package freighters are more likely to fully use available volume before making optimum use of the net structural payload. This is referred to as 'cubing' or 'bulking' out. General freight aircraft are more likely 'gross out', which is when net structural payload is reached before all available volume has been utilised. An aircraft configured for general freight operations may have a higher net structural payload and maximum packing density than an express package freighter because pallets have a lower tare weight than containers.

## Net structural payload

Based on the assumptions used in this analysis, a 777-200ER BCF would offer a net structural payload of 181,675lbs *(see table, page 78)*. This is equivalent to about 82 tonnes. Boeing's classification system would therefore consider the 777-200ER BCF as a large widebody freighter.

When compared to the current widebody freighter fleet, the 777-200ER's net structural payload would position it between DC-10-30F and MD-11 freighters *(see table, page 78)*. It would provide 12,000lbs more revenue payload than the DC-10, but 15,500lbs less than an MD-11BCF and 20,000lbs less than an MD-11F.

## WIDEBODY CONVERTED & NEW-BUILD FREIGHTER SPECIFICATIONS

| Aircraft type | A330-200F | 767-300F | A330-200P2F | A330-300P2F HGW | 767-300BCF |
|---|---|---|---|---|---|
| MTOW (lbs) | 500,449-513,677 | 412,000 | 513,677 | 513,677 | 412,000 |
| MZFW (lbs) | 392,423-381,400 | 309,000 | 374,786 | 385,809 | 309,000 |
| Gross Payload (lbs) | 154,324-143,300 | 126,250 | 130,073 | 134,482 | 125,380 |
| Total volume (cu ft) | 16,969 | 15,467 | 16,969 | 20,046 | 15,710 |
| Total tare weight (lbs) | 7,582 | 6,887 | 7,582 | 8,941 | 7,988 |
| Net structural payload (lbs) | 146,742-135,718 | 119,363 | 122,491 | 125,541 | 117,392 |
| Max packing density (lbs/cu ft) | 8.65-8.00 | 7.72 | 7.22 | 6.26 | 7.47 |
| Range (nm) | 2,900-3,750 | 3,255 | n/a | n/a | 3,120 |
| Volumetric payload @ 7.0lbs/cu ft | 118,783 | 108,269 | 118,783 | 125,541 | 109,970 |
| Volumetric payload @ 8.0lbs/cu ft | 135,752-135,718 | 119,363 | 122,491 | 125,541 | 117,392 |
| Volumetric payload @ 9.0lbs/cu ft | 146,742-135,718 | 119,363 | 122,491 | 125,541 | 117,392 |

| Aircraft type | DC-10-30F | MD-11F | MD-11BCF | 777-200ER BCF* |
|---|---|---|---|---|
| MTOW (lbs) | 580,000 | 630,500 | 630,500 | 650,000 |
| MZFW (lbs) | 414,000 | 461,300 | 461,300 | 477,000 |
| Gross Payload (lbs) | 177,400 | 209,800 | 205,400 | 190,000 |
| Total volume (cu ft) | 17,659 | 20,378 | 20,378 | 23,051 |
| Total tare weight (lbs) | 7,852 | 8,100 | 8,100 | 8,325 |
| Net structural payload (lbs) | 169,548 | 201,700 | 197,300 | 181,675 |
| Max packing density (lbs/cu ft) | 9.60 | 9.90 | 9.68 | 7.88 |
| Range (nm) | 3,168 | 3,620 | 3,483 | 3,925 |
| Volumetric payload @ 7.0lbs/cu ft | 123,613 | 142,646 | 142,646 | 161,357 |
| Volumetric payload @ 8.0lbs/cu ft | 141,272 | 163,024 | 163,024 | 181,675 |
| Volumetric payload @ 9.0lbs/cu ft | 158,931 | 183,402 | 183,402 | 181,675 |
| Volumetric Payload @ 10.0lbs/cu ft | 169,762 | 201,700 | 197,300 | 181,675 |

| Aircraft type | 777-200F | 747-400F | 747-8F | 747-400BCF |
|---|---|---|---|---|
| MTOW (lbs) | 766,800 | 811,000-875,000 | 987,000 | 870,000 |
| MZFW (lbs) | 547,000 | 635,000-610,000 | 727,000 | 610,000 |
| Gross Payload (lbs) | 228,700 | 283,056-258,056 | 292,400 | 249,360 |
| Total volume (cu ft) | 23,051 | 26,063 | 30,284 | 25,097 |
| Total tare weight (lbs) | 8,325 | 9,103 | 10,678 | 8,775 |
| Net structural payload (lbs) | 220,375 | 273,953-248,953 | 281,722 | 240,585 |
| Max packing density (lbs/cu ft) | 9.56 | 10.51-9.55 | 9.30 | 9.59 |
| Range (nm) | 4,970 | 2,825-4,455 | 4,265 | 4,090 |
| Volumetric payload @ 7.0lbs/cu ft | 161,357 | 182,441 | 211,988 | 175,679 |
| Volumetric payload @ 8.0lbs/cu ft | 184,408 | 208,504 | 242,272 | 200,776 |
| Volumetric payload @ 9.0lbs/ cu ft | 207,459 | 234,567 | 272,556 | 225,873 |
| Volumetric payload @ 10.0lbs/cu ft | 220,375 | 260,630-248,953 | 281,722 | 240,585 |

Notes:
1). 777-200ER BCF conversion has not been launched. Specifications are speculative, based on developmental figures dating back several years, and are not endorsed by Boeing.
2). Medium widebody assumptions: 767-300BCF = CF6-80 engines and no winglets, A330-200F = Trent 700 engines, A330-200P2F not engine specific, DC-10 = CF6-50C2.
3). Large widebody assumptions: 777-200ER BCF = Trent 892, 777F = GE90, 747-8F = GEnx-2B, 747-400F/400BCF = CF680C2, MD-11F/BCF = CF6-80C2.

The 777-200ER BCF would provide the lowest revenue payload among available large widebody freighters. Its net structural payload would be 100,000lbs less than that of the 747-8F, 59,000-92,000lbs less than that of the various 747-400 options, and 39,000lbs less than that of the 777F.

It would, however, provide an advantage in net structural payload over the main medium widebody freighter options from the 767 and A330 families. The 777-200ER BCF would have a revenue payload advantage of 62,000-64,000lbs over a typical 767-300ER freighter, and 34,500lbs-59,000lbs more than an A330 freighter. In both cases, the extent of the payload advantage would depend on whether 767 and A330 freighters were converted or new-build aircraft and, in the case of the A330, which variant it was.

### Volumetric payload

The proposed 777-200ER BCF would have a maximum packing density of 7.88lbs per cu ft in a typical palletised configuration, the lowest of any large widebody used in this analysis, and is more comparable to a medium widebody production freighter *(see table, this page)*. All of the in-service large widebody freighters have maximum packing densities in excess of 9.0lbs per cu ft.

The 777-200ER BCF would offer superior volumetric payload and range compared to any medium widebody freighters used in this analysis at all packing densities *(see table, this page)*. At a typical express packing density of 7.0lbs per cu ft, the 777-200ER BCF would offer a volumetric payload advantage of 53,000lbs over a 767-300F, 51,000lbs over a 767-300BCF, 42,500lbs over an A330-200F or A330-200P2F, and 36,000lbs over a HGW A330-300P2F. Compared to a DC-10-30F, the 777-200ER BCF would offer nearly 38,000lbs of additional volumetric payload.

At higher packing densities more typical of general freight operations, the 777-200ER BCF would maintain a volumetric payload advantage over medium widebody freighters. At a packing density of 9.0lbs per cu ft the 777-200ER BCF's volumetric payload advantage would be 64,000lbs over a 767-300BCF, 62,000lbs over a 767-300F, 35,000-46,000lbs over an A330-200F, 59,000lbs over an A330-200P2F, and 56,000lbs over an HGW A330-300P2F. It would have a volumetric payload advantage of nearly 12,000lbs over a DC-10-30F at this packing density.

The 777-200ER BCF would also have a range advantage over all medium

**POTENTIAL 777 LCF SPECIFICATIONS**

| Medium-widebody | 777-200 LCF GMF | 777-200 LCF UL | 777-200ER LCF GMF | 777-200ER LCF UL | 777-300 LCF GMF | 777-300 LCF UL |
|---|---|---|---|---|---|---|
| MTOW (lbs) | 545,000 | 545,000 | 656,000 | 656,000 | 660,000 | 660,000 |
| MZFW (lbs) | 420,000 | 420,000 | 442,000 | 442,000 | 495,000 | 495,000 |
| Gross structural payload (lbs) | 156,455 | 150,508 | 174,554 | 168,607 | 199,901 | 193,273 |
| Total volume (cu ft) | 16,008 | 19,128 | 16,008 | 19,128 | 20,266 | 23,555 |
| Total tare weight (lbs) | 8,100 | 12,442 | 8,100 | 12,442 | 10,350 | 14,965 |
| Net structural payload (lbs) | 148,355 | 138,066 | 166,454 | 156,165 | 189,551 | 178,308 |
| Max packing density (lbs/cu ft) | 9.27 | 7.22 | 10.40 | 8.16 | 9.35 | 7.57 |
| Range (nm) | 4,240 | 4,240 | 7,065 | 7,065 | 5,045 | 5,045 |
| Volumetric payload @ 7.0lbs/cu ft | 112,056 | 133,896 | 112,056 | 133,896 | 141,862 | 164,885 |
| Volumetric payload @ 8.0lbs/cu ft | 128,064 | 138,066 | 128,064 | 153,024 | 162,128 | 178,308 |
| Volumetric payload @ 9.0lbs/cu ft | 144,072 | 138,066 | 144,072 | 154,165 | 182,394 | 178,308 |
| Volumetric payload @ 10.0lbs/cu ft | 148,355 | 138,066 | 160,080 | 154,165 | 189,551 | 178,308 |

widebody freighters used in this analysis. Its proposed range with a maximum revenue payload is 3,925nm, representing a range advantage of 805nm over a 767-300BCF, 670nm over a 767-300F, and 175-1,025nm over an A330-200F. The 777-200ER BCF would also have a range advantage of 750nm over a DC-10-30F.

### Volumetric payload & range

The proposed 777-200ER BCF would offer inferior volumetric payloads in comparison to any of the 747 freighters at all packing densities *(see table, page 78)*. It would, however, offer competitive volumetric payloads when considered against the 777F, MD-11F, and MD-11BCF at certain packing densities.

At a typical express packing density of 7.0lbs per cu ft, the 777-200ER BCF would offer an identical volumetric payload to the 777F. Despite its lower net structural payload, the 777-200ER BCF would offer a volumetric payload advantage of nearly 19,000lbs over the MD-11F and MD-11BCF at this packing density. The 777-200ER BCF would gross out at packing densities in excess of 7.88lbs per cu ft. The 777F, therefore, offers greater volumetric payloads than the converted aircraft at all packing densities above 7.88lbs per cu ft.

At a packing density of 8.0lbs per cu ft, the 777-200ER BCF's available volumetric payload would be 3,000lbs less than the 777F, but 18,500lbs more than the MD-11F and MD-11BCF. The available volumetric payloads of the two MD-11 freighters would only exceed that of the 777-200ER BCF at packing densities in excess of 8.92lbs per cu ft. Even at a packing density of 9.0lbs per cu ft, the MD-11 freighters would only offer 1,700lbs more volumetric payload than the proposed 777-200ER BCF.

In addition to competitive volumetric payload performance, the proposed 777-200ER BCF has a 300nm and 440nm range advantage over an MD-11F and MD-11BCF. The 777F has the longest range of any large widebody freighter, with a 1,000nm advantage over the 777-200ER BCF. The 747-8F offers 340nm more range than the proposed 777-200ER BCF, plus payload superiority.

A 747-400BCF would also offer an extra 100nm in range together with a superior payload. Various weight specifications available for 747-400F production freighters mean that they could offer between 1,000nm shorter or 500nm longer range than the proposed 777-200ER BCF.

## Potential operators

Two factors that could influence the prospective user base for converted 777-200ER freighters are the business models and fleet profiles of current widebody freighter operators.

FedEx and UPS are the largest operators of widebody freighters. They account for nearly 40% of the in-service widebody freighter fleet, with 239 and 161 aircraft respectively. In recent years both have focused on adding new-build production freighters to their widebody fleets. They have both added 767-300Fs, and FedEx has also built up a fleet of 27 777Fs. FedEx has a further nine 777Fs and 72 767-300Fs on order.

Stephen Fortune, principal at Fortune Aviation Services, says that integrators generally prefer the superior reliability and fuel economy of production widebody freighters. Scale of operations and higher cargo yields mean that they can afford the higher acquisition costs.

This does not mean, however, that integrators will not consider widebody conversions. "Integrators may not be able to continue to afford higher acquisition costs, because their yields are under extreme pressure as the likes of Amazon take to the air with their own distribution networks," suggests Menen.

On a like-for-like replacement basis, the payload analysis identified that the proposed 777-200ER BCF would be most closely matched with a DC-10-30F or an MD-11 freighter.

FedEx operates 44 of the 50 DC-10 freighters still in service. It already has 767-300Fs on order to replace these aircraft, so it is unlikely to be interested in procuring 777-200ERs for this role.

Fedex is also the largest operator of MD-11 freighters, with 57 in-service. The next largest operators are UPS (37), Lufthansa Cargo (12), Western Global Aviation (6), and Sky Lease Cargo (4). FedEx has already earmarked the 777F to replace its MD-11s.

Other potential customers for a future 777-200ER converted freighter include independent cargo carriers that already operate converted medium or large widebodies, and which may consider adjusting capacity up or down in the future. The largest of these carriers are Atlas Air, which operates 30 aircraft, including converted 747s and 767s, and ABX Air, which operates a fleet of 25 converted 767-200s and 767-300ERs.

## LCF

Despite the current lack of conventional 777 P-to-F conversion options, one alternative freighter modification is already being marketed.

LCF Conversions has designed a low-cost alternative to conventional P-to-F conversions. Its LCF cabin modification maintains the passenger aircraft's certified limits and does not include installation of a large cargo door.

"The LCF cabin modification creates access between the lower and main decks of third generation widebodies such as the A340, A300 and 777," explains Duke. "It opens up the passenger aircraft to a range of alternative use options. The LCF concept is based on a lift system that uses the existing lower hold cargo doors for loading and unloading. Cut-outs in the main deck floor accommodate lift platforms that raise payloads from the lower deck to the main deck without compromising the area in the lower deck available for payloads. The LCF modification uses design solutions that do not change the existing certification limits of the passenger aircraft.

**ESTIMATED ACQUISITION COSTS FOR 777 PASSENGER AIRCRAFT**

| Aircraft Type | MTOW (lbs) | Engines | CMV ($-millions) 15-year-old | 20-year-old |
|---|---|---|---|---|
| 777-200 | 545,000 | GE/PW | 23.20 | 14.10 |
| 777-200ER | 632,500 | GE/PW | 26.20 | 18.00 |
| 777-300 | 660,000 | RR/PW | 31.50 | N/A |

Source: Avitas
Assumes half-life maintenance condition with half life engines

"Installation of LCF lifts opens up a number of alternative-use configuration options," continues Duke. "Conversion-to-freighter operations is the main LCF alternative use configuration. LCF is a low-cost, flexible conversion solution that overcomes the cost and technical challenges of conventional freighter conversion. We have developed one-third of the STCs for the main Airbus and Boeing derivatives. Once the first contract is signed, it will take 14 months to complete the certification programme and entry to service."

There are two main configuration options for aircraft modified to LCF status. These are the general market freighter (GMF) and upper lobe (UL) configurations. The GMF configuration includes loading positions on the main and lower decks. The size and contour of pallets that can be accommodated by LCF aircraft would be limited by the dimensions of the lower deck cargo doors, so they would only be able to accommodate pallets or containers up to a height of 64-inches on the main deck and could, depending on the density of cargo being carried, provide less cargo volume than a conventional freighter.

LCF Conversions points out that 90% of air cargo can be accommodated in lower-deck containers, and, therefore, by an LCF-modified aircraft. It argues that at typical intercontinental freight packing densities there is effectively no loss of volume for an LCF-modified aircraft.

To use more of the available main deck volume, LCF Conversions also markets a UL configuration that accommodates an extra row of smaller containers at the top of the fuselage above the main-deck loading positions.

Due to the relatively low cost of the LCF concept, the potential for modification will not be restricted to one 777 variant. Based on current fleet profile, this could mean that 777-200s and 777-300s are just as likely to be near-term contenders for LCF modification as the more numerous 777-200ER.

Proposed configurations for typical 777-200LCF, 777-200ER LCF, and 777-300 LCF aircraft have been summarised in both GMF and UL configurations *(see table, page 79)*. A 777-300ER could also be modified to LCF status. This would offer similar configurations and payloads to the 777-300LCF, but with longer range. Market values for the 777-300ER are likely to remain high for the foreseeable future.

A 777-200LCF would offer a similar gross structural payload to an A330-200F, while a 777-200ER LCF would be positioned between a A330-200F and DC-10-30F.

A 777-300LCF would offer a higher gross structural payload than a DC-10-30F and the proposed 777-200ER BCF, but less than an MD-11 freighter.

A 777-200 or -200ER LCF would be positioned between a 767-300F or -300BCF freighter and the proposed 777-200ER BCF in terms of net structural payload, cargo volume, and volumetric payloads. A 777-200ER LCF in the UL configuration would offer higher volumetric payloads than a DC-10-30F at lower packing densities typical of express package operations.

A 777-300 LCF could offer a higher net structural payload than a DC-10-30F. In the GMF configuration, a 777-300 LCF would provide a higher net structural payload than the proposed 777-200ER BCF. It would offer less overall volume than the 777-200ER BCF, but larger volumetric payloads at higher packing densities typical of general freight operations.

A 777-300 LCF in the GMF configuration would offer similar volumetric payloads to an MD-11F or MD-11BCF at packing densities of 7.0-9.0lbs per cu ft.

In the UL configuration, a 777-300 LCF would offer higher volumetric payloads than the proposed 777-200ER BCF at some lower packing densities typical of integrator operations. It would provide superior volumetric payload performance to a MD-11 freighter at typical express packing densities.

An advantage to the LCF approach of maintaining the certified weights of the feedstock aircraft is that range performance is maintained. This means that 777-200ERs or 777-300s converted to LCF status would offer longer-range performance than any existing widebody freighter, despite offering lower payloads in some scenarios.

## Costs

Acquisition and conversion costs will be crucial in determining potential market demand for 777 freighter conversions. Since no conventional P-to-F programmes have been launched for the 777 there is no pricing information available for this traditional conversion approach. There are indications that a conventional P-to-F conversion for a 777 could cost $25-40 million. LCF Conversions has priced its LCF GMF modification at $6.5 million, and its LCF UL modification at $7.5 million.

Market values for ageing 777 variants are in decline, which could make them more attractive conversion candidates.

"An uncertain international economy, cheaper financing for new aircraft, and a spike in the number of widebodies coming off lease has led to a glut in the market and a softening in values for the 777 family among others," claims O'Hanrahan. "One concern is the cost of transitioning large widebodies to other operators. Given that many of these aircraft are configured to high customer specifications, the transition cost could be as much as $10 million per aircraft. The more limited operator base for large widebodies means that it may be some time before this surplus in capacity can be fully reabsorbed. The cost for reconfiguring a passenger 777-200ER probably needs to be about $20 million per aircraft to economic make sense."

According to Avitas, the current market value (CMV) for a typical 20 year-old 777-200 in half-life maintenance condition with half-life GE90 or PW4000-112 engines is $14.1 million *(see table, this page)*. This would rise to $23.1 million for a 15-year-old aircraft.

A typical 20-year-old, standard weight 777-200ER with GE90 or PW4000-112 engines would have a CMV of $18.0 million, according to Avitas. This would increase to $26.2 million for a 15-year-old example, while a similar vintage 777-300 with Trent 800 or PW4000-112 engines would have a CMV of $31.5 million.

Combined acquisition and modification costs for 777-200, 200ER or -300 passenger aircraft into LCF GMF status would, therefore, be $20.6-38.0 million, depending on variant and vintage. The cost of acquiring and converting them to LCF UL status would be $21.6-39.0 million. AC