The share of airfreight carried in the belly holds of passenger aircraft has increased since 2008. The belly capacity of widebody aircraft is analysed and compared to dedicated freighters. Future trends in belly freight and its impact on main deck cargo are considered here.

The belly freight capacity of widebody passenger aircraft

Recent-generation passenger widebodies provide increased lower hold or 'belly' freight capacity. This trend was started by the A330/340 and 777 families in the 1990s, and has continued with the 787 and A350.

Aircraft Commerce has analysed the potential belly freight capacity of the main widebody types. The belly capacity of passenger aircraft is compared to the total cargo capacity of dedicated freighters. Future growth trends for belly freight are considered here.

The impact of passenger aircraft's belly freight capacity on the demand for dedicated factory-built and converted freighters is also addressed.

Growth of belly freight

The share of global air cargo carried in passenger aircraft belly holds has increased in recent years. The recent global economic downturn has contributed to this trend.

"From the early 1990s to 2008, there was a trend for an increasing percentage of air cargo to be carried on dedicated freighters," claims Jacob Netz, analyst and senior consultant at the Air Cargo Management Group, expressing his own personal opinion. "This trend has been somewhat reversed since 2008."

"The freight industry has seen significant changes since 2008," explains Didier Lenormand, head of freighter aircraft marketing at Airbus. "Following the financial crisis in 2008/2009, airlines found that the traditional approach of flying 'one-size-fits-all' 100-tonne freighters on export-driven, east-to-west trunk routes was no longer viable, and resulted in financial losses.

"The economic crisis led to lower freight loads and overcapacity," continues Lenormand. "This led to a structural change in the freight industry. Many airlines decided to leave the main deck freighter market, and concentrate on belly cargo. This was readily available from their passenger operations."

In the longer term, the increased belly freight capacity and range capabilities of new widebody aircraft could further contribute to an increase in belly cargo.

"Passenger airlines have bought a substantial number of modern widebodies in recent years," says Netz. "The latest widebodies have more belly space than earlier-generation passenger aircraft. The 777-300ER, A330 and 787 are responsible for the growth in belly freight capacity, and in the future they will be joined by the A350."

"The A350-1000 will be capable of carrying up to 30 metric tonnes (66,000lbs) of cargo in its belly, over a range of more than 5,000nm," claims Lenormand. "If the aircraft is operated on a daily passenger service, over the course of a week its cargo capacity would be superior to that of a 747-8F's single operation, and it would represent less financial risk."

Retired aviation and air cargo executive Ram Menen refers to the 777-300ER as an invisible freighter, because its belly hold capacity is nearly comparable to the total payload of older-generation narrowbody and small widebody dedicated freighters.

"The 777-300ER can accommodate 28-30 tonnes of freight in its lower hold, which is almost as much as an A310 freighter used to carry," explains Menen. "A 777-300ER will provide a useful cargo capacity, if used on regular passenger operations."

Finnair recently announced that it is moving away from dedicated long-haul freighter operations with MD-11Fs to focus on belly cargo in its passenger-configured widebodies.

"The dedicated long-haul freighter operation was not financially sustainable. This is due to deteriorating yields associated with over-capacity in the market and foreign currency fluctuations," explains Antti Kuusenmäki, head of cargo at Finnair.

"Our strategic goal is to offer customers reliable and frequent cargo services on major trade lanes between Asia, Europe and North America," continues Kuusenmäki. "This can be achieved more effectively, and without risking the viability of the whole business, by using the belly capacity available on modern passenger aircraft, such as the A350."

Finnair is the European launch customer for the A350, and has 19 of the aircraft on order.

Netz suggests that the belly space available for cargo has also increased due to the introduction of baggage fees as an ancillary revenue source. Passengers may travel with fewer bags to avoid additional fees, which leaves more room for freight.

Advantages of belly freight

Airlines can reduce costs by shipping cargo in the belly holds of passenger aircraft, rather than operating separate dedicated freighters.

The unit costs for belly freight are lower than those for main deck cargo. With a dedicated freighter, cargo revenue is required to cover the total operating costs of the aircraft. In a belly freight

The latest widebodies, including the 787 family, offer greater belly freight capacity than previous generation aircraft. The introduction of new widebody families and the recent global economic downturn has led to a larger share of freight being carried in the belly holds of passenger aircraft.

scenario, the aircraft's operating costs will have already been covered by passenger revenue. Cargo revenue is only needed to cover incremental costs, including fuel and handling.

Netz highlights interlining opportunities at major hub airports as another benefit of shipping cargo in the belly holds of passenger aircraft.

Future growth potential

"Today, about half of international air cargo shipments are carried in the belly compartments of passenger flights, while the other half are carried on dedicated freighters," claims Netz.

There are some suggestions that the share of freight carried in belly compartments could grow further.

"About 90% of cargo is loadable in belly containers," claims Menen. "The highest growth market in the freight industry is E-commerce. Most of these products can be easily accommodated in the belly holds of passenger aircraft."

Airbus also believes there is potential for an increase in the percentage of freight carried in passenger aircraft bellies, particularly for long-haul routes.

"As a result of the growing influence of very capable long-haul passenger aircraft over the next two decades, Airbus forecasts that the share of total freight capacity transported in the belly compartments of passenger aircraft will grow to about 56%," says Lenormand.

Airbus suggests that the introduction of new widebodies, such as the A350, will lead to a greater increase in belly freight on longer routes, rather than on regional or shorter-haul sectors.

"The additional belly freight capacity provided by new widebodies will affect the way cargo is transported on long-haul flights for decades to come," claims Lenormand. "Widebody belly capacity is likely to replace many very large freighters, even on markets such as the trans-Pacific."

"On shorter, regional sectors the current ratio between belly and main deck freight will be maintained," claims Lenormand. "An increase in belly freight has taken place following introduction of twin-aisle aircraft in regional markets over the past few decades."

Cliff Duke, chief executive officer at the Eolia Group, suggests that most cargo carried in passenger belly compartments to date has been general freight. "Express package operators have traditionally operated their own fleets of dedicated freighters, and these are likely to remain the mainstay of their operations."

"Fedex has indicated that it is open to using alternative modes, including belly cargo," continues Duke. "Cost is always a key driver, and expensive purpose-built freighters deployed on low-utilisation operations are not always the most efficient way to transport express cargo."

Dedicated freighters

Despite the potential advantages of belly cargo, there is general consensus that there will always be a requirement for dedicated freighters.

Boeing claims that about 55% of air cargo is carried by dedicated freighters. "There will continue to be high demand for freighters," claims Tom Hoang, regional director of cargo marketing at Boeing Commercial Airplanes. "We believe about 56% of air cargo traffic will be carried on freighters by 2033."

"It is unlikely that dedicated freighters will be pushed out by belly freight," says Netz. "Dedicated freighters offer shippers better overall service, including greater flexibility in terms of the size of the cargo that can be carried along with more flexible schedules and routes."

"Dedicated freighters offer a variety of services for outsize cargo, hazardous materials and other types of cargo that cannot be accommodated in passenger aircraft," says Hoang.

If freight is transported in belly holds on passenger flights, the size of the cargo is restricted by the dimensions of the aircraft's lower hold. Dedicated factory-built or converted freighters are required for big or bulky items that can be loaded on main decks via large cargo doors.

On a typical passenger flight, the passenger operation will take priority over cargo. This means that the origin, destination and timing of a flight are tailored to suit passenger demand, rather than the requirements of a freight shipper.

There will always be demand for freight to be shipped between destinations that are not served by scheduled passenger flights. There may also be demand for freight to be shipped outside scheduled passenger flight times. Dedicated freighters offer a more efficient solution than belly freight in both cases.

Kuusenmäki suggests that dedicated freighters will be required to supplement belly freight networks. "Airlines with belly freight capacity will still rely on dedicated freighter operators to balance the network by connecting hubs and other important markets into hubs."

Passenger aircraft belly freight capacity will face restrictions on some long-haul routes, especially the longer distance city-pairs. An aircraft's range at maximum payload is several thousand miles shorter than its range with a full passenger load. "On some long, non-stop passenger routes, payload or range restrictions need extra fuel, which means a reduction in the belly freight payload that can be uplifted," says Netz.

"Freighters are essential to the long-range market, and play a key role in major cargo trade lanes," says Hoang. "They carry about 72% of all air cargo between Europe and Asia, and 80% between Asia and North America.

Lenormand says dedicated freighters will still be required. "For a sustainable future, the cargo industry needs the capabilities of both belly capacity and dedicated freighters as a means to adjust supply and demand.

"When the financial crisis began, airlines like Lufthansa and Cathay Pacific, decided to stay in the main deck freight market, seeing it as an essential part of their product offering and revenue generation," continues Lenormand. "They replaced uneconomical 747s and MD-11s with more modern freighters. By operating combined belly and main deck freight, these airlines differentiated their product offering to create added value.

"Another group of airlines has emerged, and is growing into the freight market with belly cargo and modern main deck freighters that include 777Fs and A330-200Fs," continues Lenormand. "Mainly based in the Middle East, these airlines use their geographically well-placed airports to apply the hub-and-spoke concept to the general cargo business. They use the 777F on larger trunk routes, and use the A330-200F to develop smaller markets. Airbus forecasts a demand for up to 414 factory-built mid-size freighters, such as the A330-200F between now and 2033."

Some demand will come from Asia and China, where Airbus has identified a fragmentation of air cargo traffic as manufacturers search for the lowest labour costs among countries in Asia.

"New destinations in Western China, Vietnam, Myanmar and Indonesia will lead to smaller cargo flows that require a medium-size freighter," adds Lenormand. "On the passenger side many of these destinations are served by single-aisle aircraft with limited belly freight capacity.

"Airbus sees a demand for 390 larger freighters, with a payload greater than 80 metric tonnes, by 2033. The anticipated growth for this segment is impacted by the growing efficiency and belly cargo capacity of future long-haul widebodies such as the A350-1000," he adds.

Factory-built or converted

Menen agrees that dedicated widebody freighters will still be required, regardless of increases in the belly capacity of new long-haul aircraft. However, he cautions that these dedicated freighters will need to be cost-effective.

Menen highlights that factory-built widebody freighters are more efficient than converted aircraft, with lower fuel burn and better payload/range performance. "Not everybody can afford factory-built freighters," says Menen. "Converted widebody freighters currently play a major role, providing cheaper, right-sized capacity. Many older converted freighters are still operating."

LCF concept

An alternative to standard factory-built and converted freighters is being marketed by Low Cost Freighter (LCF) Conversions Ltd, part of the Eolia Group.

An aircraft converted to the LCF configuration would not include a large cargo door. Freight would be loaded through existing lower deck cargo doors. A pair of internal lift platforms would be installed and allow cargo to be raised from the belly hold up to the main deck.

This would restrict the size of the main deck containers, however, to those that can be loaded through standard

BELLY FREIGHT SPECIFICATIONS OF PASSENGER-CONFIGURED WIDEBODY AIRCRAFT

A/C TYPE	767-300ER	A330-200	A330-300	A340-300	777-200	777-200ER	777-200LR
MTOW (lbs)	412,000	513,677	513,677	606,271	545,000	656,000	766,000
MZFW (lbs)	295,000	374,786	385,809	399,037	420,000	430,000	461,000
OEW (lbs)	198,440	267,031	277,593	286,300	306,500	317,000	320,000
Gross structural payload (lbs)	96,560	107,755	108,216	112,737	113,500	113,000	141,000
Max payload range (nm)	3,900	4,200	3,700	5,650	3,300	5,800	7,700
Passenger capacity (OEM)	218 (3-class)	246 (2-class)	300 (2-class)	300 (2-class)	305 (3-class)	305 (3-class)	301 (3-class)
Passenger capacity (average)	229	258	295	263	338	279	279
Belly containers	30-LD2	26-LD3	32-LD3	32-LD3	32-LD3	32-LD3	32-LD3
Belly volume (cu ft)	3,720	3,978	4,896	4,896	4,896	4,896	4,896
Container tare (lbs)	6,090	5,200	6,400	6,400	6,400	6,400	6,400
Net structural payload (lbs)	90,470	102,555	101,816	106,337	107,100	106,600	134,600
Total pax & baggage weight (lbs)	58,498	65,916	75,343	67,193	86,348	71,268	71,268
Hold bag volume (cu ft)	2,200	2,480	2,832	2,528	3,248	2,680	2,680
Containers required	17.74	16.21	18.51	16.52	21.23	17.52	17.52
Containers remaining	12	9	13	15	10	14	14
Remaining payload for cargo (lbs)	31,972	36,639	26,473	39,144	20,752	35,332	63,332
Remaining belly volume (cu ft)	1,488	1,377	1,989	2,295	1,530	2,142	2,142
Max packing density (lbs/(cu ft)	21.49	26.61	13.31	17.06	13.56	16.49	29.57
Belly freight @ 8lbs/ cu ft (lbs)	11,904	11,016	15,912	18,360	12,240	17,136	17,136

A/C TYPE	A340-600	777-300	777-300ER	747-400	747-8	A380-800
MTOW (lbs)	811,301	660,000	775,000	875,000	987,000	1,235,000
MZFW (lbs)	540,132	495,000	524,000	542,500	651,000	796,000
OEW (lbs)	392,000	347,800	370,000	394,088	485,300	596,000
Gross structural payload (lbs)	148,132	147,200	154,000	148,412	167,700	200,000
Max payload range (nm)	5,800	3,650	5,700	5,750	5,900	6,650
Passenger capacity (OEM)	359 (two-class)	368 (3-class)	370 (3-class)	400 (3-class)	515 (3-class)	525 (3-class)
Passenger capacity (average)	312	394	338	381	362	487
Belly containers	42-LD3	44-LD3	44-LD3	32-LD1	38-LD1	38-LD3
Belly volume (cu ft)	6,426	6,732	6,732	5,600	6,650	5,814
Container tare (lbs)	8,400	8,800	8,800	5,760	6,840	7,600
Net structural payload (lbs)	139,732	138,400	145,200	142,652	160,860	192,400
Total pax & baggage weight (lbs)	79,662	100,639	86,348	97,296	92,375	124,357
Hold bag volume (cu ft)	2,992	3,784	3,248	3,656	3,464	4,672
Containers required	19.56	24.73	21.23	20.89	19.79	30.54
Containers remaining	22	19	22	11	18	7
Remaining payload for cargo (lbs)	60,070	37,761	58,852	45,356	68,485	68,043
Remaining belly volume (cu ft)	3,366	2,907	3,366	1,925	3,150	1,071
Max packing density (lbs/cu ft)	17.85	12.99	17.48	23.56	21.74	63.53
Belly freight @ 8lbs/ cu ft	26,928	23,256	26,928	15,400	25,200	8,568

A/C TYPE	787-8	787-9	787-10	A350-800	A350-900	A350-1000
MTOW (lbs)	502,500	557,000	557,000	573,000	590,839	681,000
MZFW (lbs)	355,000	400,000		399,000	423,288	485,000
OEW (lbs)	259,700	274,000				
Gross structural payload (lbs)	95,300	126,000				
Max payload range (nm))	5,450	5,250				
Passenger capacity (OEM)	242 (3-class)	280 (3-class)	323 (3-class)	276(2-class)	315 (2-class)	369 (2-class)
Passenger capacity (average)	246	316				
Belly containers	28-LD3	36-LD3	40-LD3	28-LD-3	36-LD3	44-LD3
Belly volume (cu ft)	4,284	5,508	6,120	4,284	5,508	6,732
Container tare (lbs)	5,600	7,200	8,000	5,600	7,200	8,800
Net structural payload (lbs)	89,700	118,800				
Total pax & baggage weight (lbs)	62,817	80,695	82,517	70,479	80,451	94,254
Hold bag volume (cu ft)	2,360	3,032	3,104	2,648	3,024	3,544
Containers required	15.42	19.82	20.29	17.31	19.76	23.16
Containers remaining	12	16	19	10	16	20
Remaining payload for cargo (lbs)	26,883	38,105				
Remaining belly volume (cu ft)	1,836	2,448	2,907	1,530	2,448	3,060
Max packing density (lbs/cu ft)	14.64	15.57				
Belly freight @ 8lbs/ cu ft	14,688	19,584				

Notes:
1). Stated OEWs are estimates only - actual OEW will vary by individual aircraft.
2).777-200 OEW based on aircraft with PW4077 engines.
3).777-200ER OEW based on aircraft with GE90-94B engines.
4). 777-300 OEW based on aircraft with TRENT engines.
5). 747-400 OEW based on aircraft with GE engines.
6). Range is rough estimate with max payload.

lower deck cargo doors. An LCF aircraft would, therefore, provide less volume than traditional conversion programmes, but the modification would, cost less than a large door conversion.

Menen believes the LCF concept could be an effective alternative to converted freighters. "Due to the low cost of the conversion, an operator could afford to have low utilisation rates for an LCF aircraft," claims Menen.

"Even if an LCF aircraft does not fully utilise its main deck volume, it has the potential to cater for more than 90% of freight traffic, because about 90% of cargo can physically fit into belly containers," adds Menen.

The LCF conversion will be available for all third-generation widebody aircraft, including the A330, A340 and 777.

The potential specifications of aircraft converted to LCF status can be compared to those of factory-built or converted freighters *(see table, page 58)*.

Belly freight capacity

The belly freight capacity on a passenger aircraft is determined by the payload and volume available, once passengers and their baggage have been taken into consideration.

Calculating the available belly cargo capacity depends on the passenger load factor, flying conditions on the day of operation, route length, and the aircraft's payload-range performance. "There will be certain routes or markets where passengers will carry much more baggage, reducing the available room for belly freight," says Menen. "The payload available for belly cargo can also be reduced if a higher fuel uplift is required due to en-route headwinds."

The potential belly freight capacity of main widebody types is analysed here and compared to the freight capacity of dedicated freighters.

Assumptions

For the purposes of this analysis it is assumed that the passenger aircraft are operating with a 100% load factor. This will help determine each type's minimum achievable belly capacity. In many cases, aircraft will operate with lower load factors, allowing additional belly freight to be carried.

Internationally recognised assumptions for average passenger and baggage weights are applied. This includes an average weight of 187lbs per passenger, including carry-on baggage. It is assumed that each passenger will carry 1.2 hold bags. Each hold bag weighs 57lbs and has a volume of eight cubic feet (cu ft). This totals about 255lbs per passenger, and the use of about 10 cu ft for each passenger's hold baggage.

This analysis is based on the use of unit load devices (ULDs) for loading baggage and freight. The container volumes and tare weights used here are based on realistic examples.

LD-2 containers are loaded in the 767-300ER's belly compartment. The LD-2s have a volume of 124 cu ft and a tare weight of 203lbs.

The 747-400 and 747-8 hold LD-1 containers, with a volume of 175 cu ft and tare weight of 180lbs.

All of the other types use LD-3 ULDs, with a volume of 153 cu ft and a tare weight of 200lbs.

ULD volumes and tare weights will vary by manufacturer.

The analysis also assumes a certain configuration of ULDs for both passenger and dedicated freighter aircraft. In reality there are many different ULDs available with multiple potential configurations.

In this analysis dedicated freighters are configured with the same lower deck ULDs as passenger aircraft. It is possible that some dedicated freighters will be operated with other lower deck ULDs optimised for cargo rather than baggage. Some carriers may choose to use pallets rather than ULDs for loading freight.

Individual weight variants of each aircraft type have been selected to

DEDICATED WIDEBODY FREIGHTER SPECIFICATIONS

NEW BUILD	767-300F	A330-200F	777-200F	747-8F
MTOW (lbs)	412,000	500,449	766,800	987,000
MZFW (lbs)	309,000	392,423	547,000	727,000
OEW (lbs)	188,000	238,098	318,300	434,600
Gross structural payload (lbs)	121,000	154,325	228,700	292,400
Max payload range (nm)	3,250	2,900	4,900	4,200
Main deck containers	22 AAX + 2 A2	18 AMV + 5 AAX	27 AMX	27 M1H +5 M1 + 2 Igloo
Lower deck containers	30-LD2	26-LD3	32-LD3	40-LD1
Total Volume (cu ft)	15,710	16,133	23,904	31,730
Total tare weight (lbs)	19,664	18,363	24,409	29,575
Net structural payload (lbs)	101,336	135,962	204,291	262,825
Max packing density (lbs/cu ft)	6.45	8.43	8.55	8.28
Volumetric payload @ 8lbs/cu ft	101,336	129,064	191,232	253,840

CONVERTED	767-300BCF	A330-200P2F	A330-300P2F	747-400
MTOW (lbs)	412,000	513,677	513,677	870,000
MZFW (lbs)	309,000	374,786	385,809	610,000
OEW (lbs)	180,800	244,713	251,327	357,000 - 360,640
Gross structural payload (lbs)	128,200	up to 130,073	up to 134,482	249,360 - 253,000
Max payload range (nm)	3,100	4,200	3,700	4,150
Main deck containers	22 AAX + 2 A2	18 AMV + 5AAX	22 AMV + 4 AAX	21 M1H + 7M1 + 2 Igloo
Lower deck containers	30-LD2	26-LD3	32-LD3	32-LD1
Total Volume (cu ft)	15,710	16,133	18,686	27,012
Total tare weight (lbs)	19,664	18,363	21,270	25,314
Net structural payload (lbs)	108,536	111,710	113,212	224,046 - 227,686
Max packing density (lbs/cu ft)	6.91	6.92	6.06	8.29 - 8.43
Volumetric payload @ 8lbs/cu ft	108,536	111,710	113,212	216,096

LCF	A330-200LCF	A330-300LCF	A340-300LCF	A340-600LCF	777-200LCF
MTOW (lbs)	513,677	513,677	606,271	837,756	656,000
MZFW (lbs)	374,786	385,809	399,037	553,360	477,000
OEW (lbs)	240,345	247,311	250,839	353,905	267,466
Gross structural payload (lbs)	134,441	138,498	148,198	187,393	172,554
Max payload range (nm)	4,200	3,700	5,400	6,100	5,100
Main deck containers	23 (96"x125"x64")	25 (96"x125"x64")	25 (96"x125"x64")	31 (96"x125"x64")	25 (96"x125"x64")
Lower deck containers	26-LD3	32-LD3	32-LD3	42-LD3	32-LD3
Total Volume (cu ft)	13,339	15,071	15,071	19,043	16,516
Total tare weight (lbs)	18,126	20,450	20,450	25,822	21,324
Net structural payload (lbs)	116,315	118,048	127,748	161,571	151,230
Max packing density (lbs/cu ft)	8.72	7.83	8.48	8.48	9.16
Volumetric payload @ 8lbs/cu ft	106,712	118,048	120,568	152,344	132,128

Notes:
1). Stated OEWs are estimates only - actual OEW will vary by individual aircraft.
2). OEW estimate for A330P2F based on post-conversion aircraft and target payloads. Final payloads to be confirmed following completion of conversion and final weighting.
3). A330LCF OEWs based on Trent powered aircraft. Some of the main deck containers for LCF aircraft will be contoured.
4). 767-300BCF spec for Boeing converted aircraft with GE engines and no winglets.
5). 747-400 OEW & payload variance accounts for difference between Boeing and IAI Bedek conversions. Weights are for aircraft with CF6- engines.
6). Range is rough estimate with max payload.

demonstrate belly freight capacity. For some of these types there are multiple weight combinations available.

The operating empty weights (OEWs) used here are estimates that provide a rough guide to each aircraft's typical gross payload. In reality OEW will vary by individual aircraft and is affected by factors, including engine variant and cabin configuration.

The number of seats installed in widebody passenger aircraft can vary widely, depending on configuration. Some airlines operate a dual-class cabin, while others may operate three- or even four-class configurations. Some airlines may utilise multiple seat configurations for the same aircraft type within the same fleet.

The typical seat capacity used in this analysis is based on the average number of seats used across the active fleet of each type. This will provide an idea of the current fleet's capabilities based on operational configurations.

Method

Each aircraft's gross payload has been calculated by subtracting estimated OEW from maximum zero fuel weight (MZFW). The net structural payload was then found by subtracting container tare weight from gross payload.

To establish the remaining payload available for belly freight, the weight of passengers and their baggage has been subtracted from net payload.

It is assumed that belly freight would not be loaded in the same ULDs as passenger baggage. If an A330-300 accommodates 32-LD3 containers in the belly hold, and about 19 are required for baggage, the remaining volume available for belly freight is therefore equivalent to 13 LD-3 containers.

The maximum packing density for belly freight is calculated by dividing the remaining available net payload by the remaining available volume.

The volumetric payload capacity of the remaining belly space has been calculated at a typical general freight packing density of 8lbs/cu ft.

To summarise the findings of this analysis, the various widebody types can be loosely grouped into three categories: medium, large and new widebodies.

Medium-widebodies

This group includes the 767-300ER, A330-200 and -300, A340-300, and the 777-200, 777-200ER and 777-200LR.

The 777-200LR has the highest structural payload remaining for belly freight among this group of aircraft at

The A380's higher average seat capacity and double deck configuration means it has less volume available for belly freight compared to other widebodies. This is because the additional passengers will lead to a larger number of hold bags that will use up most of the belly volume.

63,332lbs, but the A340-300 provides the most volume *(see table, page 56)*.

The A340-300 can hold 32-LD3 containers, the same as the A330-300, and the three 777-200 variants. Average seat capacity of active A340-300s is less than that for A330-300s and 777-200s, resulting in less baggage and more volume for freight on the A340-300.

There is 2,295 cu ft of volume available for belly freight on the A340-300 *(see table, page 56)* after deducting the relevant volume required for 263 passengers' hold baggage from the total belly volume of 4,896 cu ft.

The next highest volume is provided by the 777-200ER and 777-200LR at 2,142 cu ft *(see table, page 56)*.

At a typical general freight packing density of 8lbs/cu ft, the A340-300 offers the highest volumetric belly freight payload of 18,360lbs *(see table, page 56)*. The 777-200ER and -200LR offer the next highest volumetric payload of 17,136lbs *(see table, page 56)*.

The 777-200LR has the longest range of 7,700nm with a maximum payload in this group *(see table, page 56)*, followed by the 777-200ER and A340-300.

The 777-200 aircraft would offer the lowest structural payload for belly freight, while the A330-200 would provide the least volume.

All aircraft in this category could accommodate belly freight at packing densities up to 13lbs/cu ft, which should be satisfactory for the majority of cargo.

Large widebodies

Aircraft in this category include the A340-600, 777-300 and -300ER, 747-400, 747-8, and the A380.

The 747-8 and A380 would have the most structural payload remaining for belly freight. The 747-8 and A380 would each have 68,000lbs of structural payload remaining, which is equivalent to about 30 tonnes *(see table, page 56)*.

Despite their size, the 747-8 and A380 would not offer the most volume for belly freight. The 747-8F has a volumetric payload of 25,200lbs.

The 747-8 provides 60% more volume for belly freight than its predecessor the 747-400, partly because it is a longer aircraft and can hold six additional LD-1 containers. In addition, the active 747-8 fleet is operated with smaller average seat numbers than the average 747-400 configuration.

The A380 would provide the lowest volume for belly freight in this analysis. It only has a volume of 1,071 cu ft available for belly freight. The volumetric payload available for freight is, therefore, 8,568lbs *(see table, page 56)*. The A380's low belly freight volume is partly due to its higher average capacity.

It accommodates more passengers than any other widebody, so more belly volume is required for baggage.

The A340-600 and 777-300ER have 60,000lbs and 58,800lbs of available payload, equivalent to about 27 tonnes. The A340-600 and 777-300ER would each provide a belly freight volume of 3,366 cu ft, the highest of any aircraft in this analysis. At a packing density of 8lbs/cu ft, this translates into a volumetric payload of 26,928lbs *(see table, page 56)*.

The A340-600, 777-300ER and 747-8 would each be capable of carrying a maximum payload over a similar distance, with corresponding ranges of 5,700-5,900nm *(see table, page 56)*.

The 777-300 would offer the lowest structural payload for belly freight in this category. All of the aircraft in this category could accommodate belly freight at packing densities up to 13lbs/cu ft, which will cater for most cargo needs.

New widebodies

This category includes the 787 and A350 families. OEW data for the 787-10 and A350 variants were unavailable, so payloads could not be estimated.

Standard manufacturer seat capacities are used for the 787-10 and A350 variants, since no average operational seat configurations are available at this time. These are based on a three-class configuration for the 787-10, and a two-class cabin for the A350s.

Only the 787-8 and -9 are currently in active operation. The 787-9 offers the highest structural payload for belly freight at 38,105lbs *(see table, page 56)*. It also offers the most volume with 2,448 cu ft, more than any of the medium-widebody aircraft analysed here, and more than the 747-400 and A380.

At a packing density of 8lbs/cu ft, the 787-9 would have a volumetric payload of 19,584lbs for belly freight *(see table, page 56)*.

The 787-8 would have a volumetric

Dedicated freighters will still be required, despite a growth in passenger aircraft belly capacity. Freighters offer greater flexibility than belly freight on passenger flights in terms of routes, schedules and cargo type and size.

payload of 14,688lbs for belly freight.

The 787-10 and A350-1000 will offer the most lower deck volume in this category when they enter service. Based on standard manufacturer seat configurations, the A350-1000 would provide 3,060 cu ft of volume for belly freight, compared to 2,907 cu ft for the 787-10 *(see table, page 56)*.

The A350-1000 will accommodate 44 LD-3 containers, the same number as a 777-300ER, so an A350-1000 could offer more belly freight volume than a 777-300ER, if configured with fewer seats.

The A350-800 and 787-8 provide the smallest belly freight volume in the new widebody category.

Versus freighters

To offer perspective on the belly freight capabilities of modern widebody aircraft, their belly freight capacity and range performance can be compared to the total cargo capacity and range of dedicated freighters. A comparison with potential LCF aircraft is not included here.

The factory-built widebody freighters currently available include the 767-300ERF, the A330-200F, the 777-200F and the 747-8F *(see table, page 58)*.

Standard conversions are available for 767-300ERs, A330-200s and -300s and 747-400s *(see table, page 58)*.

The 777-300ER and A340-600 are the largest current providers of belly freight capacity. Based on the assumptions in this analysis, and a packing density of 8lbs/cu ft, the 777-300ER and A340-600 would need about four flights to carry the same volumetric payload as belly freight on passenger services as that provided by a single 767-300ERF flight.

It would take four to five passenger flights for an A340-600 or 777-300ER to shift the same volumetric payload as an A330-200F or A330-200/300P2F, and up to seven to match that of a 777-200F. This is the equivalent of a daily rotation over the course of a week.

Eight flights with either a 777-300ER or a A340-600 provide the same volumetric payload as a converted 747-400F. The 777-300ER and A340-600 would need 10 flights to match the capacity of a single 747-8F operation.

Range is one advantage that passenger-configured A340-600s and 777-300ERs have over factory-built freighters. The 777-300ER can operate up to 5,700nm_with a maximum payload, compared to a maximum range of 4,900nm for the 777-200F. This is because factory-built freighters are optimised for maximum payload rather than maximum range.

Belly freight revenue

Duke suggests that the recent increase in belly freight has led to a reduction in airfreight yields. "Airlines might carry cargo in the belly on passenger flights at 25% of the price of a dedicated freighter service," claims Duke. "They are filling space that would otherwise fly empty. With efficient handling processes, once the cost of incremental fuel has been covered, belly freight can make a positive contribution at low revenues."

"Some airlines treat belly freight as marginal revenue," explains Menen. This means they only look to cover any incremental costs incurred to accommodate belly freight.

"The costs associated with belly cargo include warehousing, handling and marketing, in addition to incremental fuel," adds Menen. "Not all carriers take these costs into consideration. The airline that quotes the lowest, sets the market rate.

"Belly freight capacity may be sold below cost on a particular route," says Menen. "In this case airlines would rely on better margins on other sectors to make up for this at a network level. Cargo can be the thin line between profit and loss for most passenger airlines."

Cargo volumes and yields can be higher in one direction on a route due to directional traffic imbalances. An example of this is Shanghai (SHA) to Frankfurt (FRA), with cargo volumes and yields likely to be higher on SHA-FRA, than on FRA-SHA.

Summary

The share of airfreight carried in the belly holds of passenger aircraft has increased in recent years. This trend has been influenced by the economic downturn and the additional belly capacity available on new widebody aircraft.

Airlines may be attracted to the lower unit costs of belly cargo, when compared to dedicated freighter operations.

Belly cargo also provides good interlining opportunities.

The main manufacturers disagree slightly in their outlook for future belly freight trends.

Airbus believes belly freight will grow to take a 56% share of the total airfreight market by 2033. Boeing forecasts that main deck freight will account for 56% of the market.

There is consensus that there will still be demand for dedicated freighter operations, which can offer more flexible service than belly cargo in terms of schedule, routes and outsized loads.

The A340-600 and 777-300ER would provide the most volume for belly freight based on the assumptions in this analysis. These aircraft could carry the same volumetric freight payload as a single 777-200F rotation in one week's worth of daily passenger flights. AC