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FREIGHTER FORECAST 2019-2038

FORECAST THE FUTURE

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TWENTY-YEAR
FREIGHTER AIRCRAFT FORECAST
2019-2038

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[1] Revisions include typos in table 1 and Freighter aircraft characteristics tables in Appendix 1.

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The restrictions noted above also apply to the accompanying interactive Freighter Forecast Analysis Tool and Passenger-to-Freighter Feedstock Analysis Tool.

Preparation of this freighter forecast benefits from the contributions of industry participants throughout the world. We welcome and appreciate comments, inquiries and information from readers of this report.

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1. Introduction and Forecast Summary

1.1 Introduction

Welcome to the 14th edition of the *Cargo Facts Consulting Twenty Year Freighter Forecast*. Since 1978, Cargo Facts Consulting (CFC), formerly also known as Air Cargo Management Group (ACMG), has been helping the global air cargo industry make better data-driven business decisions and investments. As the only comprehensive and independent freighter forecast, we hope that this report continues this tradition.

The information contained herein reflects fleet statistics and aircraft development plans announced through the first quarter of 2019. As in past editions of this report, coverage is provided of the jet freighter segment, consisting of aircraft types ranging from BAe 146 to the 747-8F (Section 2). Jet freighter fleet growth and composition is shown for three size categories: narrow-body, medium-capacity widebody and large-capacity widebody. In addition, our forecast report contains a section describing the current and future use of turboprop and small regional jet (feeder) freighters (Section 3). The scope of the feeder section has been substantially enhanced compared to last year and we trust this information will be more meaningful to the reader.

The forecasts start from the beginning of 2019, and show predicted changes through to the end of 2038, taking into account our assessment of new-build freighter production, passenger-to-freighter (P-to-F) conversion activity, and the retirement of freighters from the existing freighter fleet. The forecasts depict the future fleet evolution in five-year increments through the twenty-year forecast period. Also included is our prediction of the freighter fleet make-up in 2038 by aircraft type, for both the jet freighter and the feeder segments. There are a multitude of assumptions that go into the future fleet make up and we welcome your comments on this topic.

Both the jet freighter and feeder chapters provide a sensitivity analysis of the impact of changes in traffic growth, freighter productivity, and a shift from freighters to the belly compartments of passenger aircraft. As in prior editions, this report also contains an overview of the characteristics of the airlines that operate freighters (Section 4), and two Appendices providing a summary of principal attributes of aircraft expected to be the primary freighter models in operation through 2038, as well as a summary of each of the most popular freighter aircraft programs today.

In addition to the forecast, we have supplemented our report with an assessment of the airfreight demand environment (Section 5), and a special section on passenger-to-freighter feedstock (Section 6), the latter of which is new for the 2019 report. Many parts of the freighter market are in transition from older to newer generation types and much of this change is driven by suitable passenger aircraft available for conversion. As such, we believe a separate section on freighter feedstock is timely.

This report is supplemented with an optional *Freighter Forecast Tool* and *Feedstock Analysis Tool.* The Freighter Forecast Tool allows subscribers to conduct their own analysis on the impact of changes to key assumptions discussed in the report, while the Feedstock Analysis tool provides customizable detail on the development of passenger to freighter feedstock for different aircraft types. Both tools are hosted on the new Cargo Facts Consulting Insights platform (www.cfcinsights.com), which is being developed as a comprehensive data resource for the airfreight industry.

1.2 Forecast Summary

Over the next twenty years we forecast the addition of 2,380 jet freighters and 421 feeder aircraft to cater for both growth and retirements of older aircraft. During this period, we expect the world's jet freighter fleet to grow from 1,782 to 2,920 units, and the world's feeder fleet to grow from 239 to 431 units (Table 1).

Table 1 - 2019 - 2038 Freighter Forecast Key Numbers

	1Q-19 Fleet	Net Growth	Retired	Total Added	New	P to F	2038 Fleet
Feeders	239	192	229	421	90	331	431
Narrowbody	673	536	584	1120	0	1120	1209
Medium Widebody	544	342	338	680	340	340	886
Large Widebody	565	260	320	580	464	116	825
Total	2021	1330	1471	2801	894	1907	3351

Over the next 20 years, we expect to see the retirement of about 70% of the current jet freighter fleet and almost the entire feeder fleet. Roughly half of the new and converted aircraft added over the next 20 years will be to replace these retired aircraft and the other half to cater for freight market growth.

Factory-built freighters are forecast to make up 34% of aircraft additions in the jet freighter segment, albeit with large differences across individual categories. Forecast aircraft demand in the narrowbody segment is likely to be met entirely by conversions, whereas we expect the share of conversions in the medium- and large-widebody segments to be 50% and 20%, respectively. We foresee 21% of new additions in the feeder segment will be satisfied by production freighters.

The future fleet composition will depend on the choice of aircraft in each segment. While we have a view on which types are likely to feature in each segment, there are some major uncertainties in this regard:

- The future freighter options in the *narrowbody* jet segment are well-defined with feedstock constraints limiting future conversions of 737-300s/-400s and 757-200s. The future in this segment will belong to converted 737 NGs and A320 family. We assume that demand in this segment will be split more or less equally between the two, but initial order activity has been skewed towards the 737-800. The grounding of the 737 MAX in early 2019 makes short- to medium-term predictions in this segment somewhat difficult, however.

- While the *medium widebody* market has been very active of late, there are no new developments on the immediate horizon. The 25-year 767-300F program has no end-date, but feedstock will limit conversion numbers as the last 767-300 passenger aircraft was delivered in 2014. A330 conversions should be available throughout the forecast period, but no announcements have been made on new factory-built freighters in this category, such as the A330-900F or the 787-9F, as of early 2019.

- There is a great deal of uncertainty about the future aircraft choices in the *large widebody* segment. While the 777-200F program continues to be extremely successful, there has been no firm commitment from Boeing on how long the 747-8F will remain in production. This is worrying for the outsized cargo market. A 777-conversion program has been discussed for at least 10 years, but as of publication of this report, neither Boeing nor IAI have launched such a program.

- The *feeder* segment almost seems like a one-horse race, with the ATR 72 set to increase its dominance in this segment, with both converted and production freighters available to operators. Nevertheless, we see increased potential for Dash 8 and CRJ deliveries during the forecast period.

The forecast for freighter aircraft demand is sensitive to changes in traffic growth and other parameters. A half percentage point change in long-term traffic leads to a shift in the requirement for approximately 280 jet aircraft and 40 feeder aircraft.

Our forecast also assumes that the historical 50:50 freighter-passenger belly split will move towards a 42.5:57.5 split. If this does not happen, then this would lead to demand for an additional 300 medium and (particularly) large widebody aircraft.

Overall, we remain optimistic about the long-term prospects for growth of both air cargo demand and demand for freighter aircraft.

2. Jet Freighter Analysis

2.1 Recent Jet Freighter Developments

During 2018 we observed a net increase of 70 active freighters. A number of interesting and exciting developments have taken place in the jet freighter market during the past 12-18.

We focus first on the narrowbody segment, which includes the 737, 757 and A320/321 models. As noted below, the market for the 737-300/-400 and 757-200 freighters remains strong, as the shift to newer-generation freighter-converted 737-700/800 and A320/321 aircraft is beginning:

- Retirements of older generation types have been increasing. Approximately 26 older generation aircraft were retired from the narrowbody fleet last year – including a number of 737-300 and

737-400, for which there are still active conversion programs and redeliveries. We also saw withdrawal of the remaining three DC-8s and 707s.

- Even though feedstock for 737 Classic conversions will gradually decline over the next five years, it is not exhausted yet, particularly for the 737-300 variant. We count fifty-two 737-400s aged 21-25 years and approximately 201 737-300 passenger airframes in that age bracket.

- Twenty-six carriers currently operate about fifty 727Fs. The active life remaining on most of these units is limited. The oldest 727Fs in service are approaching 50 years of age. Although some operators may be looking to purchase second-hand 737 Classic freighters, converting additional 737 Classics could be an attractive option for those carriers seeking to modernize their 727 fleets.

- In March 2019, for example, ATSG-subsidiary PEMCO conversions completed the conversion of a 737-300F at its MRO facility in Tampa, FL. This aircraft was redelivered to Plane Business Leasing in April 2019 and it is now on lease to Colombian all-cargo carrier, LAS Cargo. This recently converted 737-300F is part of a fleet modernization strategy that aims to gradually replace the carrier's aging 727s.

- The first 737 NG freighter entered the global narrowbody fleet in 2017 when Alaska Air Cargo took redelivery of the first Israel-based Bedek Aviation Group-converted 737-700BDSF. As of the end of March 2019, a total of seven carriers operate 737 NG freighters: Alaska Airlines, West Atlantic Airlines, Air Algérie, SpiceJet, ASL Airlines Belgium, Ethiopian Airlines, and Atran Airlines.

- Aeronautical Engineers, Inc (AEI) received its STC for the 737-800SF in February 2019 and redelivered its first two units to Ethiopian in February and March, respectively.

- Bedek is expecting an STC for its 737-800 BDSF by June. Bedek has stated that two major MROs based in China will be converting 737 NGs on its behalf.

- Amazon has also started adding 737-800BCFs to its fleet. Amazon's first Prime Air narrowbody was converted at the STAECO facility in Jinan, China, in March 2019. These aircraft will be operated by Southern Air (which is owned by Atlas Air Worldwide Holdings) in North America, alongside Amazon Air's current fleet of 767Fs. The first 737 freighter joining Amazon's fleet will be leased from GECAS and the CMI agreement between Atlas and Amazon has a term of 10 years, with an option for three additional years. This situation will result in a continuous demand for 737 NG conversions.

- EFW and Precision Conversions, the joint venture between Precision Aircraft Solutions and ATSG, are expected to receive final certification for their A321 P-to-F conversion programs between 4Q 2019 and 1Q 2020, respectively. EFW is also expecting certification for its A320 program in 2020.

Redeliveries for the Airbus types should commence as soon as the programs receive certification, but the conversion rate will depend on feedstock availability and demand develop.

- So far, only Vallair has placed orders for A321 conversions, being the launch customer for both the EFW and 321 Precision programs, with orders of 10 and 1, respectively.

- At the time of writing the entire 737 MAX passenger fleet remain grounded. This is creating short to medium term delays in the introduction of 737 NG as well as 757 passenger aircraft for conversion to freighters and having a positive effect on the demand for aircraft such as the 737-300/400s and MD-80s.

- By February 2019, AEI had redelivered a total of 17 MD-80 conversions and is seeing stronger demand for an aircraft typically consigned a niche role.

Recent news on the widebody freighter market continue to show positive developments:

- China's fastest-growing express carrier, SF Express, has planned to grow its fleet to more than 100 in the next three years including more widebodies. These freighters will connect the airport in Ezhou, China, near Wuan to SF's regional hubs throughout the country.

- Atlas Air, which has a long-standing ACMI lease agreement with Qantas Freight for the operation of two 747-400 freighters, announced in April 2019 that the leased aircraft will be upgraded to two 747-8Fs. These aircraft will operate trans-Pacific routes connecting Australia, Asia and North America.

- FedEx has ordered 119 767-300Fs from Boeing, but with more than sixty of those still to come, another big order seems unlikely in the short term, while DHL has placed orders for eight freighter-converted A330-300s with EFW, and could potentially order more, although not on the scale of FedEx's 767 order.

- UPS' medium widebody fleet includes fifty-two A300-600Fs, two 767-300BCFs and sixty 767-300Fs. At least one 767-300BCF and nine 767-300Fs remain in Boeing's order backlog as of March 2019. As the A300-600Fs come up for replacement, additional medium widebody orders are likely to take place in the short term.

- Amazon is expanding the forty-unit 767F fleet used to support its US distribution network and will add ten more 767 converted freighters over the next two years from ATSG's leasing affiliate Cargo Aircraft Management (CAM).

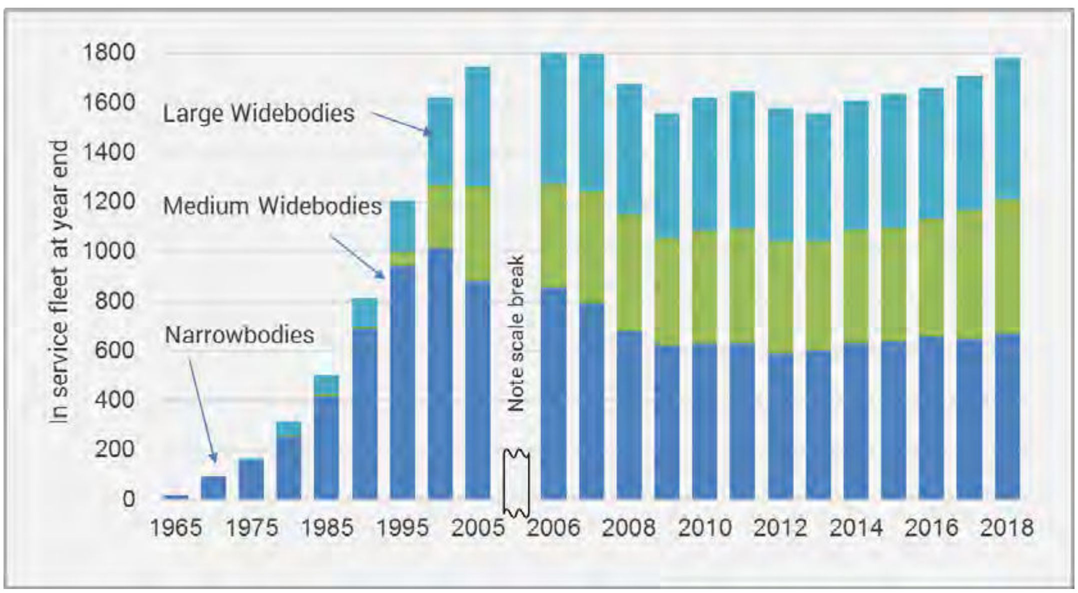
- As new aircraft are added in this segment, older types such as the A300B4, A310s, DC-10-10s and 767-200s are starting to disappear. Four 767-200s were removed from active service last year.

2.2 Jet Freighter Market Overview and Fleet Evolution

The freighter aircraft market has undergone a period of significant change since 2000. That year marked the end of a period of predicable growth in demand which had resulted in steady expansion of the global jet freighter fleet. At the same time, a major shift in freighter types was taking place as early generation jet freighters reached retirement age, and the US express industry entered a slow-growth, mature phase.

Air freight demand has been volatile since 2000, with declining year-over-year demand in five of the past eighteen years. Figure 1 shows how the global fleet of jet freighters has developed over the past fifty years. The fleet tripled in size during the 1970s, grew by a factor of 2.5 in the 1980s, and doubled during the 1990s to reach a global total of about 1,600 units by 2000. Freighter fleet growth continued thereafter, but at a significantly slower pace, with only a 15% increase in quantity in the six-year period from the end of 2000 through the end of 2006. The fleet reached a peak of 1,800 units in 2006, and remained at this level through 2007. At this point the freighter fleet registered its first-ever decline. Due in part to the weak global economy, including the 2008/09 recession, the number of freighters declined 13% to 1,560 units by the end of 2009. Later, during the economic recovery of 2010/11, the fleet grew by a small amount to reach 1,646 units at the end of 2011.

Figure 1 - Jet Freighter Fleet Evolution 1965 - 2018



The weak air freight market conditions beginning in mid-2010, coupled with more space in the freight-friendly belly compartments of a growing fleet of widebody passenger aircraft, led to a decline of about 100 units in the freighter fleet size to a total of 1,558 in 2013. The modest growth in demand starting in mid-2013 led to a small increase in the freighter fleet total to 1,609 units of all sizes as we entered 2015. Subsequent small increases resulted in fleet totals of 1,636 jet freighters entering 2016, 1,658 entering 2017 and 1,709 entering 2018. In 2019, the total jet freighter count showed 1,782 units.

Much of the post-peak reduction in the quantity of jet freighters from 2006/07 took place in the narrowbody segment of the jet fleet, where large quantities of formerly-popular first-generation freighters – 727-100Fs/-200Fs, DC-9Fs, DC-8Fs and 707Fs – were retired. This was only partially offset by additions in this market segment of passenger-to-freighter converted 737-300Fs/-400Fs and 757-200Fs. This resulted in nearly a 40% decline in the number of narrowbody freighters from 2000 to 2010. The quantity of narrowbody freighters rose in 2013 to 2016, but remained flat in 2017. The fleet grew from 652 units in 2018 to a total of 673 entering 2019, or about 3% higher. It is important to point out that in 2000, more than 62% of all jet freighters were narrowbody types. Today, the narrowbody share is just 38%.

Historically about half of the global air freight tonnage has moved in freighter aircraft, while the other half has moved in the lower deck belly compartments of passenger aircraft. Individually, freighters have more space for freight, but the in-service fleet of passenger jets outnumber freighters by roughly a ten-to-one margin. An increasing reliance on belly space is putting downward pressure on the demand for freighters, especially large-capacity widebody types. Some combination carriers such as Air France/ KLM Group have substantially reduced the size of their freighter fleets in recent year. On the other hand, we find that dramatic expansion in e-commerce is stimulating demand for rapid delivery in developed countries and in some emerging markets, most notably China. This shift in transportation requirements on a regional level has given a boost to demand for narrowbody as well as medium widebody freighters.

The robust activity in freighter conversion of narrowbody types from 2012 through 2018 led to an increase in the quantity of narrowbody freighters in the global fleet. This increase reversed the trend noted above that began in 2000 through which the narrowbody freighter fleet decreased about 40% over a decade-long period. In 2017, the narrowbody fleet total was down slightly from the previous year, despite a continuing high level of conversion activity for 737 Classics and 757-200s, plus growing demand for converted MD-80s and the first delivery of converted 737NGs. However, we note that the number of narrowbody aircraft grew by 21 units in 2018. This is in part due to the increasing redeliveries of 737 NGs, which got off to a fairly slow start in late 2017 but have been taking off in the past months.

The use of widebody freighters expanded significantly through 2007. The first widebody freighter types were large capacity models typified by the 747, but from 1995 through 2006 the greatest increase in the freighter fleet came through the application of medium-sized widebody models, specifically A300s and 767s. During the 2000-2010 period the number of widebody freighters increased from roughly 600 to 1,000. Accordingly, the distribution of the fleet between narrowbody and widebody types reversed to about 60:40 in favor of widebodies by 2010. The quantity of freighters in both the medium- and large widebody categories was about the same at the end of 2016 as it had been at the end of 2008, although a significant portion of older freighters had been replaced by newer units during the intervening years. During 2018 the widebody (medium and large) total count grew 52 units to a total of 1,109, about 5% higher than the prior peak of 1,057 in 2017. Among the widebody freighters, the current fleet consists of 565 large- and 544 medium-capacity units.

The widebody freighter market, where production freighter options exist alongside P-to-F conversions, has shown remarkable consistency in recent years, with a fleet-wide total for medium and large models, combined, stable at roughly 1,000 from 2010-though-2016. This segment grew to 1,057 in 2017 and the past year saw a boost of 5% to 1,109 units, to a level 9% above the prior peak in 2011.

The relative stability in the widebody freighter market has been a direct result of continuing deliveries in recent years of factory-built medium-capacity 767-300Fs and A330-200Fs, plus large-capacity 777Fs and 747-8Fs. The production freighter deliveries have been augmented recently by continuing strong demand for converted 767-300s, and for 2017 by the first deliveries of converted A330-300s. However, demand for additional P-to-F conversions of large-capacity widebodies remained nearly non-existent in 2018. Contraction of the narrowbody freighter fleet until recently, coupled with increasing use of widebody types, means that the widebody share of the global jet freighter fleet has been rising. Today 62% of the jet freighter fleet is comprised of widebody aircraft, consistent with the share in recent years, but up significantly from just a 50% widebody share as recently as 2006.

In addition to the trend of increasing use of widebody freighters, there has been a trend toward greater reliance on "modern" aircraft used in a freighter role. Nearly 90% of the freighters in current use are "newer" types including 737-300s/-400s, 757-200s, A300-600s A330-200s, 767-200s/-300s, MD-11s, 777s, 747-400s and 747-8s. Meanwhile, a high percentage of "older generation" freighters (727s, 707s, DC-9s, DC-8s, A300B4s, DC-10s and 747 Classics) have been retired permanently. Since 2012 even newer widebody freighters (747-400s and MD-11s) have been withdrawn in significant numbers.

The "newer" jet models noted above will be applied in increasing quantities based on active freighter conversion programs for numerous narrowbody and widebody models, and continuing production of widebody 767-300Fs, 777Fs and 747-8Fs (but perhaps not the A330-200F, a model that has seen limited market acceptance). Looking ahead, there are active programs and others under development for passenger-to-freighter (P-to-F) conversion of the "next generation" 737-700/-800, and A320/321 models, and the market for P-to-F of conversion of the A330 (in particular the -300 model) is gaining momentum. Separately, there is limited interest in a P-to-F program for the 777.

Under the baseline scenario presented in this report, 66% of the 2038 jet freighters produced through 2038 are forecast to be converted units, versus 34% that will be new-build production aircraft. The new-build units will be concentrated at the top end of the market, as nearly 60% of these will be in the large-widebody freighter market segment. In fact, in this large-capacity segment we predict almost 80% of the added freighters will be new production aircraft, as contrasted with the narrowbody freighter market in which we forecast that all units added over the next twenty years will be P-to-F conversions. Table 2 in Section 2.3 shows the details for each size category.

Modest growth in the quantity of freighters in the global fleet in recent years masks the fact that since the start of 2011 Boeing and Airbus together have delivered over 300 new widebody freighters. There has been robust activity in freighter conversion of narrowbody types, although in recent years there has been a weak market for large widebody freighter conversions. The overall jet freighter fleet size has grown less than 15% since 2009, as additions have been mostly offset by retirements in the post-recession period.

2.3 Current Baseline Jet Freighter Fleet

Table 2 shows the composition of the jet freighter fleet entering 2019, based on our three-category size segmentation. The fleet of freighter aircraft is comprised of a wide variety of narrowbody and widebody types. This fleet, which forms the point of departure for our twenty-year freighter forecasts presented later in this report, contains a mix of older technology models nearing retirement and newer, modern aircraft with a long useful life remaining. Note that while we include the Tu-204 in our narrowbody count, we exclude the IL-76TD, IL-96T and A-124 in our widebody counts. We also do not include military freighter aircraft.

Table 2 - Current Jet Freighter Fleet, 1Q 2019

Narrowbody	Medium Widebody	Large Widebody
< 85,000 lbs (< 40 tonnes)	*85,000 – 180,000 lbs (40 - 80 tonnes)*	*> 180,000 lbs (> 80 tonnes)*
673 Total Units	**544 Total Units**	**565 Total Units**
7 BAe 146	9 A310-200/-300	16 DC-10-30/-40
21 DC-9, 6 MD-80	10 A300B4	117 MD-11
12 B737-200	171 A300-600	152 B777
43 B727-100/-200	41 A330F & P2F	45 747-400SF/BCF
125 737-300, 135 737-400	56 B767-200	152 B747-400F/ERF
4 B737-700, 9 B737-800	237 767-300	83 B747-8
4 TU-204C	20 DC-10-10	
307 757-200		

It is worth noting the following features of the current freighter fleet:

- If we include the 737-300/-400, 757-200, 767-200/-300, MD-11, 747-400 and A300-600 types in the "modern" category (along with the current crop of production freighters), we find that 92% of the total freighter fleet is now comprised of such newer technology aircraft. Twelve years ago (early 2007), less than half of the freighter fleet consisted of such modern freighter types, indicating a rapid shift in fleet composition.

- Nearly 30% of the baseline widebody fleet consists of the freighters currently in production by Boeing (767 300F, 777F and 747 8F) and Airbus (A330-200F).

- The number of old technology freighters has diminished significantly in recent years, as many of the older, less-efficient aircraft were taken out of service as air freight demand contracted during the recession in 2009 or in the less than robust market of 2011-through-2016. Most of the withdrawn units will never be reactivated. Even lower fuel prices in 2015 through 2017, and significantly improved air cargo demand from mid-2016 to early 2019 did not lead to any major re-activation of parked units.

- As noted previously, we have also seen a rapid shift to widebody freighter models. The combined share of the total freighter fleet comprised of widebody types (medium- and large-capacity models) is now 62%, a relatively steady level since 2008, but up from just 38% in 2000.

There is no question that the freighter aircraft market has undergone a period of significant change since 2000, and the changes have had a significant impact on both the narrowbody and widebody segments. Three primary factors led to the post-2000 reduction in the global freighter fleet and the shift in fleet composition:

1. Early-generation freighters reached retirement age,
2. The US express industry reached maturity and underwent consolidation,
3. Global air freight demand endured a period of unprecedented volatility and low overall growth.

Regarding the first factor above, it is important to recall from earlier comments that the majority of the freighters in use through the late 1990s were 707s, 727s, DC-8s and DC-9s, all of which are narrowbody types. This fact clearly contributed to the significant decline in the quantity of narrowbody freighters after 2000, as retirement of these formerly-popular first-generation freighters was only partially offset by additions in this market segment of passenger-to-freighter converted 737 300Fs/ 400Fs and 757 200Fs.

Regarding the second factor above, we note that since 2010 the US express market has essentially been a duopoly consisting of just FedEx and UPS. Since 2000 the number of participants in this market has dropped from seven to just two, and those two have expanded their widebody fleets. As a result, the number of narrowbody freighters operated by US express carriers has declined to just 194 (all 757-200Fs) today, from 557 in 2000 when FedEx alone had 162 narrowbody freighters (all 727Fs).

Regarding the third factor above it is important to note that until 2004 the average annual air cargo market growth rates were above 6%. Most forecasters assumed that level of growth would continue, but the last two decades have been very different. Over the period from 2000-through-2018 average annual growth in air freight demand has been roughly 3% per year, about half the prior long-term rate.

Not surprisingly, this situation has had a negative impact on the demand for freighters, with the quantity of freighters in the last decade remaining down from the 2007 peak but slowly approaching this level. It should be noted that the shift to a higher concentration of widebody freighters since 2000 means that the capacity of the freighter fleet actually increased during this period, but capacity has been nearly stagnant since 2010.

2.4 Jet Freighter Forecasts through 2038

2.4.1 Jet Freighter Forecast Assumptions

We continually track air freight industry developments and use this information to produce forecasts of the future demand for jet freighter aircraft. This report contains a baseline forecast which includes our latest assessment of future trends, along with sensitivity analyses showing how the results would change based on different assumptions regarding several key variables.

Overall results are presented in five-year increments over the twenty-year forecast period, showing the predicted growth of the jet freighter fleet in three size categories – narrowbody, medium widebody and large widebody. We also venture a prediction of the freighter fleet make-up in 2038 by aircraft type, taking into account new-build freighter production, passenger-to-freighter (P-to-F) conversion activity, and the retirement of freighters from the existing freighter fleet.

Regarding retirements, we recognize that freighter aircraft types typically have useful economic lives in excess of thirty years, with small freighters applied in low-utilization regional express networks often remaining in service over forty years. On average, we predict the retirement of approximately 62 jet freighters per year. Over the next twenty years more than 1,200 freighters from the current fleet (over 70% of those now in operation) will be retired.

Weak market conditions resulted in the parking of a significant quantity of otherwise serviceable jet freighters beginning in the last half of 2012. Early in 2018 we noted that roughly fifty 747-400 freighters and fifty MD-11 freighters are parked. Fueled by strong cargo demand in 2017, about 21 previously parked MD-11F, 747-400 ERF, 747-400BCF/BDSF and even A300B4 were returned to service in 2018. However, given the weaker near-term outlook we do not believe that any more parked freighters will be reactivated.

In developing our predictions, we adopt a top-down forecasting method. We begin by establishing a baseline level of freight-tonne-kilometres (FTKs) for the total group of freighters within each size category in the base year. We then determine the number of FTKs required at the end of each five-year period based on three important input variables:

- future growth in air freight demand
- assumed shifts in freighter productivity
- changes in the ratio of freighter-to-belly use

This approach allows us to determine the required jet freighter fleet quantity in each of the three size groups at the end of each five-year period.

We then take into account the specific freighter models that will be available during the forecast period and make a detailed prediction of the make-up of the fleet by aircraft type. As noted previously, we account for additions to the freighter fleet (new production deliveries and added P-to-F conversions), along with reductions in the fleet (from retirements), to meet the needed FTK growth for the period.

The target growth can be met by a variety of combinations of additions and retirements of specific jet freighter types, so the final results reflect our best judgment about the relative popularity of the competing models.

Our baseline assumptions are as follows:

- 4.0% annual growth in air freight demand (unchanged from our 4.0% baseline rate last year)
- 1.0% annual increase in freighter productivity (unchanged from our baseline last year)
- A 7.5 percentage point shift (to a higher belly share) over 20 years in the fleet-wide freighter-to-belly use ratio (same as the baseline assumption we used last year)

A further explanation of the reasoning behind a 4% traffic growth rate can be found under Section 5.2 of this report. Our assumption of 4% growth in air freight traffic has remained unchanged since 2016. As recently as 2008, we were still assuming 6% per year, but revised these growth rates downward in subsequent years, declining to 5.0% in 2011, 4.5% in 2015, and 4.3% in 2016.

Our forecast takes into account expected enhancements in freighter productivity due to increasing freighter size, and incremental increases in freighter load factor (percent of cargo capacity used per flight) and utilization rate (hours flown per year per freighter). Increasing productivity means that on average each freighter in the future fleet will do more work than a freighter in the current fleet, a factor which reduces the number of additional freighters need over the forecast period. Our baseline forecast accounts for a 1% annual improvement in freighter productivity, mainly due to higher load factors and increased aircraft utilization. We do not see any major increase in the size of the average freighter moving forward. On a compound basis over 20 years this factor reduces the number of freighters needed by roughly 18%.

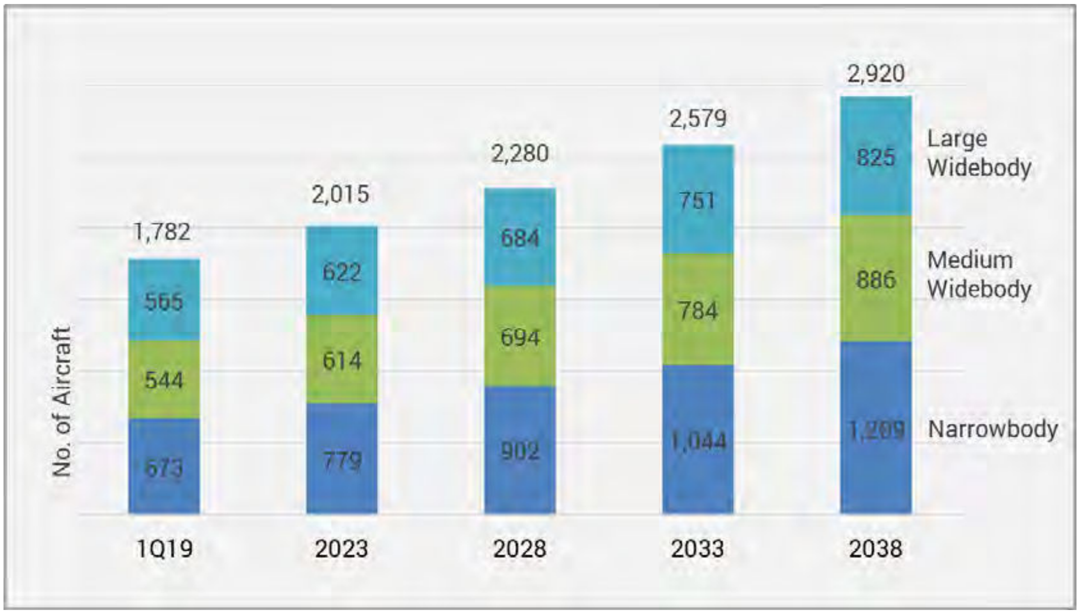
About 50% of freight is moved by freighters. Until 2010 this figure was around 60%, but has been declining since. Our baseline assumes the current roughly 50:50 ratio of freighter use to belly-space use will shift over the next twenty years to a 42.5:57.5 ratio in favor of belly use. In other words, in 2038, 57.5% of the freight will be carried in passenger aircraft bellies, down from a 50% share to-day, due in part to the large number of freight-friendly widebody passenger aircraft due for delivery in the coming years. 777s, 787s and A350s, in particular have significantly larger belly compartments than the aircraft types they are replacing. Passenger growth is forecast to outpace air cargo growth, which will impact the available belly space and facilitate a shift.

Most of the impact of the growing belly space will be felt in the large widebody freighter segment, where the majority of the freighters are used by combination and all-cargo airlines to carry general freight. The impact will be much less noticeable in the medium widebody freighter segment, where express industry use of such aircraft dominates, and it will be of little consequence in the narrowbody segment, where the routes flown have little competition from widebody passenger aircraft. The presumed shift to a greater dependence on belly freight decreases the growth of the jet freighter fleet reflected in our baseline forecast.

2.4.2 Baseline Jet Freighter Forecast

Over the next 20 years we expect the world’s jet freighter fleet to grow by about 65%, from 1,782 units today to 2,920 units at the end of 2038 (Figure 2).

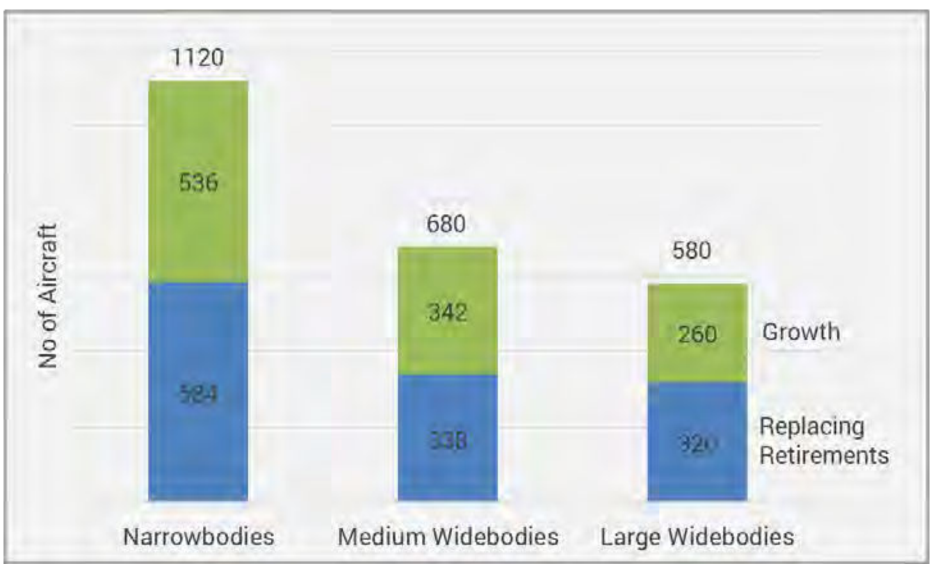
Figure 2 - Baseline Jet Freighter Fleet Forecast 2019 - 2038



The portion of freighters in the narrowbody size category is forecast to grow by nearly 3% through 2038, to about 41% of the total.

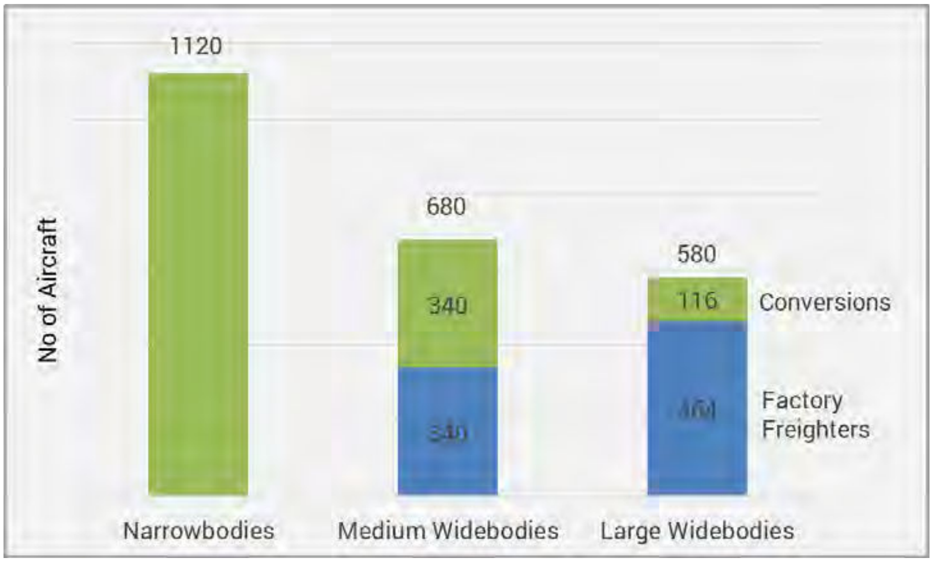
The net growth in fleet size is 1,138 (of all sizes), which when combined with 1,242 retirements, produces the overall need for 2,380 freighters through 2038. This total fleet requirement equates to an average of 119 units per year. Figure 3 shows the details of the new and replacement aircraft added for each size category through 2038.

Figure 3 - New and Replacement Jet Freighters Added 2019 - 2038



The added freighters will consist of 804 production freighters (34% of the total) and 1,576 P-to-F conversions, or 66% of the total fleet (Figure 4).

Figure 4 - New and Converted Jet Freighters Added 2019 - 2038



Nearly 60% of the production freighters will be large widebody types, and the share of production freighters added in the large widebody segment will be approximately 80%. The operator mix, cargo densities, utilization and unit cost requirements in this segment favor production freighters. Given the lack of active production programs, an abundance of P-to-F feedstock and low aircraft utilization, we do not foresee any production freighter deliveries in the narrowbody segment.

2.4.3 Future Jet Freighter Fleet Composition

The forecast reflects our assessment of manufacturers' future product strategies to determine which specific aircraft types will be offered as jet freighters over the next twenty years. Some models shown in our forecast may not become available in freighter configuration, while some that we do not show may be introduced. To the extent that such circumstances develop, it is important for readers of this report to recognize that the availability or non-availability of any particular model will not affect the overall demand for freighter aircraft. Overall demand is a zero-sum game, meaning that other models will fill the gap.

The main types of aircraft in each size category that will be involved in the future evolution of the jet freighter fleet over the next twenty years can be broken down into four sub-groups. As shown below (Table 3), three of these groups contain aircraft currently in service, but with varying outlooks for future use, while the fourth group contains aircraft under development for later entry into freighter service. This group, called "Future aircraft" also includes models expected to play a significant future freighter role. The aircraft types include both production freighters and passenger-to-freighter (P-to-F) conversions.

Note that within the Future aircraft section at the bottom of the chart the situation is well defined in the narrowbody category, where development of freighter conversions of A320s/321s is at or near the point of certification and entry into service. On the other hand, the development of freighter programs for other models, including the 737-900, 787, A330-900F, 777X and A350, is further off and much less certain. The same comment applies to any P-to-F program for the current generation 777. Nevertheless, we feel that a 777 conversion program and an A330-900F are realistic within the next five years, and 787 and A350 freighter programs within the next 10 years.

Table 3 - Jet Freighter Aircraft Available to Operators

	Narrowbodies	Medium Widebodies	Large Widebodies
Facing near-term extinction	DC-9, DC-8, 707, 727, Bae 146, 737-200	DC/MD10-10, A300B4, A310	747F Classic, DC-10-30F/40F
At peak use, or with little future growth potential	MD-80, 737-300	767-200, A300-600, A330-200F	747-400F/ERF, 747-400SF/BCF, MD-11F
Expanding role going forward	737-400, 757-200, 737-700/800	767-300F/SF/BCF, A330(P2F)	777F, 747-8F
Future aircraft	757-300, A320/321, 737-900	787-9F, A330-900F	777-200ER/300ER P2F, A350 F/P2F, 777XF

In assessing the likelihood of P-to-F conversions, we consider the number of aircraft of a particular type that were produced in passenger configuration and the period of time over which production took place. That explains, for example, why the 767-300ER (with over 500 built, mostly over sixteen years from 1988 through 2004) will be popular for future P-to-F conversion, while the A300-600 (with fewer than 200 built, mostly over twelve years from 1984 through 1996) will see no further conversion activity.

Also important in assessing P-to-F opportunities is understanding that most conversions are done on aircraft 16-to-20 years old. In the 767-300ER and A300-600 examples cited here, this leads to the conclusion that the “prime window of conversion” for the A300-600 started around 2005 but is at an end, while the prime conversion window for the 767-300ER began more recently and will extend beyond 2025. Section 6 provides further examination of the quantities in the feedstock pool for various freighter conversion candidates.

Bearing the above in min Table 4 provides details of our estimated composition of the baseline fleet on a model-by-model basis twenty years (2038) in the future.

Table 4 - 2038 Baseline Jet Freighter Fleet

Narrowbody *< 40 tonnes*	Medium Widebody *40 - 80 tonnes*	Large Widebody *> 80 tonnes*
1209 Total Units	**886 Total Units**	**825 Total Units**
11 MD-80	37 A300-600	566 777
20 737-300/400	426 A330	20 747-400
527 737-700/800	348 767-300	113 747-8
465 320/321	75 787	126 A350
186 757-200		

Note the dominance of the following types: 737NGs and A320s/321s in the narrowbody segment; A330s and 767-300s in the medium widebody segment; and 777s plus significant roles for 747-8s and A350s in the large widebody segment.

Based on our prediction, there will be less nose door capable aircraft operating in the large widebody fleet in 2038 than today – 133 vs 235. This will have fundamental implications for the outsized cargo market.

2.4.4 Jet Freighter Sensitivity Analyses

Our analysis technique allows us to determine the impact on freighter requirements given various assumed levels of demand growth, changes in freighter productivity, and shifts in the ratio of freighter-to-belly use. Small changes in assumptions can have large impacts in terms of fleet requirements.

Figure 5 shows the significance of underlying growth as a determinant of jet freighter flee size. A demand shift of half a percentage point results in roughly a 10% change – 270-290 planes – in the size of the freighter fleet in 2038.

Figure 5 - Demand Growth Impact on 2038 Jet Freighter Fleet Forecast

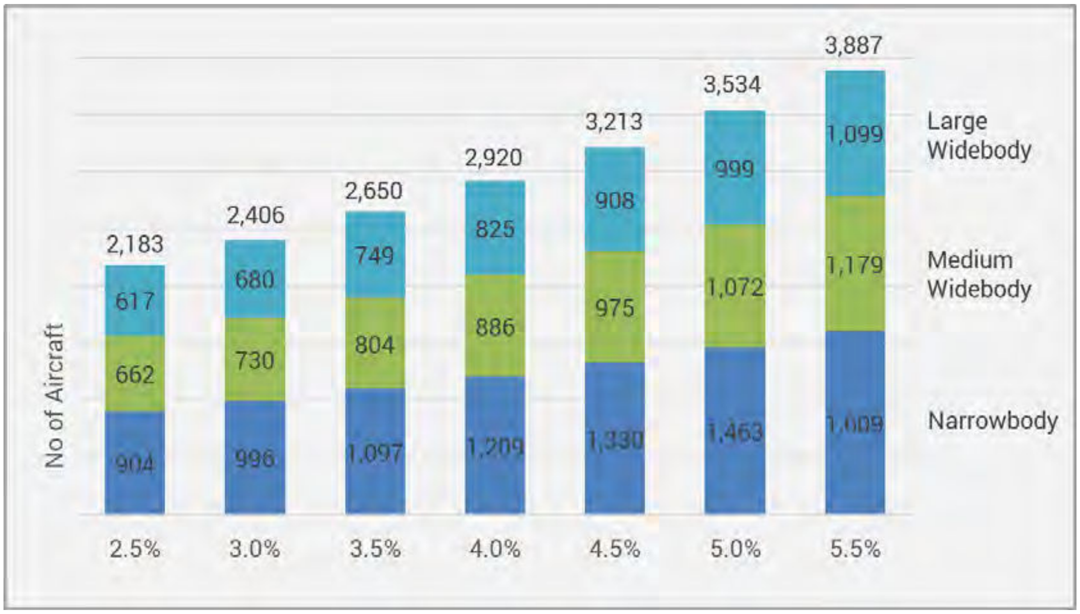
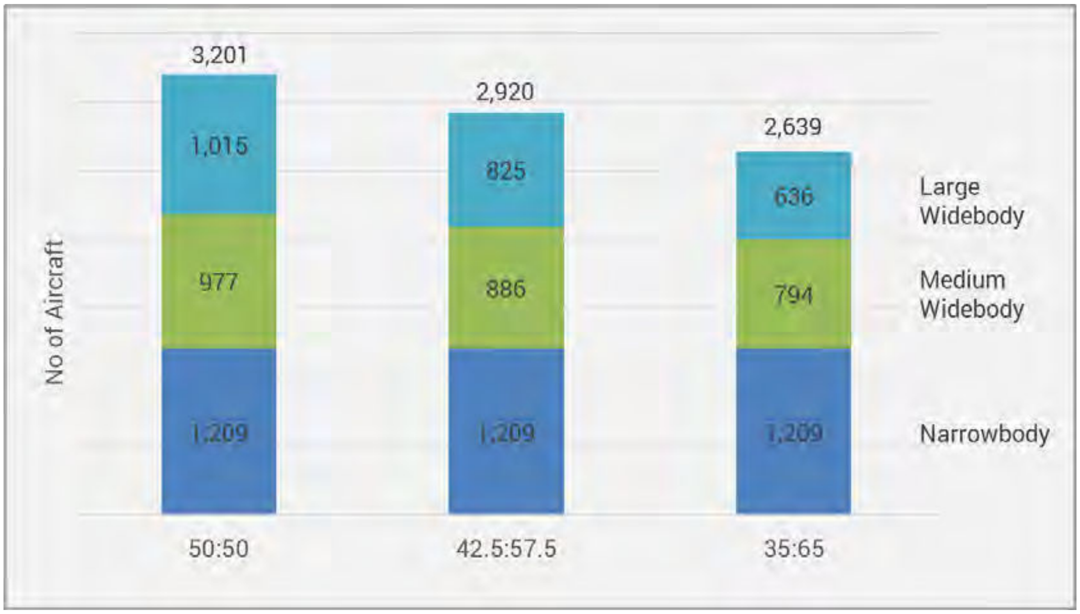


Figure 6 shows the significance of assumed shifts in freighter productivity. A 0.5 percentage point change in productivity results in roughly a 10% change – about 270 planes – in the size of the freighter fleet in 2038.

Figure 6 - Productivity Growth Impact on 2038 Jet Freighter Fleet Forecast

Figure 7 shows the significance of changes in the freighter-belly ratio. Here the middle bar depicts the baseline case, which assumes a decline in the freighter share from 50% today to 42.5% in 2038. Meanwhile, the left-hand bar reflects a continuation over twenty years of the current 50:50 ratio (i.e. no shift to greater belly use), and the right-hand bar reflects a shift twice as great as the baseline (i.e. a shift to 35% freighters and 65% bellies in 2038).

Figure 7 - Freighter Belly Ratio Changes Impact on 2038 Freighter Fleet Forecast



With no further shift from freighters to the bellies of passenger aircraft, 300 additional planes would be required, primarily to the benefit of the large widebody segment.

3. Turboprop/Regional Jet (Feeder) Freighter Analysis

3.1 Turboprop/RJ (Feeder) Freighter Market Overview

This is the third year that we have included a section on the turboprop/ regional jet (or feeder) segment in our annual 20-year forecast. Compared to last year's edition we have made some changes to the scope of this section to provide a more meaningful picture and outlook of this diverse segment. While there are a wide range of both turboprop and regional jet freighter aircraft, we have placed a lower limit of approximately 8500 lbs (3.8 tonnes) and an upper limit at roughly 20,000 lbs (9 tonnes). In volume terms, this means between 1000 ft^3 (or $30m^3$) and 3000 ft^3 ($80m^3$). In seat terms, between 40 and 100 seats. Further criteria include:

- Aircraft with a large cargo door
- Aircraft available in containerized or palletized configuration, or
- Likely to be replaced by one of the above following retirement

Specifically, we have focused on ATR 42/72 variants, Dash-8 variants, ATPs and HS 748s, F27s and F50s, CV 580s, as well as AN-26/32, AN-74 and Saab 340s.

Of these, the ATRs, Dash 8s and Saabs are of continuing interest because they remain in production and/or have active freighter conversion programs. However, it should be noted that the feedstock for the Saab 340 conversion program is quickly aging past the optimal conversion range of 16-20 years old. The remaining aircraft are older types for which retirements will see the fleet totals decline going forward.

Along with the addition of the Saab 340 to this year's Freighter Forecast, we have included the aging fleet of Antonov AN-26/32s, all of which are likely to be replaced by ATRs or Dash 8s at some point. We have also added the AN72/74 due to its size and volume characteristics. While there is a small fleet of AN72/74 in operation, we found evidence that only two flew regularly in 2018.

Our research indicates that in addition to the 239 feeders in our baseline fleet (see Table 5), there are roughly 1,200 smaller turboprop or piston engine freighters in use globally. The freighter group below the 40-seat limit consists of a diverse assortment of aircraft types, including Cessna Caravans, Beech 1900s, Metro IIIs, L-410 Turbolets, and Shorts 330s/360s, among others. Such aircraft include a mix of single-engine and twin-engine models, some pressurized, some not. In addition to their freighter applications, many aircraft in this group see use in multiple roles in both commercial airline operations and in the general aviation sector.

While we do not consider these aircraft in this report, a development worth noting in the below 40-seat segment was the 2017 launch by Textron Aviation of the new Cessna 408, including the SkyCourier freighter model. The SkyCourier is a twin-turbo design with about twice the capacity of the Cessna 208 Caravan (the passenger version has 19 seats). FedEx placed a launch order for 50 (plus options for 50 more) of the new freighters, with first delivery in 2021.

The L-100 Hercules has been excluded from the 2019 Freighter Forecast, although was included previous years. The Hercules is a special case, it is by far the largest model in the turboprop category, and it is the only one derived from a military model, the C-130, which has been in production since 1954. In the period from 1964 to 1992 Lockheed built about 125 L-100s, which were C-130s outfitted for commercial use. Only about 5% of these remain in commercial service and are rapidly nearing the end of their useful lives. Seizing on what it views as a renewed opportunity, Lockheed developed a new commercial L-100 model, designated the LM-100J, with deliveries supposed to begin during the first half of 2019. It is unlikely to be a big seller but will serve a unique role in the commercial market given its ability to carry outsized loads and operate from unprepared fields. The LM-100J could also be a potential replacement for the 40+ Russian built AN-12 scattered around the world and which have an average age of over 50 years.

An interesting characteristic of the freighters shown in the feeder jet portion of the forecast presented below is that they are in a transition zone between smaller bulk-loaded freighters and larger-capacity models that are equipped with large cargo doors, and without exception use some form of cargo loading system (CLS), sometimes with power-assist, to move palletized or containerized cargo on the freighter’s main deck. CLS’s are also used in the lower-deck cargo holds on widebody aircraft (passenger models and freighters).

The turboprop and regional jet freighters under consideration in this report are small enough that some operators will choose to forego the expense of installing a large main deck cargo door and cargo loading system in favor of bulk-loading the aircraft. The prime example is FedEx, which operates the world's largest fleet of ATR 42 and 72 freighters. None of the FedEx ATRs have a large cargo door, and all are bulk-loaded. In some unique cases, aircraft that have been equipped with large cargo doors, such as the CV580s operated by KF Cargo in Canada, are bulk loaded rather than containerized. This is done to maximize cubic space, at the expense of efficient loading. This can work well in a hub-and-spoke operation, but less so on multiple stop routings, where short turnaround times are important.

The main reason that large doors and CLS's have not been commonly incorporated in feeder freighters is the four-abreast fuselage widths in many of the turboprop and regional jet models. The narrow fuselage precludes the use of unit load devices (pallets and containers) compatible with narrowbody and widebody jet freighters. Lacking the ability to use industry-standard ULDs, and to interline directly with larger freighters, significantly diminishes the utility gained by equipping the smaller freighters with large doors and loading systems.

However, we note that in 2017 FedEx committed to acquire up to 50 newly produced ATR 72-600 freighters with large cargo doors and the ability to accommodate up to seven containers. We also note that the new Cessna 408 twin-turbo freighters FedEx is purchasing have the capability to carry LD-3 containers. Also, the Aeronautical Engineers, Inc, has certified a CRJ200 freighter conversion program that includes a large door and a CLS supporting the loading of palletized or containerized cargo as the standard configuration.

3.2 Recent Turboprop/RJ (Feeder) Freighter Developments

The turboprop/regional jet freighter market has not grown much in recent years, but is getting a boost from new program activity related to the ATR 42/72, Bombardier CRJ200, and Bombardier Dash 8 aircraft models.

- A major development for freighter application of the ATR 72 took place in late in 2017 when FedEx announced plans to acquire factory-built ATR 72-600s in freighter configuration. The express company placed a firm order for 30 units (plus options for 20 more) for delivery beginning in 2021. These ATR freighters will incorporate Large Cargo Door and Structural Tube Modifications from IPR (noted above).

- The Bombardier Dash 8 series has not seen nearly as much freighter application as the ATR 42/72 with which it competes in the passenger market. However, there continue to be conversion programs for combi or freighter applications of the Dash 8-Q300 and -Q400 models, most of which use the standard rear baggage door. A new large-door conversion for the Dash 8-Q300 is offered by Rockwell Collins (teamed with Air Inuit and Bombardier). That program will offer bulk-load and palletized cargo variants. Separately, Canada-based Voyageur Aviation in early 2017 rolled out the first freighter-converted Dash 8-100PF, with bulk loading of packages through the original aft door.

- Aeronautical Engineers, Inc. (AEI) received FAA certification late in 2016 for its CRJ200 large-door freighter conversion program, and delivered eleven through the end of 2018. The program was developed in conjunction with Bombardier, the CRJ OEM. The converted CRJ200 can carry eight pallets/containers with base dimensions of 88-inch x 61.5-inch, half the size of an industry standard ULD (unit load device). So far AEI has redelivered 10 units.

- In 2016, Swedish based, Täby Air Maintenance (TAM) received EASA and FAA certification for their Saab 340 conversion program. The conversion service will also be offered in the US in a joint venture with Kansas City-headquartered Jet Midwest. As mentioned later, in 2019 the feedstock for conversion in the optimal 16-to-20 year old range sits at two aircraft. In the 21-to-25 year old range, there are 84 aircraft available for conversion, but these will age out of the range in the next five years.

- Cebu Pacific remains eager to add dedicated ATR 72-500Fs to its fleet. In July of 2018, Cebu Pacific signed a deal with IPR Conversions for the freighter conversion of two ATR 72-500s previously flying in the carrier's passenger fleet. Both aircraft were inducted at the Sabena Technics Facility in Dinard, France, but as of this writing they have yet to be delivered.

- The regional carrier of Hawaiian Airlines, Ohana, launched scheduled inter-island cargo flights with two ATR 72-200Fs operated by Empire Airlines. Hawaiian plans to add two more ATR 72Fs to its fleet. The first aircraft has already been inducted for conversion to large cargo door (LCD) freighter configuration by IPR Conversions at Empire Airlines' MRO facility in Idaho, USA.

3.3 Turboprop/RJ Freighter (Feeder) Current Baseline Fleet

Table 5 shows the composition of the turboprop/RJ freighter fleet at the start of 2019. This fleet, which forms the point of departure for our twenty-year turboprop/RJ freighter forecast, contains a mix of older technology models nearing retirement and newer, modern aircraft.

Table 5 - Current Feeder Freighter Fleet

Feeders (Turboprops and Regional Jets) 8,500 – 20,000 lbs (3.8 – 9 tonnes)
239 Total Units
45 ATR 42
63 ATR 72
5 Dash 8-100/Q300
5 Dash 8-Q400
9 CRJ 200
14 ATP, 11 HS 748
19 CV 580, 13 F27/50
31 Saab 340
22 AN 26/32, 2 AN 74

Compared to last year, there are nine fewer ATP, eight fewer F27/50 and seven fewer CV580 in active operation. When determining whether an aircraft is active or not we analyze radar and other data to determine whether an aircraft has flown in the last 365 days. Only if it has do we include it in the current fleet. We count approximately forty parked ATPs, F27/50s and some ATRs (mainly -42s).

3.4 Turboprop/RJ (Feeder) Freighter Forecast through 2038

3.4.1 Feeder Freighter Forecast Assumptions

The turboprop/RJ forecast is presented in five-year increments over the twenty-year forecast period (2019-2038), showing the predicted growth of the freighter fleet taking into account new-build freighter production, passenger-to-freighter (P-to-F) conversion activity, and the retirement of freighters from the existing freighter fleet.

The feeder forecast presented below has been developed using the same logic as the jet freighter forecast presented in Section 2.4.1. We have used the beginning freighter fleet (see Table 5), and applied the following set of baseline assumptions:

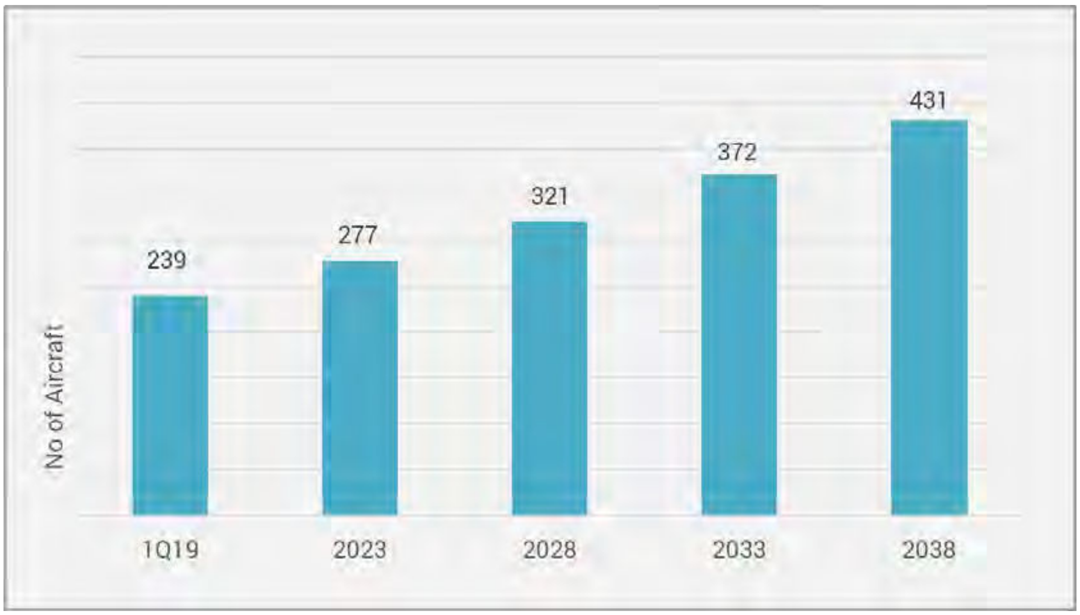
- Future growth in air freight demand of 4.0% per year
- Improvement in freighter productivity of 1.0% per year
- The feeder segment is not affected by the Freighter-to-belly share shift from a fleet-wide 50% freighter share in 2018 to a 42.5% freighter share in 2038

We grow the turboprop/RJ freighter fleet in each five-year period to match the constraints imposed by these assumptions. We take into account the specific freighter models that will be available during the forecast period, and make a detailed prediction of the composition of the fleet by aircraft type at the end of the forecast period. In so doing, we account for additions to the freighter fleet (new production deliveries and added P-to-F conversions), offset to some degree by retirements. The target growth can be met by a variety of combinations of additions and retirements of specific freighter types, so the final result reflects our best judgment about the relative popularity of the competing models.

3.4.2 Baseline Feeder Freighter Forecast

The expected evolution of the turboprop/RJ freighter fleet over the next twenty years under the baseline 4.0% scenario is depicted in Figure 8. The fleet is shown to increase from 239 units in Q1 of 2019, to 431 units at the end of 2038.

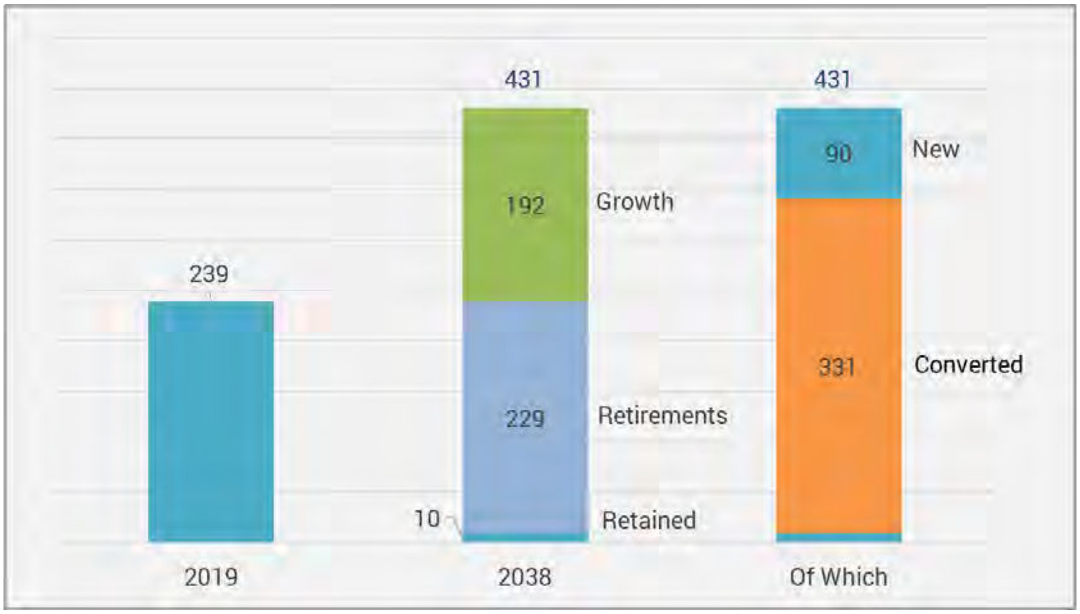
Figure 8 - Baseline Feeder Freighter Fleet Forecast 2019 - 2038



Overall, the total number of turboprop/RJ freighters in 2038 is forecast to be about double the baseline quantity.

The net growth in the turboprop/RJ fleet size is 192, which when combined with 229 retirements, produces the overall need for 421 freighters through 2038. This total fleet requirement equates to an average of 21 turboprop/RJ units per year. All of the added feeder freighters in the forecast, with the exception of 90 ATR 72-600s (about 21% of all additions), will be freighter conversions (see Figure 9).

Figure 9 - Feeder Freighter Forecast Fleet Development



3.4.3 Future Feeder Fleet Composition

As was the case for the forecast of larger jets described in Section 2.4, our forecast reflects our assessment of manufacturers' future product strategies to determine which specific aircraft types will be offered as freighters over the next twenty years. Some models shown in our forecast may not become available in freighter configuration, while some that we do not show may be introduced. To the extent that such circumstances develop, it is important for readers of this report to recognize that the availability or non-availability of any particular freighter type will not affect the overall demand for freighter aircraft. Other aircraft in the category will fill the gap.

The main types of aircraft that will be involved in the future evolution of the turboprop/RJ freighter fleet over the next twenty years can be broken down into four sub-groups. As shown in Table 6 three of these groups contain aircraft currently in service, while the fourth group contains aircraft under development for later entry into service. The aircraft types are all passenger-to-freighter (P-to-F) conversions, except the ATR 72-600 which is a new production model.

Table 6 - Feeder Freighter Fleet Available to Operators

	Turboprops/ Regional Jets
Facing near-term extinction	Saab 340, CV 580, HS 748, Fokker F27/50, Bae ATP
At peak use, or with little future growth potential	ATR 42
Expanding role going forward	ATR 72, Dash 8-Q300, Dash 8-Q400, CRJ 200
Future aircraft	ATR 72-600, CRJ 700

Note that there are several other 40-to-100 seat models with jet or turboprop power which could be adapted to a freighter role, but we have ruled them out of contention for the reasons discussed below:

- A number of new jet-powered models are entering the 80-to-160 seat market. Those models include the Sukhoi Superjet 100, in service since 2011, and the Comac ARJ21 and Bombardier C-Series (now Airbus A220), both of which entered service in 2016. Entering service in 2018-2020 will be the Comac 919, Embraer E-2 family and Mitsubishi MRJ. We believe that freighter application over the next 15-plus years of these new models will be non-existent or extremely limited. There has been almost zero market interest for production freighters of these sizes for the past twenty years, and we do not see that situation changing. At some point, say around 2030, there may be some interest in P-to-F conversion of one or more of these models, but even then, the opportunities will be limited. All of the models noted (except the Comac 919) have relatively narrow fuselages (4 or 5 seats wide), so they will face the same narrow cross section obstacle that has for years limited freighter application of the DC-9 and MD-80 models. Furthermore, there will be a well-developed market for freighter conversion of the 737NG and A320/321 aircraft families, and we believe that the use of these models will dominate the small end of the jet freighter market.

- We have eliminated from contention the ERJ 145 family and Saab 2000 at the lower end of our seat count range since these types have just three-abreast seating, which places them at a further disadvantage in future freighter application. MACC of the Netherlands lists an active ERJ 145 conversion program but there have not been any conversion, or orders to our knowledge as of writing.

- We also are not convinced that the EMB 170/190/195 and CRJ 700/900/1000 jet-powered models will find a significant role as freighters. The smaller models in these aircraft families will have trouble competing with the turboprop-powered ATR 72 and Dash 8-Q400 models, and the larger models will find it difficult to compete against freighter versions of the well-entrenched 737 and A320 models that will continue to dominate the 100+ seat market. The CRJ700 may be an exception, as the freighter application of this model is a logical extension of the freighter conversion programs of the smaller CRJ200. If the CRJ700 program does not come to fruition Cargo Facts expects ATR 72 and Dash 8-400s to fill the void.

Table 7 shows the detailed composition of the turboprop/RJ freighter fleet on a model-by-model basis at the end of forecast period in 2038 under our baseline scenario.

Table 7 - Future Feeder Freighter Fleet, 2038

Feeders (Turboprops and Regional Jets) *8,500 – 20,000 lbs (3.8 – 9 tonnes)*
431 Total Units
7 ATR 42s 209 ATR 72s 27 Dash 8-Q300s 74 Dash 8-Q400s 63 CRJ 200s 50 CRJ 700s

Based on our assessment, we see the ATR 72 being the single dominant type in the feeder segment, followed by the Dash 8 series, with upside for both if a CRJ 700 does not materialize.

3.4.4 Feeder Freighter Sensitivity Analyses

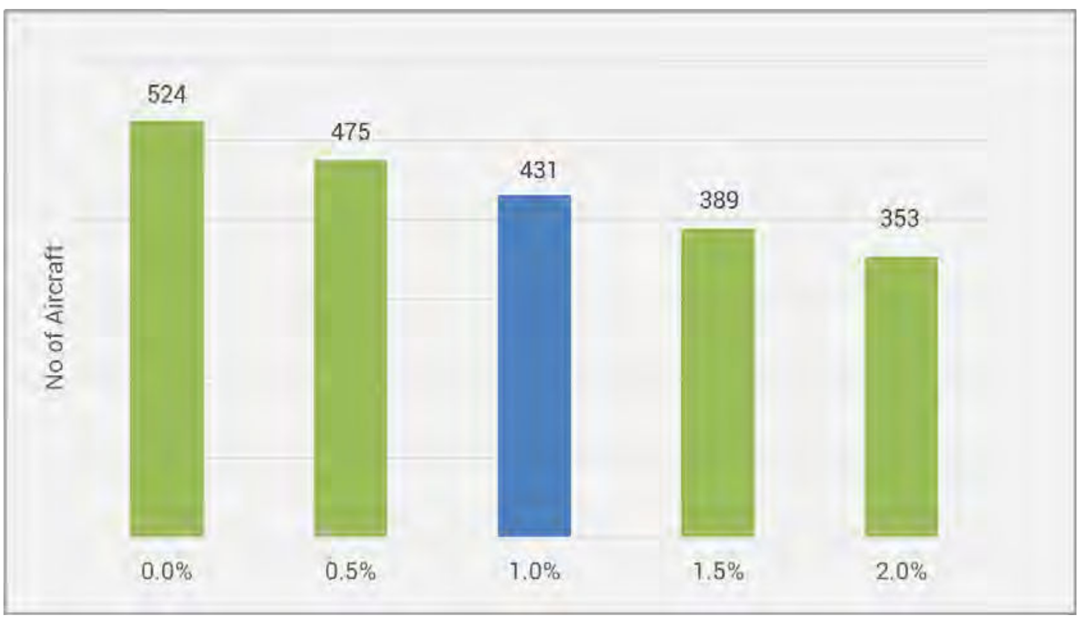
As with our analysis of the jet freighter fleet segments, we have also examined the impact of changes to the assumptions used in the baseline forecast for the turboprop/RJ market segment. The results of that sensitivity analysis are summarized below.

A demand shift of 1 percentage point per year results in roughly a 20% change – about 80 planes – in the size of the turboprop/RJ freighter fleet in 2038 (See Figure 10). For example, if demand grows by 5.0% per annum, the required fleet would grow to about 509 (compared to the baseline forecast of 431).

Figure 10 - Demand Growth Impact on 2038 Feeder Fleet Forecast

A 0.5 percentage point change in productivity results in roughly a 10% change – 40+ aircraft – in the size of the turboprop/RJ freighter fleet in 2038. For example, a 0.5% improvement in productivity would reduce the 2038 turboprop/RJ fleet to roughly 379 units (compared to the baseline forecast level of 421).

Figure 11 - Productivity Growth Impact on 2038 Feeder Fleet Forecast



Change to the freighter-belly ratio will not impact the demand for turboprop/RJ freighters as the type of networks these aircraft are operate in do not facilitate a switch.

4. Airline User Analysis

4.1 Operator Diversity

As in previous reports we provide an analysis of the distribution of how and where freighters in different size categories are used. There are over 200 airlines worldwide that operate at in at least one of the 4 categories covered in this report (feeders, narrowbody, medium and large widebodies). Specifically, we count:

- 40 airlines operating turboprops and regional jets (feeders),
- 98 airlines operating narrowbody freighters
- 76 airlines which operate large and medium widebody freighters, of which:
    - 31 airlines operate only medium widebody freighters
    - 35 airlines operate only large widebody freighters
    - 10 airlines operate a mix of large and medium widebody freighters

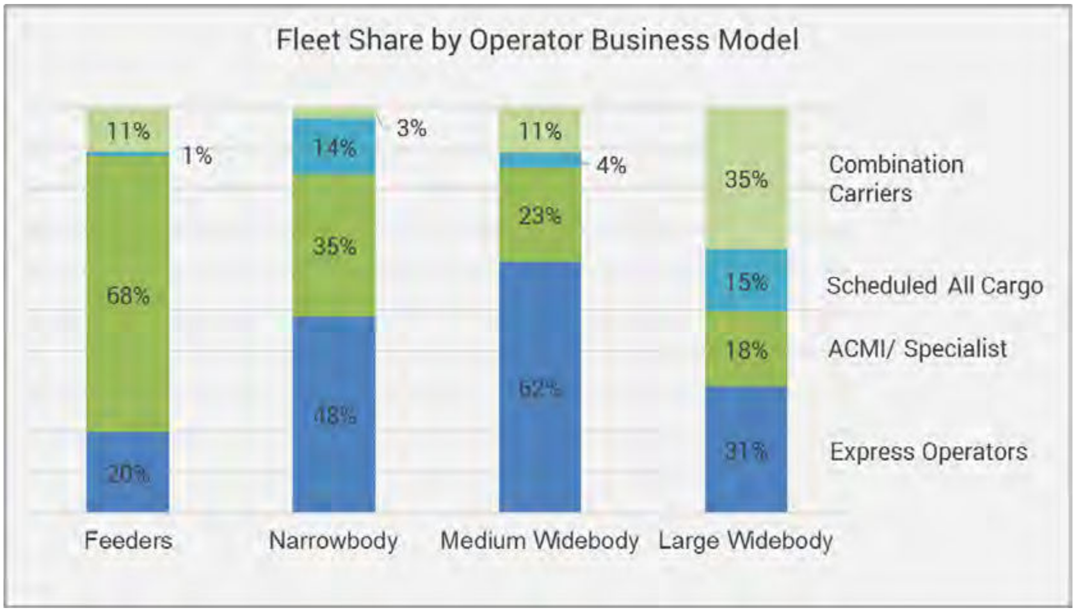
While a number of airlines operate aircraft across all segments (such as ASL Aviation Group, for example), most are focused on a single freighter size segment. For example, only 18 airlines operate both narrowbody and widebody freighters, and among the widebody freighter operators, only 10 operate both medium and large capacity types. Overall, the number of freighter operators has declined in recent years. For example, five years ago there were 111 operators of narrowbody freighters and 90 operators of widebody freighters compared to 98 and 76 today.

Another important attribute of freighter applications is the distribution of the aircraft among the airlines that operate them. For example, there are 1,782 jet freighters of all sizes operated by about 175 airlines globally. A top-level view suggests a diverse market with the average freighter operator having nearly ten freighters. A closer analysis of the fleet paints a very different picture. Examining the distribution of the fleet based on the number of freighters operated by carrier shows that the market is very top heavy. In fact, the top-two carriers (FedEx and UPS) together have 34% of all jet freighters, and adding in the next nine largest freighter operators (over 25 freighters each) brings us up to 55% of all freighters. At the other end of the spectrum, we find a group of 80 airlines (almost 50% of the total operator group) that individually operate three or fewer freighters, and that as a group operate just 7% of the total jet freighter fleet.

4.2 Fleet Use by Business Model

Most freighters are operated by or for the express, postal and increasingly also the E-commerce business. Figure 12 shows the distribution of the freighter fleet by business model.

Figure 12 – Current Fleet Share by Operator Business Model



Examining this figure allows us to gain an understanding of the relative importance of express vs. non-express segments of the market. The different business models fall into five broad groups:

Combination carriers are mainly in business to carry passengers but have some freighters in their fleets to augment the cargo capacity in the belly compartments of their passenger aircraft. Some examples in this category include Lufthansa, Singapore Airlines and LATAM.

All-cargo carriers provide scheduled common-carriage freight services operating fleets consisting entirely of freighters. Some examples include Cargolux, CAL, or Nippon Cargo Airlines.

Express carriers operate freighters in their own networks as part of their integrated express operations. The three global ones are DHL, FedEx and UPS, but for example, in China this would include companies such as SF Express or China Postal Airlines. Where scope clauses in pilot contracts allow, express carriers also outsource freighter operations to third-party carriers.

ACMI or specialist carriers provide a variety of cargo services, with a significant portion of their business generally coming from charter or ACMI services in support of express companies, forwarders or other airlines. These include airlines such as Atlas, ATSG, ASL Aviation Group, West Atlantic or Air Atlanta Icelandic.

Several noteworthy factors become apparent when examining how freighters are used:

- A 61% share of all freighters (excluding feeders) in operation today are used in express operations, leaving 39% in non-express operations.
- Roughly 62% of the medium widebody freighters are used for express, while only 31% of the large widebody freighters are used in an express role. The large freighters are much more likely to be

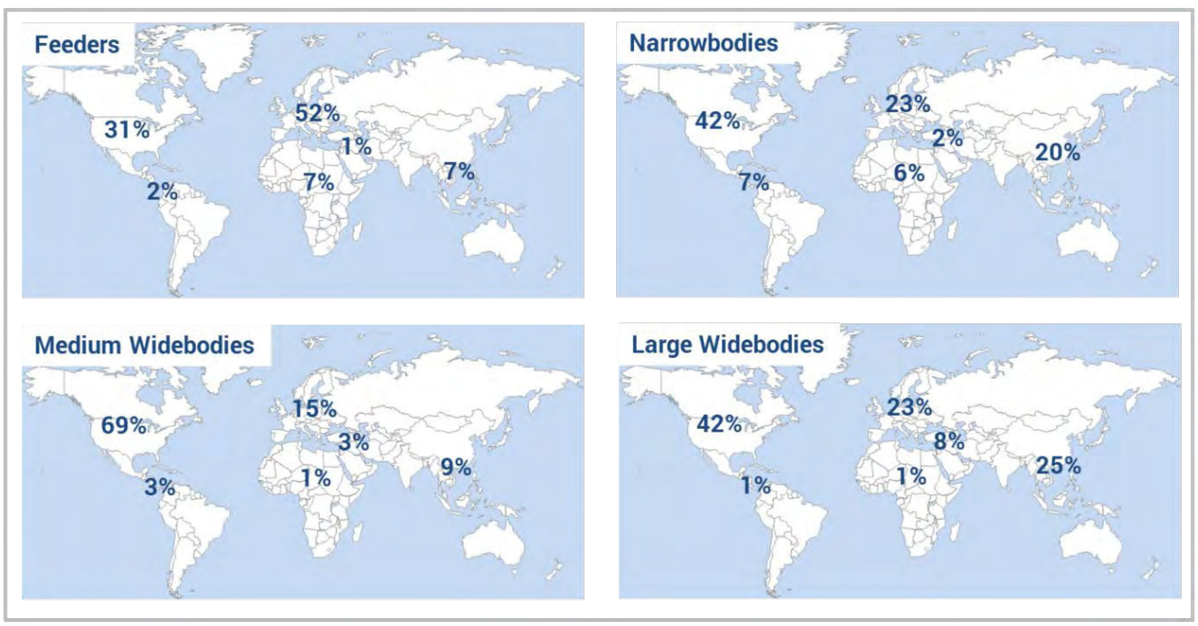
used by combination or all-cargo carriers, groups that together have over half of the large-size freighters. Cargo densities are higher in the general cargo segment, so this has implications on the suitability of different aircraft types. Specifically, this favors production 747 and 777 freighters which have higher-design densities than future converted 777 and most medium widebody freighter options.

- In reviewing these results there is no doubt that use by express operators and airlines that support them is the primary application of freighters of all sizes. Note that the large shares for express is heavily influenced by US-based express operators FedEx and UPS, which together have more than 600 freighters, approximately 34% of the world total.
- Under the feeder category, we find 80% to90% of aircraft are either operated directly by or for integrators and postal companies.
- Only a small portion of the turboprop/RJ freighter fleet is involved with scheduled operations by combination carriers or all-cargo airlines.

4.3 Fleet Use by Geography

On a worldwide basis about half of all freighters are still currently operated in North America. Figure 13 shows the distribution of the complete jet freighter fleet by domicile region.

Figure 13 – Current Freighter Fleet Distribution by Geography



Examining this figure allows us to gain an understanding of the relative geographical distribution of freighters as summarized below:

- The dominant shares in North America for all size categories are a direct result of the large fleets of integrators like FedEx and UPS

- The jet freighter fleet (excluding regional jets/turboprops) shows about 20% shares each of the total count for Asia/Pacific and Europe, with the remaining 10% divided between Central/South America & Caribbean, Africa and the Middle East.
- Nearly 70% of medium widebodies are domiciled in North America, and with most of the remainder in the Asia/Pacific and Europe regions. Meanwhile, we find North America to have a smaller 40% share of the large capacity freighters and Asia/Pacific and Europe adding up to a nearly 50%. This number is driven by the use of freighters (mostly 747Fs) in the fleets of combination carriers in these regions.
- In Asia/Pacific, we note a growing quantity of narrowbody freighters, used mainly in the fleets of expanding express carriers in China (such as SF Express and China Postal Airlines).
- Under the feeder category, most of the freighters are based in Europe or North America. The larger shares for these regions are heavily influenced by contractors to US-based express operator FedEx, and by Europe-based operators West Atlantic and ASL Ireland that provide express support.

5. Air Freight Demand and Freighter Capacity

Air freight traffic growth is the primary driver of the demand for air freight capacity and as such it is worth further discussion. In the long term, we expect freighter capacity to be added in line with demand that cannot be met with belly capacity, either because of the size of the market, nature of the freight or service requirements.

5.1 Global Air Freight Demand since 1980

Global Air Freight demand since the early 2000s has been more volatile and long-term average growth rates have trended downwards. Between 1980 and 2000, the air freight business only experienced a single year of traffic decline, between 2000 and 2018, the industry experienced five years in which traffic declined (Figure 14).

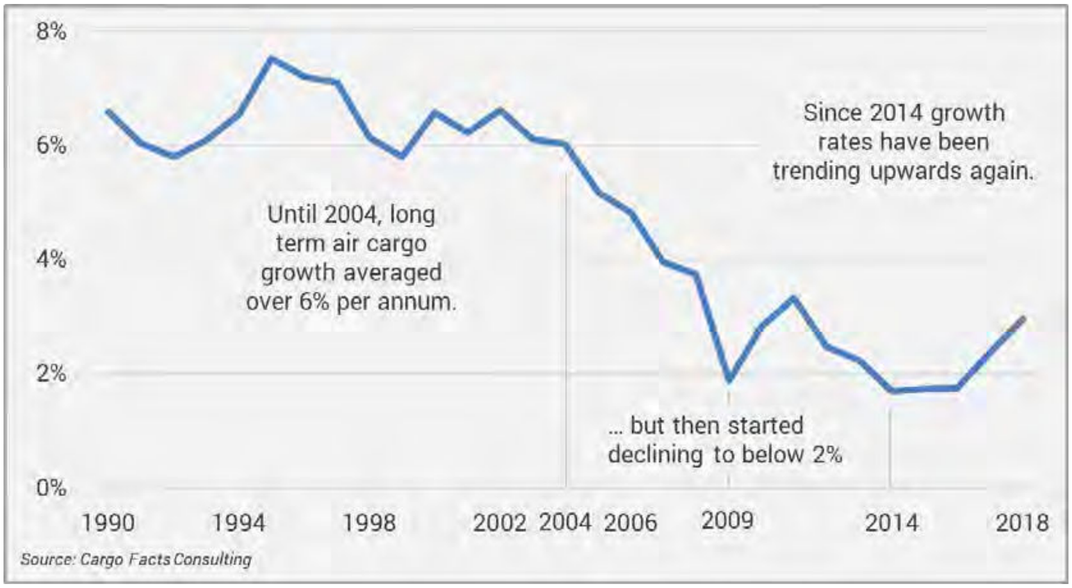
Figure 14 - Air Freight Traffic Growth 1980 - 2018

In 2001 traffic declined by just over 5%, and in 2008/2009 airfreight traffic dropped by combined a total of 13%. 2011 and 2012 again saw small declines in cargo traffic. Although traffic levels rebounded quickly, it took six years before volumes began to exceed 2007 levels. Since 2013 the industry has had a good run, and particularly 2017 and to an extent 2018 were highly profitable years. The average five-year growth rate through to the end of 2018 was 5.1%.

The airline industry has always been characterized by significant up and down swings in growth and financial performance, with cycles typically lasting about seven years. However, the magnitude of the shifts in demand for air freight since 2000, and the occurrence of several years with negative growth are unprecedented. The effect of the recent market volatility has been the loss of nine years of growth since 2000.

Until about 2004, long-term air cargo growth averaged over 6% per year (see Figure 15). What followed was a period of declining growth rates, with long-term historical rates dipping below 2% on two occasions, in 2009 and after 2014.

Figure 15 - Ten Year Moving Average Air Cargo Traffic Growth 1990 - 2018



Since 2014 growth rates have been trending upwards again and the 10-year average growth rate to 2018 currently stands at 3%.

5.2 Long Term Global Air Freight Outlook

Nevertheless, our baseline freighter forecast again assumes long-term air cargo growth of 4% per year, even though we realize that this is higher than the growth we have been experiencing for the past decade. We have not adjusted this figure since 2016. We did not adjust this figure following stellar growth in 2017 nor somewhat disappointing growth in 2018. One year does not establish a trend.

To support our freighter forecast, we prepare long-term air cargo traffic forecasts under different scenarios. While we predict an average long-term air traffic growth rate of 3.9%, we find that scenarios of between 2.6% and 5.0% appear realistic. In comparison, our baseline traffic forecast is somewhat less optimistic than recent Boeing and IATA forecasts and somewhat more optimistic than Airbus (see Table 8).

Table 8 - Cargo Facts Consulting vs Other Traffic Forecasts

Forecast	Baseline	Range
Cargo Facts Consulting 2019 – 2038	3.9%	2.6% - 5.0%.
IATA 2019 – 2028	4.2%	n.a.
Boeing 2018 – 2037	4.2%	3.7% - 4.7%
Airbus 2018 - 2037	3.6%	3.4% (General Cargo) - 5.1% (Express

Small changes in the long-term air cargo traffic growth rate have large impact on 20-year traffic levels and, consequently, freight capacity demand. An average growth of 4% per year means traffic levels in 2038 would be 2.2 times higher than 2018 levels, while a growth rate of 3% a year would lead to traffic levels of only 1.8 times 2018 levels (see Figure 16).

Figure 16 - Impact of Growth Rate on 20 Year Traffic Levels

The demand for air cargo services is driven by various interrelated factors, such as the size and strength of the global economy, growth in incomes, industrial production, the amount of world trade in goods, and the degree of globalization of supply chains. On intercontinental markets, airfreight is primarily an industrial tool, whereas in shorter haul and regional markets it is delivery tool between businesses as well as increasingly to consumers.

While airfreight and the global economy generally move in sync, the magnitude of the relationship between the two is not consistent. For example, the ratio of airfreight to economic growth has been anywhere between -0.5 and +5 in the last 16 years, but on average has been lower than the prior to 2000, where the rule of thumb was that airfreight grew at twice the rate of the global economy. On average over the past 10 years, the global airfreight traffic measured in freight tonne kilometers (FTK) has grown 12% faster than the world economy. In contrast, revenue passenger kilometers (RPK) have grown 41% faster than the global economy. Passenger traffic growth drives passenger aircraft additions, which in turn is the main reason why we see a shift from freighters to bellies going forward.

However, this global picture hides developments in individual regional markets such as domestic China, intra-Asia, and even between Europe and Asia, where growth has been much higher. And it also hides the differences between segments, where express services have consistently outperformed general cargo and mail.

5.3 The Demand for Air Freight Capacity in the Short Term

Our forecast is long term in nature, but we understand that due to the cyclical nature of the business and the time lag between aircraft orders and delivery, there is often a mismatch in supply and demand in the short term. This has an impact on yields, load factors and industry profits.

For example, 2017 represented the largest year-over-year gains for the air cargo industry since 2004, with the exception of the post-recession rebound in 2010. Excellent financial results in that year led to a scramble for capacity and the market saw the reactivation of a large number of parked or inactive freighters throughout 2018. This included converted 747s, MD-11s and even some A300B4s. Global air freight demand in 2018 showed a moderate increase of 3.5%, but was significantly down from 9.7% in 2017. Due to the time lag in adding freighters, freighter load factors in 2018 fell due to capacity increasing faster than demand.

As we head into 2019, the expectation is that demand will again be lower than 2018, although most forecasters assume that we will see some modest growth rather than declines. As such, many of the reactivated units may be parked again, depending on lease and finance arrangements of these aircraft.

In many ways, the situation in 2018 was similar to 2008. Fueled by six years of uninterrupted growth, airlines were signing up for lease terms and rates on aircraft that caused them significant financial harm in 2009 where both yields and traffic dropped substantially.

5.4 E-commerce, Express Services and Freighter Demand

There is also considerable interest in the development of cross border, intraregional and domestic e-commerce. However, there is little data to support how much e-commerce traffic is moving in intercontinental networks. Most airlines have scant idea how much they are carrying, although many estimate it is somewhere between 10% and 15%. (In the second half of 2019, we will be publishing a report on this topic which will provide quantitative estimates of e-commerce traffic and analyze how great is its likely impact on the air cargo business and, importantly, on demand for freight capacity.)

Since the deregulation of air cargo in the US in 1978, the express delivery service has been a fast-growing sector, expanding worldwide and increasing its share of the air cargo market. This industry plays a critical role in the global economy as it supports today's complex distributed logistics chains. The express industry has developed from the carriage of documents to packages of all sizes, specialty items, and general freight.

The demand of express services moves in parallel with trade in high-value goods, or those commodities with a high value-to-weight ratio, such as semiconductors, mobile phones and other electronics. There is no question that air freight and specifically, express services has been sustained by the regular introduction of new high-tech products. Perishable products, such as seafood, flowers, fruits and vegetables, also often move by air, as do goods requiring high security or a stable shipping environment, such as pharmaceuticals. Increasing demand for such products from a growing global middle class fuels sustained long-term growth. The growth of express services – at least in regional markets – has been driven by the rapid expansion of e-commerce in the last decade.

E-commerce is the latest iteration of direct-to-consumer sales, the goal of which is to cut out the middleman between buyer and seller. The traditional distribution model has developed to today's global e-commerce logistics through multiple steps, allowing the rise of global marketplace platforms such as Amazon, Alibaba's Tmall, and JD.com. These marketplaces have access to consumer and shipper behavior in the form of big data allowing them to predict product demand by region and enhance their own logistics chain using a combination of shipping modes.

Developments in data analysis, online communications, and rapid long-distance transportation have been critical enabling technologies in the ongoing expansion of e-commerce. Nevertheless, the reduction of government regulations and infrastructure investment have also been key to the development of this market. In the past decade, we have observed how the world has moved from a largely domestic producer-wholesaler-retailer-consumer logistics system to a global producer-direct to consumer system.

Alibaba and Jd.com in China and Amazon in the US and Europe are the dominant global players in B2C (Business-to-Customer), but there are also various other platforms worldwide and retailers with brands strong enough to support their own electronic storefronts. These e-commerce giants have disrupted retailing and air and surface logistics by building their own air freighter networks or becoming huge users of express services. In Amazon's case, its U.S. fleet of 40 Boeing 767 freighters is a clear indicator of the importance of e-commerce to air freight. Alibaba's captive logistics network, Cainiao and its investment in YTO Express, one of the leading Chinese couriers (express companies) is another sign. E-commerce is also growing rapidly in Europe, India, Japan, South Korea, Russia and Brazil.

One of the great areas of interest in e-commerce currently is cross-border e-commerce, from shipper to customer anywhere in the world. This new model presents both a challenge and a significant opportunity for integrators and airlines. Integrators' systems have been oriented to carry international packages via one or more hubs connected by international trunk air segments in an extension of their in-country networks (intra-European Union in the case of Europe). Cross-border e-commerce has suffered from a lack of technology and automation in the customer experience but this is shifting since IT companies have integrated applications and databases into e-commerce platforms, providing the consumer with a firm price at time of order including customs duties and exchange rates. The other and perhaps most important challenge for the air cargo business is who ultimately pays when shipping is free to the end customer.

Integrators are the best positioned to support the e-commerce expansion because they have invested in building the necessary infrastructure to move packages quickly and efficiently. On the other hand, the high capital costs of these finely tuned legacy systems can make them vulnerable to disruption.

Even though e-commerce has become a fixture in developed countries and progressively, in developing economies, its consequences are just starting to have an impact in the logistics industry. As mega-marketplace platforms like those operated by Alibaba and Amazon keep growing while leveraging big data strategies in a potentially boundary-free global e-commerce market, these giants will gradually evaluate the costs and benefits of building their own-controlled logistics networks.

This possibility presents opportunities and challenges for carriers and integrators. Responsive, low-cost providers like the ACMI providers that currently partner with the e-commerce platforms will likely benefit. Integrators will also benefit in the short term since e-commerce drives demand for rapid delivery that leverages the integrators' strength in both air and ground networks. However, the long-term doesn't look as promising for integrators if the platform own-controlled logistics network proves to be a successful model. And, all-cargo and combination carriers that have evolved to handle large cargo consolidations will have to find ways to handle individual packages cost-effectively.

There are many questions regarding e-commerce yet to be answered, including: Will the growth of e-commerce significantly impact long-distance supply chains, or will the impact mainly be last-mile related? Who will perform last-mile deliveries? Are integrators going to be the primary beneficiaries? Will airlines working with their forwarder partners find a way to compete in the cross-border e-commerce market? Will consumers continue to demand "free shipping" options, thus favoring surface-based solutions and limiting the opportunity for air freight providers? We will be on the lookout for information and trends related to these issues that could have significant consequences for the air freight industry as e-commerce continues to grow.

6. Freighter Aircraft Supply – P-to-F Feedstock Analysis

6.1 Conversion Market Drivers

Passenger-to-Freighter (P-to-F) conversion is an essential element in the development of the global fleet of freighter aircraft. Historically, the option of acquiring production freighters has been available in the widebody, but not in narrowbody or feeder market. But even in the widebody segment about half of the freighters have been converted from passenger configuration.

Three primary factors are essential to support P-to-F conversion:

1. The availability of used passenger aircraft of suitable age – often referred to as "feedstock",
2. Suitable feedstock prices, and
3. The existence of certified freighter conversion programs.

In assessing the likelihood of P-to-F conversions, we take into account the number of aircraft of a particular type that were produced in passenger configuration and the period of time over which production took place. That explains, for example, why the 767-300ER (with over 500 built, mostly over sixteen years from 1988 through 2004) will be popular for future P-to-F conversion, while the A300-600 (with fewer than 200 built, mostly over twelve years from 1984 through 1996) will see no further conversion activity.

Also important in assessing P-to-F opportunities is understanding that most conversions are done on aircraft 16-to-20 years old (and often extending beyond to age 25). In the 767-300ER and A300-600 examples cited here, this leads to the conclusion that the "prime window of conversion" for the A300-600 started around 2005 but is at an end, while the prime conversion window for the 767-300ER began more recently but will extend beyond 2025.

The section examines the quantities in the feedstock pool for various freighter conversion candidates – not all of which currently have active conversion programs. In reviewing the material that follows it is important to keep in mind the production periods and the quantities that have been produced for each model under discussion. As part of our analysis here we focus on feedstock supply only and not prices, although we have included a section on the impact of the Boeing 737-Max grounding on short to medium term feedstock availability.

Table 9, Table 10, and Table 11 provide an overview of production periods, production quantities, and feedstock totals in the 16-25 year age bracket now and into the future for narrowbody, widebody and feeder aircraft. Note that for the older types that are out of production feedstock declines going forward, while for the newer types of feedstock will increase in the future.

The optional *Feedstock Analysis Tool* provided as a supplement to this forecast and hosted on the Cargo Facts Consulting Insights site (www.cfcinsights.com) provides additional detail by aircraft type and split in 16-20 and 21-25 year age brackets for 21 different aircraft types, ranging from turboprops to large widebody jets.

6.2 Narrowbody Freighter Feedstock

The narrowbody freighter market is in transition from older to new generation aircraft types. The suitable feedstock pool for 737-300, 737-400 and 757-200 aircraft is declining, while the stock of ripe 737 NGs and A320 family aircraft are increasing (see Table 9).

Table 9 - Narrowbody Feedstock Summary

Model	Production Years	Passenger Deliveries	Feedstock Quantities for 16-25 years old aircraft		
			2019	2022	2025
737-300	1984 – 1999	1,113	91	61	0
737-400	1988 – 2000	486	26	17	2
737-700	1997 – present	1285	447	747	797
737-800	1998 – present	5,135	660	987	1,462
737-900	2001 – present	564	38	50	112
757-200	1982 – 2005	995	219	165	74
757-300	1998 – 2004	55	49	54	48
A320-200	1998 – present	4,690	596	896	1,311
A321-200	1996 – present	1,660	164	237	392

To be more specific, the pool reduces in future years as aircraft that become 26 years old in each succeeding year are removed from the pool. Such reductions in theory would be offset by aircraft 14 years of age that would be added to the pool in each succeeding year. But in the case of 737-300, as shown in Table 9, there are no such young units. The pool declines by 33% to 61 in 2022. By 2022, all of the 61 available 737-300 aircraft are in the 21-25 year age bracket. Not shown in the Table, by 2020, all the available 737-300 (81 units) should be in 21-25 year age bracket. Similarly, the conversion for the 737-400 (with only 486 deliveries from 1988 to 2000) will be coming to an end.

Moving forward to other aircraft in narrowbody segment, the feedstock for the newer generation 737 and A320/A321 family will increase in the future. As shown in Table 9, these types are still in production. The current production totals are 1,285 for 737-700, 1,660 for the A321-200, and around 5,000 each for the 737-800 and A320-200. These high quantities result in a favorable feedstock situation today for these models, with improving conditions going forward. Somewhat of an exception is the A321, for which low production totals in the late 1990s constrain age-appropriate feedstock today.

As for the most popular aircraft in the narrowbody segment, feedstock is declining. Suitable passenger aircraft for the 757-200 (and 757-300) are declining. The overall feedstock amount for 757-200 is larger than -300 due to the larger production amount. We also note that there has so far been no program announced for the 757-300, although Precision has been mulling launching one.

6.3 The 737 MAX Effect on the Narrowbody Conversion Market

As the narrowbody freighter segment started to see the first 737 NG conversions, the launch of these programs coincided with two tragic crashes of Boeing's newest model: the 737 MAX 8. At the time of writing all of the 376 delivered aircraft have been grounded since March 13. With deliveries on hold and over 4,600 orders, we ask ourselves how this event will affect the freighter market. At the time of which this report was written, Boeing was working on deploying a software upgrade to all carriers but it is uncertain when MAX flights and deliveries will resume. Estimates range from July to September. Many airlines are struggling to replace the MAX type across their networks, which in some cases, implies keeping older 737 NGs in service until the MAX is back in service. Although many of these 737 NG remaining in service with those carriers are newer models and not suitable for conversion feedstock for a while, the domino effect across the wider feedstock supply chain may remain tight in the near term. If carriers operating mid-life 737 NGs in passenger service choose to defer MAX deliveries and delay retirements of 737 NGs, the availability of narrowbody conversion stock could remain low longer than expected.

At the recent Cargo Facts Asia conference in April 2019, both AEI and Precision mentioned that they "lost" six 737-800s and five 757s scheduled for conversion in the preceeding weeks. Commentators believe that even if the MAX situation is fixed by summer, it will have a 1-2 year impact as carriers extend existing leases by 1-2 years rather than months. While this situation may have unfavorable impacts for 737NG and A321/A320 conversions, the 737-300/400 and MD-80 may benefit.

6.4 Widebody Freighter Feedstock

In the medium widebody aircraft segment, 767-300 feedstock availability declines over the period from 2019 to 2033, during which the feedstock in the older age bracket is larger than the younger ones because of the production years. In contrast, the total feedstock quantities for A330-200/-300 in the age bracket of 16-25 years old are growing over the time period from 2019 to 2033. Note that the feedstock in the older year age bracket for A330-200 is also growing over the time, while the feedstock in the younger age bracket are growing over the time for A330-300 (see Table 10).

Table 10 - Widebody Feedstock Summary

Model	Production Years	Passenger Deliveries	Feedstock Quantities for 16-25 years old aircraft		
			2019	2022	2025
767-300ER	1988 – 2014	582	176	155	105
A330-200	1988 – present	588	99	180	242
A330-300	1993 – present	775	85	135	200
777-200ER	1997 – 2013	422	245	297	223
777-300ER	2004 – present	807	0	66	202

In the large widebody aircraft segment, the feedstock situation for the 777-200ER and 777-300ER are developing in opposite directions opposite trends. The feedstock in the conversion zone for 777-200 grows from 2019 to 2022, then steadily declines over the period from 2023 to 2033. This can be explained by the production years from 1993 to 2013. Its feedstock in the younger year age bracket is declining while the older year age has a growth at the beginning before the number drops. The feedstock availability for 777-300 shows an opposite trend: both the feedstock in older year age bracket and younger year age bracket are growing over the time period from 2019 to 2033.

6.5 Turboprop/ Regional Jet (Feeder) Freighter Feedstock

Regarding feedstock in the turboprop/ regional jet segment, our analysis is focused on the ATR 42/72, Dash 8-Q300 and -Q400 as well as the Bombardier CRJ 200 and CRJ 700 (see Table 11).

Table 11 - Turboprop/ RJ Feedstock Summary

Model	Production Years	Passenger Deliveries	Feedstock Quantities for 16-25 years old aircraft		
			2019	2022	2025
ATR 42-300/-500	1984 – present	414	54	45	30
ATR 72-200/-500/-600	1988 – present	1,062	55	67	136
Bombardier Dash 8-Q300	1998 – 2007	267	64	70	65
Bombardier Dash 8-Q400	2000 – present	581	38	83	203
Bombardier CRJ200	1991 – 2006	939	337	461	461
Bombardier CRJ700	2001 – present	346	74	166	224

We see feedstock for ATR 42 and Dash 8-Q300 declining and feedstock for all other segments increasing. This will limit the potential for additional ATR 42 and Dash 8 Q300 conversions in favor of higher volume 19,000 lbs (8.5 tonne) aircraft, which will become the reference in this segment, replacing both existing 8,500 – 1,4000 lbs (3.8 – 5 tonne) aircraft currently in operation. We have excluded the Saab 340 from our feedstock analysis as we foresee very little development for this aircraft.

7. About Cargo Facts Consulting

Cargo Facts Consulting (CFC), formerly known as Air Cargo Management Group (ACMG), is a specialist advisory firm founded in 1978 in Seattle to serve the global air freight, logistics and express industries. Since 2019 we are based in Luxembourg and have offices in New York and Seattle, as well as further staff located in China, Spain, Israel and Canada.

We have provided advisory services to a wide range of clients, including airports, airlines, express companies, service providers, aircraft manufacturers and conversion companies, leasing companies, financial institutions and investment firms. In additional to this 20-Year Freighter Forecast, we produce a number of other regular reports including one on e-commerce logistics, the next version of which will be published in the second half of 2019.

Cargo Facts Consulting is affiliated with the New York and Seattle based organization that publishes the monthly *Cargo Facts* newsletter and weekly update (www.cargofacts.com), Air Cargo World (www.aircargoworld.com), and organizes the Cargo Facts Aircraft Symposium in the US, Cargo Facts Asia and since 2019 Cargo Facts EMEA. In early 2019, Royal Media, the owner of Cargo Facts since 2010, launched Cargo Airport News, a news resource on air cargo operations and trends at airports around the world (see www.cargoairportnews.com).

Our consulting experience spans projects that encompass airline network planning, fleet planning, route development, air cargo and express market analysis, and aircraft technology. As such, the firm has a deep understanding of the factors that drive profitable air cargo operations and airline decisioning in terms of choice of airports and routes. Through the media organization, Cargo Facts Consulting has a unique and high visibility insight into industry trends and individual airport and airline developments as they happen.

In recent years, we have assessed the market for a wide range of aircraft types in freighter configuration. The models reviewed ranged from a small turboprop derivative with 3,500 lb payload capacity, to the proposed A380F with 330,000 pound payload capacity. Other aircraft that we have analyzed for their suitability as freighters include the ATR 42/72, five new purpose-built turbo-prop freighters, the 737-300/-400, the 737-700/-800, the 757-200, various A300 models, the A320/A321, the A330, the 767-200/-300, the Il-76, the MD-11, the 777, and the 747-400 and -8 models. Therefore, we feel well qualified to develop and publish the freighter aircraft forecast presented herein.

Appendix 1 – Freighter Aircraft Characteristics

In this appendix we provide an overview of the indicative weights for both existing and future aircraft types in all four segments (feeders, narrowbody, medium widebody and large widebody). The data reflects manufacturers' or converters' information as interpreted by Cargo Facts Consulting.

For some aircraft types with unknown freighter capability, we have made our own indicative estimates of weights, volume and basic performance data. This includes aircraft such as a 757-300, 737-900, 787-9F, A330-900F, 777-8/9F, A350-900/100F, and 777-200ER and 777-300ER conversions.

We have included information on maximum takeoff weight (MTOW), Operating Empty Weight (OEW), Structural Payload and Volumes. We have not included indicative tare weights as these will depend on whether aircraft are being operated in palletized configuration. To get to revenue payload, readers will need to subtract tare weight. Design Density equals max structural load divided by total cargo volume. A "+" symbol in main deck positions for narrowbodies signifies a "half-sized" pallet.

Note that Operating Empty Weight (OEW) often includes tare weight. In our assessment OEW would include cargo loading systems but not the tare weight of containers and pallets.

Weights and volumes are provided both in lbs and kgs, and ft^3 and m^3.

We welcome feedback on any of these characteristics, particularly for aircraft types that have not yet been launched.

Table 12 - Narrowbody Freighter Characteristics (Imperial)

Model	Maximum Takeoff Weight (lbs)	Operating Empty Weight (lbs)	Main Deck Pallet Positions	Main Deck	Belly Holds (Contain-erized)	Bulk	Total Cargo Volume (ft^3)	Max Structural Payload (lbs)	Range with Max Payload (naut mi)	Volume Limited Payload at 7.0 lbs/ft^3 (lbs)	Design Cargo Density (lbs/ft^3)
BAe 146-300QT	97,500	55,850	7.5	2,475	none	810	3,285	23,150	960	22,995	7.0
737-200F	124,500		7	2,800	none	875	3,675	38,200	1,175	25,725	10.4
MD-83SF	160,000	76,900	12	4,400	none		5,027	45,100	1,200	35,200	9.0
737-300F	139,500	67,100	8+	3,680	none	1,065	4,745	42,500	1,600	33,215	9.0
737-400F (LGW)	143,500	69,900	10+	4,560	none	1,375	5,935	43,100	1,250	41,545	7.3
737-400F (HGW)	150,000	70,900	10+	4,560	none	1,375	5,935	47,100	1,725	41,545	7.9
737-700BDSF	154,500	76,700	8+	3,680	none		4,645	45,000	2,100	32,515	9.7
737-800SF	174,200	85,600	11+	5,000	none	1,555	6,555	52,700	2,000	45,885	8.0
737-800BDSF	174,200	85,300	11+	5,000	none	1,555	6,555	53,000	2,000	45,885	8.1
737-900F (est)	187,700	87,524	12+	5,500	none	1,555	7,055	61,976	2,000	45,885	9.5
A320-200F (est)	169,800	91,492	10+	4,693	910	208	5,811	48,280	2,000	40,677	8.3
A321-200F (est)	196,300	103,176	14	6,048	1,300	208	7,556	61,500	1,850	52,892	8.1
727-200F	203,100	98,600	12	5,280	none	1,525	6,805	56,400	1,650	47,635	8.3
757-200SF	240,000	116,000	15	6,600	none	1,790	8,270	70,000	2,400	57,890	8.5
757-300SF (est)	271,000	130,000	18	7,920	none	2,382	10,302	80,000	2,400	72,114	7.8

Table 13 - Narrowbody Freighter Characteristics (Metric)

Model	Maximum Takeoff Weight (kg)	Operating Empty Weight (kg)	Main Deck Pallet Positions	Main Deck	Belly Holds (Containerized)	Bulk	Total Cargo Volume (m^3)	Max Structural Payload (kg)	Range with Max Payload (naut mi)	Volume Limited Payload (kg) at 110 kg/m^3	Design Cargo Density (kg/m^3)
BAe 146-300QT	44,225	25,333	8	70	none	23	93	10,501	960	10,226	113
737-200F	56,472	0	7	79	none	25	104	17,327	1,175	11,440	167
MD-83SF	72,575	34,881	12	125	none	0	142	20,457	1,200	15,649	144
737-300F	63,276	30,436	8+	104	none	30	134	19,278	1,600	14,771	144
737-400F (LGW)	65,091	31,706	10+	129	none	39	168	19,550	1,250	18,476	116
737-400F (HGW)	68,039	32,160	10+	129	none	39	168	21,364	1,725	18,476	127
737-700BDSF	70,080	34,791	8+	104	none	0	131	20,412	2,100	14,460	155
737-800SF	79,016	38,828	11+	142	none	44	186	23,904	2,000	20,406	129
737-800BDSF	79,016	38,691	11+	142	none	44	186	24,040	2,000	20,406	130
737-900F (est)	85,139	39,700	12+	156	none	44	210	28,112	2,000	20,406	152
A320-200F (est)	77,020	41,500	10+	133	26	6	164	21,899	2,000	18,090	133
A321-200F (est)	89,040	46,800	14	171	37	6	214	27,896	1,850	23,522	130
727-200F	92,125	44,724	12	149	none	43	193	25,583	1,650	21,184	133
757-200SF	108,862	52,617	15	187	none	51	234	31,752	2,400	25,745	136
757-300SF (est)	122,924	58,967	18	224	none	67	292	36,287	2,400	32,070	124

Table 14 - Medium Widebody Freighter Characteristics (Imperial)

Model	Maximum Takeoff Weight (lbs)	Operating Empty Weight (lbs)	Main Deck Pallet Positions	Main Deck	Belly Holds (Containerized)	Bulk	Total Cargo Volume (ft^3)	Max Structural Payload (lbs)	Range with Max Payload (naut mi)	Volume Limited Payload at 7.0 lbs/ft^3 (lbs)	Design Cargo Density (lbs/ft^3)
A310-200F	313,000	165,920	16	7,960	2,169	610	10,129	89,000	2,200	70,903	8.8
A310-300F	346,100	169,920	16	7,960	2,169	610	10,129	86,700	3,350	70,903	8.6
767-200ERF	351,000	165,000	20	9,896	2,485	430	12,381	101,400	2,840	86,667	8.2
A300B4-200F	363,760	172,100	20	9,950	2,894	565	12,844	97,900	2,100	89,908	7.6
A300-600RF	375,900	179,230	21	10,450	3,708	610	14,158	107,400	2,650	99,106	7.7
A300-600F (production)	375,900	175,420	21	10,450	3,708	610	14,158	111,180	2,750	99,106	7.7
767-300BCF	412,000	181,520	24	11,884	3,396	430	15,280	127,480	3,100	106,960	8.1
767-300BCF (winglets)	412,000	185,720	24	11,884	3,396	430	15,280	124,580	3,150	106,960	8.2
767-300SF	412,000	180,800	24	11,884	3,396	430	15,280	128,200	3,100	106,960	8.1
767-300SF (winglets)	412,000	183,800	24	11,884	3,396	430	15,280	125,200	3,150	106,960	8.2
767-300F (production)	412,000	181,000	24	11,884	3,153	430	15,037	127,000	3,250	105,259	8.4
787-9F (est)	560,000	235,000	26	14,040	5,688	402	20,130	165,000	n.a.	140,910	8.2
A330-200F production	513,700	238,100	22	11,880	3,572	610	15,452	143,300	4,000	108,164	9.3
A330-200P2F	513,700	242,508	22	11,880	3,572	695	15,452	132,300	3,900	108,164	8.6
A330-300P2F	513,700	251,327	26	14,040	5,098	695	19,138	134,500	3,600	133,966	7.0
A330-900F (est)	553,000	260,366	26	14,040	5,098	695	19,138	138,634	n.a.	133,966	7.2

Table 15 - Medium Widebody Freighter Characteristics (Metric)

Model	Maximum Takeoff Weight (kg)	Operating Empty Weight (kg)	Main Deck Pallet Positions	Main Deck	Belly Holds (Contain-erized)	Bulk	Total Cargo Volume (m^3)	Max Structural Payload (kg)	Range with Max Payload (naut mi)	Volume Limited Payload (kg) at 110 kg/m^3	Design Cargo Density (kg/m^3)
A310-200F	141,975	75,260	16	225	61	17	287	40,370	2,200	31,532	141
A310-300F	156,989	77,075	16	225	61	17	287	39,327	3,350	31,532	137
767-200ERF	159,211	74,843	20	280	70	12	350	45,994	2,840	38,542	131
A300B4-200F	164,999	78,063	20	282	82	16	363	44,407	2,100	39,983	122
A300-600RF	170,506	81,297	21	296	105	17	401	48,716	2,650	44,074	122
A300-600F (production)	170,506	79,569	21	296	105	17	401	50,430	2,750	44,074	126
767-300BCF	186,880	82,336	24	336	96	12	432	57,824	3,100	47,567	134
767-300BCF (winglets)	186,880	84,241	24	336	96	12	432	56,509	3,150	47,567	131
767-300SF	186,880	82,010	24	336	96	12	432	58,151	3,100	47,567	134
767-300SF (winglets)	186,880	83,370	24	336	96	12	432	56,790	3,150	47,567	131
767-300F (production)	186,880	82,100	24	336	89	12	426	57,606	3,250	46,810	135
787-9F (est)	254,012	106,594	26	397	161	11	570	74,843	n.a.	62,665	131
A330-200F production	233,011	108,000	22	336	101	17	437	65,000	4,000	48,102	149
A330-200P2F	233,011	110,000	22	336	101	20	437	60,010	3,900	48,102	137
A330-300P2F	233,011	114,000	26	397	144	20	542	61,008	3,600	59,577	113
A330-900F (est)	250,837	118,100	26	397	144	20	542	62,884	n.a.	59,577	116

Table 16 - Large Widebody Freighter Characteristics (Imperial)

Model	Maximum Takeoff Weight (lbs)	Operating Empty Weight (lbs)	Main Deck Pallet Positions	Main Deck	Belly Holds (Contain-erized)	Bulk	Total Cargo Volume (ft^3)	Max Structural Payload (lbs)	Range with Max Payload (naut mi)	Volume Limited Payload at 7.0 lbs/ft^3 (lbs)	Design Cargo Density (lbs/ft^3)
MD-11F	580,000		23	13,150	3,655	510	16,805	176,500	3,350	117,635	10.5
MD-11SF	630,500	241,395	26	15,718	4,702	510	20,420	208,705	3,650	142,940	10.2
A350-900F (est)	630,500	246,200	26	15,718	4,702	510	20,420	203,900	3,550	142,940	10.0
A350-1000F (est)	617,295	n.a.	27	18,385	4,465	403	22,850	187,393	n.a.	159,950	8.2
777F production	696,661	n.a.	33	22,739	6,430	403	29,168	209,439	n.a.	204,177	7.2
777-8F (est)	766,000	295,700	27	18,385	4,465	600	22,850	240,000	4,965	159,950	10.5
777-9F (est)	775,000	n.a.	29	19,982	5,295	547	25,277	n.a.	n.a.	176,941	n.a.
777-200ERSF (est)	775,000	n.a.	35	23,832	8,131	547	31,963	n.a.	n.a.	223,744	n.a.
777-300ERSF (est)	650,000	305,000	27	18,385	4,465	600	22,850	190,000	4,000	159,500	8.3
747-400SF	775,000	314,000	33	22,739	6,430	600	29,168	210,000	4,800	204,177	7.2
747-400BCF	870,000	357,000	30	20,674	3,735	520	24,409	253,000	4,100	170,863	10.4
747-400F	870,000	360,640	30	20,674	3,735	520	24,409	250,500	4,100	170,863	10.3
747-400ERF	875,000	349,700	30	21,462	4,085	520	25,547	260,300	4,450	178,829	10.2
747-8F	910,000	350,400	30	21,462	4,085	520	25,547	260,600	4,970	178,829	10.2

Table 17 - Large Widebody Freighter Characteristics (Metric)

Model	Maximum Takeoff Weight (kg)	Operating Empty Weight (kg)	Main Deck Pallet Positions	Main Deck	Belly Holds (Contain-erized)	Bulk	Total Cargo Volume (m^3)	Max Structural Payload (kg)	Range with Max Payload (naut mi)	Volume Limited Payload (kg) at 110 kg/m^3	Design Cargo Density (kg/m^3)
MD-11F	285,990	109,495	26	445	133	14	578	94,667	3,650	63,567	164
MD-11SF	285,990	111,675	26	445	133	14	578	92,488	3,550	63,567	160
A350-900F (est)	280,001	n.a.	27	520	126	11	647	85,000	n.a.	71,132	131
A350-1000F (est)	316,000	n.a.	33	644	182	11	825	95,000	n.a.	90,800	115
777F production	347,452	134,127	27	520	126	17	647	108,862	4,965	71,132	168
777-8F (est)	351,535	n.a.	29	566	150	15	715	n.a.	n.a.	78,688	n.a.
777-9F (est)	351,535	n.a.	35	674	230	15	905	n.a.	n.a.	99,502	n.a.
777-200ERSF (est)	294,835	138,346	27	520	126	17	647	86,183	4,000	71,132	133
777-300ERSF (est)	351,533	142,428	33	644	182	17	825	95,255	4,800	90,800	115
747-400SF	394,626	161,933	30	585	106	15	691	114,759	4,100	75,985	166
747-400BCF	394,626	163,584	30	585	106	15	691	113,625	4,100	75,985	164
747-400F	396,894	158,621	30	607	116	15	723	118,070	4,450	79,528	163
747-400ERF	412,770	158,939	30	607	116	15	723	118,206	4,970	79,528	163
747-8F	447,696	190,690	34	692	151	15	843	139,072	4,390	92,742	165

Table 18 - Feeder Freighter Characteristics (Imperial)

Model	Maximum Takeoff Weight (lbs)	Operating Empty Weight (lbs)	Total Cargo Volume (ft^3)	Max Structural Payload (lbs)	Range with Max Payload (naut mi)	Volume Limited Payload at 7.0 lbs/ft^3 (lbs)	Design Cargo Density (lbs/ft^3)
Saab 340	28,000	17,200	1,470	8,500	335	10,290	5.8
CRJ 200SF ER	51,250	29,426	1,356	14,574	700	9,492	10.7
CRJ 200SF LR	53,250	29,426	1,356	14,574	1,100	9,492	10.7
CRJ700 (est)	75,000	43,142	2,525	19,158	900	17,675	7.6
ATR-42-300	37,300	22,812	2,000	14,000	460	14,000	7.0
ATR-72-500	48,500	26,933	2,700	19,000	520	18,900	7.0
Dash 8-Q300	43,000	26,000	1,865	13,500	750	13,055	7.2
Dash 8-Q400	65,200	35,200	2,730	19,800	1,100	19,110	7.3

Table 19 - Feeder Freighter Characteristics (Metric)

Model	Maximum Takeoff Weight (kg)	Operating Empty Weight (kg)	Total Cargo Volume (m^3)	Max Structural Payload (kg)	Range with Max Payload (naut mi)	Volume Limited Payload (kg) at 110 kg/m^3	Design Cargo Density (kg/m^3)
Saab 340	12,701	7,802	42	3,856	335	4,576	93
CRJ 200SF ER	23,247	13,347	38	6,611	700	4,221	172
CRJ 200SF LR	24,154	13,347	38	6,611	1,100	4,221	172
CRJ 700 (est)	34,019	19,569	72	8,690	900	7,865	122
ATR-42-300	16,919	10,347	57	6,350	460	6,226	112
ATR-72-500	21,999	12,217	76	8,618	520	8,405	113
Dash 8-Q300	19,504	11,793	53	6,124	750	5,806	116
Dash 8-Q400	29,574	15,966	77	8,981	1,100	8,498	116

Appendix 2 – Aircraft Program Summaries

This section contains descriptive profiles of the most popular aircraft in narrowbody, medium widebody, large widebody and feeder segments.

Narrowbodies

MD-80 Family

The MD-80 was produced in significant quantities from 1980 through 1999. More than 1,100 of several sub-variants were built, all in passenger configuration. Somewhat surprisingly, no P-to-F conversion program was launched for the MD-80 until early in 2010, when Aeronautical Engineers, Inc. announced plans to convert the aircraft. AEI succeeded in gaining FAA certification for its MD-80 P-to-F program in the first quarter of 2013. Four MD-80 variants, the -81, -82, -83, and -88 versions, have the same external dimensions, but have differences in engine variants, take-off weights and cockpit configurations. A shorter-fuselage MD-87 was also produced, but is not considered a candidate for freighter application. The fuselage of the MD-80 is narrower than the fuselage of other commonly used narrowbody aircraft such as 727s, 737s, 757s and DC-8s. As a result, to maximize space utilization MD-80s carry pallets/containers with 88-inch x 108-inch base dimensions. The use of such non-standard pallets/containers for many years discouraged the development of an MD-80 P-to-F program. MD-80s, which are powered by two Pratt & Whitney JT8D-200 series engines, have relatively high fuel consumption and noise compared to other two-engine narrow-body models of the same vintage, which are equipped with newer-technology higher bypass engines (e.g., the 737-300 equipped with CFM-56 engines). However, there are a lot of positive at-tributes of the MD-80, including high production quantities, and the Douglas aircraft heritage that carries a reputation for structural integrity and low maintenance cost. In addition, the value of used MD-80s has fallen significantly in recent years, which means that a freighter-converted MD-80 has a lower price than 737-300F/-400F models which offer similar capability. Despite such attributes, demand for MD 80 freighter conversions has been slow to develop, indicating the MD-80 will play a niche role.

737-300/-400: Classic Family

737-300 and 737-400 model aircraft (also referred to as 737 Classic models) were built during 1984-1999. Approximately 1,100 of the -300 type and approximately 500 of the -400 were constructed, all in passenger configuration. The -300 and -400 are similar, although the -400 type has a stretched fuselage. PEMCO has had a 737-300 conversion program since the early 1990s, developed using Boeing engineering data, and it certified a 737-400 P-to-F program in 2006. PEMCO also offers a 737-400 passenger-to-combi conversion program (certified in 2007). Israel Aircraft Industries (now Israel Aerospace Industries) certified a P-to-F program for the 737-300 in 2004, and for the 737-400 early in 2009. Aeronautical Engineers, Inc. certified a 737-300 P-to-F program in 2005, and a 737-400 P-to-F program in 2007. The 737-300/-400 types, along with the 757-200 are newer alternatives to the outgoing three-engine 727-100/200 freighter models. The relatively small size of freighter-converted 737 Classics (8-10 pallets) results in attractive cost-per-trip, but places them at a disadvantage on a cost-per-ton-mile basis against the larger 757-200. AEI offers a 737-400 conversion that can accommodate 10 full-size pallets/containers (plus an 11th smallersized pallet). Diminishing feedstock of the right age will put an end to the P-to-F conversion of 737 Classics in large quantities by 2020.

737-700/-800/-900/-900ER: Next Generation Family

The Next Generation 737 700/ 800 models succeeded the 737 300/ 400 models after 2000, with over 6,100 units of both types delivered by the end of 2018 and with production continuing while the shift to the newest 737 passenger type – the 737MAX family – began in 2017, and Boeing has over 4,600 orders on the books for this family type. First delivery of a 737MAX took place in mid-2017. The Next Generation models have entered the prime period for P to F conversion and will be popular for conversion beyond 2035. The 737-700 has the same fuselage dimensions as the 737-300, while the fuselage of the 737-800 is about ten-feet longer than that of the 400. The greater capacity of the longer 800 (11 full-size pallets/containers) will likely make it the preferred model for freighter conversion. Boeing offers a production 737-700C (Military C-40) as a convertible aircraft with a large main-deck door, but deliveries thus far mostly have been to government and private (non-airline) customers. In April 2014 AEI announced it was moving forward with development of a 737-800 P to F program, and received FAA STC for the converted 737-800 in February 2019. Israel Aerospace Industries (IAI) disclosed in mid-2015 that it was also entering 737-700/-800 freighter conversion market, starting with the -700 variant. The first IAI-converted 737-700BDSF was delivered to launch customer Alaska Airlines in September 2017, Alaska Airlines now operates three B737-700BDSF. Boeing indicated some time ago that it too was interested in this market, and it formally launched a 737-800 P to F program in February 2016, and delivered the first converted 737-800BCF to GECAS / West Atlantic on April 2018. More recently, PEMCO announced it was moving forward with a 737NG conversion program, starting with the -700 model. In combination, these various programs have orders well in excess of 100 units, mostly of the -800 type. Also of potential interest for P-to-F conversion are two variants of the 737-900: the basic -900 & the higher weight -900ER. The -900 retains the MTOW and fuel capacity of the -800, trading range for payload. Since this variant was not very successful (only 52 units were delivered), Boeing decided to introduce the -900ER in 2007, a variant that meets the range and capacity of the 757-200 and competes with the A321. A total of 505 units of the 900ER and have been delivered to date but no programs for this type have been announced yet.

A320/A321 Family

The A320 family has proven to be extremely popular in the 100-185 seat category of narrowbody passenger aircraft. The two most popular variants are the A320 introduced in 1988, and the A321 introduced in 1994. Both of these current-engine-option (CEO) models remain in serial production, but they have been joined by the so-called NEO (new-engine-option) versions that incorporate the new PW1000 geared turbofan engine or the new CFM LEAP-1A engine. Delivery of A320 NEOs began in 2016. Nearly 4,700 A320s and 1,700 A321s (CEO types alone) were delivered through the end of 2018. No production freighter or certified P to F conversion program exists for any A320 family model. Airbus, EADS-EFW and two Russia-based partners formed a joint venture partnership in 2008 called Airbus Freighter Conversion GmbH to design, certify and manufacture a freighter conversion program for A320 and A321 aircraft. That program was unexpectedly suspended in mid-2011, at which time Airbus stated that the popularity and value of A320/A321 passenger aircraft remained too high to support a viable P to F program. There also was speculation that technical issues played a role in the decision to cancel the program. More recently, in September 2014 little-known US-based PACAVI Group, Inc. announced it was "spearheading a new program for conversions of Airbus A320 and Airbus A321 aircraft from passenger to freighter con-figuration." Certification for the PACAVI A320 freighter was planned for 2017. As it turned out, PACAVI ran into financial problems, and by October 2016 had ceased operations before it had certified any P-to-F program. Separately, Airbus, this time in conjunction with EFW and ST Aero, launched a new A320 family P to F program in mid-2015. The A320 (with 10+ pallet positions) and A321 (with 14 pallet positions) have more capacity than the 737-700 and -800 models, which carry only 8 and 11 pallets, respectively. The Airbus models also are equipped to handle containers in the lower-deck compartments while the 737NGs are not. This P to F effort is headed by Dresden-based EFW, which is now a 45:55 joint venture between Airbus (with the minority share) and ST Aero. During 2017 a new entity, 321 Precision, joined the A321 freighter conversion race. The company is a joint venture between Precision Aircraft Solutions (well known for its successful 757 P-to-F program), and ATSG (known primarily for the leasing and operation of 767 freighters, but also the new parent company of PEMCO). Other parties are also interested in converting A320s/321s into freighters. C3 Aero (C-cubed Aero) announced in September 2017 it was moving forward with a program to convert both the A320 and A321, but to date has provided limited details of its program features or timing. Elsewhere, Sine Draco has disclosed plans to develop an A321 conversion program, and there are rumors that IAI and one or two other parties are also interested in the A320/321 conversion market. Despite the wide interest shown in developing A320/321 conversions, there have been limited firm orders. Vallair, a Luxembourg-based leasing company, placed firm orders for A321s with both 321 Precision (one unit) and EFW (ten units). Deliveries will begin by the end of 2019. Separately, EFW recently signed a letter of intent with China-based Guangdong Aerocity Holding Co Ltd to convert up to ten A320s. EFW expected to receive its STC for the A321 P 2 F conversion by the end of 2019 and 321 Precision is targeting 1Q 2020. EFW has indicated that it would commence its A320 conversion program following certification of the 321.

757- 200

Production of the 757-200 and 757-300 extended from 1982-through-2005, during which 914 passenger units and 80 freighters were built. The freighters were built from 1987-1999, mostly for UPS. The factory-built freighters can accommodate 15 main-deck pallets. Boeing developed a freighter conversion program for DHL and modified 34 aircraft in 2001-2003. The Boeing program found no additional customers due in part to its high price for conversion ($7.5 million). More recently Precision Aircraft Solutions certified a 757-200 P-to-F program in 2005, and Alcoa-SIE completed certification of a competing program in 2006. The Precision and Alcoa-SIE conversion programs were priced more favorably in the range of $4-$5 million. Late in 2009 PEMCO World Air Services acquired the Alcoa-SIE 757 P-to-F STC, but had no success in the market with this program, and no longer offers 757 conversions. Singapore-based ST Aero, and its Mobile Aerospace unit in the US, developed another 757-200 P-to-F program using data licensed from Boeing. The ST Aero program was certified in mid-2008, and ST was selected by FedEx to convert approximately ninety (later raised to 119) 757s to freighter configuration through 2016. The total quantity of in-service 757-200 freighters stands at 307, including more than 200 converted units. The in-service quantity takes into account retirement of a significant number of the units converted for DHL over fifteen years ago. The companies involved in P-to-F conversion of 757s also developed programs to convert 757-200s into combi aircraft that accommodate a mix of passengers and freight on the main deck. A small number of combi conversions have been completed, mainly for use in military and government support. The 757 is the largest of the competing narrowbody freighter candidates. It offers two-crew, two-engine economics with cargo volume about 25% more than the 727-200F. The 20+ year production period is an advantage for future freighter conversions. Converted 757s been used mainly as 727-200F replacement aircraft, but the relatively high cost of acquisition and conversion, plus the high cost of engine maintenance, places the higher-performance 757 at a disadvantage compared to the lower priced 737-300/-400 of similar age for applications outside the networks of major express companies. Thus, the main use of 757-200Fs to date has been in express network operations. In a similar manner to the 737 Classic models, the feedstock pool of 757s for freighter conversion is shrinking. We believe the period for conversion of 757s will come to a close around 2023.

There has been some discussion about the potential launch of a 757-300 conversion program. While there is not a large amount of available feedstock, there could be interest from existing 757-200 customers in a larger, stretched aircraft.

Medium Widebody

767-200 and -200ER

Production of the twin-engine 767 began in 1982 with the 767-200 model; the higher-weight -200ER was introduced in 1984. Approximately 120 of each of the -200 and -200ER types were built. All the 767 200/ 200ERs built for the commercial market were passenger aircraft, none were freighters. Most of the -200s were built from 1982-through-1985, and most -200ERs were built from 1984-1993 (although twenty-five commercial -200ERs were built from 1994-through-2008). Beginning in 1998 ABX Air converted 24 767 200s to “package-freighter” configuration, without installing a large main deck cargo door, for use in the Airborne Express/DHL US express network. Israel Aerospace Industries later (in 2004) certified a large-door conversion program for the 767-200/-200ER model. Approximately 60 767 200/ 200ERs have undergone P-to-F conversion by IAI, including the 24 ABX Air “small-door” units in which large cargo doors have now been installed. Boeing in partnership with Aeronavali developed a competing 767 200SF conversion program; however, the Boeing/Aeronavali program encountered delays, and only one such conversion of this type was ever completed. Freighter-converted 767 200/ 200ERs offer similar cargo capacity to the Airbus A300 freighter family, but provide somewhat greater range capability. All 767 models are limited to pallets/containers with 88-inch x 125 inch base dimensions for loading in a side-by-side arrangement (they can’t accommodate side-by-side 96-inch x 125-inch ULDs). Note: the lower decks of all 767Fs are not as cargo-friendly as other widebodies due to their narrower width. Given the low production quantities of the -200 and -200ER models, along with the effective end of their production period in 1993, no further freighter conversion of the-200 or -200ER models will take place. Attention has turned to the larger, more capable 767-300 model (profiled below).

767-300 and -300ER

Boeing 767-300 is a widebody twin engine aircraft. The Boeing 767 family was Boeing’s first two-crew glass cockpit jetliner. Boeing has produced three different series of the 767, the -200, -300 and -400. The 767-300ER entered service in 1988 as an updated extended range version of the 767-300. The MTOW of the 767-300ER was originally 407,000lbs but later increased to 412,000lbs in 1993. The 767-300ER can be outfitted (and freighter converted) with or without winglets. Freighter conversion of the 767-300ER got off to a slow start due to 787 delivery delays preventing some airlines from releasing their aging 767-300ER passenger aircraft as planned. In 1995 Boeing introduced the 767-300F, the production freighter version of the 767-300ER. The 300F has a main deck capable of holding up to 24 88x125-inch pallets and up to 30

LD2s (a container unique to the 767 fuselage belly contour) on the lower deck. The 767-300F is still in production, with a backlog of 109 orders as of March 2019. Boeing certified a 767-300BCF (Boeing Converted Freighter) program in June 2008, with conversions done at ST Aero (Singapore). Israel Aerospace Industries completed development and certification late in 2009 of a competing P-to-F program (the 767-300BDSF), marketed on a joint venture basis with Mitsui under the M&B Conversions name. Conversion activity on the 767-300ER model was weak at first, but has picked up significantly over the past five years. We expect that conversion activity will remain strong for several years, but feedstock limits will become more problematic around 2025. Orders by FedEx for more than 100 units since 2011 will keep 767-300F production going for several years, as will orders by the US Air Force for an aerial tanker based on the 767-200. There were rumors that Boeing might increase production rates for the 767 based on reported interest by UPS and SF Express for the -300F, and by passenger carriers for the 300ER. Boeing did sign a deal with UPS in 2018 for four freighters, but says it will not make any major increase in expand production rates. Production 767-300ER freighters were the largest, most capable of the twin-engine medium-capacity widebody freighters available in the market until the A330-200F entered service in mid-2010. The 767-300F has greater payload-range capability than the A300-600F, but less than the A330-200F. A major benefit of the 767 300ER as a conversion candidate is its high production totals over an extended period (nearly 600 units built over more than 20 years). P-to-F conversion of 767 300ERs is expected to extend beyond 2025.

A300-600 and -600R

Airbus freighters (A300B4, A300-600 and A310-200/-300) long dominated the medium-widebody segment of the freighter aircraft market. The A300-600 is the largest of these Airbus models, and it has proven popular mainly in regional express networks. The A300-600 was developed as a follow-on type to the A300B2/B4 that had been the first Airbus models. Airbus produced 293 A300-600 and higher-weight -600R units from 1984 through 2007, of which 106 were production freighters. The A300-600 (similar to other Airbus freighters) can accommodate 96-inch x 125-inch pallets/containers in a side-by-side arrangement on the main deck. The lower deck can handle 96-inch x 125-inch pallets and industry-standard LD-3 containers. The A300-600 is restricted to regional operations based on its relatively limited range capability with a full load. Approximately 60 A300-600s have been converted to freighter configuration in a P to F program developed by EADS EFW (Dresden). US-based Flight Structures, Inc. achieved certification of a competing A300-600 P-to-F program in December 2008, but just five FSI A300-600 conversions have been completed. Production of passenger-configured A300-600s totaled fewer than 200 units, and less than 20 such aircraft were delivered after 1995, so the supply of suitable feedstock has dropped to near zero, and as a result P-to-F conversion of A300-600s is ending.

A330-200/-300 and A340

Airbus introduced the two-engine A330 and the four-engine A340 as companion models in 1993. Both were originally offered with two fuselage lengths, carrying the -200 and -300 model designations. The A330 proved to be more popular than the A340 because of its two-engine operating economics. More than 1,400 passenger-configured A330s have been built (split about 45:55 between the -200 and -300 types). A total of 377 A340s were built (including about 220 A340-300s) in the period from 1993 through 2010; A340 production ended in 2010. (Note that this A330/340 overview excludes the stretched A340-500 and -600 types, which are not expected to become freighter conversion candidates.) EADS/Airbus announced the launch of a production A330 200F program in January 2007. This type, an all-cargo derivative of the A330-200 capable of carrying 65 tonnes over 4,000 Nm or 70 tonnes up to 3,200 Nm. To overcome the standard A330's nose-down body angle on the ground, the A330-200F uses a revised nose undercarriage layout to provide a level deck during cargo loading and unloading. The normal A330-200 undercarriage is used, but its attachment points are lower in the fuselage. The A330-200F is easily identifiable by the distinctive "bulge" surrounding the nose gear. The freighter has not been a commercial success. As of the end of 2018, 38 A330-200Fs had been delivered, with a firm order backlog of just four units. Furthermore, a number of the delivered units have been taken out of service by their owners. The lack of orders for the A330-200F calls into question whether Airbus will choose to terminate the program.

In addition to the production A330-200 freighter, in mid-2012 Airbus, EADS-EFW and ST Aerospace formed a joint venture to develop a P-to-F program for the A330 type. In conjunction with this endeavor, ST Aero took a 35% stake in EFW (later increased to 55%). First up for the venture was development of a P-to-F program for the A330 300 model, followed closely by a conversion program for the A330-200. Late in 2014 EgyptAir became the launch customer for the program, signing an agreement for conversion of two A330-200 aircraft from its own passenger fleet. DHL became the launch customer for the -300 in 2016, and it took re-delivery of the first newly certified A330-300P2F late in 2017. DHL has placed orders for eight -300 conversions (plus ten options). The converted A330-300 is aimed at express operators, which have low density cargo, and want to take advantage of the stretched fuselage of the -300 model. The production A330-200F has not gained market acceptance, despite the significant gains in both payload and range capability it offers compared to the competing 767-300F. The A330/340 have the same fuselage cross-section as the A300/310. They have wider fuselages than the 767, but narrower fuselages than the MD-11, 777 and 747 models. A330/340 models can carry side-by-side 96-inch x 125-inch pallets/containers (22 total for the A330 200F). The A330 and A340 models are smaller and have lower takeoff weights than competing 777 models. Thus converted 777 freighters (none of which exist today), are expected to offer greater payload-range capability than the A330/340 freighters. After 2022, we expect to see a noticeable decrease in the price of feedstock in combination with an increased number of airframes available, creating more favorable conditions for A330P2F conversions. In 2014, Airbus announced the A330NEO (New Engine Option) family, featuring the A330-800 and the larger A330-900. The -900 entered service in late 2018 with TAP Portugal. There have been rumors that Airbus is considering an A330 neo production freighter, perhaps based on a -900 platform. At the time of writing it remains unclear whether Airbus will invest in the design of a new medium widebody freighter.

Large Widebody

MD-11F

The MD-11 never achieved widespread popularity as a passenger model, but has proven popular as a freighter. Two-hundred MD-11s were produced from 1989-through-2001. Of these, 64 were de-livered as freighters or combis. McDonnell Douglas developed a freighter conversion program that Boeing continued after the McDonnell Douglas/Boeing merger in 1997, and about 120 units underwent conversion. Touch labor on most of the conversions was done by Aeronavali or Singapore Technologies (SASCO). Boeing stopped offering the MD-11 freighter conversion program, due to lack of demand and lack of feedstock. The MD 11F remains popular in express network applications, but its use in the general cargo market declined significantly after the 2008/09 recession.

777F (including 777X and 777 P-to-F conversions)

Boeing launched a production 777 freighter program in 2005 based on the 777-200LR passenger model. To date Boeing has received 217 orders for the freighter from twenty-four customers). Certification of the 777F was achieved in February 2009, and Boeing had delivered 160 777Fs through the end of 2018, leaving a backlog of 57 units. The 777F offers enhanced capability compared to the MD-11 freighter. The 777F has a wider fuselage than the A330/A340, and it can accommodate 10-foot-high pallets on the main deck. The 777F is the only large capacity, twin-engine freighter. Boeing disclosed in 2008 that it had begun development work on a 777 Boeing Converted Freighter (BCF), but has yet to formally launch the program. The first converted 777-200ER aircraft would enter service about three years after a launch order is secured. Boeing's interest in such a 777 P-to-F program appears to have declined over the past three years based on a lack of enthusiasm in the concept by potential customers. The 777-200ER model, on which the converted freighter would most likely be based, has substantially lower maximum weight capability than the production 777F (derived from the 777-200LR model), so a 777BCF would have significantly lower payload-range capability than the production 777F. Boeing's initial assessment indicates a 777-200ERBCF would be able to carry 180,000 pounds a distance of 3,900 nautical miles. Freighter conversions of the higher gross weight 777-300ER and 777-200LR models would come much closer to the production 777F in capability; however, these models will not be old enough, or available in sufficient quantity, to support conversion until after 2020. Israel Aerospace Industries (IAI) has also discussed development of a 777 P-to-F program, and has said on numerous occasions in 2016 and 2017 that it would be announcing soon a launch customer for the program. As of early 2019 no official program launch had taken place. Finally, Boeing is moving forward with the enhanced 777X version of the passenger model for introduction by 2020. We presume that a follow-on 777XF production freighter will be developed as well, but with service introduction after 2025. Boeing has not disclosed details about the transition of production from the current 777 model to the new 777X, nor for how long after 777X production begins that it will continue to build the existing 777F model.

747-400 and -400ER

Boeing produced the 747-400 model from 1989 through 2009, during which time it delivered 508 passenger and combi units, and 165 freighters (these totals include the extended range, ER, versions). Approximately 245 747-400 freighters were built (including the production -400F and -400ERF units, plus P-to-F conversions), although about 197 were in active service entering 2019. Boeing certified a 747-400BCF passenger-to-freighter conversion program in December 2005 and a combi-to-freighter conversion program in 2007. Israel Aerospace Industries (IAI) certified a competing program for both passenger- and combi-configured 747-400s in 2006. Boeing's conversions have been performed by TAECO (China), although Boeing sold kits to Korean Airlines and Singapore Airlines, through which the engineering units of these carriers completed some installation/conversion work. No 747-400 P-to-F conversions were completed from 2010 through 2016, and Boeing announced in 2016 that it had officially suspended its -400BCF program. Surprisingly, IAI announced about the same time that it had received an order (from EVA Air) for conversion of two combi-configured 747-400s, which were re-delivered in 2017. In theory the 747-400 remains a candidate for P-to-F conversion through 2021 based on the production period for the passenger version, although we doubt that any more -400 P-to-F conversions will be completed. The roughly 80 conversions that have been done is a much smaller quantity than originally anticipated before the 2008/09 recession and subsequent period of weakness in global air cargo demand. Until the 747-8F went into service late in 2011, the 747-400 and -400ER freighters were the largest, most capable commercial freighter aircraft. Compared to the earlier-generation 747-200/-300 models, the -400/-400ER feature a two-person flight crew, enhanced payload-range performance, lower fuel consumption and reduced noise. Production 747 freighters are equipped with side cargo doors and top-hinged nose cargo doors; converted passenger aircraft have side cargo doors only. The newer model freighters – the 747-8F and 777F – offer bigger size and/or better operating economics. The 747-400F and ERF have lost their status as "top-of-the-line" freighters, but they will play a significant role in the freighter aircraft market for many years, given that these production freighter models represent about 30% of all large freighters currently in operation. The production -400F offers the nose door and sufficient performance enhancement to distinguish it from the P-to-F versions. Thus, retirements among the 747-400 freighter family mainly have been units of the converted 747-400BCF and 747-400BDSF types.

747-8

Boeing launched the 747-8 program in 2005 based solely on orders for the freighter version (ten firm orders from Cargolux and eight firm orders from Nippon Cargo). The 747-8F's first flight took place in February 2010, and FAA certification was achieved in September 2011. First deliveries of the 747-8F took place in the fourth quarter of 2011, and 83 units had been delivered by the end of April 2019. Boeing has recorded 107 orders for the freighter version from eleven airline customers (this number includes the recent order from UPS for a total of 28), leaving a backlog of 23 units as of April 2019. The 747-8 is the only 747 model currently in production. The -8F incorporates 787 technology to provide enhanced performance and lower operating cost than the prior generation 747-400F/ERF models. The longer fuselage provides four extra main-deck pallet positions, plus three extra belly pallet positions versus the -400F/ERF. We believe the -8 model will be produced mainly in freighter configuration through about 2022, although weak demand for the 747-8I (Inter-continental) passenger version could force Boeing to end the 747 program sooner. Combined production of both models dropped to 0.5 units per month in 2016, and Boeing disclosed it might be forced to terminate the program due to a lack of sales. However, the orders from UPS for twenty-eight -8Fs in 2016/17, and a small order for three units from undisclosed customers, have provided a reprieve for the 747-8 program. The current backlog seems sufficient to allow for production through 2022. Freighter conversion of passenger-configured 747-8s is a possibility after 2025, but this is considered unlikely given the small quantity of -8I passenger units expected to be produced.

The following section contains short descriptive profiles of the most popular models in the turboprop and regional jet (feeder) segments today (with payloads of 8,000-20,000 pounds):

Feeders

Bombardier CRJ Series

The Bombardier CRJ series began as the Canadair Regional Jet program in 1989. The CRJ100 model, which entered service in 1992, was a modified Canadair Challenger business jet with twenty-foot longer fuselage. The CRJ100 had typical seating for 50 passengers. The CRJ200 is identical to the 100 model except it has more efficient engines. Production of the CRJ200 continued through 2005, by which time over 900 of the 100s/200s had been built. These 50-seaters fell out of favor as regional airlines turned attention to larger models. Following the success of the CRJ100/200 series, Bombardier produced larger variants in anticipation of increasing seat limits in US airline pilot union scope clauses in competition with Embraer's E-Jets. The CRJ700, which entered service in 2001, is a stretched 70-seat derivative of the

CRJ200 that also featured a new wing, and slightly widened fuselage. The CRJ700 was followed by the higher capacity CRJ900 and 1000 models, the latter of which entered service in 2010, with up to 100 seats. Through the end of 2018 a total of nearly 900 of the CRJ700/900/1000 family had been produced, including about 350 CRJ700s and 400 CRJ900s. The CRJ700/900/1000 family directly competes with the Embraer 170/175/190 models.

Until 2015 the only application of the CRJ models in a freighter role was a package freighter modification for the CRJ200 developed by Cascade Aerospace in 2007. The CRJ200PF (Package Freighter) was developed at the request of West Air Sweden to respond to a demanding request for proposal from the Norwegian Post. The CRJ200PF is not equipped with a large cargo door and as a result all cargo is bulk-loaded through the original aft baggage door. A large-door CRJ200SF freighter conversion was certified by Aeronautical Engineers, Inc. late in 2016. The first CRJ200SF was delivered to Gulf & Caribbean Cargo in December of that year. The program was developed in conjunction with the manufacturer, Bombardier. The converted CRJ200 can carry eight 88x61.5-inch pallets.

ATR 42/72 Series

The ATR 42 is a twin-turboprop, short-haul regional airliner built in France and Italy by ATR (Avions de Transport Régional). Final assembly takes place in Toulouse, France. The 42 in the name refers to aircraft's standard seating capacity, which varies from 40 to 52. The ATR 42 served as the basis for the larger ATR 72. The ATR 42 entered service in December 1985. In addition to the passenger 300 model, an ATR 42 300QC quick-change (convertible) freight/passenger version was offered. An upgraded 500, incorporating higher performance engines and other system enhancements, entered service in 1995, and the latest model, the -600, with further upgrades including a glass cockpit, was introduced in 2012. By the end of 2018 over 475 ATR 42s had been built, along with more than 850 of the larger ATR 72 model. The ATR 72, a stretched variant of the ATR 42 model, entered service in 1989. Seating is available for up to 78 passengers in a single-class configuration. The ATR 72 incorporates a 15 ft. fuselage stretch, increased wingspan, and more powerful engines than the ATR 42. As with the smaller companion model, passengers are boarded using the rear door, which is unusual for a passenger aircraft, and the front door is used to load cargo. That configuration feature has helped support freighter conversion of both the ATR 42 and 72 types. The original -100 and -200 versions of the ATR 72 were augmented by upgraded -500 and -600 models from 2010. Quick change and cargo versions of the ATR models were offered but saw limited acceptance. However, several freighter conversion programs by third parties have been developed.

The most successful was a program for both a bulk-load and a large door modification developed by Alenia Aermacchi. In 2015 Switzerland-based IPR Conversions acquired Alenia Aermacchi’s passenger-to-freighter conversion STCs for both types of modifications. Subsequently, IPR received EASA certification to convert the newer-generation ATR 42/72-500 models, in addition to the earlier-generation ATR 42-300 and ATR 72-200 models. First delivery of a converted -500 model took place in 2017. Other bulk load ATR freighter conversions were developed by US-based M-7 (which converted ATR 42s and 72s for FedEx), and by France-based Aeroconseil. M-7 has since left the freighter conversion market, but Aeroconseil appears still to be offering ATR conversions. A major development for freighter application of the ATR 72 took place in late in 2017 when FedEx announced plans to acquire factory-built ATR 72-600s in freighter configuration. The express company placed a firm order for 30 units (plus options for 20 more) for delivery beginning in 2021. These ATR freighters will incorporate Large Cargo Door and Structural Tube Modifications from IPR (noted above).

Bombardier Dash 8 Series

The Bombardier Dash 8 (Q-Series) began as the de Havilland Canada DHC-8 or Dash 8. It comprises a family of twin-engine, medium-range, turboprop airliners first introduced in 1984. Dash 8s are now produced by Bombardier Aerospace. The aircraft has been delivered in four series: the -100 with maximum seating for 39; the -200 with the same capacity but more powerful engines, the -300 with a stretched fuselage and 50-seat capacity, and the -400 with a further stretch that can carry 78 passengers. Models delivered after 1997 have cabin noise suppression and are designated with the prefix "Q" (quiet). Production of the -100 series ceased in 2005, and the Q200 and Q300 in 2009. A total of 671 Dash 8 -100/-200/-300s were produced; production of the -400 series reached about 630 by the end of 2018.

There has never been a production freighter version of the Dash 8 series, but there have been some recent freighter-related developments. In 2009 Canada-based Cascade Aerospace developed a package-freighter conversion for the Q400 model, but had sold only five conversion kits by the end of 2017. Separately, Air Inuit, a Dash 8 operator serving the northern Canada market, on its own converted two of the Dash 8-300s in its fleet into bulk-load freighters. Both the Cascade Aerospace and Air Inuit conversions load cargo through the standard aft baggage door. Bombardier is also making moves to expand the freight offerings of the Dash 8 line. In 2016 it began delivery of a production Q400 combi, and it is supporting an Air Inuit led program to develop and certify a large-door freighter conversion for the Q300. The Bombardier/Air Inuit program also includes Rockwell Collins (B/E Aerospace) as a team member. Certification by Transport Canada of a bulk-load Q300 P-to-F program was awarded in mid-2017, and work continues on a large cargo door version. The refreshed design features enhancements over the modification previously done by Air Inuit, and can be sold in kit form for installation by a third party. Both the small door and large door versions will be available in bulk-load and palletized cargo variants. Separately, Canada-based Voyageur Aviation early in 2017 rolled out the first freighter-converted Dash 8-100PF, with bulk loading of packages through the original aft door.