

The significance of the Chinese domestic market for narrow-body passenger-to-freighter (P2F) jet aircraft conversions

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Abstract

This paper examines the reasons for the predicted growth in demand for air cargo in China over the next 20 years, and discusses why standard body freighters will dominate the air cargo sector. Because there are no new-build factory produced freighters available in the standard-body segment, this market is based solely on the conversion of passenger-to-freighter (P2F) aircraft. A survey is conducted of the entire Chinese commercial jet aircraft fleet which reveals a generous feedstock of candidate P2F aircraft (B737/738 and A320/321). This strongly suggests China could easily be self-sufficient in supplying its own standard-body freighters. The major conversion houses are well aware of this market potential, and they are now striking various collaborative arrangements with Chinese MROs. The details of these liaisons are presented which reveal how the nascent P2F ecosystem in China is developing.

1.Introduction

The air transportation of goods and freight for commercial purposes plays a significant role in the global economy and the demand for the speed and reliability benefits that air freight offers continues unabated. Industries that need to transport low-volume, light-weight, time sensitive and high-value commodities, such as consumer electronics, industrial components, pharmaceuticals, medical devices, and goods that have a relatively short marketing life such as seafood, fresh fruit and freshly cut flowers, all recognize the value of air freight, and the value proposition this plays in their shipping decisions (Wang 2007).

Air cargo shipments can be transported in the lower-deck belly-hold of commercial passenger aircraft or by using a scheduled or charter all-cargo service operated by dedicated freighter aircraft with all the available capacity dedicated to air cargo transportation. Dedicated freighters remain an essential part of the air cargo business because certain factors, such as the departure and arrival times, type and size of cargo, and difference between cargo and passenger destinations, limit the use of passenger flight belly hold cargo (Wensveen 2015). Dedicated freight services offer shippers a combination of reliability, predictability, and control over timing and routing that is generally superior to that of passenger operators.

Dedicated freighter aircraft are generally divided into three size categories (Boeing 2003): small capacity narrow-body freighters (payload < 30 tonnes), medium capacity wide-body freighters (payload 30-70 tonnes), and large capacity wide-body freighters

(payload > 70 tonnes). The focus of this work is on narrow-body freighters, which will henceforth be referred to as standard-body freighters to align with US classifications. These are unique in the sense that currently there are no new-build factory-produced freighters available in this particular market segment, only converted passenger-to-freighter (P2F) aircraft (Aircraft Commerce 2017; Woods 2015). These aircraft are commonly known as “single-aisle” aircraft, referring to the same model when it was operated in a passenger configuration (Boeing 2003).

Current projections forecast major growth in world air cargo, from 200 billion RTKs¹ (2015 estimate) to 500 billion RTKs by 2035, assuming a 4% compound annual growth rate (Boeing 2016a). See Figure 1. When considered by region, it is apparent that much of this growth will be centred on China and the greater Asia-Pacific rim. According to Boeing (2016), “Intra-Asia traffic is forecast to grow faster than any other international world market, averaging 5.5 percent growth per year.” This growth will be driven primarily by e-commerce and it is predicted that by 2020 the internal Chinese market alone will outstrip those of the USA, Japan, Germany, the UK and France combined (Boeing 2016a).

Figure 1. Boeing (2016a) forecast for world air cargo RTKs.

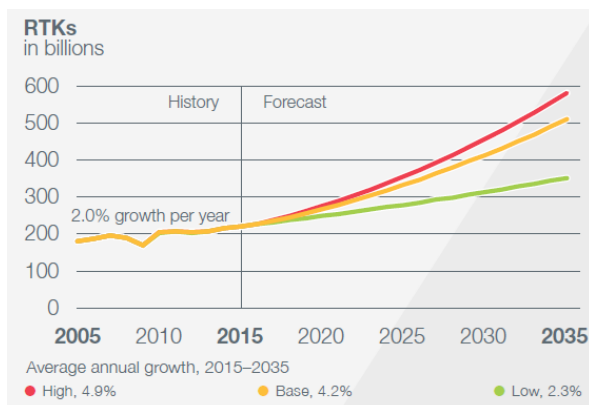
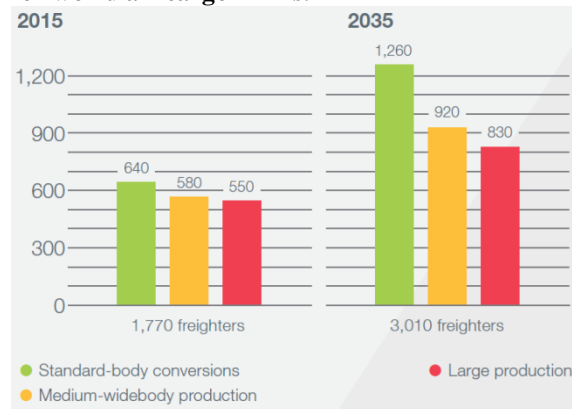


Figure 2. Boeing (2016a) forecast for world air cargo RTKs.



Accordingly, Boeing (2016a) and Airbus (2017) also predict that the next 20 years will see a corresponding requirement for a substantial number of new freighter aircraft to service the growing demand for world air cargo traffic. With reference to Figure 2, it can be seen that standard-body aircraft are anticipated to outnumber the medium-widebody and large production freighters, with numbers predicted to increase from 640 (in service in 2015) to 1,260 by 2035. This is largely because standard-body aircraft are ideally suited to servicing large regional domestic markets like the USA, Europe, and China. Given the projected growth figures, there is a lot of interest in the standard-body future market. Hence the aim of this paper is to discuss the future of the standard-body air freighter in the context of the Chinese domestic/regional market.

¹ Air cargo traffic is measured in RTKs, Revenue Tonne-Kilometres, A revenue tonne-kilometre is generated when a metric tonne of revenue load is carried one kilometre.

2. Methodology

The research undertaken in this study was broadly exploratory in nature (Farquhar 2012; Yin 2014) and uses secondary data analysis to investigate the title problem. The three principles of data collection suggested by Yin (2014) were followed in this study: the use of multiple sources of case evidence, creation of a database on the subject, and the establishment of a chain of evidence.

The database developed for this work is central to much of what follows – it features a compilation of key information about every single in-service commercial jet aircraft currently operated on the Chinese civil aviation register. For each aircraft, the following information was collected: CAAC Registration Number, Aircraft Type, Configuration, Delivery Date, Age, Current Operator, and any Remarks. A partial view of this database is shown in Figure 3, valid at 31 March 2018. The aircraft information is sourced from Planespotters.net which is a powerful, reliable, open-domain aircraft search engine; these data are subsequently verified through each operator's official website. Figure 3 shows a typical excerpt of the compiled data.

Figure 3. Excerpt from the database of current in-service Chinese Commercial Airlines.
Source: Original from the study.

In-service Commercial Chinese Aircraft Database							
* By March, 2018							
S/N	Reg	Aircraft Type	Config	Delivered	Age*	Operator	Remark
1	B-1472	Boeing 737-800	Y189	Jun-17	0.8 Years	9 air	
2	B-1473	Boeing 737-800	Y189	Jun-17	0.7 Years	9 air	
3	B-1551	Boeing 737-800	Y189	Aug-16	1.6 Years	9 air	
4	B-1552	Boeing 737-800	Y189	Jul-16	1.7 Years	9 air	
5	B-1553	Boeing 737-800	Y189	Dec-16	1.5 Years	9 air	
6	B-1556	Boeing 737-800	Y189	Dec-16	1.3 Years	9 air	
7	B-1592	Boeing 737-800	Y189	Mar-17	1.2 Years	9 air	
8	B-1715	Boeing 737-800	Y189	Aug-14	3.7 Years	9 air	Leased
9	B-1716	Boeing 737-800	Y189	Feb-15	3.3 Years	9 air	Leased
10	B-1719	Boeing 737-800	Y189	Sep-14	3.6 Years	9 air	Leased
11	B-6989	Boeing 737-800	Y189	Jul-15	4.7 Years	9 air	Leased
12	B-6990	Boeing 737-800	Y189	Jul-15	4.9 Years	9 air	Leased
13	B-6991	Boeing 737-800	Y189	Mar-16	4.7 Years	9 air	Leased
14	B-6992	Boeing 737-800	Y189	Mar-16	4.6 Years	9 air	Leased
15	B-2364	Airbus A319-100	C8Y120	Jun-05	12.8 Years	Air China	
16	B-2404	Airbus A319-100	C8Y120	Apr-05	12.9 Years	Air China	

3. Background - Air freight and the Chinese domestic market

China has experienced strong economic growth since the beginning of the economic reform started in December 1978 (Jiang, Ren, & Hansman 2003) and by 2016 its total yearly GDP had exceeded US\$11 billion (China GDP 2018). Direct investment in core aviation businesses was permitted in 1997 (Zhang & Round 2008) and at the time of writing (March 2018) there are some 3,320 jet airliners on the Chinese register, operated by 53 government-owned and privately-held airlines. To maintain its economic growth, and to overcome the immaturity in the country's current passenger air system, China is investing heavily in its own aviation infrastructure by establishing a US-style "hub-and-spoke" route network. It plans to build 66 new civil airports in the next five years, taking the number of such airports on the Chinese mainland from 206 to 272 (China Daily, 2016). This will make

many small cities accessible and allow them to become an integral part of the air traffic supply chain.

From a transportation perspective, China has a challenging geography that includes plateaus, plains, basins, foothills, and mountains. Mountainous terrain occupies nearly two-thirds of the land, which is highest in the west, and steps lower progressively through the centre before levelling out along the Eastern coastal region. See Figure 4. Clearly, given the vast size of the country, and the somewhat inhospitable terrain, shipping goods from the retailer to the customer can be rather problematic. For instance, the direct distance between the southern economic centre, Guangzhou (IATA airport code: CAN), and the biggest western city, Urumqi (IATA airport code: URC), is 3,280 km. By surface transportation, deliveries between these two centres are estimated to take approximately 46 hours by truck and 67 hours by train, but the exact delivery time could be much longer depending on the weather, the time of year and prevailing traffic conditions (Batisse 2005). In contrast, this route takes just 5 hours and 20 minutes by air, offering far greater reliability than the alternative surface modes.

Figure 4. Outline map of China, showing key geographic regions and distances. Adapted from http://mccleskeyms.typepad.com/files/worksheetworks_geography_of_china_1.pdf



This is why *e-commerce* companies like *Amazon*, *Alibaba*, *eBay*, and others, rely on the express delivery services made possible by aviation to ship their goods to their customers. For example, Chinese “Single’s Day” in 2016 saw online shoppers buy goods worth US\$17.8 billion, representing 657 million packages – and air transport plays an essential role in their delivery (IATA 2018). As *e-commerce* has rapidly developed in China, delivery quality has become one of the critical factors used to judge the service of online retailers. Whilst speed is one important reason why most online shoppers request their goods to be shipped by air, predictability and reliability both come a very close second.

Besides the Business-to-Customer (B2C) model just described, the flow of goods supporting the Business-to-Business (B2B) market is another driver that is increasing the demand for air cargo traffic. For example, manufacturers from the electronics industry are primarily located in the coastal region of China (see Figure 4), but many of its suppliers are situated in the

centre or even in the western regions. The short delivery time, reliability, and predictability of the air cargo mode is essential to this time-critical industry, which explains why air freight has become an integral part of the B2B supply chain.

China's regulatory reforms have also had an impact on air cargo traffic. In 2015 China scrapped its one-child policy, and citizens are now encouraged to have two children per family. This has subsequently increased the consumption of mother and baby products, and in the wake of the Chinese tainted milk scandal, Chinese retailers are now importing significant quantities of baby milk formulas, pharmaceuticals, vitamins and healthcare products from trusted Western countries like Australia and New Zealand. In May 2018 China removed import tariffs on all common drugs including cancer drugs, cancer alkaloid-based drugs, and imported traditional Chinese medicine (Liang 2018), which means more such drugs will be imported from overseas. As mentioned above, these kinds of products, many of which have a limited shelf-life, are more likely to be delivered to the end users by air.

4. The passenger-to-freighter (P2F) potential within China

4.1. Introduction to passenger-to-freighter (P2F) conversions

At the time of writing (March 2018) there is no new-build factory produced freighter available in the standard-body market segment - the market is based solely on the conversion of passenger-to-freighter (P2F) aircraft (Aircraft Commerce 2017; Woods 2015). Thus, with a business model that is largely focussed on delivering the lowest cost, the world's air cargo-carrying airlines are increasingly relying on the inherent savings and efficiencies that can be obtained from converting retired aircraft into a full cargo configuration (Smith 2017).

When considering P2F conversions, airlines tend to focus on the true and direct operating costs of the aircraft, which take into consideration the initial aircraft acquisition cost, conversion costs, leasing rates in the event the airline is not purchasing the aircraft directly, maintenance costs and whether the aircraft's available payload is an ideal fit for its intended role. This is especially critical in the standard-body P2F conversion segment, which not only provides freighters to the express carriers but also to niche airlines that provide cargo services around the world, often in developing regions (Karp 2010). In addition, there are two other key factors that must exist to create an active market for airlines seeking to acquire passenger-to-freighter (P2F) converted aircraft. The first is that there needs to be a strong demand for air cargo services, which has already been noted in Section 3, and in Figures 1 and 2. Secondly, there also needs to be the availability of sufficient suitable aircraft (feedstock) at prices low enough to justify their conversion into a full freighter configuration (Flint 2002).

The conversion from passenger-to-freighter (P2F) configurations normally occurs when an aircraft is between 15-20 years in age (Morrell 2011). Many operators of standard-body P2F freighter aircraft often have quite low aircraft utilization rates; hence the strategy of these operators has often been to acquire aircraft with the lowest acquisition cost (Aircraft Commerce 2007). These express airlines prefer smaller-capacity aircraft on cargo routes. That's because cargo is often produced and distributed from transport hubs far away from major cities, which is one way to reduce operational costs. Unlike wide-body freighters which have high daily utilization rates, standard-body freighters generally fly fewer hours. Accordingly, this places a high emphasis on the feedstock acquisition costs (Dahl 2011).

The ideal candidate aircraft type for P2F conversion should have high production totals as a passenger aircraft to provide a sufficiently large feedstock inventory to select from. At least 200 passenger units is considered an ideal number. The aircraft type should also be losing its passenger appeal, which will result in relatively lower residual values. Furthermore, the candidate aircraft will require a source of freighter conversion. This could be provided by the original equipment manufacturer (OEM), or alternatively, by a well-respected third-party maintenance organization or conversion house.

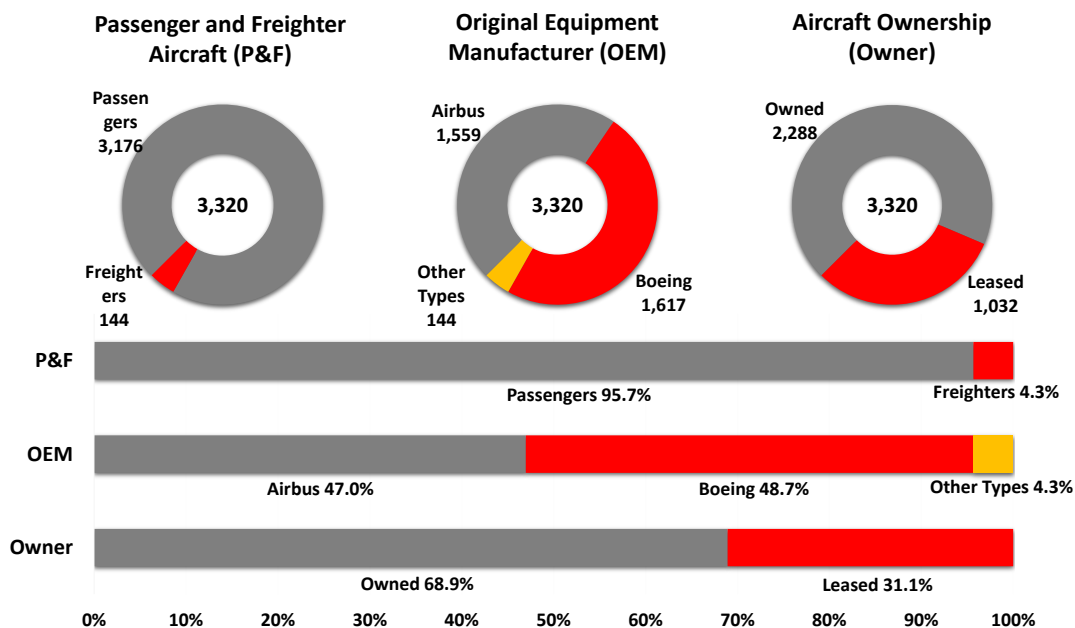
4.2. A brief review of civil jet aircraft on the Chinese register

The database described in Section 2 was used to examine the composition of China's entire civil aircraft fleet, which comprises some 3,320 jet aircraft. See Figure 5. Clearly, Boeing and Airbus have each achieved more or less equal market penetration, with passenger aircraft dominating the mix at almost 96% and freighters accounting for just over 4%.

For the whole Chinese fleet, 2,288 of them are owned by the operators and 1,032 are leased. The top three lessors are GE Capital Aviation Services (GECAS), AerCap, and ICBC Leasing (ICBC), with 136, 122, and 81 aircraft respectively leased to Chinese operators. This illustrates how aircraft lessors may also be key stakeholders in the P2F conversion business.

Figure 5. Composition of China's entire aircraft fleet (current at March 2018).

Source: Original from the study.



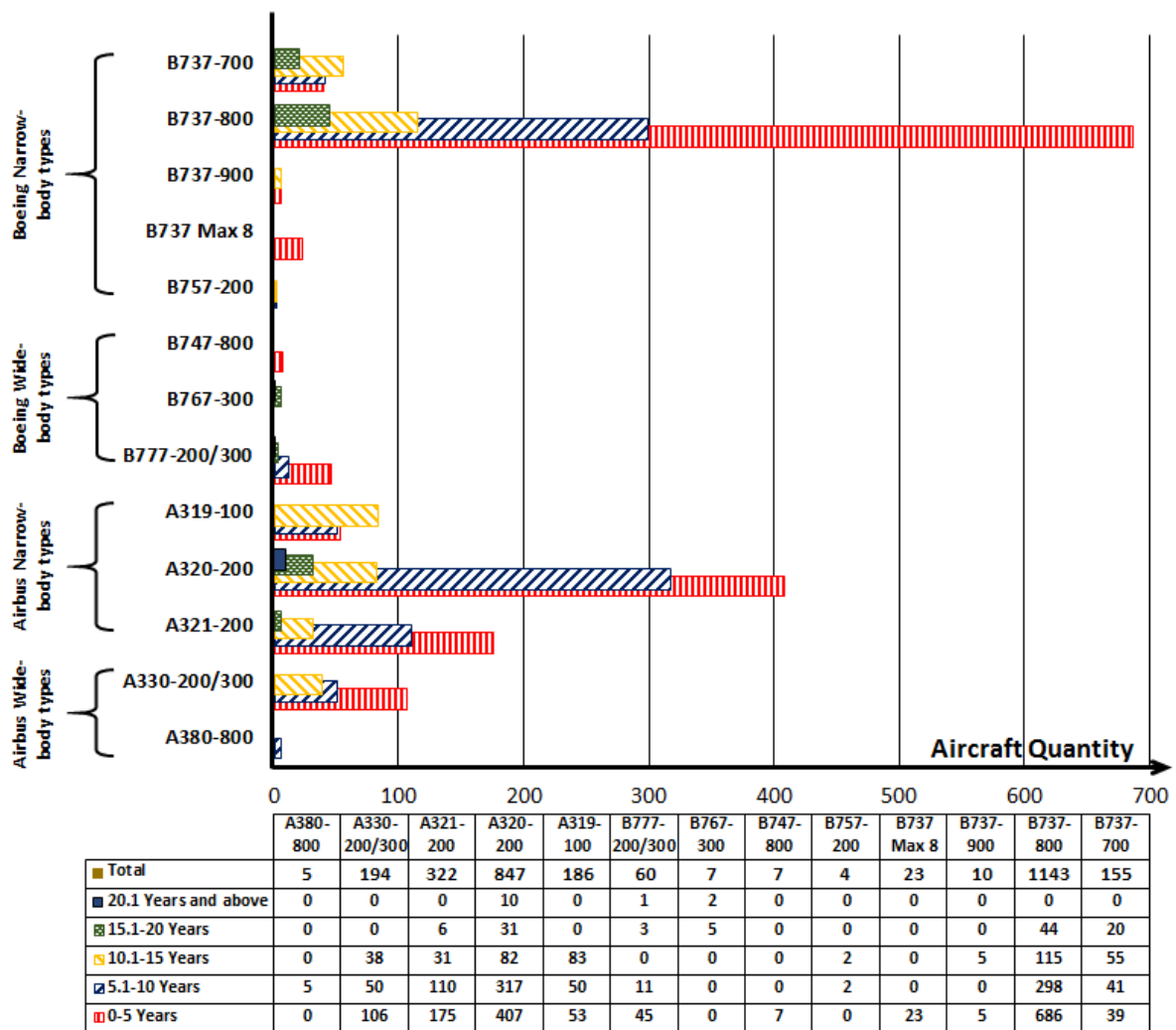
4.2.1. The potential feedstock of Chinese standard-body aircraft types

Figure 6 shows the age profile (current at March 2018) of all the Boeing and Airbus aircraft found in the Chinese civil aircraft fleet, grouped into 5 year intervals. Clearly the Boeing B737-800² is the most widely used single-aisle aircraft among Chinese operators, with 1,143 aircraft of this type in-service, comprising 34.4% of the whole fleet. This is followed by 847 A320 aircraft, 322 A321 aircraft, and 155 B737 aircraft. Thus standard-body types dominate the Chinese civil aviation market. In contrast, the most popular wide-body aircraft in China is the A332 / A333 which totals just 194.

² The ICAO Aircraft Type Designator 737/738 for the Boeing 737-700 and 737-800 and A320/321 for the Airbus A320-200 and A321-200 will be used henceforth (ICAO 2018).

The average ages of the B738, A320, A321, B737, and A332/333 types are 5.2, 6.0, 5.4, 9.4, and 5.3 years old respectively, which reveals that China has a relatively young fleet of passenger aircraft. It is noted from Figure 6 that there are 686 B738 aircraft under 5 years of age, and 10 A320 aircraft that are reaching the end of their economic life as a passenger aircraft. Hence it is evident that China will be able to provide a significant quantity of feedstock for the new generation of standard-body freighters over the next fifteen to twenty years. From an indigenous viewpoint, the B737 has not been particularly popular, and is not a likely candidate for a P2F conversion within China given the limited (155) local feedstock. Whether Chinese cargo airlines decide to purchase this particular freighter from other external sources, such as Bedek (2017) or PEMCO (2018), remains to be seen.

Figure 6. The age distribution of the Chinese civil aircraft fleet (current at March 2018).
Source: Original from the study.



4.2.2. The Chinese cargo airlines

The Chinese cargo fleet is summarized in Table 1, noting that there is a total of just 144 freighters currently in service, 38 of which are wide-body freighters (B747 and B777), 10 are medium-body freighters (B767 and A300), and 96 are standard-body freighters (B737 and B757). The largest three Chinese cargo airlines are SF Airlines, China Postal Airlines, and Suparna Airlines, who operate 41, 27, and 18 dedicated freighters respectively.

According to Table 3, it is clear that the most popular standard-body freighters in China currently are the P2F converted Boeing 737 (Classic series) and the Boeing 752, accounting for 66% of the total freighter fleet. However, there are few of either type still flying as passenger aircraft, so the feedstock within China – and indeed worldwide - for these classic standard-body freighters is almost exhausted. Consequently, it falls to the next generation of standard-body passenger aircraft - the Boeing 737/738 NG and Airbus A320/321 types - to supply the feedstock that will satisfy the future demand for new standard-body P2F freighters.

Table 1. The Chinese freighter fleet (current at March 2108). Source: Original from the study.

Operators	Airline Type	Total	B777	B747	B767	A300	B737	B757
			Wide-Body		Medium-Body		Standard-Body	
		144	28	10	5	5	63	33
China Southern	FSNC	14	14	-	-	-	-	-
China Cargo	All-cargo	9	6	3	-	-	-	-
China Postal	Integrator	27	-	-	-	-	22*	5*
YTO Cargo	Integrator	8	-	-	-	-	7*	1*
Air China Cargo	All-cargo	15	8	3	-	-	-	4*
SF Airlines	Integrator	41	-	-	5*	-	17*	19*
Uni-Top	All-cargo	5	-	-	-	5*	-	-
Longhao	All-cargo	3	-	-	-	-	3*	-
China Air Cargo	All-cargo	1	-	-	-	-	-	1*
Suparna	FSNC	18	-	3+1*	-	-	14*	-
Loong Air	FSNC	3	-	-	-	-	-	3*

* Entries in bold font, with an asterisk, refer exclusively to P2F converted freighters

Regarding the Chinese civil aircraft fleet, the most plentiful feedstock for P2F conversion over the next twenty years is the B738 (1143), followed by the A320 (847), and the A321 200 (322). Their age distribution, determined from the authors' database on a year-by-year basis, is illustrated in Figure 7 and the potential feedstock forecasting is shown in Figure 8. These two charts are effectively the mirror image of each other, assuming a passenger aircraft would start the P2F conversion process when it reaches 20 years old.

Figure 7. Passenger Jet Aircraft Age Distribution in China: B738 and A320/321 (current at March 2018)
Source: Original from the study.

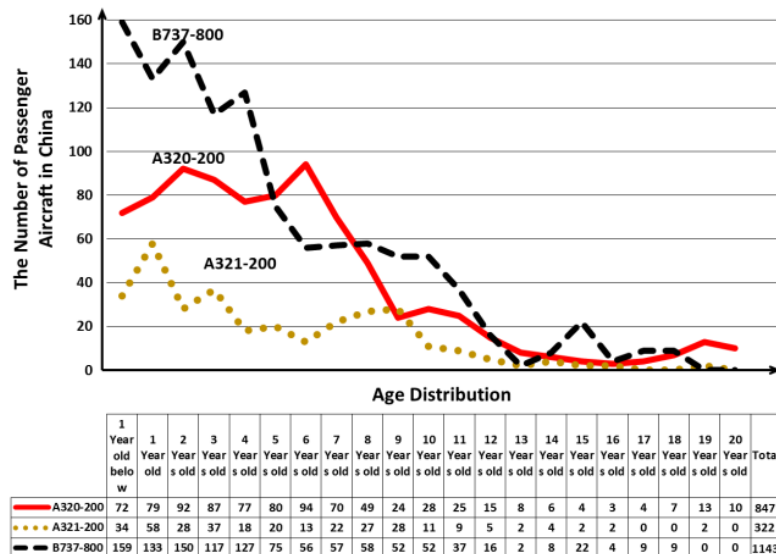
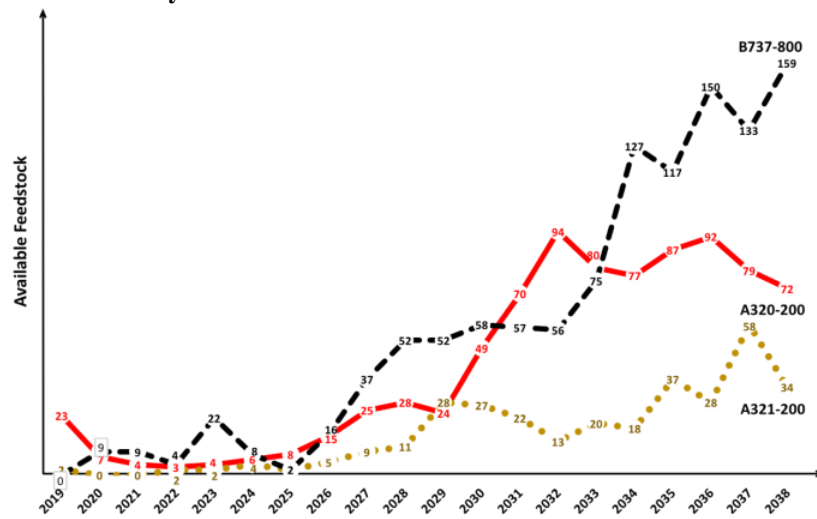


Figure 8. The potential Chinese feedstock of B738, A320, and A321 for P2F Conversion from 2019-2038.
Source: Original from the study.



5. The passenger-to-freighter (P2F) conversion process

The P2F conversion process involves four major steps, as outlined by Berlowitz (2014).

- Pre-conversion ground and flight tests to collect the necessary data;
- design for the modifications;
- qualification and certification for the newly designed modifications;
- ground and flight tests to verify the modifications comply with all the relevant airworthiness regulations.

In brief, the actual conversion process involves removing all the various equipment items necessary for the passenger configuration, and installing the cargo conversion kit – this stage generally takes 4-6 months and requires the addition of a new main cargo deck door and the related structural reinforcing parts (Berlowitz 2014; Karp 2008) to facilitate loading the aircraft with unit load devices³ (ULDs) or containers on the main deck (Ma et al. 2015). The cabin floor that was previously designed for passengers is replaced with a new stronger floor structure (Berlowitz 2014; Morrell 2011). Powered cargo handling systems, ball mats and roller tracks are installed in the aircraft cargo deck to facilitate the loading and unloading of aircraft pallets and containers (ULDs) during the aircraft's turn-around process (Morrell 2011). Special locks are also installed in the aircraft's main deck to lock the ULDs in position to prevent any movement in flight, and a 9g forward-restraint barrier net or an equivalent bulkhead will also need to be installed to avoid loads shifting into the flight deck (Brady, 2017). Windows are replaced by special metal covers for ease of aircraft maintenance, and to prevent damage that may occur to the cargo from sunlight (Morrell 2011).

³ Aircraft unit load devices (ULDs) are pallets and containers which are used to carry air cargo, mail and passenger baggage on wide-body passenger and dedicated freighter aircraft (Baxter *et al.* 2014).

Appropriate levels of fire protection⁴, that includes fire detection and suppression devices, must be integrated into the aircraft systems and fire-retardant ceiling and sidewall liner panels are added. Also, the essential structural components of the original aircraft are often strengthened and corrosion and fatigue resistance will be improved for fatigue sensitive areas. This is undertaken to extend the service life of the aircraft (Berlowitz 2014; Ma et al. 2015). Since a P2F conversion is considered a major change, the company responsible for the conversion must obtain a Supplemental Type Certificate (STC) from its national civil aviation regulator and, if it wishes to produce conversion kits, also a Production Certificate (PC) (Berlowitz 2014). The specialist converters generally aim for STC certification from the FAA and EASA in order to cover all the major markets in which their aircraft will be operated. Many other countries will accept FAA and/or EASA certification, without requesting further compliance demonstrations, by issuing a Type Acceptance Certificate (TAC) or equivalent (De Florio 2016). If an aircraft is to be converted and operated in China, then in accordance with CAAC AP-21-01R2, a Validation Supplemental Type Certification (VSTC) is required.

5.1. A brief review of the Boeing 737NG and the Airbus 320/321-200 P2F

To date, the standard-body freighter market has been dominated by Boeing without any competition from equivalent Airbus types. Large fleets of Boeing aircraft, such as 727F, 737-300SF, and 737-400SF are still operating with express and regional cargo carriers primarily in the USA, Europe and China, but most of these are now reaching their end of serviceable life and will need replacement in the near-term. Candidate replacement P2F freighters are limited to Boeing 737NG types and Airbus A320/321 types. Clearly, any Boeing 737NG P2F freighters will enjoy a large competitive advantage in this market based on operator experience, product knowledge, maintenance type ratings, flight crew familiarity and brand loyalty. This is especially true in China, where all the cargo airlines, with the exception of Uni-Top, use Boeing products. (See Table 1). In fact, apart from the five very old A300's operated by Uni-Top, Airbus is not represented in the Chinese cargo market at all.

The specifications of the Boeing and Airbus New Generation of P2F standard-body freighters, as reported by the various conversion houses, are summarised in Appendix 1. From these data, it is evident the B737, B738, A32 and A321 are all ideally suited to the Chinese domestic market because their payload-range profile is a perfect match considering the sort of goods (express cargo) to be delivered and the distances between any two medium or large civil airports within China. Figure 9 shows the B737/738 and the A320/A321 P2F converted freighters' volume-limited payload⁵ and range capabilities, centred on the city of Guangzhou. Of all four new generation P2F freighters, the B737 can fly the furthest but with the least payload (15 tonnes). Both the B738 and the A320 are capable of flying the CAN-

⁴ Certification standards (according to 14 CFR Part 25 or EASA CS-25) define Cargo compartment classifications as follows:

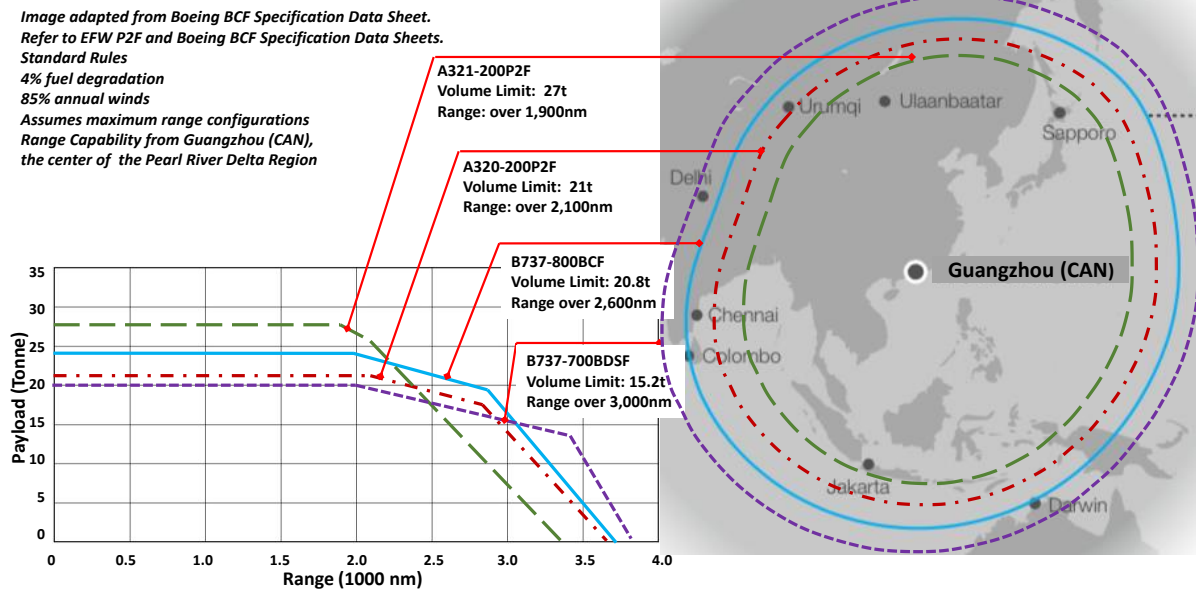
- Class A and Class B are cargo compartments accessible to a crew member
- Class C and Class D are cargo compartments not accessible to a crew member
- Class E are cargo compartments on aircraft used only for the carriage of cargo
- Class F is a cargo compartment located on the main deck and fitted with means to extinguish or control a fire without requiring a crewmember to enter the compartment.

⁵ Freighter aircraft not only have a weight-limited payload, but also have fixed volumetric capacity. According to Aircraft Commerce (2016: 75), "the maximum packing density is that at which cargo can be packed to make full use of the available revenue payload and volume". Express packages, such as small parcels and documents, typically have a packing density less than this optimal value (typically around 6.3 lbf/ft³ or 100 kg/m³). Hence express packages are more reliant upon volumetric capacity, or volume-limited payload.

URC route whilst carrying approximately 20 tonne payloads, whereas the A321 has a marginally shorter range, but can carry a more substantial payload of up to 27 tonnes.

Figure 9. Boeing B737-700/800 and Airbus A320/321 P2F Payload-Range Capabilities.

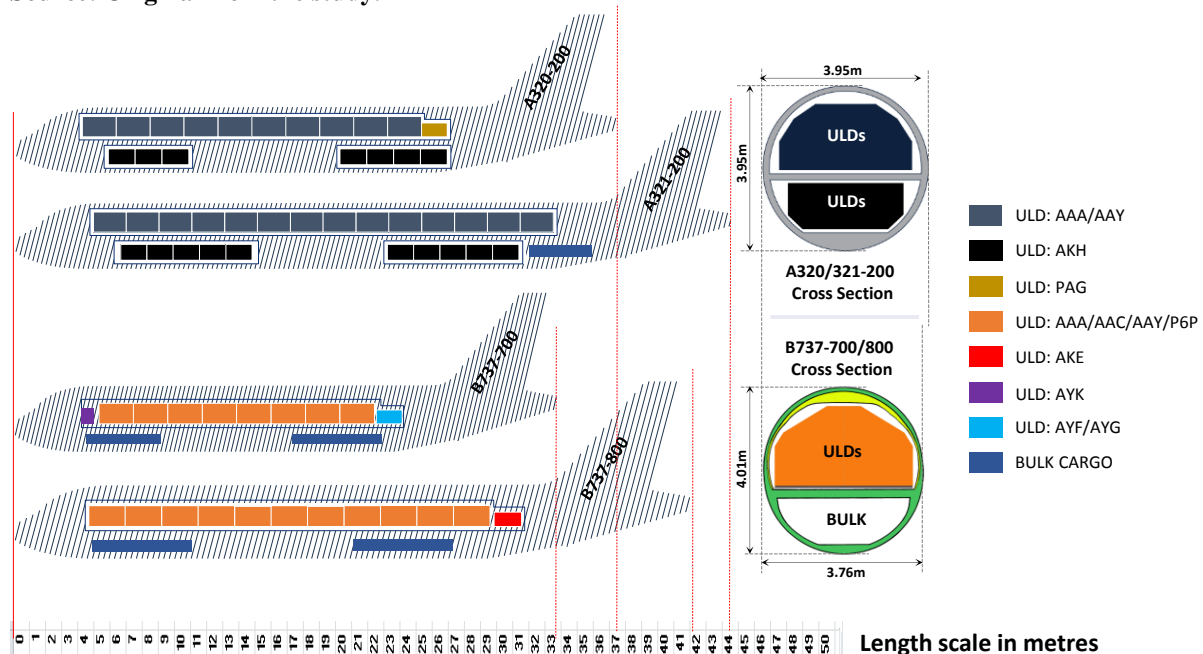
Source: Adapted from Boeing 737 BCF specification data sheet (Boeing 2016b)



Typical internal layouts for a P2F conversion of the A320/321-200 and the B737/738 are illustrated in Figure 10. It is noted that the cargo capacity and arrangement is much the same for a given aircraft type, regardless of which conversion house is responsible for the actual P2F conversion, and the illustrations are indicative of current designs.

Figure 10. Typical cargo configurations for the P2F converted A320/321 and B737/738.

Source: Original from the study.



The Boeing and Airbus P2F freighters display two key differences: (i) The A320 and the A321 can carry ULDs on both the main cargo deck and the lower deck. In fact, the A321-200 can carry up to 14 full-size AAA/AAY ULDs on the main cargo deck plus another 10 AKH ULDs on the lower-deck. This offers a comparable freight volume to that of the Boeing 757F

and will make a competitive replacement option; (ii) in contrast, the B737/738 cannot carry any ULDs in the lower deck (only bulk cargo) but they do have a more generous main deck cabin height which means they can carry taller and larger capacity ULDs that the A320/321 cannot. For further information about the many different types of aircraft ULDs and pallets, please refer to <https://vrr-aviation.com/uld-types/>

5.2. The world's major conversion houses and their current projects

Conversion houses are the aviation engineering companies who deal with the National Airworthiness Authorities (e.g., FAA, EASA, CAAC) and the aircraft manufacturers (Airbus, Boeing) to develop the P2F conversions. Currently, there are six key players dominating the P2F conversion market, which are: (i) Aeronautical Engineers, Inc., (ii) Bedek Aviation Group, (iii) Boeing, (iv) Elbe Flugzeugwerke EFW (a joint venture involving ST Aero), (v) PEMCO World Air Services, and (vi) 321 Precision Conversions. The conversion capabilities of each company, and the projects they are currently involved with, are summarized in Table 2.

Table 2. The key P2F conversion providers and their capabilities (March 2018). Source: Aeronautical Engineers, Inc. (2018); Boeing (2016b); Bedek (2017); PEMCO (2018), EFW (2018), and 321PC (2018).

Aircraft Type	Potential Feedstock in China	IAI Bedek	Boeing	PEMCO	AEI	321PC	ST Aero	EFW
A300-600	0							X
A330-200	81							X
A330-300	115							X
A320-200	848							*X
A321-200	323					*X		*X
B747-400	0		X					
B767-300	5	X	X					
B737-300	0			X	X			
B737-400	0			X	X			
B757-200	4						X	
B737-700	156	X		*X				
B737-800	1144	*X	X		*X			

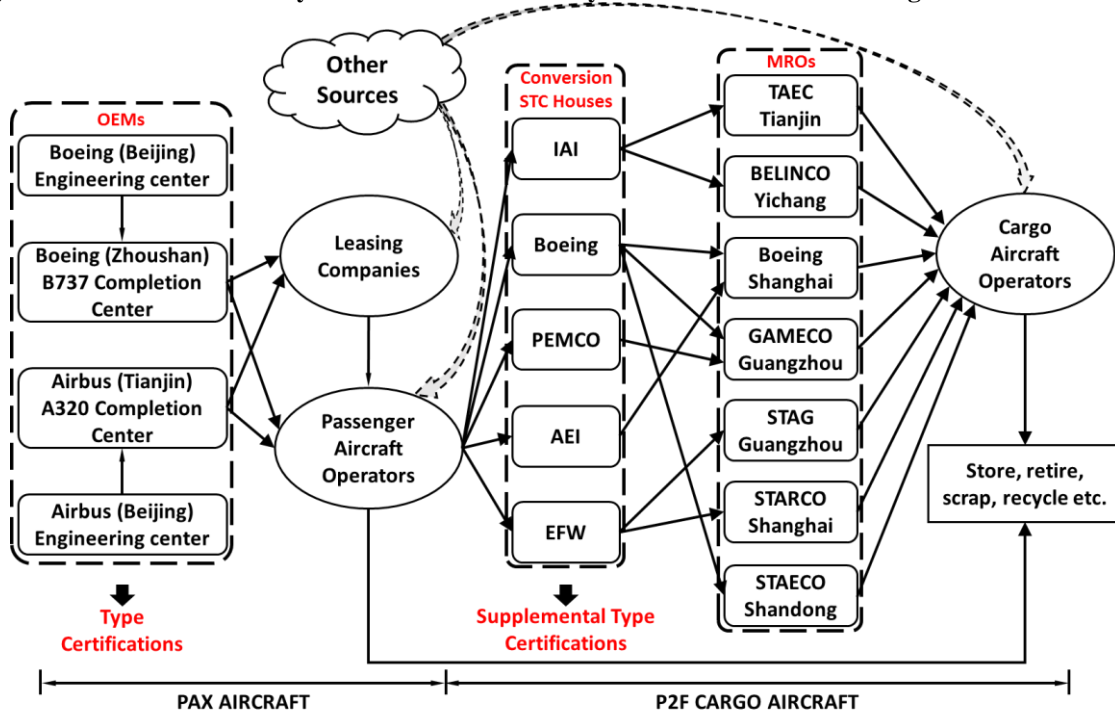
* STC is under development but has not been awarded at the time of writing (March 2018)

It is noted that as far as new generation standard-body conversions are concerned, all except Boeing are awaiting one or more STC approvals from the relevant regulator. Also, the potential feedstock in China is noted against each type – clearly there is a compelling business case here for B738 and A320/321 feedstock acquisition within China.

Apart from 321 Precision Conversions, the other five conversion houses have all developed strong links and collaborative agreements with Chinese-based MROs in anticipation of the significant growth expected in the domestic Chinese air cargo market. Figure 11 shows the standard-body conversion ecosystem as it currently exists in China. Once the conversion houses have gained the necessary STC and PC, they will often sub-contract the actual conversion work to a reputable MRO, in this case in China.

For example, Boeing formally launched the Boeing Converted Freighter (BCF) program for its B738 at Boeing Shanghai facilities on February 24, 2016 (Harris, D., 2016). Boeing Shanghai Aviation Services (Boeing Shanghai) is a Shanghai-based MRO and a joint venture among Boeing, China Eastern Airlines, and the Shanghai Airport Authority. The first Boeing 737-800BCF was redelivered from Boeing Shanghai to the aircraft leasing company, GE Capital Aviation Services (GECAS) and operator West Atlantic in late 2017. Boeing has also signed an agreement with Taikoo (Shandong) Aircraft Engineering Co., Ltd. (STAECO), a Jinan-based MRO, authorizing STAECO as one of its 737-800BCF service conversion providers. In February 2018, Boeing also signed an agreement with China Southern Airline to set up a 738 conversion line with its partner, Guangzhou Aircraft Maintenance Engineering Co, Ltd (GAMECO), which is a Guangzhou-based MRO and a joint-venture between China Southern and Hutchison Whampoa. China Southern has 157 B738 in service, which makes it the largest Chinese source for 738 conversion feedstock. As Boeing holds all the intellectual property and is the OEM of the 738, it is expected to dominate the 738 P2F conversion market in the long term; to date, Boeing has won some 59 orders and commitments from customers around the globe for its 737-800BCF.

Figure 11. The Standard-body aircraft conversion ecosystem in China. Source: Original from the study.



By establishing collaborative arrangements with Chinese MROs, the conversion houses can leverage a number of advantages, especially if the final P2F is destined for use within China itself. Chinese MROs have longstanding partnerships with other Chinese airlines and cargo operators, making feedstock acquisition in China relatively straightforward. Chinese MRO labour costs are significantly lower than the corresponding western rates, and significant tax savings are made by not sourcing the aircraft from outside China. Therefore, it is reasonably certain that many future Chinese converted P2F standard-body freighters will primarily be sourced from existing Chinese feedstock, modified by Chinese MROs (using the STC and PC of a reputable conversion house), and finally operated by Chinese cargo operators. The continuing airworthiness assurance of all cargo (and passenger) aircraft on the Chinese register remains the responsibility of the CAAC.

6. Conclusions

This paper has discussed the reasons for the growth of air cargo in China, such as the increasing GDP, the e-commerce boom and the associated demand for the quick and reliable delivery of goods purchased online, and the various levels of de-regulation that are occurring. Independent sources (Boeing 2016a, Airbus 2017) predict a significant level of growth in air transportation in Asia-Pacific in general - and China in particular - over the next 20 years, with standard-body P2F freighters dominating the air cargo sector.

This work has also surveyed the entire Chinese commercial jet aircraft fleet; a database was created which provides comprehensive information for every single jet that is currently in service with Chinese operators. The fleet size and age distribution for each type has been summarized, which clearly shows the B738, A320, and A321 are the three most popular and numerous standard-body passenger aircraft currently operating in China. These are the natural candidates (feedstock) for future P2F freighter conversions in the standard-body category. By assuming a P2F conversion would take place once a passenger variant reaches 20 years of age, a prediction of the available annual feedstock within China was presented. Initial studies indicate that China could easily be self-sufficient in supplying its own standard-body freighters; this fact has not been lost on most of the major conversion houses, who are now striking various collaborative arrangements with Chinese MROs.

The relationships between the various conversion houses and their Chinese associates have been charted, and it is clear that five of the six major players are seeking a share of the Chinese market, which promises to be the single largest market worldwide for standard-body P2F conversions over the next 20 years. Even though Chinese MROs have not yet acquired the engineering capabilities to develop P2F conversions and gain STCs by themselves, but have to rely on partnerships with other western companies like Boeing, PEMCO, AEI etc., the time will doubtless come when Chinese companies will acquire P2F know-how in their own right and start selling converted freighters overseas as well as supplying the home market.

P2F freighters destined for the local Chinese domestic market will most likely be converted by Chinese-based MROs because they already have a close working relationship with Chinese domestic airlines and hence will have access to feedstock, and they can provide a cost-competitive quote due to the lower labour costs – for express freight airlines, in which acquisition costs are of paramount importance, these factors cannot be underestimated.

From the flurry of initial orders it looks as if the 738 P2F is going to be the freighter of choice and will form the mainstay of the standard-body conversions that are predicted to dominate the freighter market over the next 20 years (see Figure 1). By being the first company to develop an STC and PC for a 738 freighter, Boeing has taken the lead in this P2F sector and looks set to dominate the future P2F market, both in China and worldwide. It remains to be seen whether Airbus can gain a respectable share of this market, especially in China where most of the future demand will come from.

APPENDIX 1. Summary of the new generation standard-body P2F freighter specifications

New generation standard-body P2F freighter specifications Source: Aeronautical Engineers, Inc. (2018); Boeing (2016b); Bedek (2017); PEMCO (2018), EFW (2018), and 321PC (2018).			
Aircraft Type	<u>A320 P2F</u>	<u>A321 P2F</u>	<u>A321 PCF</u>
Conversion provider:	<i>EFW</i>	<i>EFW</i>	<i>321Precision Conversion</i>
Vol-limited Range: (nm / km)	2,100 / 3,890	1,900 / 3,520	1,900 3,520
Gross struct payload (lbf / kg)	up to 48,280 / 21,900	up to 61,500 / 27,900	Up to 61,500 / 27,900
Main deck positions (typ)	10 AAA + 1 PAG	14 AAA	14 AAA
Lower deck positions	7 LD3-45W	10 LD3-45W	10 LD3-45W or Bulk
Total volume (cu ft / cu m)	5,603 / 160	7,348 / 210	Up to 7,904 / 225
Aircraft Type	<u>737-700BDSF</u>	<u>737-700F</u>	
Conversion provider:	<i>IAI Bedek</i>	<i>PEMCO</i>	
Vol-limited Range: (nm / km)	3,000 / 5,550	No information	
Gross struct payload (lbf / kg)	up to 45,000 / 20,400	up to 45,000 / 20,400	
Main deck positions (typ)	1 AYK + 8 AAA + 1 AYP	No information	
Lower deck positions	Bulk Only	Bulk only	
Total volume (cu ft / cu m)	4,782 / 135	Up to 4,810 / 136	
Aircraft Type	<u>737-800BDSF</u>	<u>737-800SF</u>	<u>737-800BCF</u>
Conversion provider:	<i>IAI Bedek</i>	<i>AEI</i>	<i>Boeing</i>
Vol-limited Range: (nm / km)	No information	No information	2,600 / 4,800
Gross struct payload (lbf / kg)	up to 53,000 / 24,000	up to 52,000 / 23,500	up to 52,800 / 24,000
Main deck positions (typ)	11 AAC + 1 AKE	11 AAY + 1 AEP	11 PAG + 1 pallets
Lower deck positions	Bulk Only	Bulk Only	Bulk only
Total volume (cu ft / cu m)	6,542 / 185	6,555 / 185	6,540 / 185

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