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Business opportunities in aircraft cabin conversion and refurbishing

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Abstract. This paper identifies several meaningful business opportunity cases in the area of aircraft cabin conversion and refurbishing and predicts the market volume and the world distribution for each of them: 1) international cabins, 2) domestic cabins, 3) aircraft on operating lease, 4) freighter conversions and 5) VIP completions. This implies the determination of cabin modification/conversion scenarios, along with their duration and frequency. Factors driving the cabin conversion and refurbishing are identified. Several aircraft databases, containing the current world feet as well as the forecasted fleet for the next years, are analyzed. The results are obtained by creating a program able to read and analyze the gathered data. It is shown that about 38000 cabin redesigns will be undertaken within the next 20 years. About 2500 conversions from jetliners into freighters and 25000 cabin modifications at VIP standards will emerge on the market. The North American and European markets will keep providing good business opportunities in this area. The Asian market, however, is growing fast, and its very strong influence on demand puts it in the front rank for the next 20 years.

Nomenclature

$age_{scenario\_limit}$ = aircraft age for which the refurbishing is no longer planned by the operator
$date_{aircraft\_delivery}$ = date of the aircraft first delivery
$date_{modification}$ = date at which the end of the next modification program is planned
$date_{previous\_modification}$ = date at which the last retrofit program ended (for the same aircraft)
$duration_{equivalent}$ = equivalent duration of one aircraft refurbishing
$duration_{scenario}$ = duration of the retrofit program (it depends on the conversion scenario)
$duration_{scenario\_period}$ = duration of the period within cabin modifications should be undertaken
$volume_{fleet}$ = volume of the fleet (the same aircraft type) of an airline
$frequency_{scenario}$ = time between the end of the last retrofit program and the start of the next scheduled retrofit program (it depends on the conversion scenario)
n = total number of cabin modifications/conversions
$n_{additional\_airplanes}$ = number of freighter deliveries

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$n_{aircraft}$ = number of cabin modifications that could be undertaken for one air craft
$n_{freighter\ \ conversion}$ = total amount of freighter conversions
n_{loop} = number of loop executions of the program
$p_{freighter\_conversion}$ = proportion of conversions in the freighter deliveries
$n^{world\_region}_{freighter\_corversion}$ = amount of freighter conversions in a specific world region
$\mathrm{n}^{world\_region}_{freighter\_fleet}$ = proportion of the freighter fleet in a specific region

1. Introduction

The need to modify the aircraft interior during its useful life has grown to an unprecedented level over the last years. For several reasons, airlines and aircraft owners are undertaking the retrofit of their airplanes in a shorter cycle than before. The future seems to belong to the type of work covering the entire process chain of a complete cabin conversion, outsourced by the aircraft manufacturer to what is called Completion Centers.

This paper aims to investigate this emerging and growing market, and to forecast its evolution for the next 20 years. It is known that the companies in cabin conversion and refurbishing are currently overbooked. Predicting the future of this tendency becomes a key factor in determining whether a business opportunity arises or other factors, like the present economical crisis, would increase the risk for the investors in this area. Small engineering offices, working as subcontractors in this field for large manufacturers, are very interested to find out if growing into a Completion Center represents a business opportunity or not.

The paper is divided into four parts: First, the characteristics of the current cabin conversion and refurbishing market are investigated and market segments and cabin modification scenarios are identified (Section II). Second, factors driving the demand for each conversion/refurbishing scenario are identified along with the duration and frequency of each scenario (Section III). Third, literature research is conducted in order to understand the current and future trends of the aircraft world fleet (Section IV). Fourth, a market forecast, that determines the business opportunities in this area, is made based on the results gathered in the previous parts (Section V). The forecast is made with the help of an *Excel* program that uses an enclosed aircraft database. In order to predict the demand for cabin conversions, the program scans the database, reads the input parameters (represented by the scenario characteristics listed in Section III) and checks the aircraft age, in order to determine the number of refurbishing cycles or if the aircraft are convertible into freighter or not.

2. Characteristics of the current cabin conversion and refurbishing market

The aircraft cabin undergoes several transformations along the useful life of the aircraft. Depending on the age of the aircraft, correlated with the operator requirements, the cabin may either be *upgraded or refurbished*, or it may completely change its destination through a *conversion* process. Complete cabin transformation scenarios are conducted within what is called *completion center*. The completion center represents the design organization being able to deliver an airworthy design for all modifications of cabin, starting from customer request up to the delivery of the complete cabin.

Most of the existing completion centers [1] are situated in the North America (especially USA, but also Canada). Almost 64% of the completion centers deliver VIP completions.

This Section treats two main topics: First, current comfort standards and trends are investigated for three identified market segments. Second, characteristics of a modification scenario for each segment are identified, based on examples.

2.1. Market segments

Three market segments are investigated in this paper. First, *airlines* need periodical cabin interior upgrades. Second, older passenger aircraft become the perfect candidate for *freighter* conversions. Third, private aircraft owners demand *VIP* conversions. A completion center is able to deal with all three aspects. However, in practice it can be seen that completion centers specialize in a specific market segment.

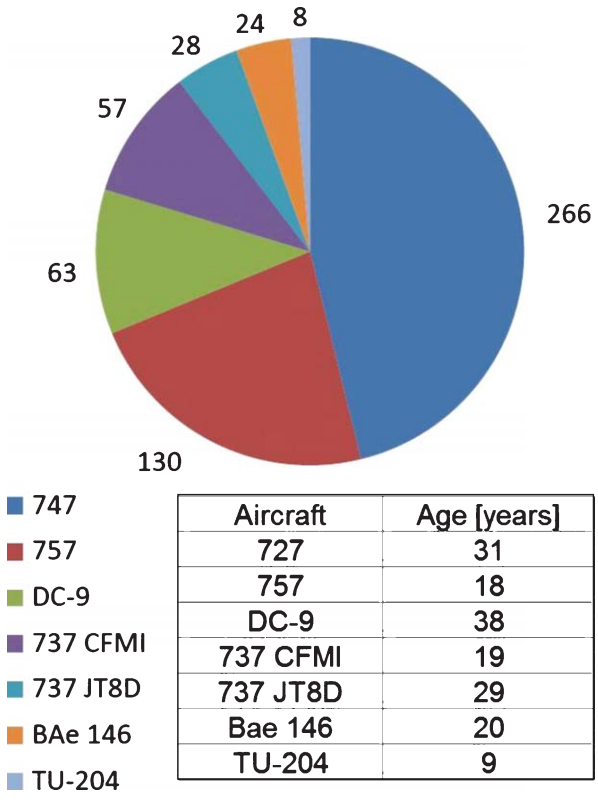
Airline Cabins are divided into several *class types* and *class divisions*:

- Domestic cabins – with economy, business and first class.
- International cabins – with economy, premium economy, business and first class.

The new premium economy concept appeared at some of the airlines as an upgrade of the economy class, tentatively checking to improve comfort for a rather low investment, in comparison with the business class.

Freighter Cabins are usually transformed from older passenger transport aircraft. Statistics [2] show that almost 400 airliners in North America, about 100 in Europe and 110 in Asia and Africa fulfill the requirements to be transformed into freighters. Figure 1 shows the number and age of some aircraft models convertible from pax-to-freighter configuration.

VIP Cabins, owned either by private individuals or corporations, represent a challenging but fruitful market segment. The cabin interior plays an increasingly important role and the range of cabin options available to these operators is limited only by what can be certified.



Aircraft	Age [years]
727	31
757	18
DC-9	38
737 CFMI	19
737 JT8D	29
Bae 146	20
TU-204	9

Fig. 1. Number and age of selected aircraft models, convertible from pax-to-freighter configuration [2].

2.2. Characteristics

Airline Cabins. The main class differences involve parameters like seat pitch, recline angle of the seat, seat type or IFE system. Airlines decide to upgrade the inner layout by changing these items. Some of the characteristics [3] of each class are summarized in Table 1.

Freighter Cabins. The main differences between the airliners and freighters are the strengthened cabin floors and the broad top-hinged door on the port fuselage in addition to the absence of passenger cabin windows, which are "plugged". Other characteristics which differentiate the cargo aircraft are: the loading system and the flight deck systems. Table 2 incorporates these characteristics along with the usually affected aircraft.

VIP Cabins. The operators of this market segment have challenging requirements ranging from waterbeds to stationary bikes, from custom artwork to special materials, like granite or marble. The interior of the modern business aircraft has evolved in line with the current technology, incorporating cabin management systems, wireless Internet and PDA (Personal Digital Assistant) connections. The engineers must develop the design under the certification constraints, while respecting the timelines. Completion scenarios based on such boundaries require increased effort in the preliminary design phase, in order to extract and define the wishes of the customer in technical terms. The VIP cabin characteristics are listed together with each possible modification scenario in Section C, Table 5.

Table 1
The different comfort standards on passenger aircraft

Class	Seat pitch (inch)	Seat width (inch)	Degree of recline	Electric seat controls	Leg-rest and lumbar support	Overhead/ personal TV	Laptop power ports	Mini-cabin
Domestic Economy	30–32 (average)	17–18 (average)	+	No	No	0	No	No
Domestic First or Business	35–39 (legroom)	19–20	+	No	No	0	No	No
International Economy	30–36	17–18	+	No	No	+	No	No
Premium Economy	35–43 (legroom)	19–20	++	No	Yes	++	Yes	No
International Business	62–64 (legroom)	20–21	+++	Yes	Yes	+++	Yes	No
International First	73–93 (legroom)	21–23	++++	Yes	Yes	++++	Yes	Yes

Table 2
Usual specifications for freighter conversions

Type of modification	Description	Aircraft type affected	Airline affected
Freighter conversion	Incorporating a large wide cargo door in the fuselage Installing a new reinforced main deck floor Integrating cargo loading systems	B737-300/400 B757-200 A300-600 B767-200 B747-400	All airlines which provide freighter service and passenger service

2.3. Modification scenarios

Airline Cabins are regularly upgraded or refurbished. Each class classification can be associated with such a scenario. The renewal activities may affect:

- the cabin systems – IFE (In-Flight Entertainment), CIDS (Cabin Intercommunication Data System), in-seat power system, passenger oxygen, general illumination of the cabin, emergency lighting;
- the cabin layout – seating configuration (for passengers and flight attendants), position of monuments (galleys, lavatories), crew rest compartments, stowage room;
- or other cabin interior items – linings and furnishings like PSU (Passenger Service Units), curtains, partitions, ancillary equipment; placards and markings like cabin emergency equipment, floor covering.

Tables 3 and 4 gather some exemplary specifications of the scenarios conducted by known airlines in the past year [4–14]. The characteristics, and therefore the refurbishing scenarios, depend on the destination of the aircraft. Usually wide body aircraft are furnished for international flights and single aisle aircraft for domestic flights.

Freighter Cabins are completely converted by changing the destination of old passenger aircraft. Popular candidates for the pax-to-freighter conversion are, according to ACMG (Air Cargo Management Group) [15], for the narrow-body models, the Boeing 737-300s/−400s and 757-200s. For the medium wide-body category, the A300–600s and 767-200s are the major candidates. In the large capacity segment the preferred aircraft are 747-400s and MD-11s. Only the A300–600F, 747-400F, 747-8 Freighter, 777F, A320P2F and A321P2F are available as new-built production freighters, which means the majority of

Table 3
Exemplary specifications for airline cabin upgrading for international cabins (Ref. 4 to 14)

Airlines	Aircraft type affected	Entire fleet type redesign	Premium economy introduction	Layout reconfiguration	New seat facility		
					FC	BC	YC
Malaysia Airlines	B777-200	Yes	No	Yes	removed	Yes	Only IFE
	B747-400	Yes	No	Yes	Yes	Yes	Only IFE
Japan Airlines	B777	Yes	Yes	Yes	Yes	Yes	Yes
United Airlines	Entire long-haul fleet	Yes	No	No	No	Yes	No
Swiss Airlines	A330-300 A340	Yes	No	No	Yes	Yes	No
China Southern Airlines	B777 B777	Yes	No	Yes	Yes	No	No
Air France	A330 A340	Yes	Yes	Yes	Yes	Yes	Only IFE
Philippine Airlines	B747-400	Yes	No	Yes	removed	Yes	Yes
Dragonair	Entire long-haul fleet	Yes	No	Yes	Yes	Yes	Only recovered
Cathay Pacific	Entire long-haul fleet	Yes	No	Yes	Yes	Yes	Yes

Table 4
Exemplary specifications for airline cabin upgrading for domestic cabins (Ref. 4 to 14)

Airlines	Aircraft type affected	Entire fleet type redesign	Cabin surfaces upgrade	Seats reconfiguration	New seat facility	
					BC	YC
Swiss Airlines	Entire short-haul fleet	Yes	Yes	No	Yes	Yes
Finnair	A320	Yes	–	Yes	Yes	Yes
KLM	Entire short-haul fleet				Removed	
SAS	Entire short-haul fleet				Removed	
Olympic Airways	Entire short-haul fleet	Yes	Yes	Yes	Yes	Only recovered
Cronus Airlines	Entire short-haul fleet	Yes	Yes	Yes	Yes	Only recovered
Air Canada	Entire short-haul fleet	Yes	Yes	–	Yes	Yes
Delta Airlines	MD 90, MD 88	Yes	Yes	–	Yes	Yes

Table 5
VIP Cabin characteristics for each modification scenario

Type of modification	Description	Aircraft type affected	Type of owner
	Stripping and replacing:	All Executive aircraft:	
VIP High-End Completion	Cabinetry veneers	Business jets	VIP owner
VIP Cabin Refurbishing	Seats soft coverings	Business turboprops	State government
Pax-to-VIP conversion	Carpets and lighting	Corporate versions of airliners	Business airlines
	Installation of specific equipment		

the additional freighters will be passenger-to-freighter conversions [16]. It is interesting to note that no civil freighter exists that was designed specifically for this purpose. All civil freighters have been derived from passenger aircraft. Military freighters play only a minor role for civil freight transport.

VIP Cabins. Several scenarios are possible in the case of VIP cabins:

- VIP High-End Completion – the completion center takes responsibility over the design and certification of the interior furnishing of the 'green' (i.e., new) aircraft.
- VIP Cabin refurbishing – refers to aircraft which receive a new outfit while removing an old one; this scenario is valid especially for business jets. Such scenarios involve stripping and replacing of cabinetry veneers, soft coverings of the seats, carpets or the lighting.
- Pax-to-VIP conversion – some VIPs buy a former jetliner to use it as an executive aircraft.

Some of the difficulties encountered by these scenarios are:

- Exotic materials that have never been installed in the aircraft environment have to pass flammability and certification tests.
- Getting into bigger changes in the cabin, such as reconfiguring seating or repositioning lavatories and galleys, involves meeting recertification requirements.

3. Driving factors in cabin conversion and refurbishing

3.1. Airline cabin upgrades

Context. In order to remain competitive, an airline needs to periodically refurbish its fleet. Cabin equipment together with service and speed are the decisive factors in forming passenger perception of the airline's efficiency. Industry experts [17] explain that carriers now pay more attention to their cabin layout, design and IFE rather than the level of their aircraft performance. The aviation sector was affected by the current global economy crisis. Important observations are:

- Passenger and cargo traffics have dropped by 10.1% and 23.2% respectively compared to the level before the crisis (according to the *International Air Transport Association*'s statistics [17] released in March 2009).
- Airlines preserve cash. This is forcing them to postpone major expenditures such as jet orders and deliveries.
- Middle East carriers apparently received support from their state governments and have more cash than other airlines.

Driving Factors. All these economical factors have made competition tougher for European, American and Asian airlines. As a result, airlines have to focus more on cabin design in order to win passengers. On the background of the economical crisis, an attempt to attract passengers was made by creating the new Premium Economy Class, which first of all requires the reconfiguration of the seat distribution. In the same time airlines began eliminating the first class and improving the business class, in order to respond to the 'more comfort for less money' demand. These considerations are especially valid for international cabins. However, the same long haul travelers keep their criteria when they fly inside a domestic cabin of a short haul aircraft. Table 6 summarizes the driving factors for international and domestic cabins, as well as for aircraft on operating lease.

Table 6
Driving factors for international, domestic cabins and aircraft on operating lease

International Cabins	Type of demand	Factors
	Upgrade of	Tool for differentiating between airlines
	International Cabins	Aircraft orders and deliveries are postponed
	Premium Economy	To enhance airline reputation among travelers in Standard Economy
	introduction	To retain a base of loyal customers
	First Class redesign	Demand from successful people even in economical downturn
		Demand from passengers upgraded to First Class
	First Class removal	More and more luxury in Business Class for a lower fare
		Rise of all-business-class airlines
Domestic Cabins	New business	Short-haul flights drive the reputation
	seats facility	of the airline among long-haul business travelers
	New seats facility	Reduction of fuel burn
		Extra seating capacity
All	Aircraft lease	Lower cash outlays
		Protects against aircraft obsolescence
		Fleet flexibility (change of capacity, new routes introduction, changing laws)

Another variant approached especially by the low cost airlines is represented by the aircraft on operating lease. Some of the benefits/driving factors [18] are:

- lower cash outlays to preserve working capital,
- fleet flexibility to introduce new routes or aircraft types,
- flexibility to increase or reduce capacity quickly,
- no residual value risk,
- newer aircraft models with no need for pre-delivery payments or significant down payments with the manufacturers.

Frequency and Duration. Redesign and refurbishing activities occur in cycles. A fleet refurbishing program is initiated periodically in order to avoid the worn out look and to keep up with the challenges of the market. Table 7 gathers the data extracted after analyzing the current refurbishing projects of some of the major airlines [4–14]. It is concluded that the duration of a retrofit program is *65 months* for international cabins and *84 months* for domestic cabins and operating lease aircraft. Normally, several aircraft are refurbished in the same time; in this case an equivalent duration can be defined, which represents the retrofit duration divided by the number of aircraft involved.

For aircraft on operating lease, cabin upgrades occur only when the aircraft is transferred from an airline to another. Operating leases typically range 3–12 years in length [18]. Considered here is here an average lease duration of 7 years (*84 months*). Table 8 summarizes the durations calculated based on the examples extracted in Table 7.

3.2. Freighter Cabin Conversions

Driving Factors. The conversion of passenger aircraft into freighters offers an economic alternative to the purchase of new freighter aircraft. The pax-to-freighter conversions combine the advantages of a low empty weight with the resulting possibility to increase the useful load [19]. The situation is more dynamic in the freighter conversion market than in freighters production, where the Original Equipment Manufacturers (OEM's) and independent third-party converters offer modifications for every modern aircraft type [16]. The economical efficiency of such conversions is obtained through the use of wide-body aircraft (having a large fuselage cross-section). Such aircraft provide sufficient space for standard containers and pallets in the main and under-floor cargo compartments. The strategy used by freighter operators is to combine the increased freight volume with quick cargo handling [19]. Table 9 summarizes the driving factors of the demand for freighter conversions.

Frequency and Duration. The conversion of a passenger aircraft into freighter may occur only one time in the aircraft life. After the age of fifteen to twenty years, aircraft would not receive any more upgrades for passenger service due to their marketability. These aircraft become perfect candidates for freighter conversion [20]. The simple conclusion to be drawn is that the pax-to-freighter conversions occur when the aircraft is no longer suitable for passenger use. These conversions take approximately four months [19].

3.3. VIP cabin designs/redesigns

Driving Factors. A number of factors persuade business jet owners or operators to refresh the interior of their aircraft. The need to refresh the cabin structures and surfaces is growing especially among the fractional owned aircraft. In this case airplanes interior is more likely to become worn out, as there are

Table 7
Frequency and duration for international, domestic cabins (Ref. 4 to 14)

International cabins	Airline	Aircraft type affected	Number of aircraft	Begin of retrofit program	End of retrofit program	Retrofit duration (months)	Equivalent duration for one aircraft retrofit (days)	Date of last retrofit program begin	Retrofit frequency (months)
	United Airlines	Entire Fleet	–	–	2009	17–29	–	–	–
	British Airways	B777	32	2006-11	2010-01	39	37	2004-04 (end of program)	65
		B747	56	2006-11	2009-04	30	16	2004-04 (end of program)	60
		B767	–	None in 2007	–	–	–	2000	–
	Air Canada	–	20	2004-10	2007-02	29	44	1994	(120)
	Cathay Pacific	A340, A330, B777-300/400	42	2006-09	2009-04	32	23	2001	57–69
	Singapore Airlines	–	–	–	–	–	–	2002	46–58
		B777-300ER	18	2006-10	2009	27	43	(new delivery)	–
	Japan Air Lines	B777-200	15	2007-04	–	–	–	–	–
	Air New Zealand	B777-200ER	8	–	2009-06	–	–	2005-10	45
	Delta Airlines	B777	–	–	2010	38–50	–	–	–
		B767	63	2006-10	2010	38–50	21	–	–
	Swiss Airlines	A330, A340	34	Early 2009	2011-07	31	27	–	–
	Malaysia Airlines	B777-200	17	2004-12	2006-09-30	22	40	–	–
		B747-200	19	2004-10	2006-07-31	20	32	–	–
	Finnair	–	–	2009-04	–	–	–	2000	108
Domestic cabins	Olympic Airways	B737-400	13	2000-09	2001-03	7	16	–	–
	Cronus Airlines	B737-300/400	6	2000-09	2001-03	7	36		
	Swiss Airlines	Entire short-haul fleet	52	2006-10-15	2008-04-10	18	10	–	–
	Air Canada	Entire short-haul fleet	142	2006-04	2008-06-01	22	5	–	–
	Delta Airlines	MD88, MD90	94 (2/3 of the fleet)	2004	2006-09	21-33	9	–	–

Table 8
Frequency, duration and average age of aircraft for each type of cabin

Type of modification	Frequency of of cabin redesign program	Duration of one aircraft refurbishing	Equivalent duration of one aircraft refurbishing	Lower age limit	Upper age limit
Upgrade of International Cabins	65 months	3 months	31 days		
Upgrade of Domestic Cabins	84 months	15 days	15 days	0	20
Upgrade of aircraft on operating lease	84 months	–	15 (narrow bodies) or 31 days (wide bodies)		

Table 9
Driving factors for freighter conversions

Type of demand	Factors
Freighter conversion	Economic alternative to the purchase of new freighter aircraft
	Possibility to keep an aircraft no longer suitable for passenger use
	Modifications possible for virtually every modern aircraft type
Wide-body conversion	High degree of economic efficiency

more owners, who do not pay as much care and attention as a single owner. The market for refreshing these interiors to keep up with the required standards should be busy over the next years 21].

The demand for high-end completions has grown at a rate of 25% to 30% in the last 10 years [22]. The unprecedented growth is due to:

- the high demand for large business and VIP aircraft,
- new airplanes and technologies,
- the arrival of new types of VIP aircraft.

The arrival of new types creates a secondary market for the ones that operators will trade in when they receive the delivery of their new jets. If those earlier BBJs (Boeing Business Jet), ACJs (Airbus Corporate Jet) and other VIP transports change their owners, they are likely to have their cabins refurbished.

This demand has been driven to a large extent by the demand from emerging markets such as Middle East countries, India, China and many of the former Soviet republics. These results are gathered in Table 10.

However, in the context of the market instability experienced in the year 2009, the BBJs and ACJs have suffered cancellations for many of their orders. According to Ref. 23 BBJ has signed (until May 2009) only two orders: one for a BBJ and one for a 777 VIP, while receiving four cancellations, three from the Russian market (two 747-8 VIP and one 787 VIP) and one from the Chinese one, in Hong Kong (a 787 VIP). In this rather unstable market, the tendency is to conduct a performance improvement policy instead of investing large amounts of money into new products. In Ref. 23 examples can be found:

- Airbus has increased the A320 ACJ family's MTOW by 1 t by enabling a new load alleviation function that requires no structural changes to the aircraft.

Table 10
Driving factors for VIP Conversions

Type of demand	Factors
VIP Hi-end completion	High demand for large business aircraft
	New airplanes and technologies
	New emerging markets: China, India, Russia
VIP cabin refurbishment	The need to keep interiors looking up to date
	Fractional owners make the cabin more worn out

- Boeing succeeded to bring a 2% improvement in fuel burn through engine improvement for the B737 fleet.
- Boeing succeeded weight savings of 320 kg for the BBJ by using carbon brakes already used for the B737.
- Boeing has also announced that the BBJ was made convertible from an all-passenger to all-cargo mission in less than 8 hours.

Frequency and Duration. For determining the frequency and duration of a VIP completion, several examples are analyzed.

PATS Aircraft Completions undertook the completion of a green Embraer Lineage 1000 in 9 months [22]. On average, Lufthansa Technik completes a VIP BBJ in approximately five months, but when specialized cabin elements are involved, it can take up to eight or nine months.

The completion center of *Lufthansa Technik* conducts a requirement capturing phase, as an initial design process, before a contract is signed. This phase, which can take between a few weeks up to eight months and averages around six months, involves answering questions about the mission profile of the aircraft, typical city pairs the operator flies, how the living quarters should look like and if the operator is willing to trade off some range to include unique interior elements [22].

328 Support Services will complete the conversion of two VIP Dornier 328s in 6 months time for each aircraft [24].

BizJet International, Lufthansa Technik's wholly owned US subsidiary, has received its first Airbus A318 Elite which is scheduled to be completed and delivered back to Airbus in autumn with an FAA and EASA Type Certificate. The green completion will last around 6 months [25].

The frequency, at which the interiors are refreshed during the aircraft useful life, could not be determined precisely. It is estimated that the time between two VIP modifications amounts approximately *100 months*. Usually, the refurbishing of the aircraft interiors occurs when the aircraft is purchased by a new owner [21]. The average duration used for generating the forecast was *10 months*. The age limit considered is 10 years.

4. Aircraft world fleet – Current and future trend

A further analysis towards the current fleet distribution and its evolution for the next 20 years is performed. Based on the results of this section, along with the criteria identified in the previous ones, the forecast for the cabin conversion demand will be presented in Section V.

4.1. Passenger aircraft

Each scenario identified so far is suitable for a specific type of aircraft. For instance, the class division inside an aircraft is different for a short haul in comparison with a long haul aircraft.

Long-haul service or international flights are operated by aircraft with extended range. Generally wide-body aircraft are operated for long-haul flights. Air range is increasing as the number of one class seats is increasing [26]. Therefore, it will be considered that all wide-body aircraft are operated for long-haul routes.

For performing the forecast a great number of airplanes were included into a database. The data was filtered by criteria like airline, or type of aircraft. Table 11 presents the type of aircraft considered for the study.

Passenger Fleet Evolution. The tendency for the future estimated by market statistics [27] show that until 2027 aircraft will become more productive, being able to transport a larger amount of passengers. Each aircraft will be able to carry about 40% more passengers than the average airplane today. Fewer airplanes will be needed to accommodate the same number of travelers. The consequence is that the fleet needs to grow by only 3.2% each year, although RPK (Revenue Passenger Kilometers) will grow at 5.0%, as shown in the Fig. 2.

Table 11
Aircraft classification by size

Aircraft body size	Type of flight	Aircraft model
Wide-body	long-haul routes	B747, B767, B777, B787; A300, A310, A330, A340, A350, A380; MD-11, DC-10;
Narrow-body	Short-haul routes Medium-haul routes	B717, B727, B737, B757; A319, A320, A321; ARJ-21; BAe-146; CRJ-700, CRJ-900; Embraer models; Dornier models; Fokker 100, Fokker 70; MD-80, MD-90; SSJ-100

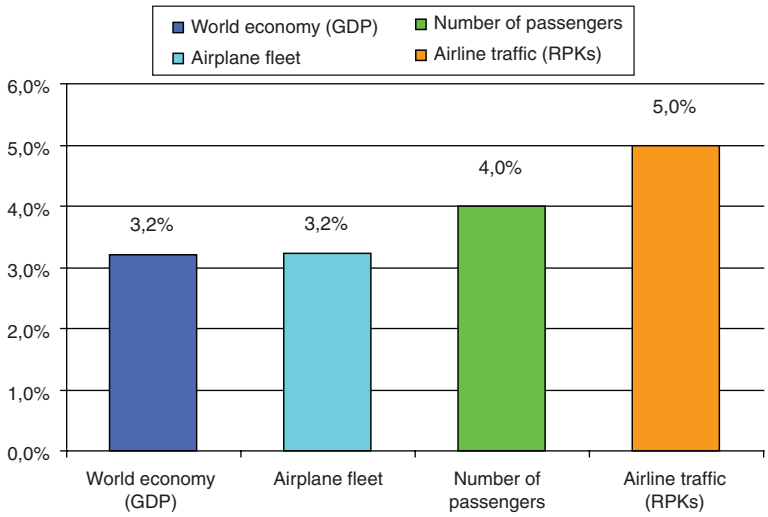


Fig. 2. Passenger key growth rates (based on Ref. 27).

66% of the fleet development will be due to new deliveries. 3% of the current fleet will be converted, generating demand for freighter conversions. The current fleet counts *17050* airplanes and this number will rise to *31910* airplanes, as shown in the Fig. 3.

As market liberalization stimulates opening of new international routes and aircraft capabilities improve, twin-aisle airplanes will be the fastest growing market segment. The numbers will rise from *3200* to a fleet of *7130* airplanes [27].

Single-aisle airplanes primarily serve markets within regions. The sheer size of these markets means that the single-aisle category accounts for the largest share of future deliveries (from 63% to 70% of the global market in 2027) [27] (Fig. 4).

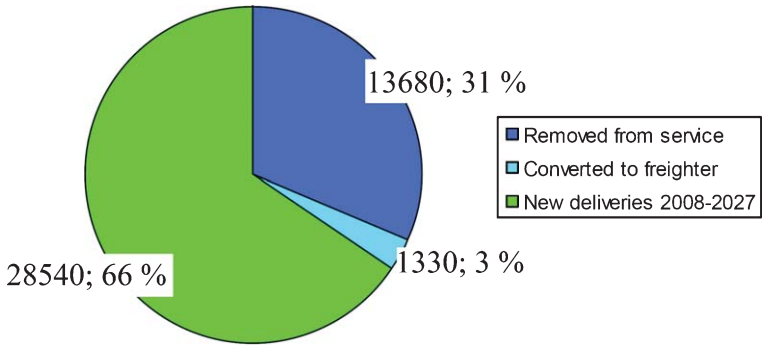


Fig. 3. Passenger fleet development 2008–2027 (based on Ref. 27).

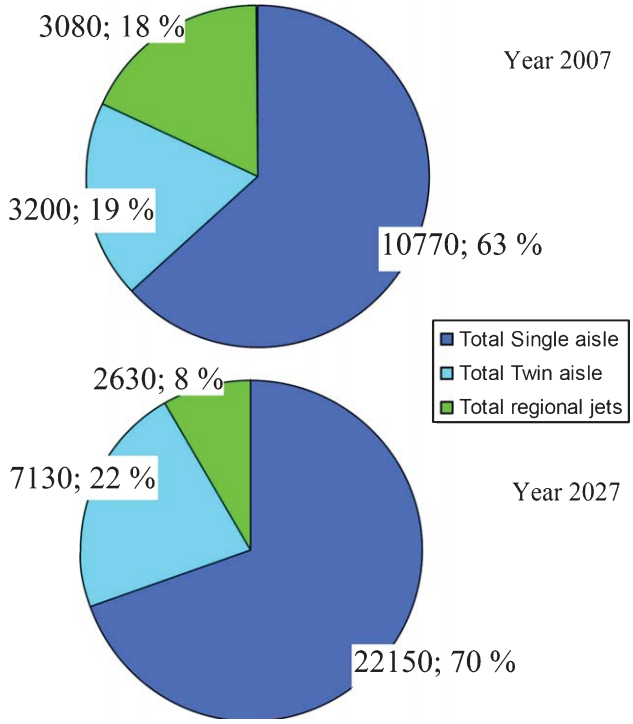


Fig. 4. Passenger fleet by airplane size in 2007 and 2027 (based on Ref. 27).

Airline requirements for economical and environmental efficiency are pushing towards larger aircraft, and congestion at major airports is driving demand away from the smallest airplanes.

Therefore, regional jets currently account for 18% of the worldwide fleet, but this will reduce to 8% by 2027 [27]. This means twin-aisle and single-aisle demand should be investigated.

World Repartition. According to Fig. 5, 20% of the world fleet is currently operated by airlines in Asia-Pacific and this will rise to 30% by 2027. The conclusion to be drawn is that there is a significant growth in the Asian market as European and North American market growth rates will decline [27]. Asia-Pacific, Middle East, and European markets will drive the demand of twin-aisle airplanes. Over 40% of twin aisles will be delivered to airlines in Asia-Pacific (see Fig. 6). Strong domestic growth in China, India, and other emerging Asian nations is contributing to high demand for single-aisle airplanes in Asia-Pacific. Approximately 60% of new airplanes needed in Asia will be in the single-aisle category [27]. The conclusion to be drawn is that the market is growing especially in Asia-Pacific for single-aisle and for twin-aisle category.

4.2. Freighter aircraft

In 2003 the ACMG (Air Cargo Management Group) estimated that growth in the global economy can sustain a long-term growth rate of 6% per year in the air freight market [16]. Boeing has obtained the same result in the Current Market Outlook [27]. These results are shown in Figs. 7–9.

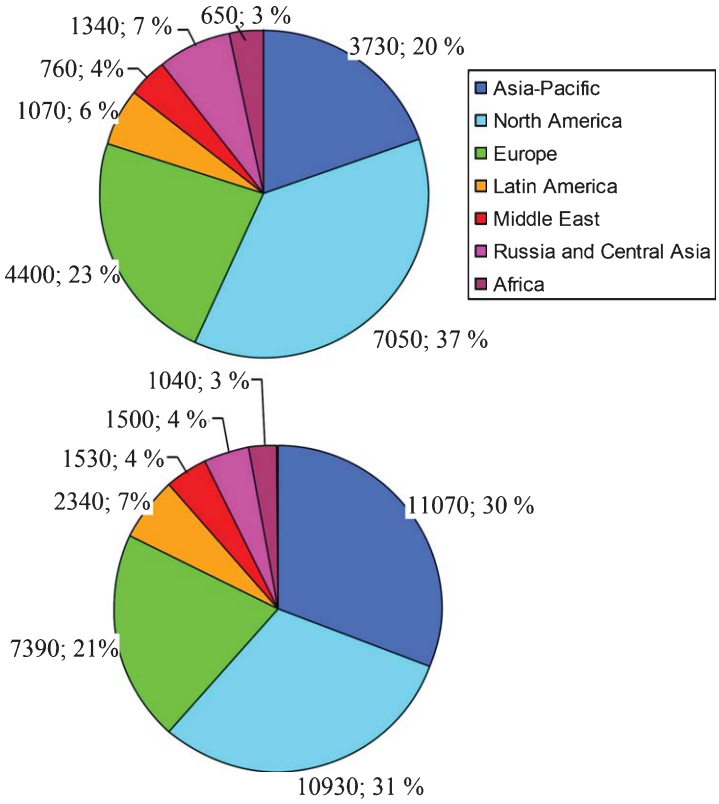


Fig. 5. Passenger fleet by region in 2007 and 2017 (based on Ref. 27).

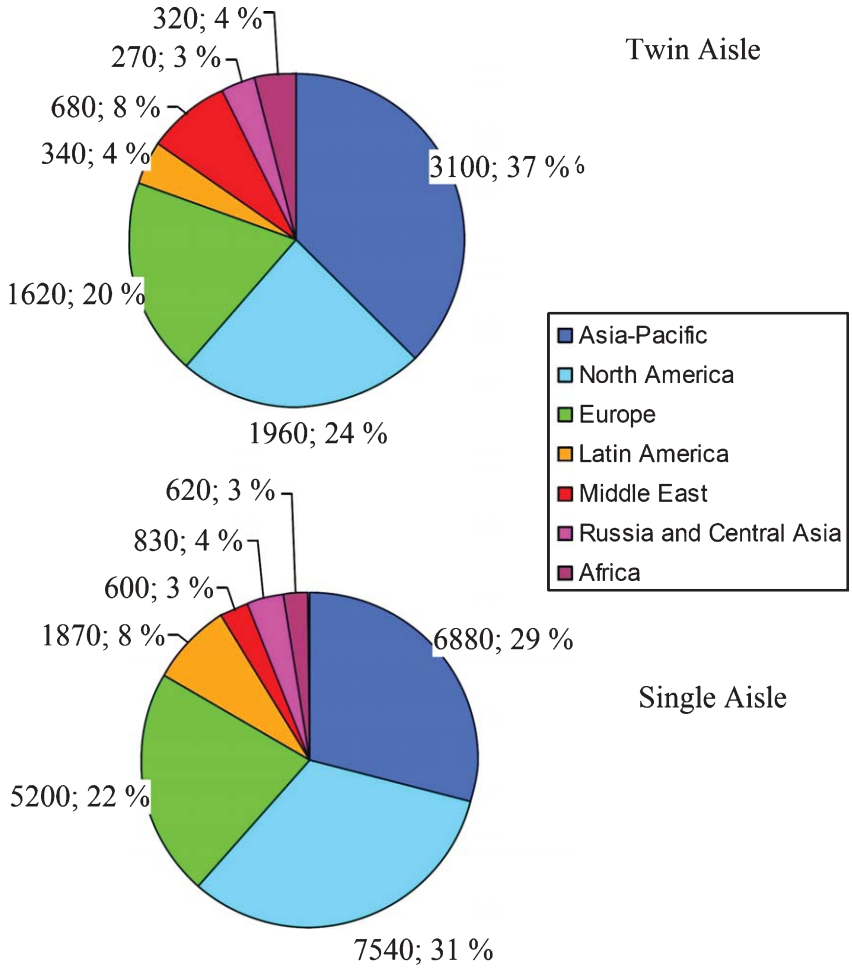


Fig. 6. Twin and single-aisle demand by region in 2027 (based on Ref. 27).

From the EADS's point of view, in the next two decades, the average annual growth of the world airfreight fleet is forecasted to a number of 6%. The world freighter fleet is predicted to double, while the air freight will triple. More than *3000* additional freighters will be needed to accommodate the traffic growth and to allow the fleet renewal – three quarters of this demand will be satisfied by the conversion of mid-life passenger aircraft [19]. From Boeing's point of view, the freighter fleet will nearly double over the next 20 years, expanding from *1948* airplanes in 2007 to *3892* in 2027.

Taking the forecast of *1414* retirements into account, *3358* airplanes will be added to the freighter fleet by 2027. Nearly three-quarters of freighter fleet additions will come from modified passenger and combi airplanes, with *863* new production freighters entering the fleet during the forecasted period [27].

This identical conclusion drawn by both sources confirm the validity of the results.

The disparity between tripling traffic growth and doubling fleet growth owes to the shift toward wide-body freighters, which will result in a fleet-wide increase in average freighter airplane payload. More than 60% of all additions to the fleet will be in the wide-body category, that is, medium wide-body plus large freighters. This aggregate category will increase in share to 65% of the fleet in 2027 [27].

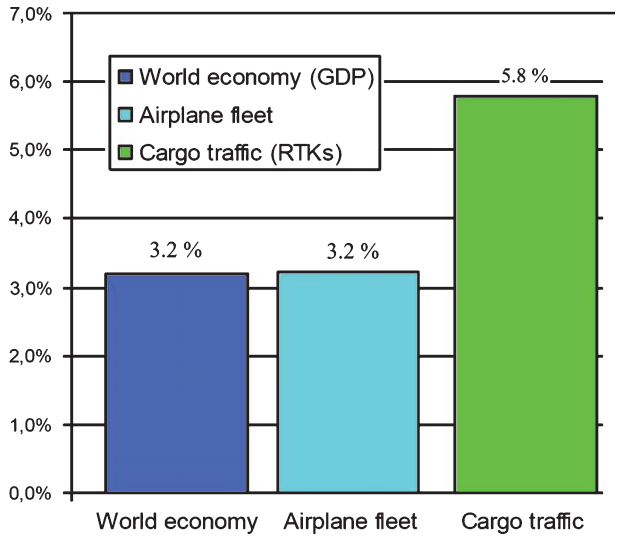


Fig. 7. Air cargo key growth rates (based on Ref. 27).

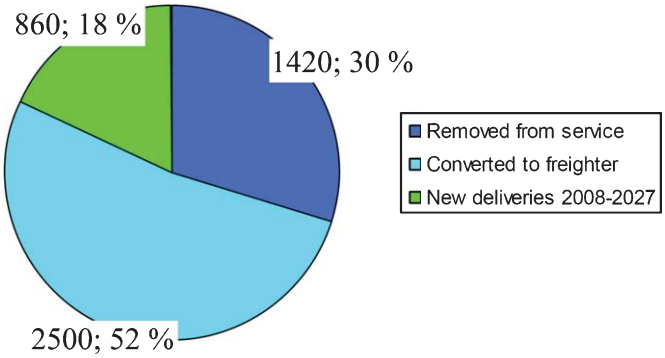


Fig. 8. Cargo fleet development 2007–2027 (based on Ref. 27).

In many cases, operators such as express carriers prefer medium wide-bodies as replacements for retiring standard-body freighters. Thus, the share of standard-body freighters will slightly decrease from 39% to 35% over the next two decades. Nevertheless, more than *1334* standard-body units will be delivered, representing an 84% increase in their number. As with production models, breadth of product family is important in the conversion market, so both airplane manufacturers continue to expand their offerings. Freighters will maintain about a 10% share of the total airplane fleet during the forecast period [27].

There is, as well, a significant growth in the demand for large freighters which rises from 26% to 34% of the global market until 2027 (Fig. 9) [27].

4.3. Executive jets

In 2008, the global business aircraft fleet was considered to comprise of *27000* turbine airplanes (jets and turboprops), of which 68% belong to U.S. operators [28]. The latest market forecast of the Teal Group

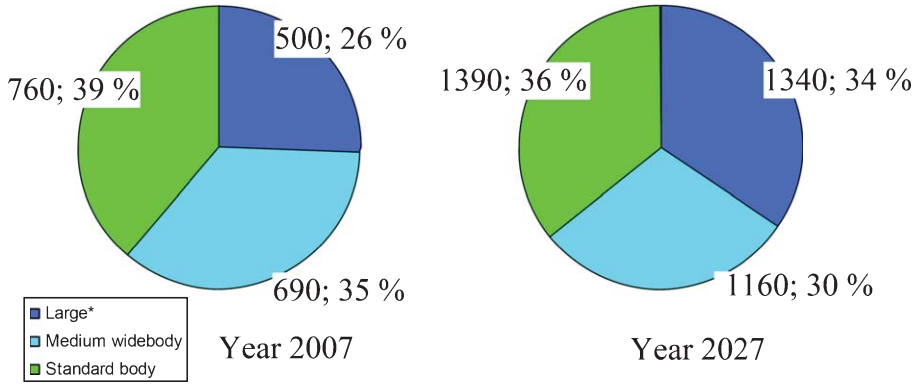


Fig. 9. Cargo fleet by airplane size in 2007 and 2027 (based on Ref. 27).

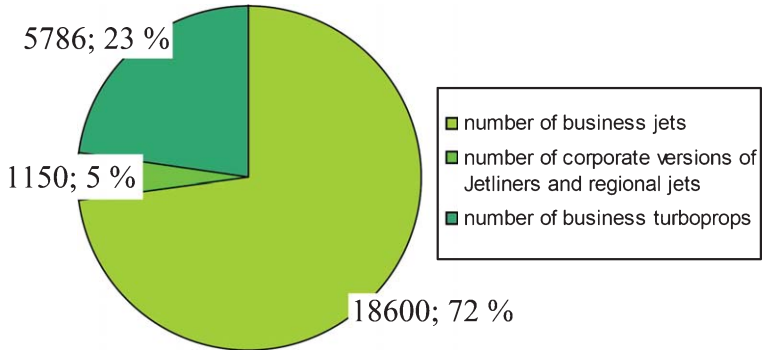


Fig. 10. Business aircraft deliveries 2009–2029 (based on Ref. 29).

predicts deliveries of *12768* business aircrafts worth 195.7×10^9 US$ over the next 10 years [29]. If the same annual growth rate and the same market share between the different segments are kept, then the forecast for the period 2009–2029 can be obtained (Fig. 10). Business jet deliveries will take a big part of the market with a share of 72%. Comparatively, Teal's previous report, issued one year ago, mentions a number of *18401* business aircraft deliveries between 2008 and 2017 [29].

Indeed, the business aircraft market has been hit harder by the economic crisis than any other aircraft market. After unprecedented growth, the market is falling at an unprecedented rate. All meaningful indicators – utilization, prices, used aircraft availability and corporate profits – indicate a prolonged and painful downturn. Financing business jets is also more difficult than financing jetliners. Teal's forecast assumes a three-year downturn. The key demand drivers – economic growth and corporate profits – will only recover in late 2010 to early 2011 [29].

5. Forecast of the market volume

This section illustrates the forecast method and delivers the market volume for the cabin upgrades and conversions for the next 20 years. The forecast uses an enclosed *Excel* database which groups the entire current and future world fleet of freighters and executive jets. It also includes 63 types of the biggest airplanes on commercial use (*23311* aircraft).

Computation Parameters for the Cabin Modification Scenarios (modifiable by the user)

	Occurrence (aircraft age in years)	Frequency of modifications (months)	Duration of one aircraft modification (days)	Equivalent Duration (days)	Aircraft Age Lower Limit (years)	Aircraft Age Upper Limit (years)
Upgrade of International Cabins		65		31	0	20
Upgrade of Domestic Cabins		84		15	0	20
Cabin Conversion for Narrow-bodies on Operating Lease		84	15		0	20
Cabin Conversion for Wide-bodies on Operating Lease		84	90		0	20
Pax-to-Freighter Conversion	20					
VIP completion		100	300		0	10

Fig. 11. Forecast Sheet: parameters for each scenario.

The *Excel* database can be updated with new information and can generate up to date forecasts according to the new input data. The VBA (Visual Basic for Applications) tool was used to program and compute the results. The size of the database makes the generation of the results take almost 2 minutes on a average personal computer. Figure 11 shows a print screen of the first sheet, where the frequency and duration obtained in Section III where used as input data.

The program also identifies the suitable scenario for each type of aircraft or if an airline is low cost or not. Each aircraft included in the database encloses data with respect to the world region, airline, first delivery date or lease termination. Finally the code writes, for each aircraft, the number of upgrades/conversions which are going to be undertaken in the next 20 years.

Hypothesizes. The following hypothesizes will be considered when performing the forecast:

- Normal, utility, aerobatic and commuter (i.e., CS-23) airplanes are not considered, as not enough elements could be found about cabin conversions for these small airplanes. This demand certainly does not affect the whole market of cabin modifications. The error coming along when estimating the cabin design/redesign volume is therefore considered negligible.
- Future aircraft (i.e., the world fleet forecast) which will be operated within the next 20 years and which will modify the future world fleet are not specifically identified, as the fleet forecast is already included in the database under aircraft orders. This will lead to a negligible error as airlines usually plan their fleet at least for the next twenty years.
- A forecast is computed for the next 20 years i.e., all cabin conversions which will be undertaken before 01/07/2029 are counted.
- For each aircraft, the modification scenario is identified; it contains the specific time between two modification programs undertaken by the operator.
- For each aircraft, the number of modifications is obtained by the computation of the specific time between two modification programs and the duration of a refurbishing program.
- For each aircraft, the first modification calculated will occur after the 01/07/2009.
- For each aircraft, the last modification that will be calculated will occur either before the 01/07/2029 or before the end of the aircraft useful life.

5.1. Forecast methods

Passenger Aircraft. The method used for the computation is to scan each sheet and each row of the database while looking for specific characteristics. For each aircraft:

- the table sheets are scanned,
- the characteristics of the aircraft are filtered,
- the scenario parameters are scanned and the scenario is identified and written in the database,
- the number of modifications is computed and written in the database.

The date at which the next cabin modification is predicted to occur is calculated with relation (1) by adding the frequency duration, $frequency_{scenario}$ and the scenario duration, $duration_{scenario}$ to the date at which the last retrofit program ended. Equation (1) is executed until the condition (2) is no longer valid. It is checked if the date of the computed retrofit program ($date_{modification}$) is not exceeding the deadline of the forecast (01/07/2029) or the second deadline, corresponding to the aircraft age ($age_{scenario\_limit}$) for which the refurbishing is no longer planned by the operator. This second deadline is calculated thanks to the date of the aircraft first delivery ($date_{aircraft\_delivery}$).

$$date_{modification} = date_{previous\_modification} + frequency_{scenario} + duration_{scenario} \tag{1}$$

$$date_{modification} < max\left(01/07/2009, date_{aircraft\_delivery} + age_{scenario\_limit}\right) \tag{2}$$

The number of modifications, n is given by the number of loop executions, n_{loop}:

$$n = n_{loop} + 1 \tag{3}$$

For aircraft on operating lease, the duration of the retrofit program ($duration_{scenario}$) is the duration of one aircraft refurbishing, $duration_{modification}$. It is considered that these aircraft do not take part into a refurbishing program (like wide-bodies and narrow-bodies owned by the operator), but they need to be reconfigured just after the aircraft lease termination.

$$duration_{scenario} = duration_{modification} \tag{4}$$

For aircraft owned by an operator, a retrofit program is usually undertaken by the airline for the whole fleet. Therefore the volume of the fleet ($volume_{fleet}$) has to be taken into account. Along with the equivalent duration of one aircraft refurbishing ($duration_{equivalent}$), it helps to determine the duration of the whole retrofit program for the fleet ($duration_{scenario}$). The $duration_{scenario}$ variable does not correspond to the real duration of one aircraft refurbishing, but determines the real time between two refurbishing programs for the same aircraft.

$$duration_{scenario} = duration_{total} = duration_{equivalent} \cdot volume_{fleet} \tag{5}$$

Freighter Aircraft. Only those aircraft on commercial use, which have reached a specific age and could be further involved in a pax-to-freighter conversion, are considered in the database. Additional input information is represented by the Boeing forecast [27], which predicts a number of *3500* airplanes required. According to Boeing, 75% of this amount will be represented by pax-to-freighter conversions (Eq. 6). In order to get the amount of freighter conversions in a specific world region, $n^{world\_region}_{freighter\_conversion}$, the Eq. (7) is used, where $p^{world\_region}_{freighter\_fleet}$ is the proportion of the freighter fleet in this specific region:

$$n_{freighter\_conversion} = n_{additional\_airplanes} \cdot p_{freighter\_conversion} \tag{6}$$

$$n^{world\_region}_{freighter\_conversion} = n_{freighter\_conversion} \cdot p^{world\_region}_{freighter\_fleet} \tag{7}$$

Executive Jets. No database with enough detailed information has been found about the executive jets fleet world distribution, neither about the current fleet volume. Therefore only the fleet volume for the 2009–2029 is used, based on the data gathered in Section IV, C.

For each aircraft, the number of VIP completions is computed in the following way:

- First, the duration of the period, $duration_{scenario\_period}$, within which VIP completions should be undertaken, is computed.

$$duration_{scenario\_period} = age_{scenario\_limit} \tag{8}$$

where $age_{scenario\_limit}$ represents the limit at which VIP completions are not undertaken anymore.

- Within this time, the number of VIP completions, $n_{aircraft}$, which could be undertaken for one aircraft, are computed.

$$n_{aircraft} = \text{int}\left[duration_{scenario\_period} / \left(duration_{scenario} + frequency_{scenario}\right)\right] \tag{9}$$

- Finally, the total number of VIP completions, n, for the entire business aircraft forecasted fleet, is computed.

$$n = n_{aircraft} \cdot volume_{fleet} \tag{10}$$

5.2. Forecast results

The results of the forecast applied on the several databases are presented in Fig. 12. Over the next twenty years, *10154* programs for the retrofit of international cabins and *23226* for domestic cabins will be undertaken. The demand for the cabin conversion of leased aircraft will create *4244* additional cabin modifications on airliners. *2625* conversions from jetliners to freighters will be planned. Last but not least, the most important demand will come from *25536* modifications of executive aircraft cabins at VIP standards.

Demand for Upgrades of International Cabins. A large part of the *10100* forecasted wide-body cabin redesigns come from Asia-Pacific area (29%). Together with China and Middle East, more than 55%

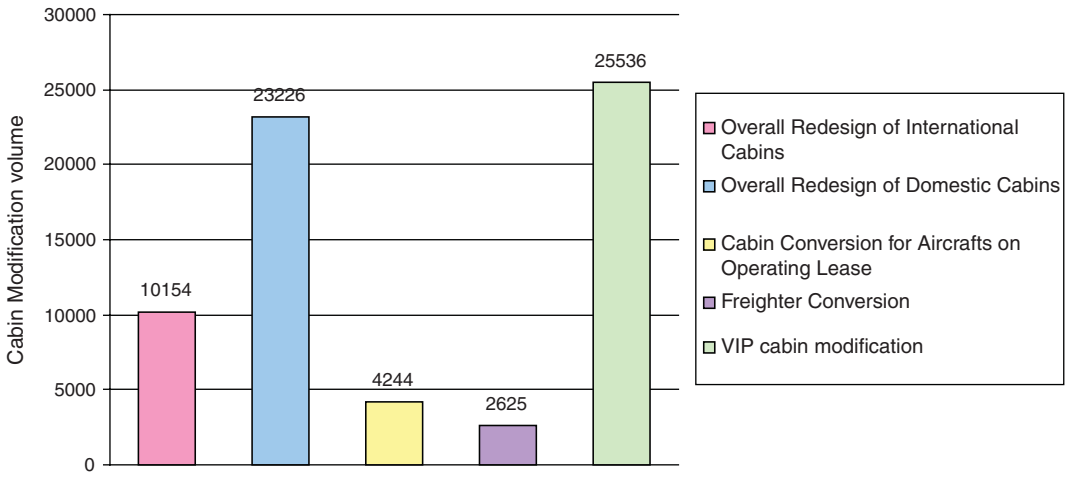


Fig. 12. Cabin modification world volume 2009–2029.

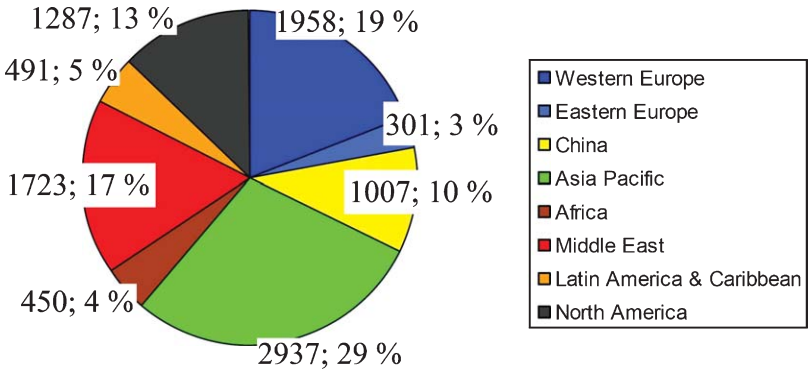


Fig. 13. International Cabins: Cabin Retrofit World Distribution 2009–2029.

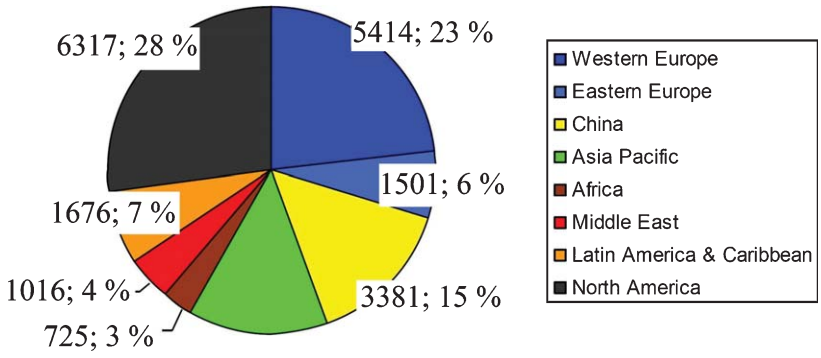


Fig. 14. Domestic Cabins: Cabin retrofit world distribution 2009–2029.

(*6000* cabin retrofits) of the demand will be concentrated in a single world continent. Therefore, the Asia-Pacific market will have an important influence on this segment (see Fig. 13).

In following positions come Western Europe and North America with respectively 19% and 13% of the market share. These results were expected due to the relative small part of the wide-body deliveries in these two regions. Moreover, as it has already been shown, the redesign of wide-body cabins is a tool for differentiation between airlines.

That means, even if aircraft deliveries and orders could be postponed due to possible economical downturns, such as today, airlines will continue to redesign their cabins in order to attract customers at minimal expenses (compared to the purchase of a brand new aircraft). Therefore, the demand for the redesign of international cabins will continue to grow.

Although premium cabins are considered by airlines as very large profit centers, some specialists believe the margins will start to erode as retrofit and innovation costs go up and fares go down from competition. As a result, it will be more difficult to recoup their investment. These specialists believe too that innovation on premium cabins has a limit as customers may not be able to afford it every time they travel [30].

Demand for Upgrades of Domestic Cabins. The North American market will drive the global demand of *23200* domestic cabin retrofits along with the Western European market (respectively 28% and 23% of the market share). This is due to the high number of existing narrow-bodies in these regions. However, Asian

markets (China, Middle East, Asia-Pacific) are still strong and approximately 60% of new narrow-bodies will be delivered in these regions (Fig. 14).

The world demand for cabin redesign of narrow-bodies appears to be a lot stronger than the demand for international cabin redesign. It has to be reminded that the price of such a retrofit is a lot higher than the domestic cabin retrofit price, and this is due to the expenses required by the innovation in premium cabins.

Although comfort and amenities on short-haul flights also drive the airlines reputation, most of them do not currently put the emphasis on it and focus on wide-bodies.

The real advantage for the domestic cabin redesign is the reduction of fuel burn (through weight reductions) or the increase of seating capacity (as mentioned in the previous sections). However North American and Western European markets have to be investigated if this segment is suddenly growing because of a future trend.

Demand for Cabin Upgrades of Aircraft on Operating Lease. The chart below (Fig. 15) shows that most of the *4200* cabin conversions of leased aircraft will be undertaken in Europe and in North America with respectively 41% and 17% of the market share. This world distribution of the demand is certainly due to the great proportion of Low Cost Carriers (LCC) in Europe and in North America, which operate a great percentage of the leased aircraft. However, the Asian market follows the trend of the market share (China, 13%, Asia Pacific, 10% and Middle East, 6%).

It is to be remembered that the leasing of aircraft allows carriers to be more flexible towards the market expectations: they can preserve their cash in time of economical downturn; they can meet the market change by quickly remodeling their fleet and they can always offer the passengers new aircraft. For these reasons, the market of aircraft leasing is expected to grow as more and more full service carriers (along with LCC) decide on aircraft leasing, due to the above mentioned advantages.

As such operators deal with short-term lease contracts, cabin retrofits occur in relative short cycles. As a result, the leasing of aircraft generates an additional strong demand for cabin redesigns for narrow-bodies, as well as wide-bodies.

Demand for Freighter Conversions. A strong demand for freighter conversions comes from North America with 55% of the market share. The second position is shared by Western Europe and Asia-Pacific. This is probably due to the high number of freighters operated in North America.

As already mentioned, a pax-to-freighter conversion is an economical alternative to the purchase of a new aircraft. Moreover, it allows a carrier to keep in service a former airliner, which is no longer suitable for passenger use. This scenario generates, as well, a strong demand for cabin conversions (Fig. 16).

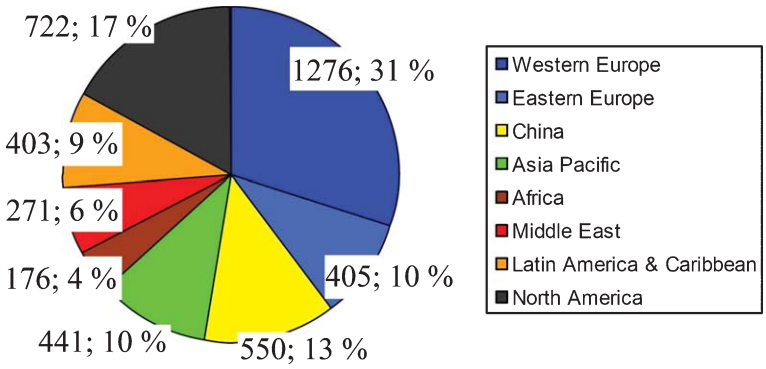


Fig. 15. Aircraft on operating lease: cabin retrofit world distribution 2009–2029.

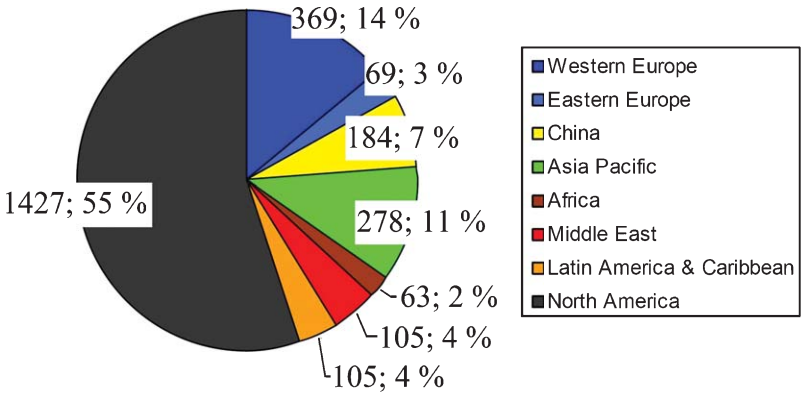


Fig. 16. Pax-to-freighters conversion: World distribution 2009–2029.

Demand for VIP Completion. Among the *25500* VIP modifications that are forecasted for the next twenty years, specialists currently see strong interest from India, Russia, the Middle East as well as China. Traditionally, most of the VIP conversion business has been generated by the Middle East. Specialists think there is enough potential for further growth of the market in this area. It seems that individuals from Russia can afford to ask for bathrooms, dining areas, bedrooms, libraries, children rooms. Russia could dominate the sector within five years, exceeding even the Middle East in its demand. However, the recent crisis has put many of the demands on hold [31].

Growth is also coming from the South American market, especially in Brazil, and mainly in the business jet segment [31].

India's fast-growing economy is increasing demand, where a lot of interest in the ACJ and BBJ for both VIP and corporate transport is foreseen [31].

The very high price of a VIP conversion transforms this market segment into the most profitable, therefore most important scenario of the market. The AeroStrategy estimates that more than 3.3×10^9 US$ were spent in 2007 on completing green VIP aircraft and upgrading in-service large executive airplanes. AeroStrategy forecasts that those expenditures could grow to more than 3.8×10^9 US$ annually by 2015. Typically, VIP aircraft buyers spend up to 100×10^6 US $ for a top-of-the-range completion [22].

6. Conclusions

Forecast method. Based on the researched data, argued assumptions were made with respect to the frequency and duration of the refurbishing cycles, based on which the cabin modification volume was forecasted. Especially for VIP conversions, where not enough data regarding these two parameters was found, the results may not be completely accurate. However, the trend line of the results was confirmed by industry [32].

Forecast results. The demand for the *10100* international cabin retrofits represents a major segment of the cabin conversion global market even if the total amount of modifications is lower than the demand for the *23200* domestic cabin upgrades. This demand is driven by markets having a high growth rate, concentrated in a single world region: the Asia-Pacific, the Middle East and China. The demand is expected to be stable even in economical downturn. The high price of a retrofit program of a wide-body fleet, compared to narrow-bodies, indicates that this scenario will have a meaningful influence on the global market.

Although comfort and amenities on short-haul flights also drive the airlines reputation, most of them do not currently put the emphasis on domestic cabins. The real advantages of the domestic cabin upgrades are the reduction of fuel burn and the increase of seating capacity and do not involve high expenses. Thus, this scenario is less interesting than international cabin redesigns from the point of view of a design organization wanting to deliver cabin design and redesign engineering work. However, as innovation on international premium cabins has a limit and should not always generate high margins for airlines, North American and Western European markets have to be investigated if this segment will suddenly grow.

Aircraft on operating lease create an additional strong market of *4200* cabin conversions for wide-bodies as well as narrow-bodies. Moreover, this segment is expected to grow in the future due to the advantages of operating such aircraft even for full service carriers. Therefore, European and Asian markets should be considered with priority as this demand will concentrate in these regions.

The market segment of freighter conversions remains still interesting with *2600* cabin conversions forecasted, most of them taking place in North America.

Last but not least, the *25500* VIP modifications will perhaps be the strongest segment of the cabin conversion and refurbishing market for the next twenty years. The high prices of VIP cabin completions, along with the need for business aircraft to be refurbished, makes this segment very interesting. North American and West European markets should have the greatest influence on this market segment. However, an emerging and growing demand for the next years should draw the attention towards the Russian and Asian markets.

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