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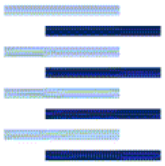

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CARISMA:
Aircraft Cabin and Cabin Systems Refurbishing,
Optimization of Technical Processes

Market Research for a Completion Center

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This Technical Note is part of the cooperation project between ELAN GmbH and HAW Hamburg, having the purpose to preliminarily describe the set-up requirements for a Completion Center. Work Package 2 presented here, delivers a market research showing the present and future trends in the area of cabin upgrades and conversions. Several working scenarios are identified and analyzed. For drawing the conclusions many real life examples are studied. A database containing a large number of aircraft and aircraft data is used for making the forecast. The database, created in EXCEL can be upgraded, allowing the generation of new results. The information contained by the database will be delivered to ELAN together with this Technical Note. The results show, that despite the current economical situation, the cabin conversion market is a reliable one.</td></tr>
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Diese Technische Niederschrift ist Teil des Kooperationsprojektes CARISMA zwischen ELAN GmbH und HAW Hamburg. Aufgabe ist, den Weg in die Vision „Completion Center“ für die ELAN vorbereitend zu beschreiben. Arbeitspaket 2 liefert als Forschungsergebnis eine Marktstudie, die gegenwärtige und zukünftige Trends auf dem Gebiet der Kabinenumrüstungen zeigt. Verschiedene Szenarien werden identifiziert und analysiert. Viele praxisbezogene Beispiele werden recherchiert. Eine Datenbank, die viele Informationen über Flugzeuge und Fluggesellschaften enthält, wird für die Prognose benutzt. Die Datenbank wurde in EXCEL aufgebaut und kann damit laufend aktualisiert werden, um immer die neuesten Ergebnisse zu zeigen. Das EXCEL-Dokument wird ELAN zusammen mit der Technischen Niederschrift übergegeben. Die Ergebnisse zeigen, dass trotz der Krise, die Kabinenumrüstungen ein sicherer Markt ist.</td></tr>
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Abstract

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 Center. A completion center carries out the conversion of an aircraft starting from the customer request up to aircraft delivery. This technical note aims to investigate this emerging and growing market, and to forecast its evolution for the next 20 years. It is known that 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 subcontracting work in this field from large manufacturers are very interested to find out if growing into a Completion Center represents a business opportunity or not. This technical note identifies several meaningful cases 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 cabin modifications. 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.

Table of Content

Page

List of Figures

List of Tables

List of Symbols

$age_{scenario\_limit}$	Aircraft age for which the refurbishment 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 ended the last retrofit program for the same aircraft
$date_{today}$	Date of computation
$duration_{equivalent}$	Equivalent duration of one aircraft refurbishment as if aircrafts were retrofitted one after the others
$duration_{scenario}$	Duration of the retrofit program. It also depends on the scenario.
$duration_{scenario\_period}$	Duration of the period within which cabin modifications should be undertaken
$frequency_{scenario}$	Time between the end of the last retrofit program and the begin of the Next scheduled retrofit program. It depends of course of the cabin modification scenario in which the aircraft is involved.
n	Total number of cabin modifications
$n_{AdditionnalAirplanes}$	Number of freighter deliveries
$n_{aircraft}$	Number of cabin modifications that could be undertaken for one aircraft
$n_{FreigtherConversion}$	Total amount of freighter conversions
n_{loop}	Number of loop executions of the program
$n^{world\_region}_{FreighterConversion}$	Amount of freighter conversions in a specific world region
$p_{FreighterConversion}$	Proportion of conversions in the freighter deliveries
$p^{world\_region}_{FreighterFleet}$	Proportion of the freighter fleet in a specific region
$volume_{fleet}$	Volume of the fleet (same aircraft type) of an airline

List of Abbreviations

ACJ	Airbus Corporate Jetliner
ACMG	Air Cargo Management Group
BBJ	Boeing Business Jet
BC	Business Class
CC	Completion Center
CS	Certification Specification
DO	Design Organization
DOA	Design Organization Approval
EASA	European Aviation Safety Agency
FAA	Federal Aviation Administration
FC	First Class
FY	Fiscal Year
GDP	Gross Domestic Product
HMV	Heavy Maintenance Visit
IFE	In-Flight Entertainment
LCC	Low Cost Carrier
MRO	Maintenance, Repair and Overhaul
MTOW	Maximum Take-off Weight
NM	Nautical Mile
OEM	Original Equipment Manufacturer
PAX	Passengers
RAeS	Royal Aeronautical Society
RPK	Revenue Passenger Kilometer
TV	Television
URL	Universal Resource Locator
VBA	Visual Basic for Applications
VIP	Very Important Person
YC	Economy Class
WP	Work Package

List of Terms and Definitions

All-business-class airlines
These are airlines which operate jetliners with a single-class cabin configuration (which is Business Class).

Cabin Configuration
Each cabin configuration is linked to a specific type of cabin as well as to a specific seat layout: passenger configuration with a specific seats layout, freighter configuration and VIP configuration.

Cabin Conversion
The cabin conversion is the modification of the cabin interior of an aircraft, from a configuration to another. For instance, a freighter conversion is the modification of a cabin in passenger configuration into one of freighter configuration.

Cabin Modification
The cabin modification groups all the existing scenarios about the modification of the aircraft interior: refurbishing of a used cabin, conversion of the cabin from one seat configuration to another, completion of a VIP cabin.

Cabin Refurbishing
The cabin refurbishing consists of the redesign of a used aircraft interior and its installation onboard the aircraft.

Cargo
The term refers to anything other than passengers, carried for hire, including both mail and freight (**ATA 2009**).

Charter service
A transport service when an aircraft (typically the entire aircraft) is hired for a non-scheduled trip (**ATA 2009**).

Check C
In maintenance, a C-Check usually refers to a comprehensive inspection performed at rather large increments of either aircraft time in service or calendar years since certification. The actual inspection increment varies between aircraft models and is determined by the manufacturer along with the governing authority over the certification each individual aircraft. Thus the same model of airplane may require inspections at different times depending on the country it is

registered in. The scope of a C check is usually entirely comprehensive, meaning every square inch of the aircraft structure is inspected and every system tested/serviced.

Check D
This type of maintenance program is the heaviest check for an airplane, also known as a Heavy Maintenance visit (HMV). This check occurs approximately every 4-5 years. This is the check that, more or less, takes the entire airplane apart for inspection. This requires more space and time than all other checks, and must be performed at a maintenance base. Often, older aircrafts being phased out of a particular airlines' fleet are stored or scrapped upon reaching their next check.

Coach
This is another name for Economy Class.

Full Service Carrier
A Full Service Carrier provides in-flight meals, entertainment and other complementary services compared to Low Cost Carriers (which delivers only some of the services against money). Hence, the fares charged are generally higher. The services also incorporate hub and spoke networks and it offers a variety of air travel classes such as first (F), business (C) and economy (E) classes.

Green aircraft
This term designates an aircraft just after being manufactured which has still no painting. Usually, this aircraft goes to a Completion Center to get its interior completed.

Low Cost Carrier
A low-cost carrier or low-cost airline is an airline that offers generally low fares in exchange for eliminating many traditional passenger services.

Narrow-body aircraft
It designates an aircraft which is not a wide-body aircraft.

Premium cabins
Refer to those cabins for which the operators decided to bring improvements: an example is the Premium Economy Classes.

Scheduled service
Refers to a transport service based on published flight schedules, including extra sections (**ATA 2009**).

Seat pitch
The distance between seats in an aircraft‟s passenger cabin as measured from any point on a given seat to the corresponding point on the seat in front of or behind it (**ATA 2009**).

Seat width
The distance from armrest to armrest.

Single-aisle
Refers to aircrafts having a single aisle in the cabin. Usually, it designates a narrow-body aircraft.

Twin-aisle
Refers to aircrafts having two aisles in the cabin. Usually, it designates a wide-body aircraft.

VIP Hi-end Completion
This type of completion consists of designing and delivering the aircraft interior after its manufacturing according to the specific requirements of the aircraft owner (who is not an airline, but a VIP).

VIP Cabin Modification
The cabin VIP modification groups all the existing scenarios about the modification of the aircraft interiors in the VIP configuration: VIP Hi-end Completion, VIP Cabin Refurbishing and the conversion from the passenger configuration to the VIP configuration.

Wide-body aircraft
It is generally an airliner with more than one aisle in the passenger cabin. Examples of wide-body aircraft include the Airbus A300, A310, A330, A340, A350 and A380; the Boeing B-747, B-767, B-777, B-787, DC-10 and MD-11. Technically, any aircraft with a fuselage diameter in excess of 200 inches may be considered a wide-body (**ATA 2009**).

1 Introduction

1.1 Motivation

This Technical Note is part of the research project CARISMA which is aimed to deliver results for ELAN GmbH with respect to the vision „Completion Center". The subject treated here refers to the WP 2, described in the appendix of the collaboration contract between Hamburg Innovation GmbH and ELAN GmbH as follows (**CARISMA 2009**):

> ***WP 2: Market Research 'Completion Center'***
> *The department CCO of ELAN executes primarily cabin conversions for the 'Long Range' and 'Single Aisle' Airbus aircrafts and therefore serves only a limited segment of the market. The demand for cabin conversion beyond this area should be appreciated through a Market Research. The following approach is being proposed:*
>
> - *Investigation of aircraft data (manufacturer, aircraft family/class/model, age)*
> - *Deduction/derivation of criteria which are relevant for conversion (conversion cycles, conversion scenario, like: Pax-to-Freighter, Pax-to-VIP, Pax-to-Pax, small/large aircrafts, area of conversion)*
> - *Forecast of the market volume*
> - *Investigation of companies offering cabin conversion and classification of these companies: position inside the process chain, aircraft types, type of conversion*

1.2 Definitions

Market Research — A market analysis is conducted with the purpose of delivering a forecast (**Ferreri 2003**) for a specific area of products in a specific area of time. Notions like *market segmentation* or *market trends* are included in such a study, which delivers in the end *numbers* and *evolutions* based on which the decision is taken whether or not to invest money in developing a product or an idea.

Completion Center — This is the commonly used notion (especially in West Europe and North America) to define a design organization (DO), having received its DOA from EASA/FAA in order to conduct engineering and design work in the cabin conversion area. Some of the Completion Centers" (CC) most important characteristics are: **1.)** The customers are usually high paying and high demanding (therefore the preferred scenario is the VIP Completion); this demands a big work volume, including in the project preparation phases, but brings profit as well. **2.)** The work is done, directly by the CC or indirectly through subcontractors, starting from customer request up to delivering the expected results. **3.)** The CC can

deliver only the engineering and design documentation to the customer, who decides for himself (or is counseled by the CC) where to send the airplane for processing. **4.)** The certification work needs to be done under the Aviation Authorities, which usually require a certificate showing the capability of performing the design (EASA and FAA call it DOA – Design Organization Approval). **5.)** Usually those CCs having the capability to conduct the work itself on the airplane take the VIP conversion contracts, while those CC‟s delivering only the documentation work, cover the hole palette of conversions, and often offer support to overbooked CC‟s having the infrastructure for placing the aircrafts for processing.

1.3 Objectives

The main objectives are:

- Presentation of the existing Completion Centers, their tasks, market share and location
- Investigation of aircraft data (manufacturer, aircraft family/class/model, age)
- Investigation of current market demands related to conversion and refurbishing of aircraft cabins
- Identification of conversion scenarios and factors driving these scenarios
- Determination of the duration and frequency of the modification scenarios for each case
- Determination of the aircraft fleet for the present and for the next 20 years
- Prediction of the market volume for the next 20 years

The information for achieving these goals is gathered from many examples found

1.4 Structure of Work

The Technical Note is comprised of 6 chapters, besides the introductory chapter.

Chapter 2 **Existing Completion Centers – Overview** – presents a list of current Completion Centers, their activities, type of aircrafts for which the work is done, as well as their world wide location.

Chapter 3 **Characteristics of the Current Market** - presents the current status of the cabin refurbishing and conversion market. The current standards required by the customers (airliners or private owners) are identified, along with conversion/modification scenarios and their characteristics.

Chapter 4 **Driving Factors in Cabin Refurbishing and Design** - identifies relevant parameters for each cabin modification scenario. Such parameters are: frequency and duration of the modification scenario or factors driving the demand for the respective scenario.

Chapter 5 **CS 25 World Fleet – Present and Future Trends** - includes data about the current aircraft fleet and its future trends. In order to predict the work volume for the different modification scenarios over the next 20 years, the number and world distribution of CS 25 aircrafts (pax, freighter and business fleet) is an issue investigated here.

Chapter 6 **Forecast of the Market Volume** - all the factors determined in the previous chapter are introduced into an aircraft database. The information is computed into a VBA code which delivers the forecasts results valid up to 2029.

Chapter 7 **Summary** - presents the summary of the results and interprets them from the point of view of an engineering office with the size of ELAN.

2 Existing Completion Centers

The notion **Completion Center**, in the common understanding, refers to those organizations able to deliver complete, highly specialized conversions, usually attributed to VIP aircrafts. The design and engineering work normally demands a complex certification process, especially if the customer is asking for unusual furnishings. However, a Completion Center is able to perform any type of cabin upgrade, as well.

Usually, the existing Completion Centers have the possibility to execute the assembly work, as well. *Lufthansa Technik* extended its maintenance capability and became a Completion Center, able to perform the design and engineering work, as well the work on the airplane itself. However, **a design organization can call itself a Completion Center** even without seeing the aircraft, by delivering the design work. Another possibility for a company to call herself Completion Center is to conduct the work for the customers through intermediaries. In the end, the customer has the interest to receive its certified conversion on time, at the lowest price possible. A combination between the two last variants is also possible.

With OEM backlogs for large executive jets at record levels, Completion Centers are working overtime to finish green aircraft and refurbish older airplanes. For the foreseeable future, there will be more aircrafts in the market than Completion Centers can take. For instance, the **backlog** at *Jet Aviation* stretches out to 2011 for U.S. facilities and to 2014 for Basel facilities. *Associated Air Center* also reported that its facilities are fully booked throughout 2009, and *Gore*'s backlog extends into 2010 (**Searles 2008**).

Due to the unprecedented demand for green completions, commitments to complete green aircrafts affect the quantity and type of refurbishing projects that Completion Centers can accept. Nearly all Completion Centers are therefore scrambling to add floor space to enhance their ability to handle **VIP completions and refurbishings**. For example, 85 percent of *Jet Aviation* Basel's work involves completions, and *Fokker Services* is concentrating on finishing green aircraft and performing executive conversions. Other companies, however, are taking on some refurbishing projects such as *Lufthansa Technik* which has one production line dedicated to wide-body completions and another devoted to refurbishings. The company plans to open a second wide-body completion line in 2010 (**Searles 2008**).

Limited completion capacity obviously can inhibit new sales of large VIP aircraft, so *Airbus* has joined in efforts to **expand the industry's ability** to finish green aircraft by opening in July 2007 the *Corporate Jet Centre*. The facility, which features a 70,000-square foot hangar, is expected to eventually be able to outfit three ACJs per year (**Searles 2008**).

An investigation towards the existing Completion Centers and their activities resulted in gathering meaningful data for generating the view on this market segment. The results are

included in the Excel document attached to this Technical Note, in the sheet called „Modification Centers" (Figures 2.1, 2.2 and 2.3).

The information gathered refers to the **type of aircrafts** on which the work is performed, the **type of work scenario** carried out and the **location of the Completion Center.**

On the first look (Figures 2.1, 2.2 and 2.3) one can notice the fact that Completion Centers are **mainly focused in the North America (USA and Canada) and Western Europe**. A strategy for a design organization (located in Europe) wanting to become a Completion Center would be to assimilate the **market niche** represented by the Asian market. The engineering work could be conducted in Europe, while the embodiment of the design can be transferred to the cheaper work force in the east (including Eastern Europe).

The following chapters will focus on the current market situation and will deliver the forecasted results in the cabin conversions/upgrades market. It was found relevant to include from the beginning the overview of the existing CC"s.

From a total of 97 Completion Centers included in the database, 61 deliver VIP conversions: the most expensive, therefore the most profitable market segment. Some conduct pax to freighter conversions and the rest is specialized in delivering cabin upgrades for aircrafts operated by airlines.

Modification Center name	Type of work	In-house Interior Design	Aircraft types involved	Location
ADI Interiors	VIP cabin modification	yes		US
Aero Air, Inc.	Interior modification		Galaxy, Astra, Westwind and Twin Commander	US
Aero Industries / Richmond Jet	Interior modification	yes		US
Aerosmith Aviation, Inc.	VIP cabin modification	yes	Gulfstreams, Hawkers, Learjets, Challengers, Jet Stars, Diamonds, King Airs, Falcons, Citations and Westwinds	US
Airbus Corporate Jet Centre	VIP cabin modification		Airbus	
AirCraft Interiors Inc	VIP cabin modification	yes	Medium sized jet	Canada
Aircraft Interiors of Memphis, LLC	Interior modification	yes	piston and turbine aircraft	US
Air Hanson Engineering, Ltd	VIP cabin modification			England
AiROVATION Interior Restyling, Inc	Interior modification	yes		US
Akridge Aircraft Interiors, Inc.	VIP cabin modification	yes	Gulfstream	US
American Aircraft Interiors	VIP cabin modification		Citation, King Air, Conquest, Hawker, Lear, Falcon, Gulfstream, and Boeing.	US
Associated Air Center, Inc.	VIP cabin modification	yes	BBJ & ACJ	US
Austin Jet International	VIP cabin modification		Lears, Citations, King Airs, Hawkers, Gulfstream	US
AvCraft Support Services, Inc.	Airliner interior modification	yes	Dornier 328	US
AVMATS	Airliner interior modification	yes	Falcon, Hawker, and Sabreliner	US
Bizjet International Sales & Support	VIP cabin modification	yes	Citation, Learjet, Dassault Falcon Jet, Embraer, Gulfstream, BBJ	US
Bombardier Aerospace - Montreal	VIP cabin modification	yes	Bombardier Global Express, Bombardier Challenger	Canada
Bombardier Aerospace - Tucson	VIP cabin modification	yes	Challenger, Learjet and other aircraft	US
Bombardier Aerospace - West	Interior modification		commuter aircraft types	US
Bombardier Aerospace - Wichita	VIP cabin modification	yes	Learjet	US
Burnet Interiors sa	VIP cabin modification	yes		Switzerland
Cabin Crafters	upholstery and cabinetry	subcontract	up to Gulfstream V size aircraft	US
Capital Aviation, Inc.	VIP cabin modification	yes	up to Gulfstream IV size aircraft	US
Classic Interior Completions, Inc.	Interior modification	yes		US
Cypress Aviation, Inc.	Interior modification	no		US
Dassault Falcon Jet	VIP cabin modification	yes	Falcon Jet	US
Dassault Falcon Jet - ILG	VIP cabin modification	yes	Falcon, Challenger, Bae, Gulfstream. NDT and DAS	US
Dassault Falcon Service	VIP cabin modification	yes	Dassault Falcon Jet	France
Delta Interior srl	VIP cabin modification	yes		Italy
DO328 Support Services	Airliner interiors		Dornier	Germany
	VIP cabin modification			
Duncan Aviation Inc. - BTL	VIP cabin modification	yes	Citations, Learjets, Hawkers, Falcons, Gulfstreams, Challengers and Astras	US
Duncan Aviation Inc. - LNK	VIP cabin modification	yes	Citations, Learjets, Hawkers, Falcons, Gulfstreams, Challengers, Astras	US

Fig. 2.1 Completion Centers and their characteristics, letters A to D

EADS EFW	Freigher Conversion		Airbus	Germany
EADS Sogerma Services	VIP cabin modification		Airbus	France
Eagle Aviation, Inc.	Interior modification	yes		US
Elliott Aviation	VIP cabin modification	yes		US
Executive Aircraft Corp. - Newton	Interior modification			US
Executive Aircraft Corporation - Wichita	Interior modification	yes		US
Field Aviation East Ltd.	VIP cabin modification	yes		Canada
Field Aviation East Ltd.	VIP cabin modification	yes		Canada
Florida Aircraft Interiors	Interior modification		single engine to small jets	US
Fokker Services	VIP cabin modification	yes		Netherlands
	Airliner interior modification		Fokker	
Flying Colours Corp.	VIP cabin modification	yes	Gulfstream, Cessna, Falcon, Lear Jet, Challenger, Sikorsky, Hawker, Beechjet. Extensive experience with Citation Series.	Canada
Garrett Aviation Services - SPI	Interior modification	yes	Falcon Service Center	US
Garrett Aviation Services - VNY	VIP cabin modification	subcontract	Gulfstream, Challenger and Global Express	US
Goderich Aircraft, Inc	VIP cabin modification	yes	Bombardier	Canada
Goodner-Crider Aircraft Painting	Interior modification	yes		US
Gore Design Completions, Ltd	VIP cabin modification	yes	BBJ, A340, 767, executive jets	US
Greenpoint Technologies, Inc.	VIP cabin modification	yes	Boeing	US
Gulfstream Aerospace Corp. - Dallas	VIP cabin modification	yes	Gulfstream	US
Gulfstream Aerospace Corp. - Long	VIP cabin modification	yes	Gulfstream	US
Gulfstream Aerospace Corp. - SAV	Interior modification	yes	Gulfstream jets	US
Hillaero Modification Center	VIP cabin modification	yes	King Air 200, Citation Bravo, Citation VII	US
Indianapolis Jet Center	VIP cabin modification	yes	Challenger & Learjet	US
Innotech - Execaire Aviation Group	VIP cabin modification	yes		Canada
International Jet Interiors	VIP cabin modification	yes	Gulfstreams, Challengers, Falcons, Hawkers, Jetstars, Citations and Learjets	US
Irkut	Freigher Conversion			Russia
Jet Aviation Basel	VIP cabin modification	yes	Gulfstream, Canadair for Challenger, Learjet, Dassault for the Falcon series	Switzerland
	Airliner interiors refurbishment		aircraft up to the size of a Boeing 747-400 and 767	
Jet Aviation West Palm Beach	VIP cabin modification	yes	Dassault Falcon Jets, Gulfstreams, Challengers and Hawkers	US
JetCorp	VIP cabin modification	yes	Falcon, Learjet, Gulfstream, Jetstar, Sabreliner, HS125, Citation and others	US
Jet Source, Inc.	VIP cabin modification			US
Jet Works Air Center	VIP cabin modification	yes	up to large cabin jets such as Gulfstreams and Challengers.	US
KD Aviation Inc. / Reese	Interior modification	yes		US
L-3 Communications Integrated Systems	VIP cabin modification	yes	narrow and wide-body aircraft.	US
Lufthansa Technik AG	VIP cabin modification	yes		Germany
	Airliner interior modification			

Fig. 2.2 Completion Centers and their characteristics, letters D to M

Marshall Aerospace	VIP cabin modification Airliner interior modification	yes		England
MAV Aircraft Services	Interior modification	yes		US
McKinney Aerospace	VIP cabin modification	yes	Gulfstreams, Challengers,Falcons, Hawkers, Jetstars, Citations and Learjets	US
Mena Aircraft Interiors	Interior modification	yes	from Cessna 150 to Gulfstream II	US
Midcoast Aviation Inc.	VIP cabin modification	yes	Challenger, Embraer, Falcon, Global, Gulfstream, Hawker,	US
MJET	VIP cabin modification Airliner interior modification	yes	 Bombardier CRJ100/200	Canada
Mobarak Aircraft, LLC	Interior modification	yes	from a Cessna 150 to a Gulfstream GIII	US
Ozark Aircraft Systems	Interior modification	yes		US
Phazar Aerocorp Inc.	VIP cabin modification	yes		US
PrivateSky® Aviation Services, Inc.	VIP cabin modification	yes	Gulfstream GII, GIII, GIV, and GV	US
Ranger Aviation Enterprises, Inc.	VIP cabin modification	no	turboprops through midsize corporate aircraft.	US
Raytheon Aircraft Services - Little Rock	VIP cabin modification	yes	Raytheon aircrafts	US
Raytheon Aircraft Services - San Antonio	Interior modification		Raytheon	US
Raytheon Aircraft Services - Tampa	VIP cabin modification	yes	Raytheon aircrafts	US
Raytheon Aircraft Services - Wichita	VIP cabin modification		Raytheon	US
Savannah Air Center	VIP cabin modification	yes	Bombardier Challenger and Global Express aircraft, Gulfstream II's through Vs, Raytheon Hawker series, and Falcon 50 aircraft.	US
Sierra Industries Inc.	VIP cabin modification		Cessna Citation	US
Sky Harbour Aircraft	VIP cabin modification Airliner interior modification	yes	 	Canada
Stevens Aviation Inc. - Dayton	Interior modification	yes		US
Stevens Aviation Inc. - Greenville	Interior modification	yes		US
The Aircraft Completion Centre	VIP cabin modification			Australia
Trace Aircraft Completions	VIP cabin modification	yes		UK
	Airliner interior modification			
UAC	Freigher Conversion			
West Star Aviation, Inc.	VIP cabin modification	yes	Challenger, Citation, Conquest, Lear, Falcon and Hawker.	US
Western Aircraft, Inc.	Interior modification	yes	Beechcraft King	US

Fig. 2.3 Completion Centers and their characteristics, letters M to W

3 Characteristics of the Current Market

Three market segments are investigated in this report. On the one hand the **airlines** need periodically cabin interior upgrades. Then, older passenger aircraft become the perfect candidate for **freighter conversions**, while personal aircraft owners demand **VIP conversions**. A Completion Center is able to deal with all three aspects. However, in practice can be seen (chapter 2) that engineers specialize on a specific market segment.

This chapter is divided into 2 main parts: first the currently comfort standards and trends are investigated for all three categories mentioned earlier. Secondly the characteristics of a modification scenario for each category are identified, based on many existing examples.

3.1 Airline Cabins

3.1.1 Comfort Standards

The Domestic Economy Class
Domestic Economy Class is found on domestic flights. This type of cabin has the lowest comfort level and the lowest class of seating compared to other classes. There are slight variations in seat pitch and width among airlines and airplanes (**Seat 2009***)*. In addition, some airlines (like Cathay Pacific and Quantas) offer in-flight video services or laptop power ports that can make the flight more enjoyable. Low-cost carriers often offer only economy class. This type of airlines is often associated with short-pitch seats but also lower fares (**Ferreri 2003**). Figure 3.1 shows a typical Domestic Economy Class.

Domestic First and Business Classes
Domestic First and Business Classes are as well only found on domestic flights. There are only small improvements in comparison to most coach class seats and they do not usually offer leg-rests. Airlines have started offering these seats to customers that pay for full fare coach tickets as they try to increase their revenue from these seats (**Seat 2009**). There may be a curtain to separate business from economy class, on demand, but the seats are in the same cabin compartment. Some airlines (like Lufthansa and British Airways) use convertible seats allowing three passengers per bench in economy class, or two passengers with a half seat length between them for business class use (**Wikipedia 2009a**). Figures 3.2 and 3.3 show what to expect from a Domestic First Class.

Fig. 3.1 Domestic Economy Class on a Jazeera Airways A320-200 (**Airliners 2009a**)

Fig. 3.2 Domestic First Class on an Air Canada A320-200 (**Airliners 2009b**)

Fig. 3.3 Domestic First Class on Japan Airlines (**JAL 2007**)

The International Economy Class

The International Economy Class is found on international flights i.e. on long-haul routes. There are slight variations in seat pitch and width among airlines and airplanes. In addition, some airlines offer in-flight video services or laptop power ports that can make the flight more enjoyable (**Seat 2009**). Usually video screens, especially on older planes, are mounted on the ceiling of the aircraft or on a bulkhead so that all passengers in the cabin watch the same film. If there is an individual screen for each seat or partial row of seats, it may be smaller than first and business class screens, or there may be fewer video channels available to differentiate the classes (**Wikipedia 2009b**). Figure 3.4 and Figure 3.5 show a typical Economy Class.

Fig. 3.4 International Economy Class on a Finnair A330-300 (**Airliners 2009c**)

Fig. 3.5 International Economy Class on a Singapore Airline B777-200ER (**Airliners 2009e**)

The International Premium Economy Class

Premium Economy is a travel class offered on some airlines, taking one of two forms **(Wikipedia 2009c)**:

- a simple upgrade to the Economy class as a section of the economy/coach cabin, which generally provides more legroom by removing a few rows of seats, along with some form of leg rest, possibly enhanced In-flight entertainment and dedicated cabin crew.
- a more comprehensive upgrade, which will normally be in the form of a separate cabin section, combining the enhanced legroom of the simple upgrade with better seats.

Premium Economy is found mostly on international flights (**Seat 2009**). Figure 3.6 and Figure 3.7 show typical Premium Economy cabins.

Fig. 3.6 International Premium Economy Class on a Japan Airline B777 (**JAL 2007**)

Fig. 3.7 International Premium Economy Class on a BMI A330-200 (**Airliners 2009d**)

The International Business Class

Business Class is found mostly on international routes and planes that are configured for long-haul travel (**Seat 2009**). Its level of accommodation is higher than Domestic Economy, Domestic First and Premium Economy but lower than International First Class. However, many international airlines offer only Business Class as the highest level of service. In fact, they have installed "lie flat" seats into Business Class, whereas previously seats with such a recline capability were only available in International First Class. In Figure 3.8 an example is shown.

Fig. 3.8 International Business Class of Singapore Airlines (**Wikipedia 2009a**)

There are essentially three types of long-haul Business Class seats today. These are listed in the Table 3.1 in ascending order of perceived "quality".

Table 3.1 Seat Types in International Business Class (**Seat 2009**)

Seat Type	Drawing	Description
Recliner Seats or Cradle Seats		around 160 degrees of recline
Angled Lie-Flat Seats		recline 180 degrees to provide a flat sleeping surface
Flat Bed Seats		recline into a flat sleeping surface which is parallel to the floor

The International First Class

International First Class is only found on long-haul routes (**Seat 2009**). This class of service offers more comfort and amenities than International Business. There are not significant differences between airlines concerning IFE, service and amenities. However, the type of seat offered can vary significantly. Additionally to all seat types offered in International Business, another type of seats called Suites is available. It is an individual mini-cabin which includes a fully-flat bed, work station and television. Figures 3.9 and 3.10 show an example of an International First Class layout.

Fig. 3.9 International First Class of Swiss Air Lines (**Swiss 2009**)

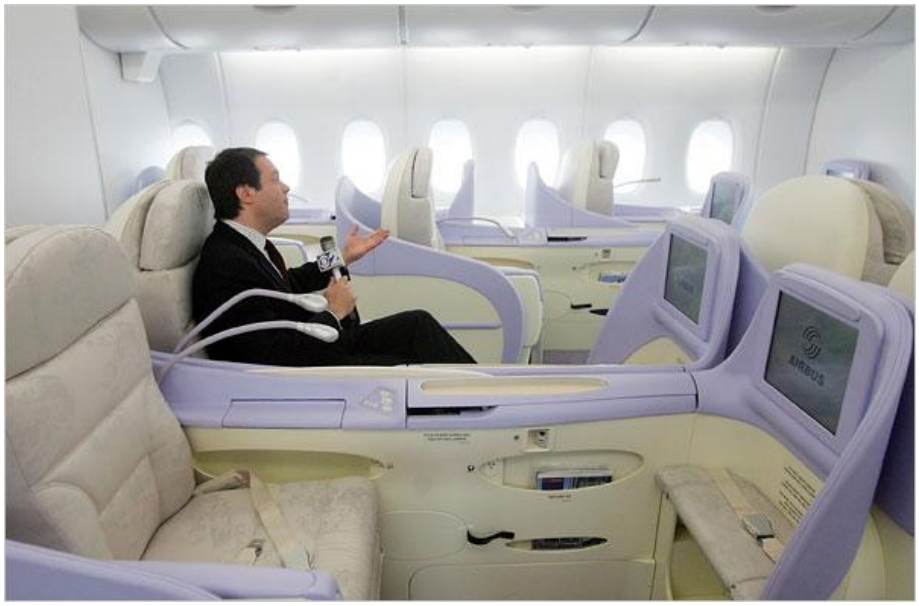


Fig. 3.10 International First Class on a A380 of Lufthansa (**Brothers 2009**)

Comfort Comparison between Classes

Table 3.2 summarizes the differences between all classes briefly discussed in the previous paragraph (**Seat 2009**). These are all the class levels which can be currently found on passenger aircrafts.

Table 3.2 The different comfort standards on passenger aircrafts

	Seat Pitch (inch)	Seat Width (inch)	Degree of recline	Electric Seat Controls	Leg-rest and Lumbar Support	Overhead or 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

3.1.2 Upgrade Scenarios

As showed in the last paragraph, in order to meet passenger requirements from different categories, airlines divide the available cabin interior space in classes. Each class classification can be associated with a **refurbishing scenario**. As the demand quickly changes, airlines need to reconfigure the seats layout and retrofit the cabin in order to remain competitive. In order to determine the modification possibilities, the strategy used here is to analyze as many real life examples as can be found.

Usually the term **upgrade** refers to those activities which bring the status of the interior layout of a cabin into a newer one, satisfying the current requirements of the operators. The renewal activities can affect:

- The cabin systems
    - IFE
    - CIDS
    - In Seat Power System
    - Passenger Oxigen
    - 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
- Other cabin interior items
    - Linings and furnishings
        - Passenger Supply Channel
        - Curtain partitions
        - Ancillary Equipment
    - Placards and Marking
        - Cabin emergency equipment
        - Floor covering

The Upgrade Services Department at Airbus has had a growing activity in the last years (**Williams 2009**):

- 50% growth in 2008
- 28% expected growth in 2009

This growth reflects the global current market status in the cabin upgrades sector (see Figure 3.11) (**Williams 2009**).

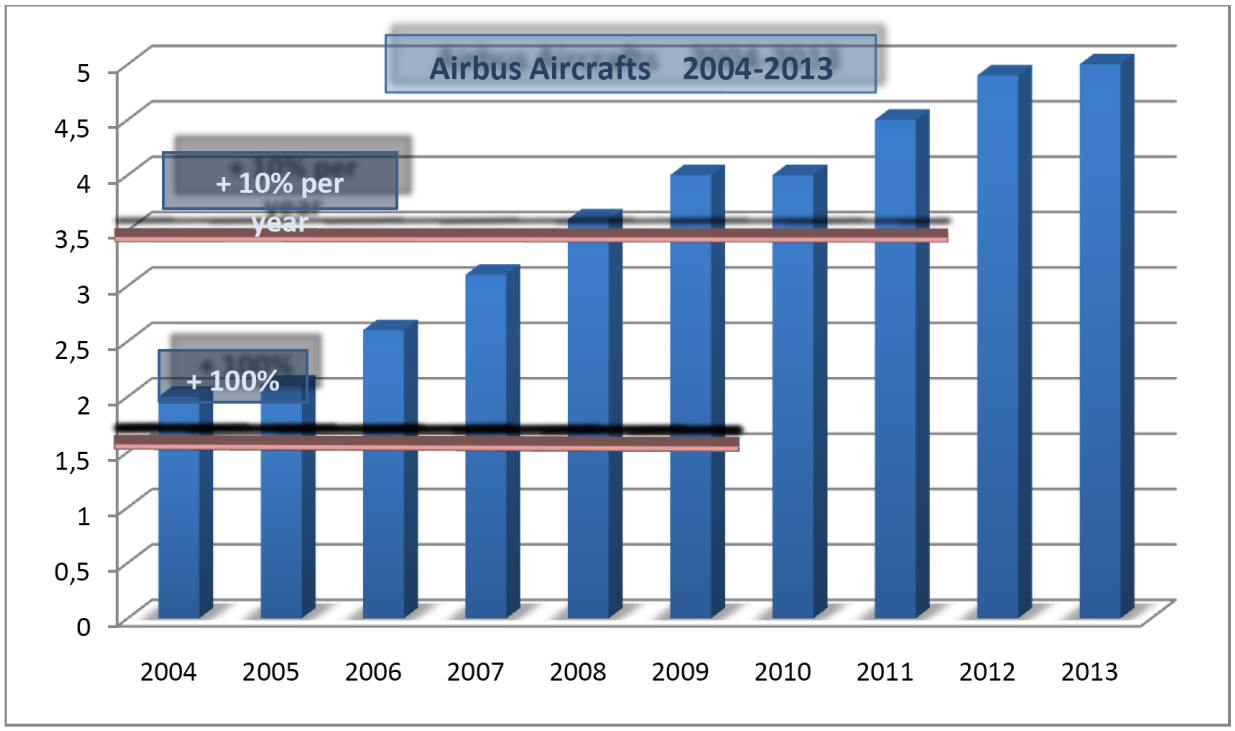


Fig. 3.11 Cabin Upgrade Engineering and Certification Market at Airbus for the Upgrade Services Department (**Williams 2009**)

Upgrading of International Cabins

The first modification scenario considered is the overall redesign and upgrade of international cabins. *International cabin* refers to:

- The International First and Business Class
- The International Premium Economy and Economy Class

Swiss Air has redesigned its *First Class* cabin in 2009 (**Swiss 2009**). It has completed the installation of new seats offering passengers additional privacy, space, and connectivity (23″ screen, fold out tables, full length bed, touch screen remote to control all seating and rest arrangements).

In 2004, *China Southern Airlines* has retrofitted its International First Class on B777s (**BNet 2004**). The carrier has undertaken:

- a reconfiguration of its *premium cabin*, by increasing the number of seats in the First Class cabin while removing some Business Class seats.
- the new First Class seats facility with more degree of recline (expanding from 60 inches to 70 inches)

United Airlines has undertaken a refurbishing process (that should be finished in 2009) of their *Business Class* cabin for the entire international fleet (**Woollard 2007**) including the installation of new seats (reclining to a 6-foot and 4-inch lie-flat bed, audio and video on-demand, and video screen).

Malaysia Airlines began in 2004 to overhaul its B777-200 fleet (**ATT 2004**). The upgrading includes:

- Cabin Reconfiguration from three to two classes (Business Class and Economy Class)
- 58-inch seat pitch with angled flat beds facility for the Business Class
- Installation of new IFE system for Economy Class

In 2009, *Finnair* renews for its brand new A330 the look of the cabin interior and its seats, the form of fittings, the colors, textiles and coverings as well as materials and lighting. The designer began preparing for the latest cabin facelift two years ago (**Finnair 2009**).

Japan Airlines has introduced in FY 2007 a *Premium Economy Class* on long-haul B777 (**JAL 2007**). In FY 2008, they introduced new seats in all international passenger classes (First, Business and Economy)

Figure 3.12 shows an example of an A340-300 cabin reconfiguration undertaken by *Cathay Pacific* (**Cathay 2009**). On the left side is the new version where First Class has been included.

Table 3.3 groups all examples found about the redesign of International Cabins (**PAL 2009, JAL 2007, Swiss 2008, Woollard 2007, ATT 2004, BNet 2004, Air France 2009, Swiss 2009, Dragonair 2003, Cathay 2007, Cathay 2009**).

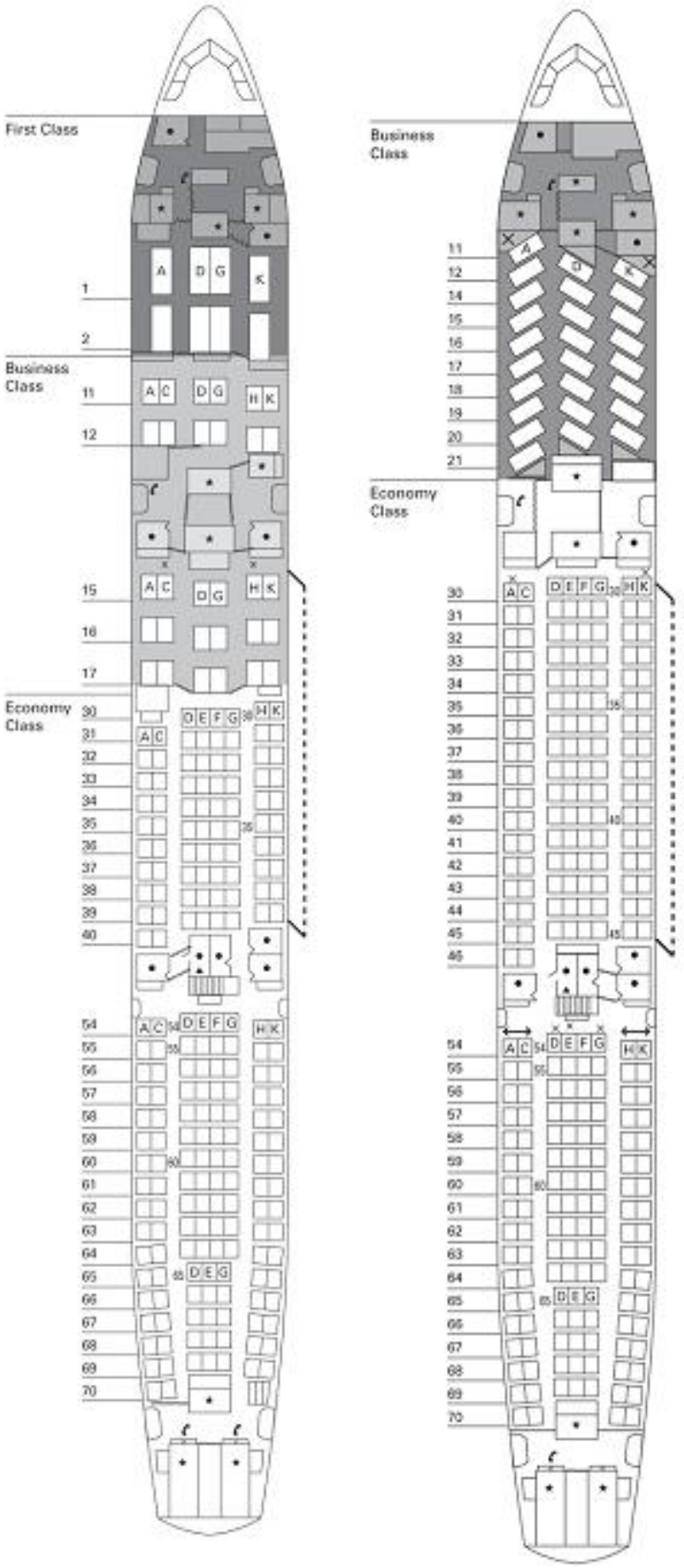


Fig. 3.12 A340-300 Cabin Reconfiguration Example from Cathay Pacific: before and after modification (**Cathay 2009**)

Table 3.3 International Cabin Upgrading: exemplary specifications

	Aircraft Type Affected	Entire fleet type Redesign	Premium Economy Introduction	Layout reconfiguration	New seats 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	Yes	No	Yes	Yes	No	No
Air France	B777 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

According to the Table 3.3, most of the refurbishings include:

- New distribution of classes due to:
    - Premium Economy Class apparition
    - First Class removal
    - Seats Removal to gain space
- New seats facility for First Class and Business Class
- New look of the cabin (new carpets, curtains, lighting, galleys, lavatories)
- IFE upgrading for Economy Class

The refurbishing of an aircraft type affects always the entire fleet as part of a **retrofit program**. If the retrofit is undertaken, the layout is reconfigured; First and Business Class are upgraded. If new Economy Class seats are needed, the upgrade is done in the same time.

Aircrafts affected by this type of modifications are usually configured for **long-haul flights**. These aircrafts are usually **wide-bodies**. Moreover, these aircrafts are not leased ones (see next paragraphs).

Airlines that undertake such cabin upgrades are **full service carriers** operating wide-bodies with premium service. Therefore they should be differentiated from LCC (Low Cost Carriers) or full service carrier operating in charter service. Indeed almost all LCC do not operate wide-bodies.

Table 3.4 summarizes the specifications of the Upgrading of International Cabins and the characteristics of the airlines and aircrafts affected by this modification.

Table 3.4 Upgrading of International Cabins: usual specifications

Type of modification	Description	Aircraft Type affected	Airline Type affected
Upgrading of International Cabins	New distribution of classes, new seats facility for premium cabins, IFE upgrading for Economy Class, New cabin look	Wide-body No aircraft on operating lease	Full service carrier without charter service

Upgrading of Domestic Cabins

The second modification scenario that should be considered is the overall redesign and upgrade of *domestic cabins*. This term includes:

- The Domestic Economy Class
- The Domestic Business or First Class

Business class has started to disappear from some short/medium haul routes, and to be replaced with full fare economy and discount economy (e.g. KLM and SAS). On these routes, the seats are the same for all passengers.

On shorter routes (typically less than one hour) many airlines have removed business class entirely (e.g. BMI on many routes) and offer only **one class of service**.

Most low-cost carriers (LCC), such as Ryanair in Europe and JetBlue in the United States, do not offer any premium classes of service (**Wikipedia 2009a**).

The program to re-equip all 52 aircraft of *Swiss*"s *European* fleet with new seats has been recently completed. As a result, passengers on all Swiss flights within Europe have greater legroom and seating comfort offered by the new seats. Since then, not only its entire short-haul Airbus fleet but also all the Avro RJ100s of its Swiss European Air Lines subsidiary have been equipped with the new seats. By having the seat pocket at the rear placed higher than on previous seating models, the new Recaro seats provide more legroom for the passenger seated behind (**Swiss 2008**). Figure 3.13 shows an example of seats refurbishing program for short-haul aircrafts.

Fig. 3.13 Seats refurbishing program for an A320 of Swiss Airlines. News seats are on the left figure (**Airliners 2009f, Airliners 2009g**).

In 2007, *Finnair* fitted its Airbus A320 aircrafts with new light structure seating which makes possible to add 15 seats to the normal configurations. The Recaro Slimline CL3510 seating model uses new technology with a light build and modern design, allowing more leg room even though the seats are closer together (**BNet 2007**).

In 2001, *Olympic Airways* undertook the fully refurbishing of 11 Boeing 737-200, 3 Airbus and 13 Boeing 737-400s. The refurbishing which affects the entire **short-haul fleet** consists of changing the colors and materials used on carpeting, wallpaper, the plastic and foam rubber on passenger seats, seatbelts, wall coverings and flight attendants seats. All entrance ways and other surfaces of the cabin have been upgraded. Part of the refurbishing program is the installation of new Business Class seats in the Boeing 737 -200, -300 and -400 aircraft family. Convertible leather seats which convert from a 3-3 layout to a more comfortable 2-3 layout and 35 inches of seat pitch give increased personal space. A spacious drinks table separates two seats from each other. The seats also have footrests, adjustable headrests and backs that recline at a greater angle than before (**Chris 2000**).

Cronus Airlines refurbished the cabins of its 6 aircrafts (B737-300 and B737-400) in 2001. All cabins have comfortable leather seats with leg room with new configuration for the Business Class from 3-3 to 2-3 seats abreast (**Chris 2000**).

Delta Airlines undertook in 2004 a refurbishing for the MD 90 and MD 88 fleet which includes all-new leather seating, both in first class and coach, new wall coverings, and updated lavatories (**Flights 2006**).

Table 3.5 summarizes the characteristics of all the examples found about the upgrading of Domestic Cabins (**Swiss 2008, BNet 2007, Wikipedia 2009a, ATT 2005, Chris 2000, Flights 2006**).

Table 3.5 Domestic Cabin Redesign: exemplary specifications

Airlines	Aircraft Type affected	Entire fleet type Redesign	Cabin surfaces upgrade	Seats reconfigu-ration	New seats 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 3.6 summarizes the specifications of the Upgrading of Domestic Cabins scenarios and the characteristics of the airlines and aircrafts involved in this process.

Table 3.6 Overall Redesign of Domestic Cabins: usual specifications

Type of modification	Description	Aircraft Type affected	Airline affected
Overall redesing of Domestic Cabins	New distribution of classes, new seats facility for all classes, New cabin look	Narrow-body No aircraft on operating lease	All carriers

Upgrading of Aircrafts on Operating Lease

A special category of aircrafts is represented by leased aircrafts. The aircraft lease is for airlines an alternative solution to the purchase of new aircrafts (**Aeroconseil 2009**). It seems this is the best way for these operators to adapt their fleet to the air traffic and passenger demand. As a result, more and more aircrafts are transferred from an airline to another during their useful life.

Once these aircrafts are operated by a new airline, they need to meet the operator‟s **policy and requirements**. The airline needs therefore to modify the cabin interior according to its criteria. The aircraft is sent for what is called Post Delivery Modification (PDM) and is refurbished so as to fully conform to the equipment and location specification of the airline standards (**SAS 1998**).

This operation usually includes:

- New seats facility
- New classes distribution
- New seat pitch

For instance, a former Swissair DC-9-80 was leased in 1998 by SAS. The work required along, included the cabin refurbishing to SAS standards (**SAS 1998**).

Table 3.7 summarizes the specifications of the cabin upgrade scenarios for aircrafts on operating lease and the characteristics of the airlines and aircrafts involved in this modification.

Table 3.7 Cabin Conversion for aircrafts on operating lease: usual specifications

Type of modification	Description	Aircraft Type affected	Airline affected
Cabin refurbishing for aircrafts on operating lease	Same operations as for international or domestic cabins	aircrafts on operating lease	All carriers

3.2 Freighter Cabins

3.2.1 Requirements

A very important market segment is represented by the pax-to-freighter convertible aircrafts. The aged pax aircrafts can be further used as freighters by companies like DHL, Fed-Ex or UPS, once they are converted. Figure 3.14 shows the **world wide distribution** of the passenger aircrafts fulfilling the requirements to be transformed into freighters. Figure 3.15 gives the **age** and shows the **number** of some of the most used aircraft models, which represent the row material in this market segment (**Williams 2009**).

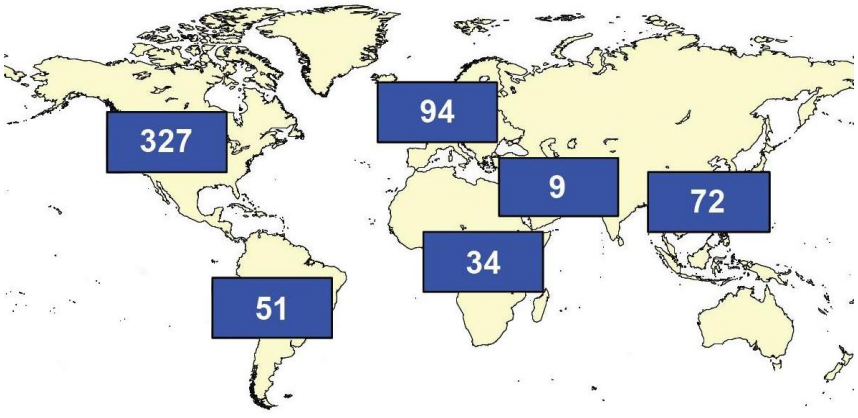
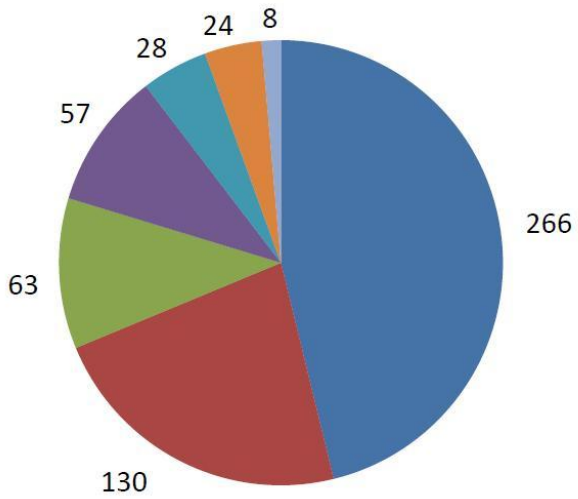


Fig. 3.14 The aircraft replacement market (pax-to-freighter) in number of units (**Williams 2009**)



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

Fig. 3.15 Number and age of some aircraft models, convertible from pax-to-freighter configuration (**Williams 2009**)

Freighter aircrafts normally have **strengthened cabin floors** and a **broad top-hinged door** on the port fuselage in addition to the absence of passenger cabin windows, which are "plugged".

When a passenger aircraft is to be converted into freighter, the following parts of the aircraft suffer modifications, as part of the conversion program (**Williams 2009**):

- The floor structure (reinforced)
- The main deck cargo compartment
- The main deck cargo door
- Manual main deck cargo loading system
- Barrier wall between courier area and cargo compartment
- Courier area seating layout (usually 2 seats)

Figure 3.16 gives an example of a Freighter cabin.

Fig. 3.16 Freighter Cabin of an A300 (**EADS 2009**)

3.2.2 Conversion Scenario

The conversion of an airliner cabin (in PAX configuration) into a freighter cabin is done by Modification Centers, or Completion Centers. Such organizations utilize **aircrafts which have completed their useful lives as passenger jetliners** and transform them to freighter configuration.

As an example, the freighter conversion completed by *EFW* is investigated. After removal of all structural and system components that are no longer needed, such as seats or floor structures, the new freighter kits are installed (**EADS 2009**):

- A cargo door and the related structural parts are installed;
- The cabin floor designed for passengers is replaced by a new floor structure with higher strength;
- Ball mats and roller tracks for loading of containers complete the conversion of the floor structure;
- Necessary adjustments and completions of the aircraft systems are carried out.

Finally, system tests are performed. After the customer inspection and acceptance flight, the conversion work is documented and the aircraft handed over to the customer.

Figure 3.17 shows the completion of such a conversion with new floor structure installation (**EADS 2009**).

Fig. 3.17 Freighter Conversion of an A300 (**EADS 2009**)

For the freighter conversion completed by *Boeing*, the B747 will be modified with a side cargo door and layout that is identical to the 747-400 production freighter, with 30 pallets on the main deck and comparable volume. The longer upper deck of the Special Freighter will include

seating for up to 19 people, an option found on no other converted freighter. The conversion includes a strengthened main-deck floor, full main-deck lining, provisions for a new cargo handling system and revised flight-deck systems (**Boeing 2003**).

The process of freighter conversion usually includes incorporating a large wide cargo door in the fuselage, installing a new reinforced main deck floor, and integrating cargo loading systems.

Not each type of aircrafts would be used as freighter. Over the next decade, ACMG predicts that 737-300s/-400s and 757-200s will be the most popular **narrow-body models** for freighter application (**Dahl 2003**). In the **medium wide-body** category, the A300-600s and 767-200s are the major candidates. In the large capacity segment the preferred aircrafts are 747-400s and MD-11s. Only the A300-600F, 747-400F, 777F, A320P2F and A321P2F are available as new-built production freighters, which means the majority of the additional freighters will be passenger-to-freighter conversions.

Table 3.8 summarizes the specifications of the Freighter Conversions, the characteristics of the airlines and aircrafts affected by this conversion scenario.

Table 3.8 Freighter Conversion: usual specifications

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

3.3 VIP Cabins

3.3.1 Comfort Standards

The cabin interior plays an increasingly important role for business jet operators and private individuals. The range of cabin options available to these operators is **limited only by what can be certified**. Therefore, in the VIP retrofitting business one has the flexibility to ask the Completion Center to provide the highest comfort standards, such as: taking a warm shower, relaxing on a corner couch, sleeping on a queen-size mattress or enjoying a Ralph Lauren or Versace-themed interior. Over the years, customers have asked for a lot of different things ranging from waterbeds, hot tubs, stationary bikes, bean bag chairs, chandelier to unique materials, whether it be cork flooring or a granite or marble floor in the entry area, to custom

artwork that they wanted to display or stingray skins on the lower sidewalls (**Parker 2008**). Some examples are shown in Figures 3.18 and 3.19.

Fig. 3.18 Lufthansa Technik includes a conference dining room in its concept of the A380 main deck (**Parker 2008**).

Fig. 3.19 On the same A380, the upper deck includes a separate office area in the forward cabin (**Parker 2008**).

The interior of the modern business aircrafts has evolved, incorporating cabin management systems, wireless Internet and PDA connections, stain-proof seat fabrics and modern design elements. People now outfit the aircraft much like they outfit their home. The cabin represents for them the place to relax, while going from point A to point B and the aircraft is treated as a house or a mobile office (**Parker 2008**).

3.3.2 Design/Redesign Scenarios

VIP High-End Completion
The term Completion Center (CC) is rather known for VIP conversion activities. When a VIP owner buys a new „green" aircraft he sends it to a Completion Center having the resources to fulfill its requirements. The CC **takes responsibility over the design and certification** of the interior furnishing of the aircraft. This type of work is called Hi-End Completion.

The biggest **challenges** assumed when completing a custom interior are the *certification*, the engineering and design and the timelines, which need to be respected. The initial conceptual design phase has a high importance and needs a lot of energy and effort in parallel with efficient communication with the customer, in order to exactly determine and understand its requirements (**Parker 2008**).

Specialized cabins that involve one or more elements which have never been certified before can add time to a completion project. Therefore, especially in such cases, it is important to establish **realistic timelines** together with the customer, to set milestones and keep **communication** open throughout the process. Additional **weight** is always a major issue, as well as **fastening** the unusual objects required by the customers (**Parker 2008**).

VIP Cabin Refurbishing
This scenario refers to aircrafts which receive a new outfit while removing an old one and is valid especially for business jets. For several reasons, executive jet owners need to refurbish the aircraft interior during its useful life.

Aircraft private owners often use corporate jets to impress new clients or strengthen the long-awaited business deals. An aircraft interior can reflect, in this case, a positive or negative **image** about its owners and/or corporation. Therefore, the need to refurbish the business jets interiors becomes a major issue (**Kraft 2009**).

In the corporate/private/charter market, extra pounds don't mean as much in the cabin as they do for the airframe. The owners of these aircrafts do not want to reduce weight for comfort only to save a few dollars by conserving fuel. They aim to maximize the comfort and functionality of the flying office/hotel room where they spend the time to get from Point A to Point B (**Moody 2008**).

Rather than gutting an aircraft to install all-new structures, the desire to make these structures look less dated and more suited to one's personal tastes underlines most of the projects. These projects, called **'refresh' projects**, usually involve stripping and replacing (**Moody 2008**):

- cabinetry veneers
- soft coverings of the seats
- carpets

- the lighting

Sometimes these refresh projects involve exotic materials, such as inlaying cabin surfaces with rare, imported hardwoods from Asia and Africa. This trend is now identified by several manufacturers and equipment providers for completion centers and leads to big challenges (**Moody 2008**):

- The use of exotic materials that never have been installed in the aircraft environment has to pass flammability and certification tests.
- Getting into bigger changes in the cabin, such as reconfiguring seating or moving lavatories and galleys around, involves meeting recertification requirements.

PAX to VIP Conversion

Some VIPs buy a former Jetliner to use it as an executive aircraft. Therefore they need to convert the cabin according to their taste.

As an example of conversion from PAX to VIP configuration, *328 Support Services* has signed a contract for the conversion of two VIP Dornier 328s with a private individual. This aircraft, a former 31-seat airliner-configured 328 Jet, will be modified into a 10-seat VIP aircraft. Special interiors features will include new sidewalls with electric window blinds, a noise reduction kit, a Sat phone system, IFE system with eight individual TV monitors and soft leather seats. 328 Support Services will also carry out a series of heavy maintenance checks and other modifications prior to delivery (**BJII 2009**).

VIP Cabin Design/Redesign Summary

Table 3.9 summarizes the specifications of the VIP Cabin Modification and the characteristics of the airlines and aircrafts involved in this process.

Table 3.9 VIP Cabin Modification: usual specifications

Type of modification	Description	Aircraft Type affected	Type of owner
VIP Cabin Modification: VIP High-End Completion VIP Cabin Refurbishing PAX to VIP conversion	Stripping and replacing: Cabinetry veneers Seats soft coverings Carpets Lighting Installation of specific equipment	All Executive aircrafts: Business Jets Business Turboprops Corporate versions of Airliners	VIP owner State Government Business Airlines

4 Driving Factors in Cabin Redesign and Refurbishing

Knowing why and when the refurbishing of an aircraft cabin occurs represents a **key factor** for the organization wanting to perform these activities. It is therefore necessary to further investigate the driving factors for each scenario identified so far. The frequency and duration are as well key parameters for making a forecast.

Usually a cabin modification **occurs when a Check-D is scheduled**, as shown in the Figure 4.1. The Check-D requires the aircraft to be parked for a while. The operator can take this advantage to complete a cabin modification, as well. According to **Arzenheimer 2009**, airlines can even schedule a cabin retrofit for the check C. Airlines minimize, therefore, the expenses if they carry out a cabin upgrade between two checks.

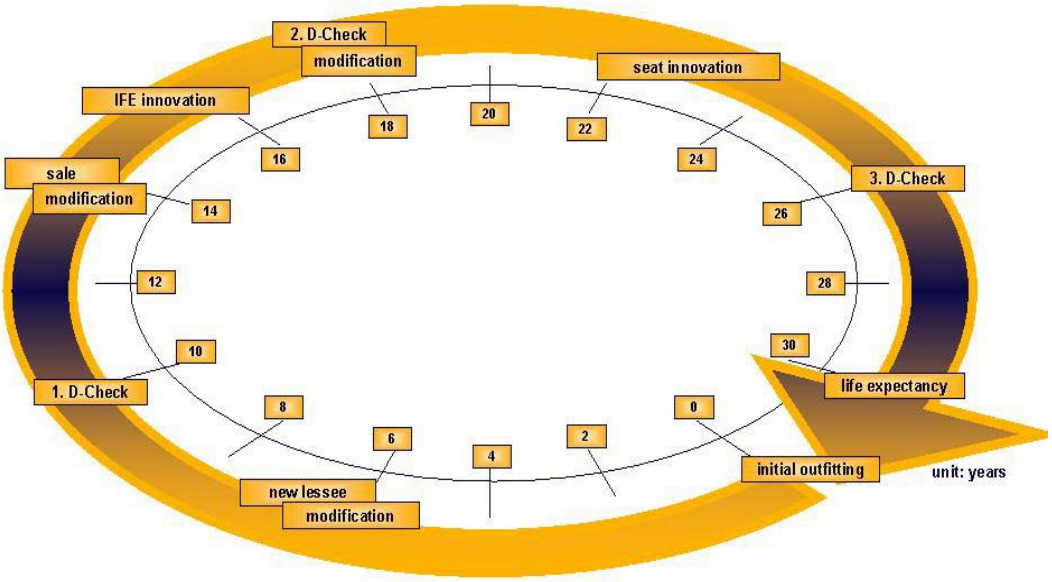


Fig. 4.1 Exemplary life cycle of an aircraft (**Lufthansa 2009**)

This observation is verified by some examples.

First Air Pacific"s Boeing 747-400 refurbishing was part of a planned maintenance program in Singapore in October and November 2008. *Air Pacific*"s second Boeing 747-400 aircraft received the same extensive refurbishing during scheduled maintenance in February and March 2009 (**Air Pacific 2008**).

Currently, *Pakistan International Airlines* has launched a cabin refurbishing program for the entire fleet wherein all the aircrafts coming in for scheduled maintenance, will go out after a cabin upgrade is performed. So far one Boeing 737, two Airbus A310 and one Fokker F-27 have suffered the changes caused by the refurbishing program. In addition one Airbus A-300B4, one Airbus A310 and one Fokker F27 are also undergoing the cabin refurbishing (**Bashar 2000**).

On average, a **C-check on a narrow-bodied aircraft is carried out every 4,000 flying hours** or every 20 months, whichever comes first. The duration is between five and eight days, meaning 2,500-3,500 man hours (**Mcdonald 2007**).

A **D-check on a wide-bodied aircraft** means a complete strip-down and refurbishing of the aircraft. This is the heaviest check for the airplane, also known as a *Heavy Maintenance Visit* (HMV). This check occurs approximately **every 4-5 years**. This takes an average ground time of 30 days and between 28,000-40,000 man hours depending on the condition of the aircraft and additional work requested by the customer (**Mcdonald 2007**).

4.1 Airline Cabins

4.1.1 Driving Factors for Airline Cabin Upgrades

International Cabins
In order to remain competitive, an airline needs to periodically refurbish its fleet. An alliance partner or another competitor may have a better product and may be better in creating an image for its passengers. Passengers expect comfort, service and entertainment, especially for long distances. Cabin equipment together with service and speed are the decisive factors in forming **passenger perception** of the airline's efficiency. Therefore interiors are becoming an increasingly important element for differentiating between airlines (**Lufthansa 2009**).

In **Flouris 2008**, industry experts explain that carriers now pay more attention to their cabin layout, design and IFE rather than the level of their aircraft competitivity. The aviation sector has become one of the hardest hit by the current global economy crisis:

- According to the *International Air Transport Association*"s statistics released in March 2009, passengers and cargo traffics continue to drop, standing at 10.1% and 23.2 % respectively.
- Middle East carriers, apparently with more cash, received support from their state governments.
- The meltdown has led to the preservation of cash among airlines and it is now forcing them to postpone major expenditures such as jet orders and deliveries.

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 to win passengers.

On the background of the economical crisis, an attempt to attract passengers was made by creating a **new class** called *Premium Economy*: a higher standards economy class. This requires the reconfiguration of the seats distribution. If a full-service airline has a good reputation for flying premium class passengers, it is not difficult to attract economy class passengers, assuming the fares are structured in a competitive way. Moreover, many business travelers do not have

permission from their employers to fly in traditional premium cabins. Providing an upgraded economy product, for high-mileage passengers or those willing to pay a few hundred dollars more, represents a key strategy at the moment for the airlines to build and retain a base of loyal customers (**Arnoult 2007**).

In the last decade, some airlines began eliminating first class, though they have kept the amenities that made their highest-paying passengers feel comfortable. Once they improved business class - with bigger seats that opened into fully flat beds, menus designed by celebrity chefs, individual entertainment systems and airport lounges, it became more difficult for travelers to justify the additional exorbitant price of first class. The recent rise of all-business-class airlines has added pressure, as well, on first class. With corporate business travelers demanding the most comfortable ride possible but not willing to pay the price, **the demand for first class shrunk** (**Garfinkel 2008**).

However, for airlines, at a time of immense financial pressure, the strategy of using bonus points to upgrade to first class may make the difference between a passenger taking one airline or another. Bonus programs, and upgrades into first class, play an important role in keeping first class. Also, it makes sense for an airline to allow a high fare-paying passenger into the first class as this creates the space to meet the extra demand for other classes. This represents a marketing tool in a recession period, and in the best of times it‟s a genuine yield tool. Moreover, in some circles, flying first class remains the status symbol of a person's success in business (**Brothers 2009**). Table 4.1 summarizes the driving factors of the demand for the upgrade of international cabins.

Table 4.1 Upgrade of International Cabins: driving factors

Type of demand	Factors
Upgrade of International Cabins	Tool for differentiation between airlines Aircrafts orders and deliveries are postponed
Premium Economy apparition	To enhance airline reputation among travelers in Standard Economy 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

While most carriers view upgrades as a way to attract or ensure loyalty from passengers willing to pay premium fares (on long-haul flights), others also see the importance of tending to customers in the back of the bus on short-haul flights. If the short-haul services do not provide the expected quality, the long-haul traveler would not choose the same airline (**Arnoult 2007**).

Swiss Air has chosen lightweight construction seats which substantially lower the aircraft weight, permitting the corresponding reductions in fuel burn (**Swiss 2008**). *Delta*'s cabin refurbishing program enabled, as well, the installation of lighter seats and the removal of coach-class ovens and airphones for reducing weight onboard the MD-88 and MD-90 aircrafts (**Orbit 2005**).

With new light structure seating, *Finnair* makes it possible to add as many as 15 seats to their configurations. As a result of this extra seating, Finnair's capacity on European and domestic routes increased by 5% (**BNet 2007**).

Table 4.2 summarizes the driving factors of the demand for upgrading of domestic cabins.

Table 4.2 Upgrade of Domestic Cabins: driving factors

Type of demand	Factors
New business seats facility	Short-haul flights drive the reputation of the airline among long-haul business travelers
New seats facility	Reduction of fuel burn Extra seating capacity

Aircrafts on Operating Lease

Airlines interested in aircrafts on operating lease, speculate the following benefits (**GECAS 2009**):

- 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
- and newer aircraft models with no need for pre-delivery payments or significant down payments with the manufacturers

Operating leases are generally short-term solutions, attractive when aircrafts are **needed for a start-up venture, or for the expansion tentative of an established carrier**. The short duration of an operating lease also protects airlines against obsolescence of their aircrafts, which is an

important consideration in many countries due to changing noise and environmental laws. In some countries where airlines may be deemed less creditworthy (e.g. the former Soviet Union countries) operating leases may be the only way for an airline to acquire aircrafts.

Table 4.3 summarizes the driving factors of the demand for cabin upgrades for aircrafts on operating lease.

Table 4.3 Cabin Conversion for Aircraft on Operation Lease: driving factors

Type of demand	Factors
Aircraft lease	Lower cash outlays
	Protects against aircraft obsolescence
	Fleet flexibility (change of capacity, new routes introduction, changing laws)

4.1.2 Frequency and Duration of the Upgrade Scenarios for Airline Cabins

International Cabins
Redesign and refurbishing activities **occur in cycles**. Full service carriers do not wait until the international cabins become worn out. A fleet refurbishing program is initiated periodically in order to keep up with the challenges of the market. Based on the number of announcements over the past months (October 2006 - April 2007), the conclusion arises that **a new cycle is underway**.

Certain numbers of airlines in the top 20 carriers (such as British Airways, Emirates, Air France, Qantas, Continental Airlines, United Airlines, Japan Airlines and Korean Air) are always programming their fleet renewal even in times of an economical downturn (**Arnoult 2007**).

Table 4.4 groups all the examples found on cabin upgrades cycles (**Woollard 2007, Arnoult 2007, Flouris 2008, El Segundo 2009, Kirby 2006, Swiss 2008, ATT 2004, British Airways 2009a, Air Canada 2004, Finnair 2009, British Airways 2009b**). This data should be considered with attention.

The column „Begin of retrofit program“ contains the date of the retrofit program announcement. Where possible, the date of the first aircraft refurbishing of the program was entered. However these two dates seem to be close compared with the total retrofit program duration.

The column „End of retrofit program" contains the date of the completion of the last aircraft affected by the retrofit program. The column „Date of last retrofit program" contains the date of the last program initiation.

Table 4.4 International Cabin Redesign: average frequency and duration

	Aircraft Type affected	Number of aircrafts	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	-	No refurbish-ing in 2007	-	-	-	2000	-
Air Canada	-	20	2004-10	2007-02	29	44	1994	(120)
Cathay Pacific	A340, A330, B777-300, B747-400	42	2006-09	2009-04	32	23	2001	57-69
Singapore Airlines	-	-	-	-	-	-	2002 (new delivery)	46-58
	B777-300ER	18	2006-10	2009	27	43		-
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

According the Table 4.4, **the cabin redesign program of one wide-body type is undertaken each 65 months in average.** This is the frequency of international cabin makeovers cycle. In

Searles 2008, it was also estimated that business class upgrade happen typically in a 5-7 year cycle.

The refurbishing of one *Air Pacific*"s Boeing 747-400 lasted 2 months (**Air Pacific 2008**) and the retrofit of one *Philippines Airlines*" B747-400 lasted 3 months (**PAL 2009**). It can be assumed that the refurbishing for *one* wide-body aircraft usually last *3 months*.

The refurbishing program lasts around 31 months but this duration depends of the number of aircrafts that are refurbished at the same time. That is why the **equivalent duration of one aircraft refurbishing**, which **amounts up to 31 days**, should be considered. This describes the duration of one refurbishing as if aircrafts were completed one after the other. Of course, this is not the case because completion centers have usually more than one production line. However the equivalent duration of one aircraft refurbishing will give the duration of a redesign program, no matter how many aircrafts are retrofitted.

Table 4.5 summarizes the average frequency and the average duration of the Upgrade of International Cabins. These parameters will be used to make the cabin redesign and refurbishing forecast.

Table 4.5 Upgrade of International Cabins: average frequency and duration

Type of modification	Frequency of cabin redesign program	Duration of one aircraft refurbishing	Equivalent duration of one aircraft refurbishing
Upgrade of International Cabins	65 months	3 months	31 days

Domestic Cabins

Table 4.6 groups all the examples found about domestic cabin refurbishing cycles (**Chris 2000, Swiss 2008, FFL 2008, ATT 2005, Flights 2006**).

The column „Begin of retrofit program" contains the date of the retrofit program announcement. When available, the date of the first aircraft refurbishment of the program was entered.

The column „End of retrofit program" contains the date of the completion of the last aircraft affected by the retrofit program.

The column „Date of last retrofit program" contains the date of the last program begin.

Table 4.6 Domestic Cabin Redesign: average frequency and duration

Airline	Aircraft Type affected	Number of aircrafts	Begin of retrofit program	End of retrofit program	Retrofit duration (months)	Equivalent duration for one aircraft retrofit (days)	Date of Last Retrofit program	Retrofit Frequency
Olympic Airways	B737-400	13	2000-09	2001-03	7	16	-	-
Cronus Airlines	B737-300, B737-400	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	-	-

No example has been found on the frequency of domestic cabin upgrade cycle. However, it can be assumed that **domestic cabins retrofits happen less frequently** than international cabin retrofits. This frequency is estimated to an amount of **84 months** (7 years).

The retrofit of an *Air Canada* A320 was completed in 16 days time (**Achorizons 2008**). It can be assumed that **the refurbishment for one narrow-body aircraft usually last 15 days**.

The refurbishing program last around 16 months but this duration depends of the number of aircrafts that are refurbished at the same time. That is why the equivalent duration of one aircraft refurbishment, which amounts up to 15 days, should be considered. This describes the duration of one refurbishment as if aircrafts were completed one after the other. Of course, this is not the case due to the fact that completion centers usually have more than one production line. However the equivalent duration of one aircraft refurbishing will give the duration of a redesign program, no matter of how many aircrafts are retrofitted.

Table 4.7 summarizes the average frequency and the average duration of the Upgrade of Domestic Cabins which will be taken into account for making the forecast.

Table 4.7 Overall Redesign of Domestic Cabins: average frequency and duration

Type of modification	Frequency of cabin redesign program	Duration of one aircraft refurbishment	Equivalent duration of one aircraft refurbishment
Overall redesing Of Domestic Cabins	84 months	15 days	15 days

Aircrafts on Operating Lease

The duration of operating leases are generally less than 10 years (**Wikipedia 2009d**). However, each transaction has individually tailored lease terms. According to **GECAS 2009** operating leases typically range 3-12 years in length. It is here an **average lease duration of 7 years** (*84 months*) considered.

Regarding the frequency of an overall cabin redesign planned by an airline for an owned aircraft, the investigation shows that the cabin upgrades occurs only **when the aircraft is transferred from an airline to another**. Moreover, this type of airlines usually chooses the aircraft leasing in order to operate a young fleet and therefore they don"t have to refurbish the interiors.

Table 4.8 summarizes the average frequency and the average duration of the Upgrade for Aircrafts on Operating lease (**Wikipedia 2009d, GECAS 2009**).

Table 4.8 Cabin Conversion for Aircraft on Operation Lease: Frequency and Duration

Type of modification	Frequency of cabin conversion	Equivalent duration of the aircraft conversion
Cabin conversion for aircrafts on operating lease	84 months	15 or 31 days

It is assumed that the conversion program has the same duration as a complete cabin redesign. Indeed, the tasks are quite the same. Therefore, an **equivalent duration of 15 days for Narrow-bodies and 31 days for Wide-bodies** will be considered. The Equivalent Duration describes the duration of one refurbishment as if aircrafts were completed one after the other. Of course, this is not the case due to the fact that Completion Centers have usually more than one production line. However the equivalent duration of one aircraft refurbishing will give the duration of a redesign program no matter of how many aircrafts are retrofitted.

Aircraft Age Limits for a Cabin Refurbishing of an Airplane Owned by an Airline

The airlines undertake cabin completions on new aircrafts, just after their delivery (green aircraft). For instance, Air France will install its new cabin design on all new ordered aircrafts, including the forthcoming A380 (**Caswell 2008**).

Then, the airline proceeds to regular cabin refurbishing until the aircraft age makes it no longer suitable for passenger use (**Feir 2001**). This **age ranges from 15 to 25 years** (**Feir 2001**, **Norkus 2006**, **Deveau 2009**). For instance, in 2008 Air France didn"t plan to retrofit its B747 fleet with an average age of 17 years as it is due to be phase out at the average age of 21 years (**Caswell 2008**).

Table 4.9 summarizes the average lower and upper aircraft age limits for which a cabin refurbishing is no longer planned.

Table 4.9 Upgrade of International Cabins: average age limits for a refurbishing

Type of modification	Lower age limit	Upper age limit
Overall redesing Of International Cabins	0 year	20 years

4.2 Freighter Cabins

4.2.1 Driving Factors for Freighter Cabin Conversions

Most conversions are carried out on **older aircrafts** no longer suitable for passenger use, often due to changing of safety or noise requirements, or when the aircraft type is considered to have become uncompetitive in passenger airline service (**Wikipedia 2009e**).

The conversion of passenger aircrafts into freighters offers an **economic alternative** to the purchase of new freighter aircrafts. The pax- to-freighter conversions combine the advantages of a **low empty weight** with the resulting **possibility to increase the useful load** (**EADS 2009**).

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 (**Dahl 2003**).

Table 4.10 Freighter conversion: driving factors

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

The economical efficiency of such conversions is obtained through **the use of wide-body aircrafts** (having a large fuselage cross-section). Such aircrafts 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 (**EADS 2009**).

Table 4.10 summarizes the driving factors of the demand for freighter conversions.

4.2.2 Frequency and Duration of the Conversion Scenarios for Freighter Cabins

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, aircrafts would not receive any more upgrades for passenger service due to their marketability. These aircrafts become perfect candidates for freighter conversion (**Feir 2001**). 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 (**EADS 2009**).

Table 4.11 summarizes the occurrence and duration of the demand for freighter conversions.

Table 4.11 Pax-to-Freighter conversion: occurrence and duration

Type of modification	Occurrence of the conversion	Duration of one conversion
Pax-to-Freighter conversion	Aircraft average age : 20 years	4 months

4.3 VIP Cabins

4.3.1 Driving Factors for VIP Cabin Design/Redesign

A number of factors persuade business jet owners or operators to refresh the interior of their aircrafts. Typically, the reasons why changes to these aircraft interiors are initiated, are rather aesthetical than due to the fact that the cabin becomes worn out (**Moody 2008**).

The need to refresh the cabin structures and surfaces is growing especially among the **fractional owned aircrafts**, where:

- More traffic from extra people means additional wear.
- Airplanes are more likely to see some wear and tear on the interior, as there are 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 (**Moody 2008**).

The demand for **high-end completions** has grown, as well, at a rate of 25 to 30 percent in the last 10 years (**Searles 2008**):

- The unprecedented growth is due to the high demand for large business and VIP aircrafts;
- New airplanes and technologies are also expanding additional demand for large-cabin airplanes;
- The arrival of these new types of VIP aircrafts will create a secondary market for the ones that operators will trade in when they receive the delivery of their new jets. If those earlier BBJs, ACJs and other VIP transports change hands, they are likely to be repainted and have their cabins refurbished;
- This demand has been driven to a large extent by the demand from emerging markets such as Middle East representatives: India, China and many of the former Soviet republics.

However, in the context of the market instability experienced this year (2009), the *Boeing Business Jets* and *Airbus Corporate Jets* have suffered **cancellations** for many of their orders. According to **Ostrower 2009** 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 the same time, the Airbus Corporate Jets has received two orders for two A340-500 Prestige for the third quarter of 2009.

Still, even in this context of an instable market, depending on high-net-worth individuals, performance improvements continue to be initiated in the production line of business jets and VIP. The tendency is rather to conduct a **performance improvement policy** instead of investing large amounts of money into new products. In **Ostrower 2009** examples can be found:

- Airbus has increased the A320 ACJ family"s MTOW by 1t by enabling a new load alleviation function that requires no structural changes to the aircraft.
- Boeing succeeded to bring a 2% improvement in fuel burn through engine improvement for the 737 fleet
- Weight savings of 320kg for BBJ by using carbon brakes already used for the 737
- Boeing has also announced that BBJ C was made convertible from an all-passenger to all-cargo missions in less than 8 hours

Table 4.12 summarizes the driving factors for the demand for VIP cabin design/redesign.

Table 4.12 VIP Cabin Modification: driving factors

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

4.3.2 Frequency and Duration of the Design/Redesign Scenarios for VIP Cabins

For determining the frequency and duration of a VIP completion several real life examples are analyzed.

PATS Aircraft Completions undertook the completion of a green Embraer Lineage 1000 in 9 months (**Searles 2008**).

On average, *Lufthansa Technik* (LT) completes a VIP BBJ in around five months, but with specialized cabin elements involved, it can take up to eight or nine months. The Completion Center of LT conducts a **requirement capturing or fact finding 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 (**Searles 2008**).

328 Support Services will complete the conversion of two VIP Dornier 328s in 6 months time for each aircraft (**BJII 2009**).

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 (**ATI 2009**).

The frequency, at which the interiors are refreshed during the aircraft useful life, couldn"t be determined precisely. It is estimated that the time between two VIP modifications amounts to approximately **100 months**.

Usually, the refurbishing of the aircraft interiors occurs when the aircraft is purchased by a new owner (**Moody 2008**).

Table 4.13 summarizes the average frequency and the average duration of the Cabin Conversion for Executive Aircrafts.

Table 4.13 VIP Cabin Modification: Frequency and Duration

Type of modification	Frequency of cabin modification	Duration of the cabin modification
VIP Cabin Modification	100 months	10 months

Aircraft Age Limits for a Cabin Refurbishing of an Airplane Owned by a VIP

Table 4.14 shows the average lower and upper aircraft age limits for which a VIP cabin modification could be no longer planned.

Table 4.14 VIP Cabin Modification: average age limits

Type of modification	Lower age limit	Upper age limit
VIP Cabin Modification	0 year	10 years

5 CS 25 World Fleet – Present and Future Trends

A further analysis towards the current **fleet distribution and its evolution** for the next 20 years is performed. Based on the results of this chapter, along with the criteria identified in the previous ones, the forecast for the cabin conversions demand will be presented in chapter 6.

5.1 Passenger Aircrafts

5.1.1 Aircraft Classification

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 aircrafts with extended range. Generally **wide-body aircrafts are operated for long-haul flights**. Figure 5.1 shows that air range is increasing as the number of one class seats is increasing. Therefore, it will be considered that all wide-body aircrafts are operated for long-haul routes.

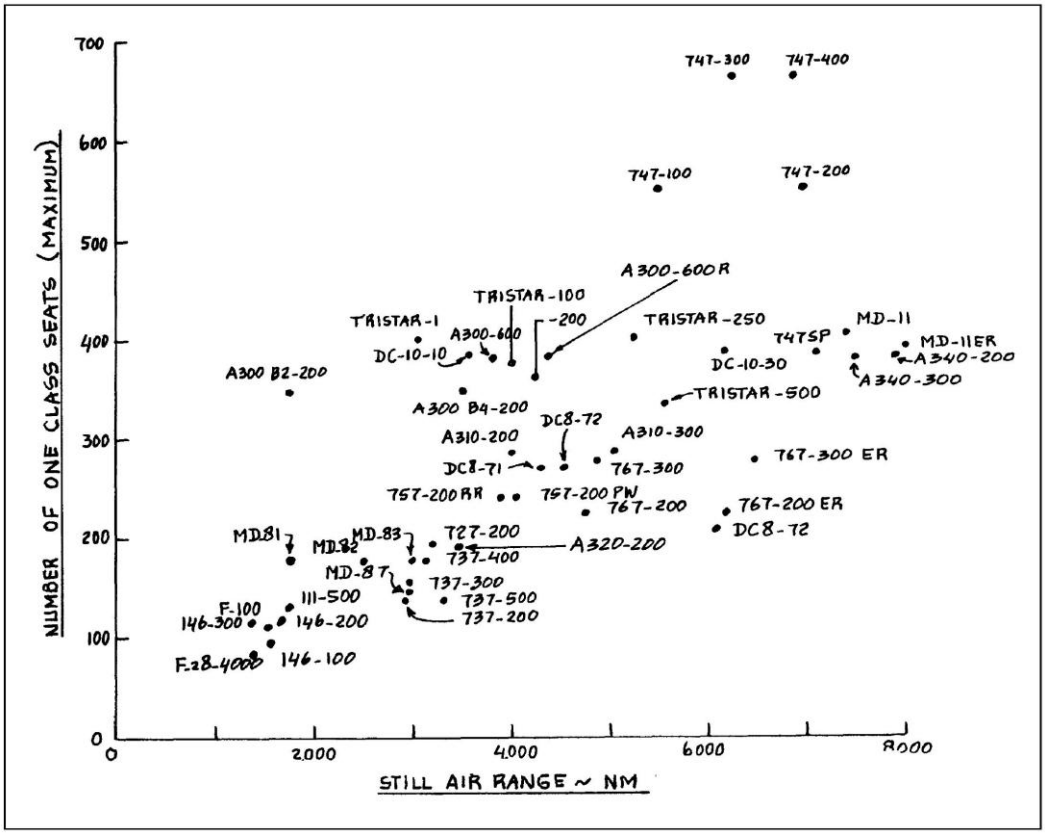


Fig. 5.1 Typical Seat-Range Diagram (**Scholz 1999**)

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 5.1 presents the **type of aircrafts** which were **considered** in our study.

Table 5.1 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

5.1.2 Passenger Fleet Evolution

The tendency for the future estimated by market statistics show that until 2027 **aircrafts will become more productive, being able to transport a larger amount of passengers**. Each aircraft will be able to carry about 40 percent more passengers (RPKs) than the average airplane today. Fewer airplanes will be needed to accommodate the same volume of travelers. The consequence is that **the fleet needs to grow by only 3.2 percent each year, although travel volume will grow at 5.0 percent**, as shown in the Figure 5.2 (**Boeing 2009**).

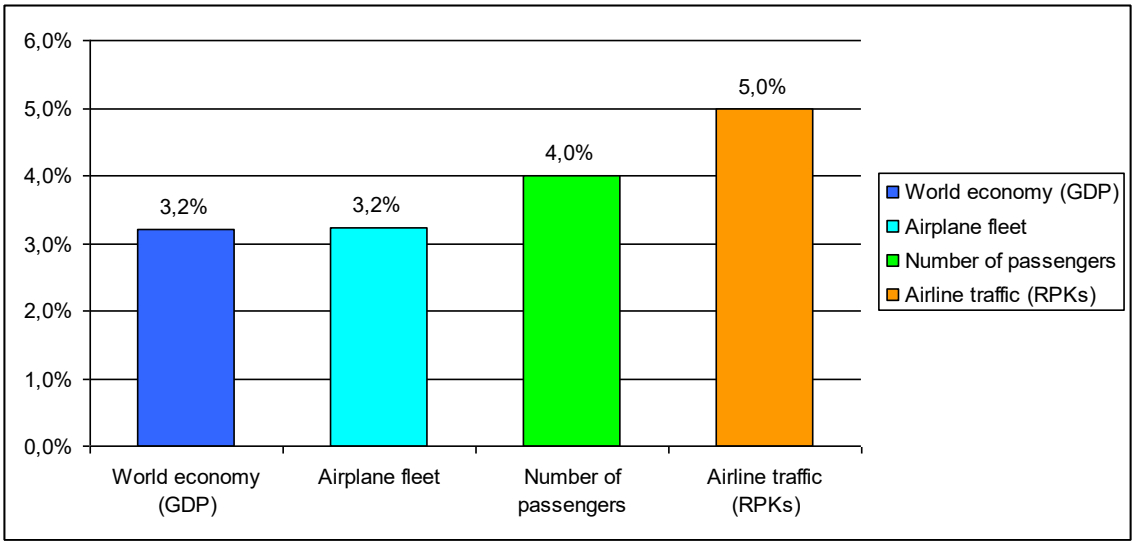


Fig. 5.2 Passenger key growth rates (based on data from **Boeing 2009**)

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 Figure 5.3.

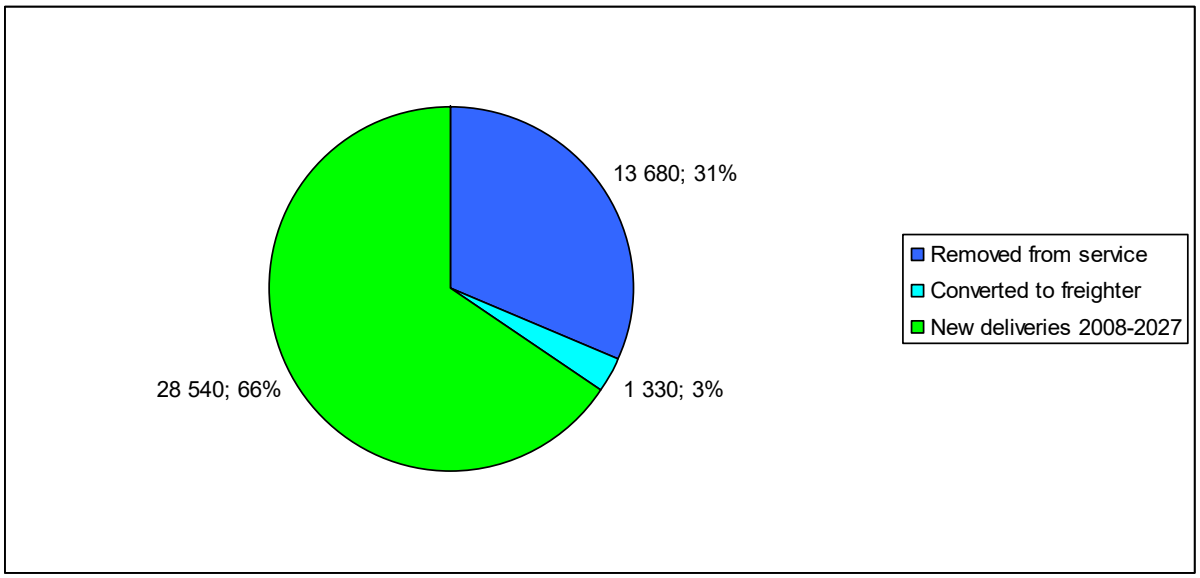


Fig. 5.3 Passenger fleet development 2008-2027 (based on data from **Boeing 2009**)

Aircraft Categories

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 (**Boeing 2009**).

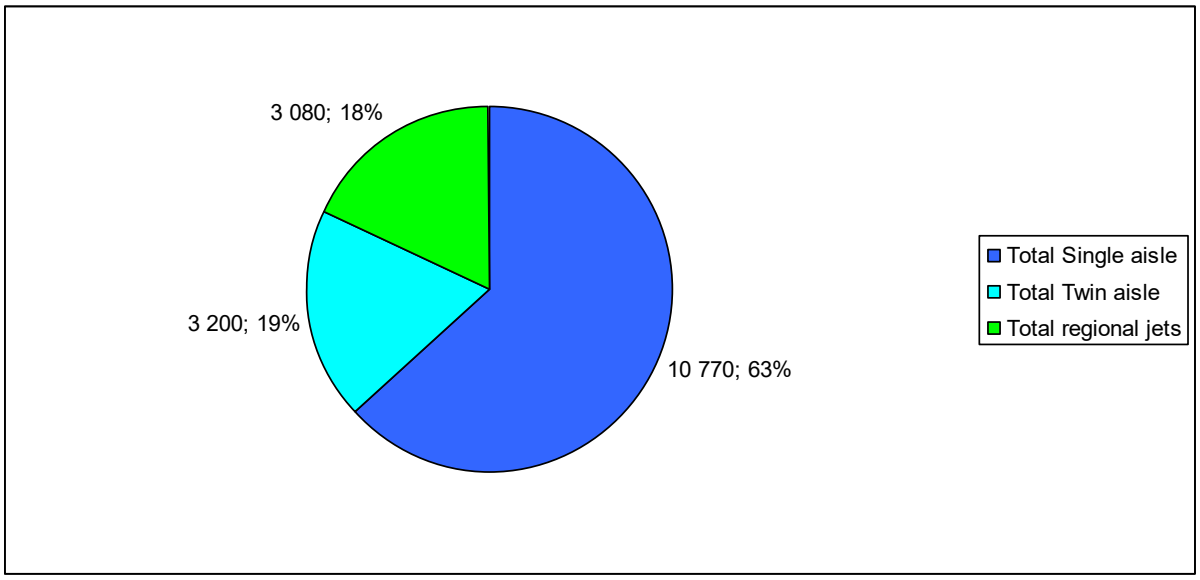


Fig. 5.4 Passenger fleet by airplane size in 2007 (based on data from **Boeing 2009**)

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) (**Boeing 2009**).

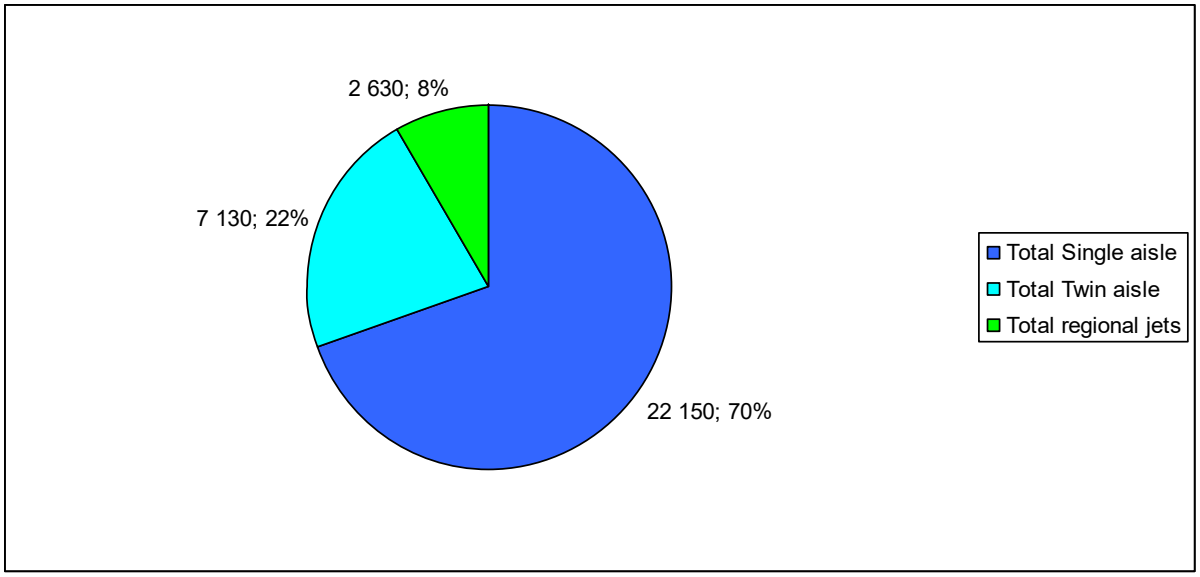


Fig. 5.5 Passenger fleet by airplane size in 2027 (based on data from **Boeing 2009**)

Airline requirements for economical and environmental efficiency are pushing towards larger aircrafts, and congestion at major airports is driving demand away from the smallest airplanes. Therefore, **regional jets** currently account for 18 percent of the worldwide fleet, but this will **reduce to 8 percent** by 2027 (**Boeing 2009**). Therefore, twin-aisle and single-aisle demand should be investigated.

World Repartition

According to Figures 5.6 and 5.7, **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 Asian market as European and North American market growths will decline (**Boeing 2009**).

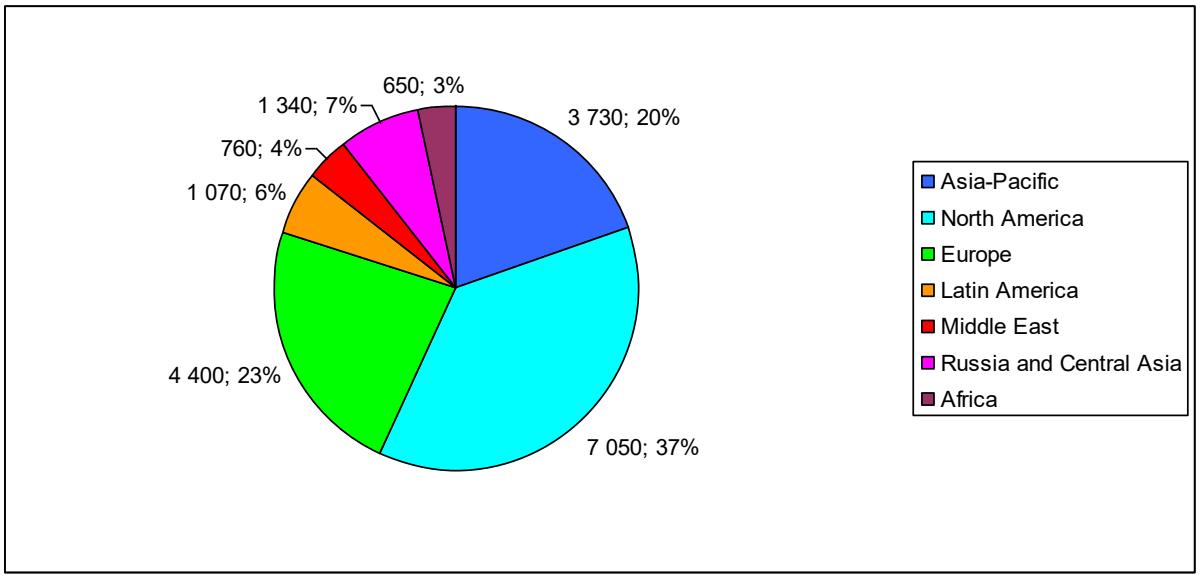


Fig. 5.6 Passenger fleet by region in 2007 (based on data from **Boeing 2009**)

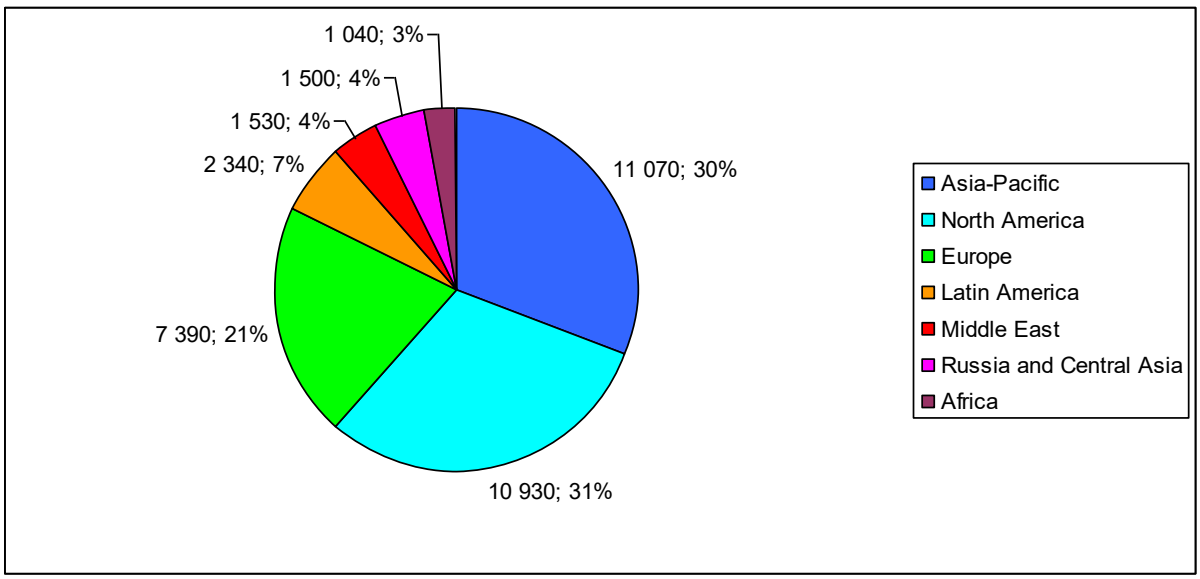


Fig. 5.7 Passenger fleet by region in 2027 (based on data from **Boeing 2009**)

Twin-aisle Demand by Regions

Asia-Pacific, Middle East, and European markets will drive the demand of **twin-aisle** airplanes. Over **40 percent** of twin aisles will be delivered to airlines in Asia-Pacific.

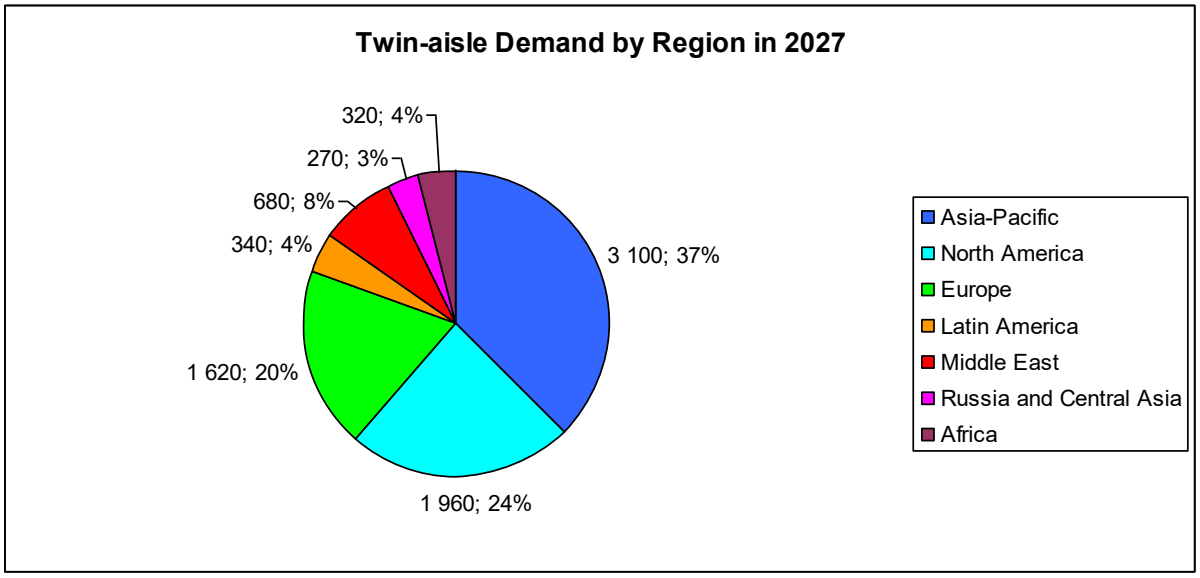


Fig. 5.8 Twin-aisle demand by region in 2027 (based on data from **Boeing 2009**)

Single-aisle demand by regions

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 percent** of new airplanes needed in Asia will be in the **single-aisle** category (**Boeing 2009**).

The conclusion to be drawn is that the market is growing especially in **Asia-Pacific** for single-aisle or for twin-aisle category.

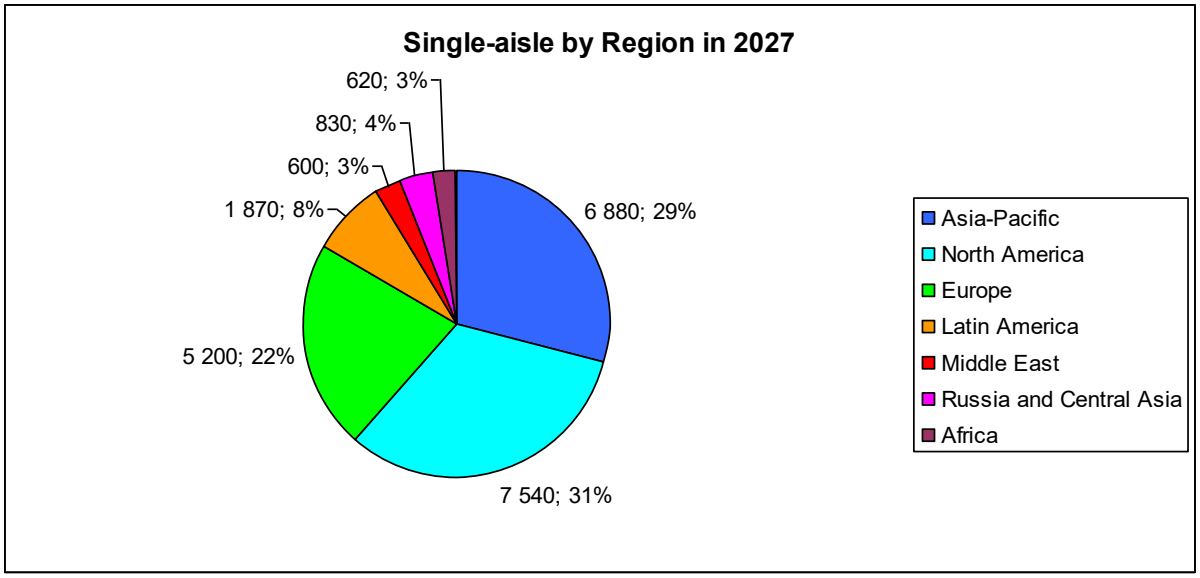


Fig. 5.9 Single-aisle demand by region in 2027 (based on data from **Boeing 2009**)

5.2 Freighter Aircrafts

In 2003 the *ACMG* (Air Cargo Management Group) estimated that growth in the global economy can sustain a long-term **growth rate of 6 percent per year in the air freight market (Dahl 2003)**. *Boeing* has obtained the same result in the Current Market Outlook (**Boeing 2009**). These results are shown in the Figures 5.10, 5.11, 5.12 and 5.13.

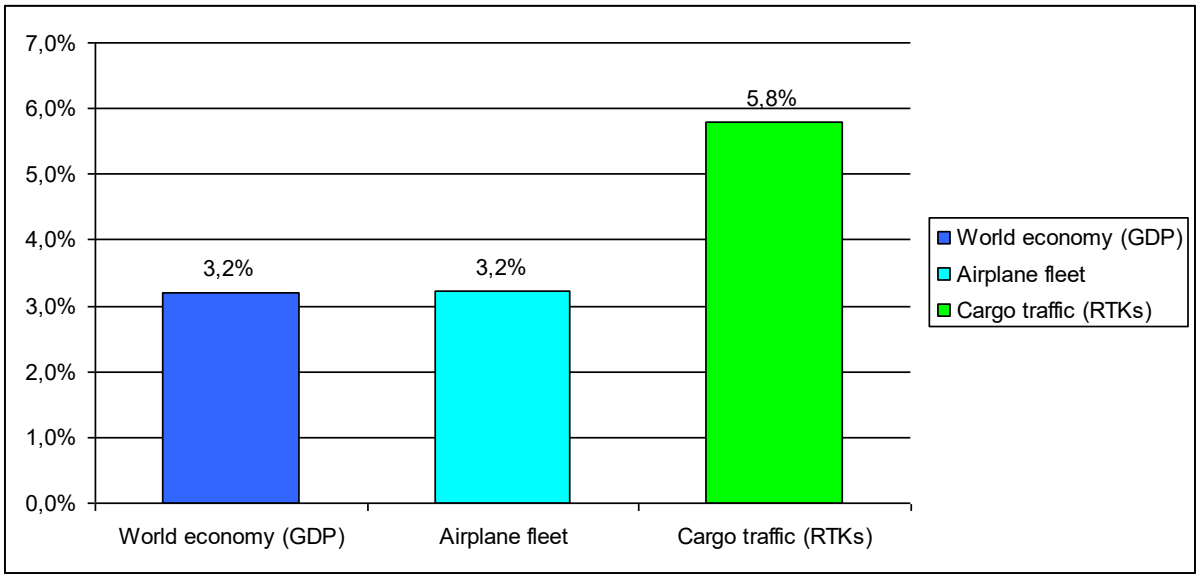


Fig. 5.10 Air cargo key growth rates (based on data from **Boeing 2009**)

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 aircrafts** (**EADS 2009**).

From the *Boeing*"s point of view, the freighter fleet will nearly double over the next 20 years, expanding from *1.948* airplanes in 2007 to *3.892* airplanes in 2027. Taking the forecast of *1.414* retirements into account, *3.358* 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 (**Boeing 2009**). This identical conclusion drawn by both sources confirm the validity of the results.

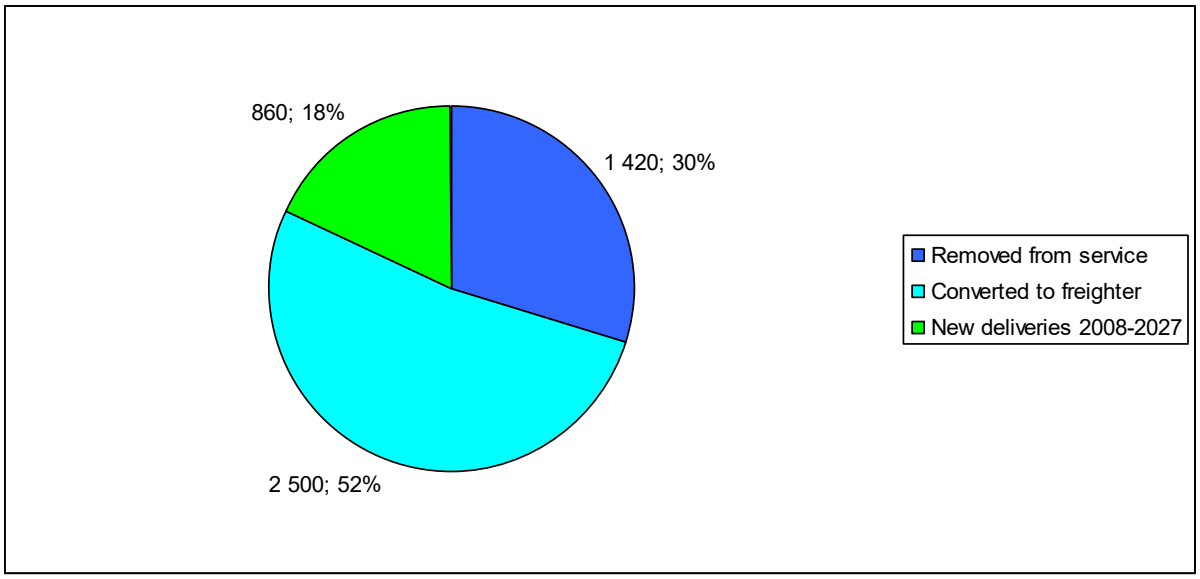


Fig. 5.11 Cargo fleet development 2007-2027 (based on data from **Boeing 2009**)

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 percent** 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 percent of the fleet in 2027 (**Boeing 2009**).

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 percent to 35 percent** over the next two decades. Nevertheless, more than **1,334** standard-body units will be delivered, representing an 84 percent 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 percent share of the total airplane fleet** during the forecast period (**Boeing 2009**).

There is, as well, a significant growth in **large freighters demand** which **rises from 26% to 34%** of the global market until 2027 (Figure 4.13) (**Boeing 2009**).

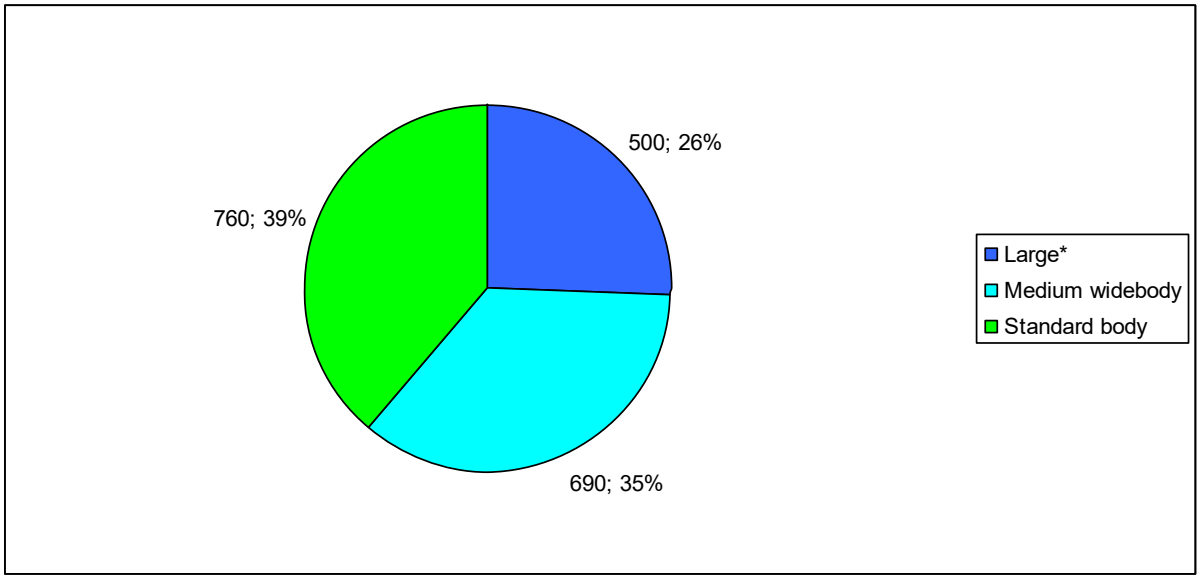


Fig. 5.12 Cargo fleet by airplane size in 2007 (based on data from **Boeing 2009**)

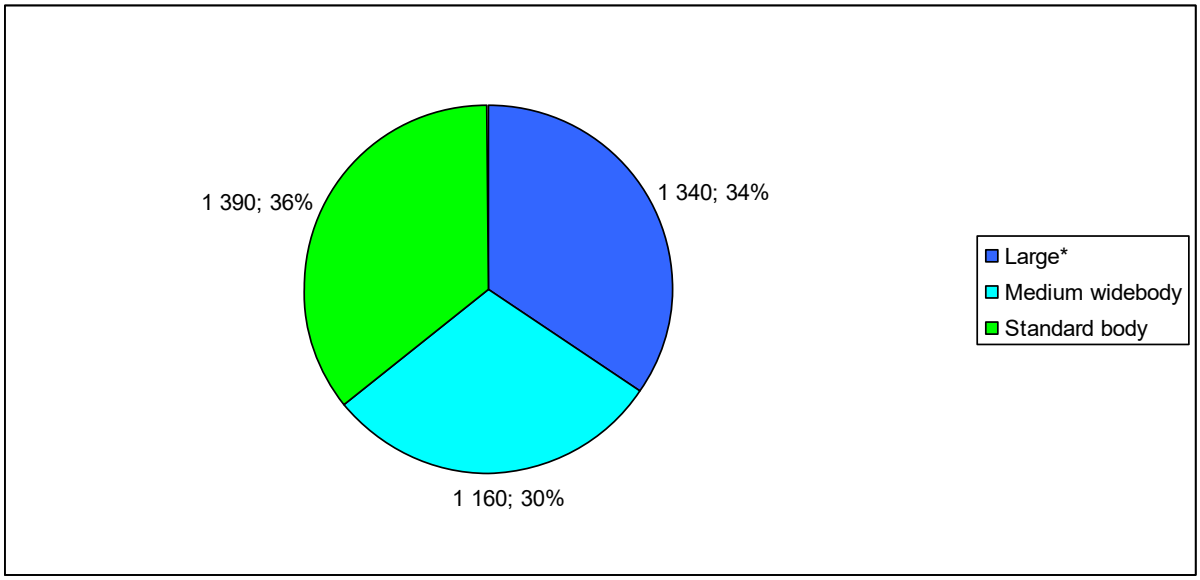


Fig. 5.13 Cargo fleet by airplane size in 2027 (based on data from **Boeing 2009**)

5.3 Executive Jets

In 2008, the global business aircraft fleet was consisted to comprise of **27,000** turbine airplanes (jets and turboprops), of which 68 percent belong to U.S. operators (**Watson 2009**).

The latest market forecast of the *Teal Group* predicts deliveries of *12,768* business aircrafts worthing $195.7 billion over the next 10 years (**Starfield 2009**). 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 (see the chart in Figure 5.14):

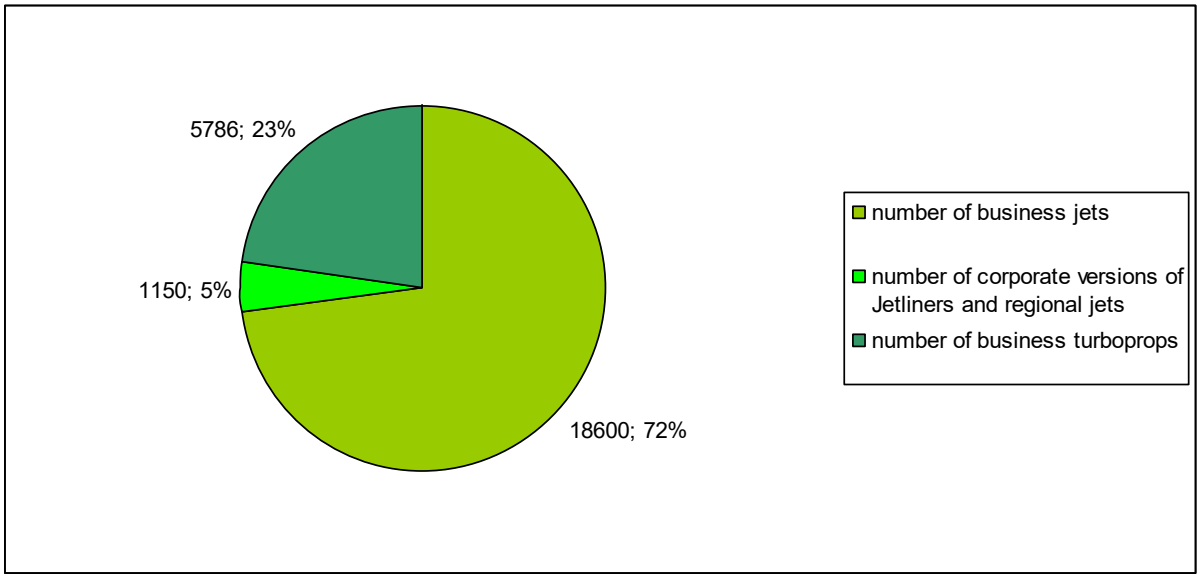


Fig. 5.14 Business Aircraft Deliveries 2009-2029

Business jet deliveries will take a big part of the market with a share of 72%. This forecast is in strong contrast to Teal's previous report issued a year ago in which it called for 18,401 business aircraft deliveries between 2008 and 2017. Indeed, the business aircraft market has been hit harder by the economic crisis than any other aerospace 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/early 2011 (**Starfield 2009**).

6 Forecast of the Market Volume

6.1 Aircraft Database

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* aircrafts). The Excel file is part of this Technical Note and will be delivered together with it.

The Excel Document can be updated with new information and **can generate up to date forecasts according to the new input data.** The VBA 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 normal computer.

The first sheet of the Excel document is called **'Forecast'** and contains all the **parameters of the different scenarios** determined in the previous chapters, as well as the **results of the computation.** Figure 6.1 shows the table where the frequency and the duration of each modification scenario can be modified by the user. This table groups all the results of the market investigation done in chapter 3. It is read by the code in order to compute the amount of cabin modifications for each aircraft. Later the functioning of the code will be explained.

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. 6.1 Database: scenarios parameters

Figure 6.2 shows the table which groups all the results of the market investigation done in the chapter 2. This table is used by the code to identify the cabin redesign/refurbishing scenario for each aircraft.

Figure 6.3 shows the table with the results generated by the code. The total amount of cabin modifications for each scenario and each world region can be founded.

Criteria for the identification of the Cabin Modification Scenarios for airplanes on commercial use (not read by the code)

	Wide-body Aircraft	Narrow-body Aircraft	Freighter	Full Service Carrier	LCC or Charter Service	Aircraft on Operating Lease
Upgrade of International Cabins	1	0	0	1	0	0
Upgrade of Domestic Cabins	0	1	0	1	1	0
Cabin Conversion for Narrow-bodies on Operating Lease	0	1	0	1	1	1
Cabin Conversion for Wide-bodies on Operating Lease	1	0	0	1	1	1

Fig. 6.2 Database: scenarios identification

Forecast Results (written by the code)

	Total Number of Cabin Modifications	Western Europe	Eastern Europe	China	Asia Pacific	Africa	Middle East	Latin America & Caribbean	North America
Upgrade of International Cabins	10154	1958	301	1007	2937	450	1723	491	1287
Upgrade of Domestic Cabins	23226	5414	1501	3381	3196	725	1016	1676	6317
Cabin Conversion for Aircrafts on Operating Lease	4244	1276	405	550	441	176	271	403	722
Freighter Conversion	2625	369	69	184	278	63	105	105	1427
VIP cabin modification	25536	?	?	?	?	?	?	?	?

Fig. 6.3 Database: Forecast results

The second sheet of the document is called **'Aircrafts'** and indicates the **characteristics of each aircraft model** which can be found in the database. As shown in the Figure 6.4, the table indicates if a specific aircraft model is a wide-body or not.

Aircraft Model Characteristics

type of body for airplanes on commercial use in this database (read by the code)

Aircraft full name	Aircraft model	Wide-body?
Sukhoi Superjet 100	Superjet 100	0
Boeing (McDonnell Douglas) MD-90	MD-90	0
Boeing (McDonnell Douglas) MD-80	MD-80	0
Boeing (McDonnell Douglas) MD-11	MD-11	1
Fokker 100	100	0
Fokker 70	70	0
Embraer 195	195	0
Embraer 190	190	0
Embraer 175	175	0
Embraer 170	170	0
Dornier 328JET	328JET	0
Boeing (McDonnell Douglas) DC-10	DC-10	1

Compute fleet volume of airplanes on commercial use

Fig. 6.4 Database: aircraft characteristics

The sheet **'Airlines'** provides the **characteristics of all the airlines** of the database could be found. As shown in the Figure 6.5, the table indicates if a specific airline is a LCC or not.

2	
3	**Airline Characteristics**
4	identification of the Low Cost Carriers of this database (read by the code)
5	
6	

	Low Cost Carriers Name
8	Air Arabia
9	Air India Express
10	AirAsia Sdn Bhd
11	AirAsia X
12	AirTran Airways
13	Allegiant Air
14	Atlas Blue
15	Atlasjet Airlines
16	Atlasjet Airlines
17	Avolar
18	Bahrain Air
19	Blu-Express
20	bmibaby
21	BRA Transportes Aereos Ltda.
22	CanJet Airlines
23	Cebu Pacific Air
24	Centralwings
25	Click Mexicana
26	Clickair S.A.
27	Corsairfly
28	easyJet Airlines Co. Ltd.
29	easyJet Switzerland

Fig. 6.5 Database: airline characteristics

The following two sheets show the information regarding **executive jets and freighters** (see Figures 6.6 and 6.7).

Executive Jets Database (Teal's Outlook 2009)

Business Aircraft Deliveries 2009-2029

total number of business aircrafts	number of business jets	number of corporate versions of Jetliners and regional jets	number of business turboprops
25536	18600	1150	5786

Fig. 6.6 Database: Executive Jets (**Starfield 2009)**

Freighters Database (Boeing Current Market Outlook 2008)

Forecast of the Fleet World Volume 2009-2029 (EADS 2009)

Future Fleet (additionnal airplanes)	Freighter Conversion proportion	Tolal amout of Freighter Conversion
3500	0,75	2625

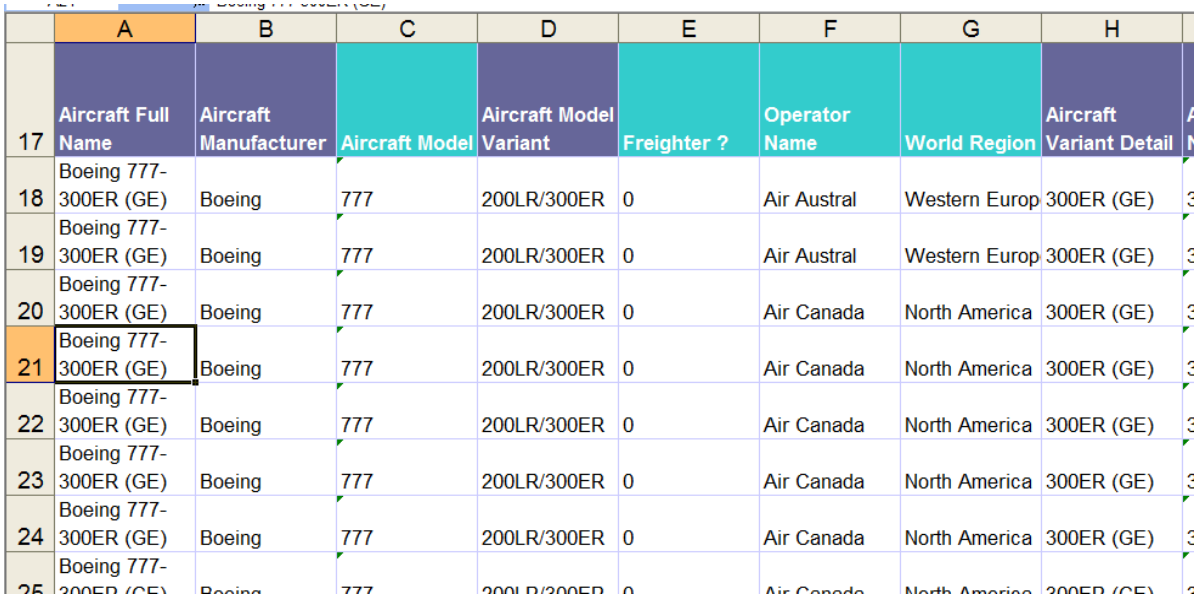
Current Fleet World Distribution (data from this database)

World fleet in the database	Western Europe	Eastern Europe	China	Asia Pacific	Africa	Middle East	Latin America & Caribbean	North America
1702	0,140423032	0,026439483	0,069917744	0,10575793	0,02408931	0,039953	0,039952996	0,543478261

Fig. 6.7 Database: Freighters (**Boeing 2009**)

All the other sheets of the document group a **database of the major large airplanes** in the world. Each of the remaining sheets groups all the aircrafts of the same model and type. Each row corresponds to a specific aircraft. The database provides a large amount of useful information, however, for performing the forecast only some of the parameters were extracted, as shown in the Figure 6.8 and 6.9 (columns in light blue):

- Aircraft model
- Freighter
- Operator name
- World region
- Aircraft First Delivery date
- Aircraft Lease termination

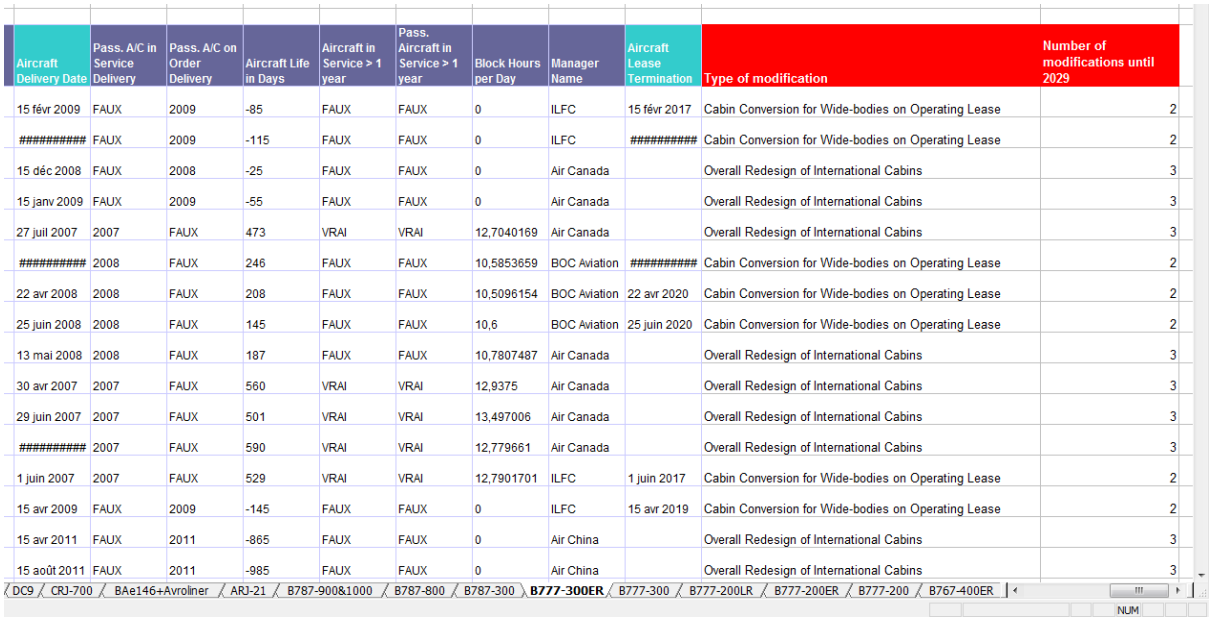


	A	B	C	D	E	F	G	H
17	Aircraft Full Name	Aircraft Manufacturer	Aircraft Model	Aircraft Model Variant	Freighter ?	Operator Name	World Region	Aircraft Variant Detail
18	Boeing 777-300ER (GE)	Boeing	777	200LR/300ER	0	Air Austral	Western Europ	300ER (GE)
19	Boeing 777-300ER (GE)	Boeing	777	200LR/300ER	0	Air Austral	Western Europ	300ER (GE)
20	Boeing 777-300ER (GE)	Boeing	777	200LR/300ER	0	Air Canada	North America	300ER (GE)
21	Boeing 777-300ER (GE)	Boeing	777	200LR/300ER	0	Air Canada	North America	300ER (GE)
22	Boeing 777-300ER (GE)	Boeing	777	200LR/300ER	0	Air Canada	North America	300ER (GE)
23	Boeing 777-300ER (GE)	Boeing	777	200LR/300ER	0	Air Canada	North America	300ER (GE)
24	Boeing 777-300ER (GE)	Boeing	777	200LR/300ER	0	Air Canada	North America	300ER (GE)
25	Boeing 777-	Boeing	777	200LR/300ER	0	Air Canada	North America	300ER (GE)

Fig. 6.8 Database: aircraft major parameters

Finally the code writes, for each aircraft, the scenario in which this aircraft is involved and the number of upgrades/conversions which are going to be undertaken. This information can be found in the two red columns:

- Type of modification
- Number of modifications until 2029



Aircraft Delivery Date	Pass. A/C in Service Delivery	Pass. A/C on Order Delivery	Aircraft Life in Days	Aircraft in Service > 1 year	Pass. Aircraft in Service > 1 year	Block Hours per Day	Manager Name	Aircraft Lease Termination	Type of modification	Number of modifications until 2029
15 févr 2009	FAUX	2009	-85	FAUX	FAUX	0	ILFC	15 févr 2017	Cabin Conversion for Wide-bodies on Operating Lease	2
##########	FAUX	2009	-115	FAUX	FAUX	0	ILFC	##########	Cabin Conversion for Wide-bodies on Operating Lease	2
15 déc 2008	FAUX	2008	-25	FAUX	FAUX	0	Air Canada		Overall Redesign of International Cabins	3
15 janv 2009	FAUX	2009	-55	FAUX	FAUX	0	Air Canada		Overall Redesign of International Cabins	3
27 juil 2007	2007	FAUX	473	VRAI	VRAI	12,7040169	Air Canada		Overall Redesign of International Cabins	3
##########	2008	FAUX	246	FAUX	FAUX	10,5853659	BOC Aviation	##########	Cabin Conversion for Wide-bodies on Operating Lease	2
22 avr 2008	2008	FAUX	208	FAUX	FAUX	10,5096154	BOC Aviation	22 avr 2020	Cabin Conversion for Wide-bodies on Operating Lease	2
25 juin 2008	2008	FAUX	145	FAUX	FAUX	10,6	BOC Aviation	25 juin 2020	Cabin Conversion for Wide-bodies on Operating Lease	2
13 mai 2008	2008	FAUX	187	FAUX	FAUX	10,7807487	Air Canada		Overall Redesign of International Cabins	3
30 avr 2007	2007	FAUX	560	VRAI	VRAI	12,9375	Air Canada		Overall Redesign of International Cabins	3
29 juin 2007	2007	FAUX	501	VRAI	VRAI	13,497006	Air Canada		Overall Redesign of International Cabins	3
##########	2007	FAUX	590	VRAI	VRAI	12,779661	Air Canada		Overall Redesign of International Cabins	3
1 juin 2007	2007	FAUX	529	VRAI	VRAI	12,7901701	ILFC	1 juin 2017	Cabin Conversion for Wide-bodies on Operating Lease	2
15 avr 2009	FAUX	2009	-145	FAUX	FAUX	0	ILFC	15 avr 2019	Cabin Conversion for Wide-bodies on Operating Lease	2
15 avr 2011	FAUX	2011	-865	FAUX	FAUX	0	Air China		Overall Redesign of International Cabins	3
15 août 2011	FAUX	2011	-985	FAUX	FAUX	0	Air China		Overall Redesign of International Cabins	3

DC9 / CRJ-700 / BAe146+Avroliner / ARJ-21 / B787-900&1000 / B787-800 / B787-300 / **B777-300ER** / B777-300 / B777-200LR / B777-200ER / B777-200 / B767-400ER

NUM

Fig. 6.9 Database: aircraft major parameters

6.2 Hypothesizes

The following hypothesizes will be considered when performing the forecast:

- **CS-23** airplanes are **not considered**. As not enough elements could be found about cabin conversions for these small airplanes, this demand certainly doesn‟t affect the whole market of cabin modifications. The error coming along when estimating the cabin design/redesign volume is therefore considered as negligible.
- Future aircrafts (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.

6.3 Forecast Methods

6.3.1 Method for Passenger Aircrafts Conversions

The **method** used for the computation is to scan each sheet and each row.
For each aircraft:

- the tables „Aircraft Model Characteristics“ in the sheet „Aircrafts“ and „Airline Characteristics“ in the sheet „Airlines“ are scanned.
- the characteristics of the aircrafts are filtered.
- the scenario is identified thanks to the table „scenarios identification“ in the sheet „Forecast“ and is written in the database under the column „Type of modification“.
- the scenario parameters are scanned in the sheet „Forecast“ (table „Computation Parameters“)
- the number of modifications is computed thanks to the scenario parameters and is written in the database.

The total amount of cabin upgrades/modifications is obtained through the following **process**: for each sheet and each row the code scans in the database:

- the world region where the aircraft is based
- the scenario in which it is involved
- the number of upgrades/modifications

The modifications for each scenario and each world region are counted and results are written in the table „Forecast table“ in the sheet „Forecast“.

For aircrafts which are not on operating lease, the total duration of the whole retrofit program has to be determined. As airlines are always undertaking retrofit programs, the code has to compute the fleet volume (same aircraft model, aircraft type and operator). This is multiplied with the equivalent duration in order to get the real duration of a retrofit program. Figure 6.10 describes all these processes.

The formula used in the computation is the **recursive formula**.

$date_{\mathrm{modification}}$ is the date at which the end of the next modification program is planned and $date_{today}$ is the date of computation. A new retrofit program has already been completed for the aircraft from the date of computation, as described in the formula (6.1).

$$date_{\mathrm{modification}} = date_{today} \tag{6.1}$$

With the formula (6.2), the date at which the next modification program ends, $date_{\mathrm{modification}}$, is computed. $date_{previous\_\mathrm{modification}}$ is the date at which the last retrofit program ended for the same

aircraft. $frequency_{scenario}$ is the time between the end of the last retrofit program and the begin of the next scheduled retrofit program. It depends of course of the cabin modification scenario in which the aircraft is involved. $duration_{scenario}$ is the duration of the retrofit program. It also depends of the scenario.

$$date_{\mathrm{mod}ification} = date_{previous\_\mathrm{mod}ification} + frequency_{scenario} + duration_{scenario} \tag{6.2}$$

The equation (6.2) is executed until (6.3) is no more valid. It is checked if the date of the computed retrofit program ($date_{\mathrm{mod}ification}$) is not exceeding the deadline of the forecast (01/07/2029) or the second deadline, corresponding to the aircraft age ($age_{scenario\_\mathrm{lim}it}$) for which the refurbishment is no longer planned by the operator. This second deadline is calculated thanks to the date of the aircraft first delivery $date_{aircraft\_delivery}$.

$$date_{\mathrm{mod}ification} < \max(01/07/2009, date_{aircraft\_delivery} + age_{scenario\_\mathrm{lim}it}) \tag{6.3}$$

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

$$n = n_{loop} + 1 \tag{6.4}$$

For aircrafts on operating lease, the duration of the retrofit program ($duration_{scenario}$) is the duration of one aircraft refurbishing, $duration_{\mathrm{mod}ification}$. It is considered in fact that these aircrafts don‟t 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.

$$duration_{scenario} = duration_{\mathrm{mod}ification} \tag{6.5}$$

For aircrafts 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 refurbishment ($duration_{equivalent}$), it helps to determine the duration of the whole retrofit program for the fleet ($duration_{scenario}$). $duration_{scenario}$ do not correspond to the real duration of one aircraft refurbishing, but determine the real time between two refurbishing programs for the same aircraft.

$$duration_{scenario} = duration_{total} = duration_{equivalent} \times volume_{fleet} \tag{6.6}$$

Figure 6.10 describes how the total number of upgrades/modifications for an aircraft on commercial use is computed, while Figure 6.11 describes this for one aircraft.

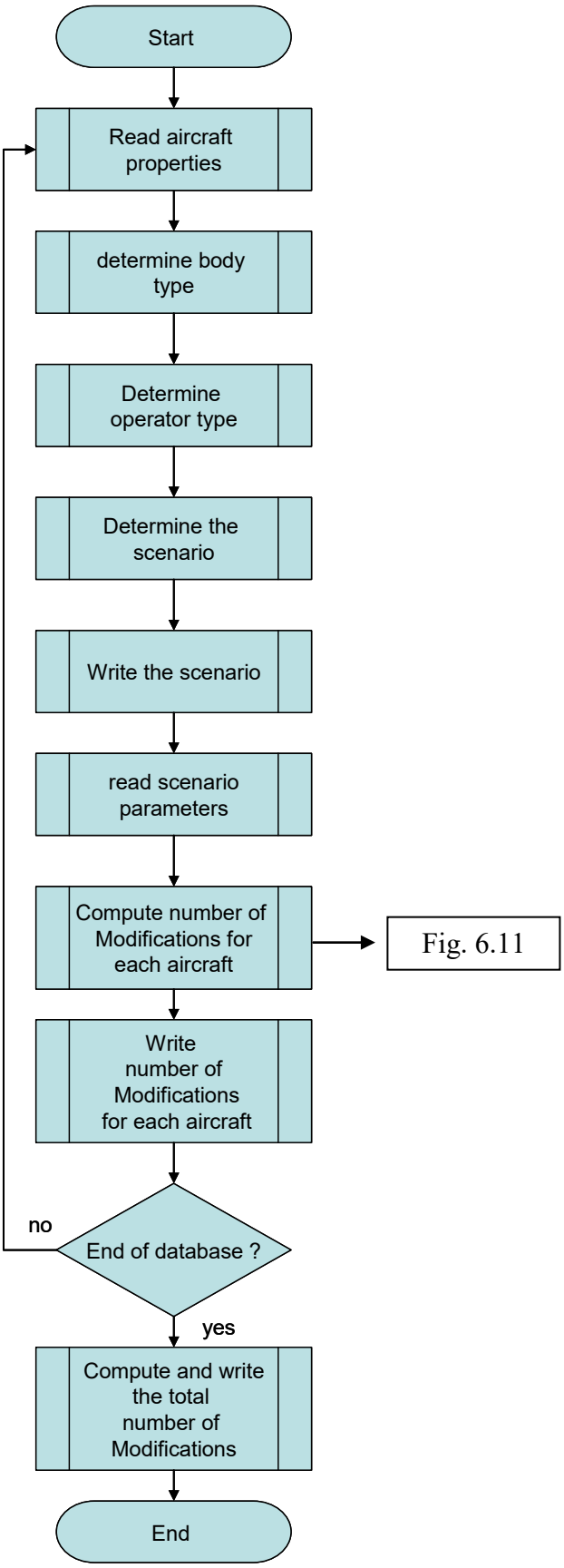


Fig. 6.10 Database: computation method for aircrafts on commercial use

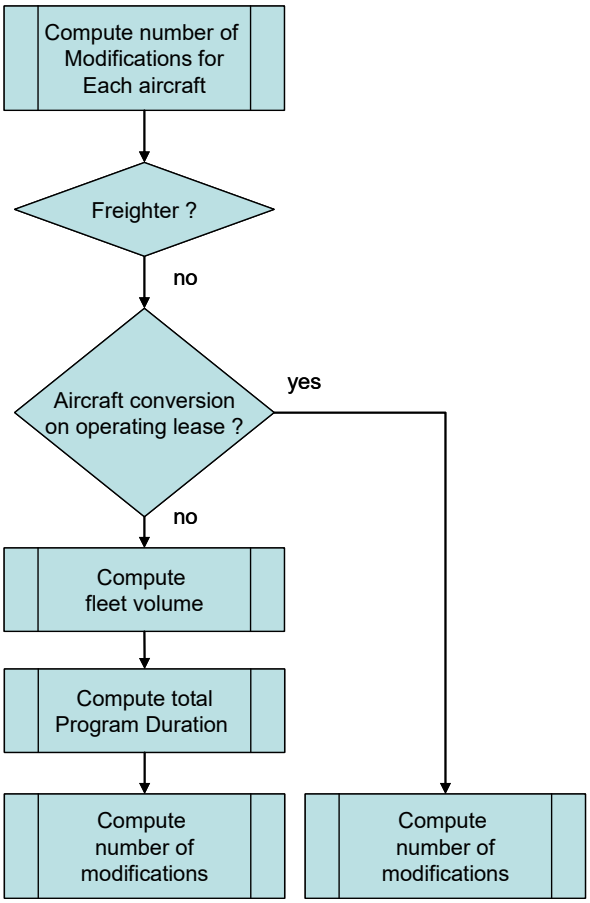


Fig. 6.11 Database: computation method for aircrafts on commercial use

6.3.2 Method for Pax-to-Freighter Conversions

Existing freighters in the database are, of course, not considered when computing the number of pax-to-freighter conversions. It is relevant to consider only those aircrafts on commercial use which have reached a specific age and could be further involved in a pax-to-freighter conversion. The fleet forecast made by **Boeing 2009** is rather used, wherein a specific percentage indicates the amount of freighter conversions for the future. Moreover, the numbers indicated by *Boeing* are verified by *EADS* in **EADS 2009**.

The additional airplanes which are required in the future amount to a number of *3500*. 75% of this demand is to be met by freighter conversions. The following formula is therefore used to get the number of freighter conversions by 2029, where $n_{FreigtherConversion}$ is the amount of freighter conversions, $n_{AdditionnalAirplanes}$ the number of additional airplanes forecast by *Boeing* and $p_{FreighterConversion}$, the proportion of conversions in these additional airplanes.

$$n_{FreigtherConversion} = n_{AdditionnalAirplanes} \times p_{FreighterConversion} \tag{6.7}$$

However, the world distribution of this demand is not yet available. Therefore, the distribution of the current freighter fleet is computed and extrapolated to the number of freighter conversions. In order to get the amount of freighter conversions in a specific world region, $n_{FreighterConversion}^{world\_region}$, the following formula is used, where $p_{FreighterFleet}^{world\_region}$ is the proportion of the freighter fleet in this specific region:

$$n_{FreighterConversion}^{world\_region} = n_{FreighterConversion} \times p_{FreighterFleet}^{world\_region} \quad (6.8)$$

6.3.3 Method for 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 *Teal*'s 2009 forecast (see paragraph 5.3).

Each business aircraft has the same modification scenario. This means that all of them will be involved in several VIP completions (as described in paragraphs 3.3 and 4.3.) until they reach the limit at which VIP completions will not be undertaken anymore ($age_{scenario\_limit}$), with the same duration ($duration_{scenario}$) and the same frequency of occurrence ($frequency_{scenario}$).

All business aircrafts have the same number of modifications. Of course some aircrafts are to be delivered in 2028, therefore they will not have the same number of completions in one year time than others which have been in service for years. This hypothesis will therefore lead to an error regarding the VIP completions volume. However, this error is compensated by the VIP completions of business aircrafts which are already in service in the current fleet and which have not been taken into account due to the lack of information.

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.

$$duration_{scenario\_period} = age_{scenario\_limit} \quad (6.9)$$

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

$$n_{aircraft} = \text{int}\left[duration_{scenario\_period} / (duration_{scenario} + frequency_{scenario})\right] \quad (6.10)$$

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

$$n = n_{aircraft} \times volume_{fleet} \tag{6.11}$$

6.4 The VBA Program

The VBA code, which executes the forecast computation, is separated in 4 main functions which are explained in the following paragraph:

- "Sub project_commercial_airplanes()"
- "Sub project_commercial_airplanes_total_modifications()"
- "Sub project_freighter_conversion()"
- "Sub project_VIP_modification()"

Access to the code itself is executed by the command „ALT+F11" in Excel and can also be read in the appendix A.

The parameters of each scenario, such as „frequency" or „duration", are user modifiable in the sheet „Forecast".

6.4.1 Passenger Aircraft

„Sub project_commercial_airplanes()", which can be read under „Module3", is the part of the code which computes the cabin upgrade/modification scenario and the cabin upgrade/modification volume for each aircraft on commercial use. It writes the results in the database for each aircraft on commercial use. The computation can be executed with its linked command button available in the sheet „Forecast".

Two important variables are used in this function, as shown in Figure 6.12:

- Aircrafts
- Scenarios

These variables are filled each time another aircraft is considered (i.e. for each sheet and each row). The compact form of these variables helps for the computation and the understanding of the code. All the details about these variables are described in Figure 6.12 (as green comments).

```
Type aircrafts
    model As String 'model of the aircraft
    wide_body As Boolean 'indicates if the aircraft is a wide-body or not
    operator As String 'gives the airline name that operate this aircraft
    LCC As Boolean 'indicates if this operator is a LCC or not
    freighter As Boolean 'indicates if this aircraft is operated in the freighter configuration
    delivery_date As Date 'gives the delivery date of the aircraft to its first operator
    lease_termination As Date 'gives the date of the lease contract termination and indicates if the aircraft is on operating lease or not
    region As String
End Type

Type scenarios
    type As String 'gives the name of the scenario that affects this aircraft
    occurence As Integer 'time at which the conversion of leased aircraft is undertaken (useful just for aircrafts on operating lease)
    frequency As Integer 'time between two modification programs in the aircraft useful life
    duration As Integer 'duration of the cabin modification of one aircraft (useful just for aircrafts on operating lease)
    equ_duration As Integer 'equivalent duration of the modification program for one aircraft
    tot_duration As Integer 'duration of the modification program for an entire fleet (same aircraft model and type)
    age_limit As Integer 'aircraft age at which this modification scenario is no longer planned
    date_limit As Date 'date at which this modification scenario is no longer planned
End Type
```

Fig. 6.12 Database: major variables of the VBA code

„Sub project_commercial_airplanes_total_modifications()“, which can be read under „Module2“, is the part of the code which computes the total cabin modification volume of aircrafts on commercial use, for each scenario and each world region, by using the results from the function „Sub project_commercial_airplanes()“. It writes the results in the sheet „Forecast“. The computation can be executed with its linked command button available in the sheet „Forecast“.

6.4.2 Freighter Conversions

„Sub project_freighter_conversion()“, which can be read under „Module1“ is the part of the code which computes the freighter conversion volume for each world region. It writes the results in the sheet „Forecast“. The computation can be executed with its linked command button available in the sheet „Forecast“.

6.4.3 VIP Conversions

„Sub project_VIP_modification()“, which can be read under „Module5“ is the part of the code which computes the VIP modification volume. It writes the results in the sheet „Forecast“. The computation can be executed with its linked command button available in the sheet „Forecast“.

6.5 Forecast Results

6.5.1 Demand for Cabin Upgrades – Overview

The results of the forecast applied on the several databases are presented in Figure 6.13. 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 aircrafts** 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**.

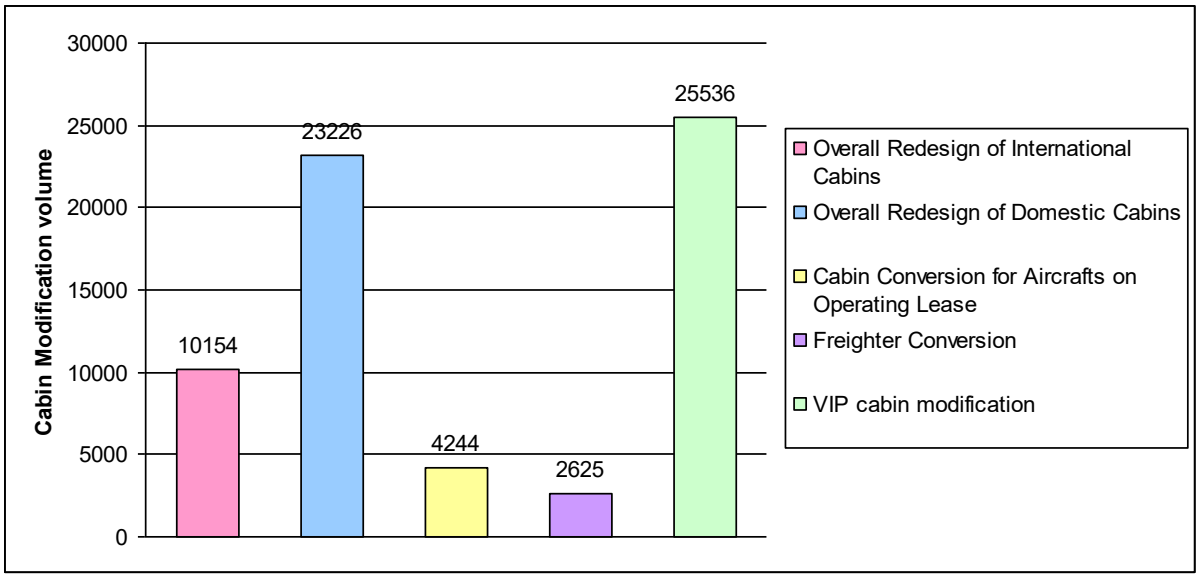


Fig. 6.13 Cabin modification world volume 2009-2029

6.5.2 Demand for Upgrades of International Cabins

A big part of the 10100 wide-body cabin redesigns forecasted come from **Asia-Pacific area (29%).** Indeed, over 40 percent of twin aisles will be delivered to airlines in Asia-Pacific. Therefore, the Asia-Pacific market will have an important influence on this segment (see Figure 6.14).

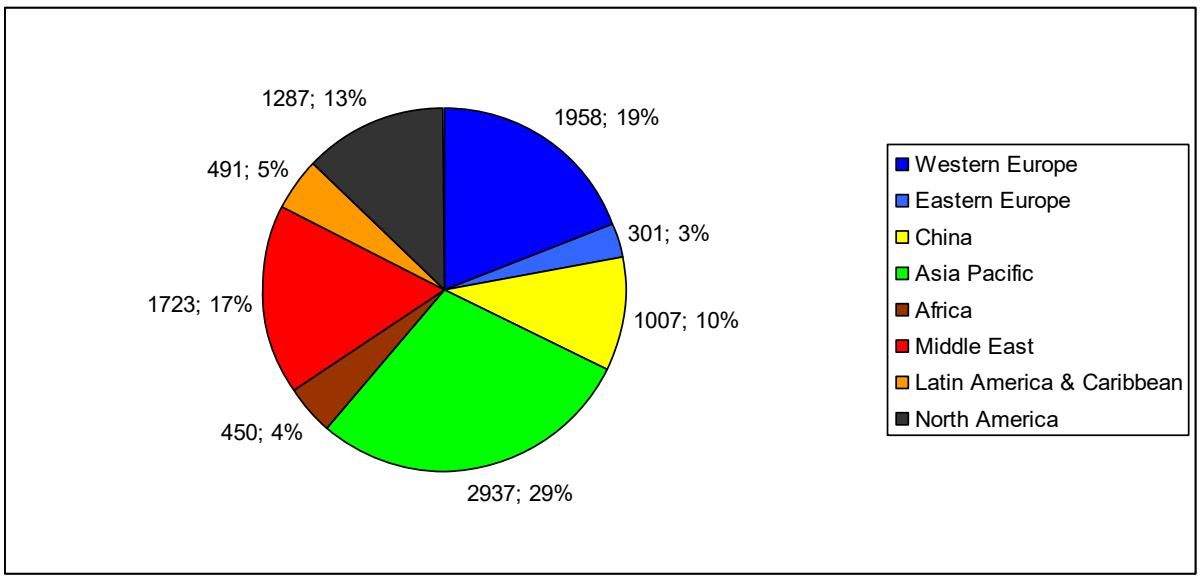


Fig. 6.14 International Cabins: Cabin Retrofit World Distribution 2009-2029

If the market share of the Middle East and China are added to this consideration, more than **55%** (6000 cabin retrofits) of the demand will be concentrated **in a single world continent**.

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 **(Arnoult 2007)**.

6.5.3 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.

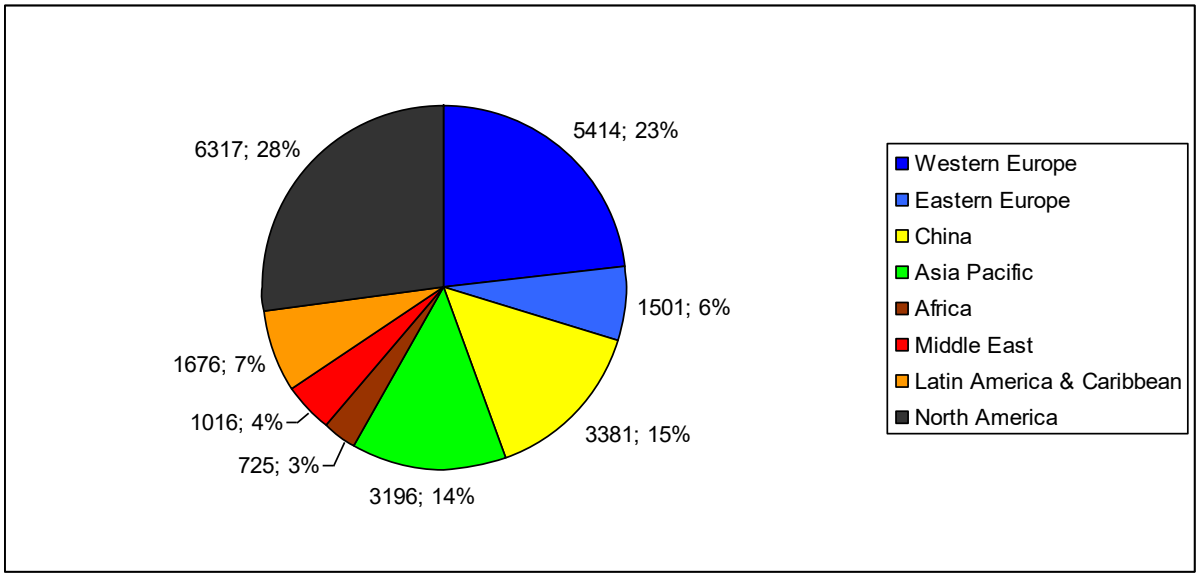


Fig. 6.15 Domestic Cabins: Cabin Retrofit World Distribution 2009-2029

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, 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 chapters). However North American and Western European markets have to be investigated if this segment is suddenly growing because of a future trend.

6.5.4 Demand for Cabin Upgrades of Aircrafts on Operating Lease

The chart below (Figure 6.16) shows that most of the **4200** cabin conversions of leased aircrafts 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 aircrafts. However, the **Asian market follows the trend** of the market share (China, 13%, Asia Pacific, 10% and Middle East, 6%).

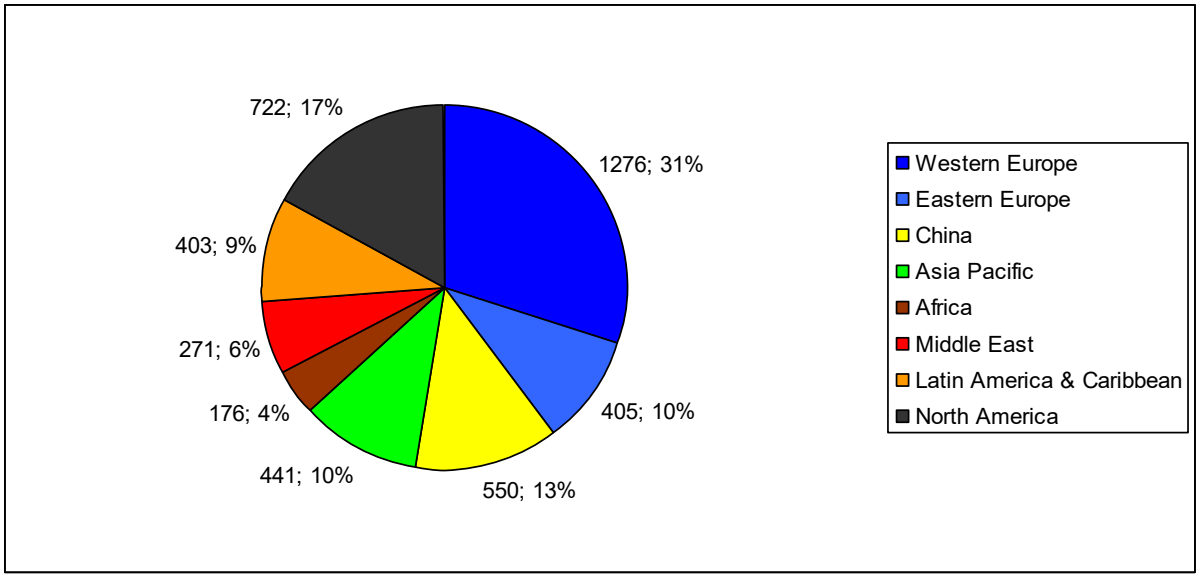


Fig. 6.16 Aircrafts on Operating Lease: Cabin Retrofit World Distribution 2009-2029

It is to be remembered that the **leasing of aircrafts** 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 remodeling** quickly **their fleet** and they can always offer the passengers new aircrafts. 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 aircrafts generates an additional strong demand for cabin redesigns for narrow-bodies, as well as wide-bodies.

6.5.5 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.

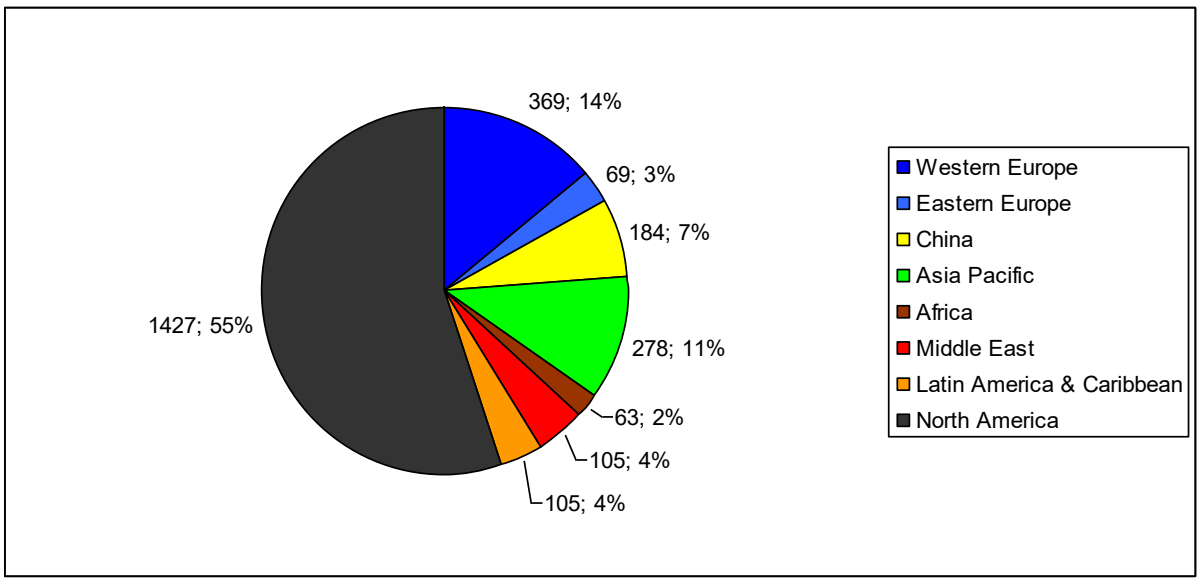


Fig. 6.17 Pax-to-Freighters Conversion: World Distribution 2009-2029

6.5.6 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 and the Middle East** and they think **China** will also become a strong market. Traditionally, most part 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 the best, therefore they‟re asking for: bathrooms, dining areas, bedrooms, libraries, children rooms. Russia could dominate the sector within five years, exceeding even the Middle East in its demand for the ultimate in opulence. However, the recent crisis has put most of the demands on hold (**Parker 2008**).

Growth is also coming from the **South American** market, especially in **Brazil,** and mainly in the business jet segment (**Parker 2008**).

India‟s fast-growing economy is fuelling demand, where a lot of interest in the Airbus ACJ and Boeing BBJ for both VIP and corporate transport is foreseen (**Parker 2008**).

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 billions were spent in 2007 on completing green VIP aircrafts and upgrading in-service large executive airplanes. AeroStrategy forecasts that those expenditures could grow to more than $3.8 billion annually by 2015. Typically, VIP aircraft buyers spend up to $100 million for a top-of-the-range completion **(Searles 2008).**

7 Summary

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 redesigns. 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. Therefore it has to be considered with the biggest attention.

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 Redesigns 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 company wanting to deliver cabin design and redesign 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.

Aircrafts on operating lease creates 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 real advantages of operating such aircrafts even for full service carriers. Therefore, European and Asian markets should be anew considered with attention as this demand will concentrate in those 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 Modifications market for the next twenty years. The high prices of VIP cabin completions, along with the strong need for business aircrafts to be refurbished as soon as possible, makes this segment very interesting. Therefore, North America and European markets should have the biggest influence on the Cabin Modifications market. However, an emerging and growing demand for the next years should draw the attention towards the Russian and Asian markets.

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Appendix A: The VBA Code

The code presented here was used to obtain the results of the forecast, based on the aircrafts database attached to this Technical Note. Helpful in understanding the code are the attached green comments.

Sub project_commercial_airplanes()

```
Dim aircraft As aircrafts 'contains all the characteristics of the aircraft we work on
Dim scenario As scenarios 'contains all the characteristics of the cabin modification scenario related to this aircraft
Dim sheet As Worksheet 'describes the worksheet we work on
Dim row As Integer 'describes the row of this worksheet we work on
row = 18 'row gives the number of the current row. Information begins at row number 18.
Dim number_modifications As Integer 'gives the number of modifications for one aircraft either until 01/07/2009 or before the aircraft end of life

For Each sheet In Worksheets
   If ((sheet.Name = "Forecast") Or (sheet.Name = "Aircrafts") Or (sheet.Name = "Airlines") Or (sheet.Name = "ExecutiveJets") Or (sheet.Name = "Freighters") Or (sheet.Name = "B737-BBJ")) Then
   Else 'scan only the worksheets about commercial airplanes
      row = 18
      Do While sheet.Cells(row, 3) <> "" 'scan all the rows until the end of the sheet(we consider only one aircraft each time
         number_modifications = 0 'before the computation there is no modification for this aircraft
         Call read_aircraft_properties(aircraft, ByVal row, ByVal sheet) 'scan all the characteritics of this aircraft from the database
         Call determine_body_type(aircraft) 'determine if this aircraft is a wide-body or a narrow-body
         Call determine_operator_type(aircraft) ' determine if the aircraft operator is a LCC or not
         Call determine_scenario(aircraft, scenario) 'determine, with all these information, the cabin modification scenario related to this aircraft
         Call write_scenario(scenario, ByVal row, ByVal sheet) 'write the type of scenario of this aircraft in a specific column of the database
         Call read_scenario_parameters(scenario, aircraft) 'read the parameters of the scenario required for the computation
         Call compute_modifications(aircraft, scenario, number_modifications, ByVal sheet) 'compute the number of cabin modifications for this aircraft either until 01/07/2029 or until the aircraft end of life.
         Call write_number_modifications(number_modifications, ByVal row, ByVal sheet) 'write the number of modification for this aircraft in a specific column of the database
         row = row + 1 'goes to the next row
      Loop
   End If
Next sheet
End Sub


Sub read_aircraft_properties(aircraft As aircrafts, ByVal row, ByVal sheet)
aircraft.model = sheet.Cells(row, 3).Value
aircraft.operator = sheet.Cells(row, 6).Value
aircraft.freighter = sheet.Cells(row, 5).Value
aircraft.delivery_date = sheet.Cells(row, 21).Value
aircraft.lease_termination = sheet.Cells(row, 29).Value
End Sub

Sub determine_body_type(aircraft As aircrafts)
Dim row As Integer
```

```
row = 8 'row gives the number of the current row. Information begins at row number 8.

Do While Worksheets("Aircrafts").Cells(row, 3).Value <> "" 'scan all the rows until the end of the sheet
   If Worksheets("Aircrafts").Cells(row, 3).Value = aircraft.model Then ' if the aircraft model is found
      aircraft.wide_body = Worksheets("Aircrafts").Cells(row, 4).Value ' the type of body is saved in the variable aircraft
   End If
   row = row + 1 'goes to the next row
Loop
End Sub

Sub determine_operator_type(aircraft As aircrafts)
Dim row As Integer
row = 8 'row gives the number of the current row. Information begins at row number 8.
aircraft.LCC = False

Do While Worksheets("Airlines").Cells(row, 2).Value <> "" 'scan all the rows until the end of the sheet
   If Worksheets("Airlines").Cells(row, 2).Value = aircraft.operator Then ' if the aircraft operator is found
      aircraft.LCC = True ' the type of operator is saved in the variable aircraft
   End If
   row = row + 1 'goes to the next row
Loop
End Sub

Sub determine_scenario(aircraft As aircrafts, scenario As scenarios)
If aircraft.freighter = False Then 'if the aircraft is not a freighter
   If aircraft.lease_termination = "00:00:00" Then 'if the aircraft is not on operating lease
      If aircraft.wide_body = True Then 'if it is a wide-body
         If aircraft.LCC = False Then 'if it is a Full service carrier
            scenario.type = "Overall Redesign of International Cabins"
         Else  'if it is a LCC
            scenario.type = "No Modification Scenario"
         End If
      Else 'if it is a narrow-body
         scenario.type = "Overall Redesign of Domestic Cabins" 'no differentiation here between LCC and Full service carrier
      End If
   Else 'if the aircraft is on operating lease
      If aircraft.wide_body = False Then 'if it is a narrow-body
         scenario.type = "Cabin Conversion for Narrow-bodies on Operating Lease" 'no differentiation here between LCC and Full
service carrier
      Else 'if it is a wide-body
         scenario.type = "Cabin Conversion for Wide-bodies on Operating Lease" 'no differentiation here between LCC and Full
service carrier
      End If
   End If
Else 'if the aircraft is a freighter
   scenario.type = "No Modification Scenario"
End If
End Sub


Sub write_scenario(scenario As scenarios, ByVal row, ByVal sheet)
sheet.Cells(row, 30).Value = scenario.type
End Sub

Sub read_scenario_parameters(scenario As scenarios, aircraft As aircrafts)
If scenario.type = "Overall Redesign of Domestic Cabins" Then
   scenario.frequency = Worksheets("Forecast").Cells(13, 5).Value
```

```
    scenario.equ_duration = Worksheets("Forecast").Cells(13, 7).Value
    scenario.duration = 0 'duration is not useful for this scenario
    scenario.age_limit = Worksheets("Forecast").Cells(13, 9).Value
End If

If scenario.type = "Overall Redesign of International Cabins" Then
    scenario.frequency = Worksheets("Forecast").Cells(12, 5).Value
    scenario.equ_duration = Worksheets("Forecast").Cells(12, 7).Value
    scenario.duration = 0 'duration is not useful for this scenario
    scenario.age_limit = Worksheets("Forecast").Cells(12, 9).Value
End If
(….)
If aircraft.delivery_date + scenario.age_limit * 365 < "1 / 7 / 2029" Then 'if the date at which there is no more modification do not exceed the date 1/7/2029
    scenario.date_limit = aircraft.delivery_date + scenario.age_limit * 365 'then we take this date as upper limit for the computation
Else
    scenario.date_limit = "1 / 7 / 2029" 'else we take the date 1/07/2029 as upper limit for the computation
End If
End Sub

Sub compute_modifications(aircraft As aircrafts, scenario As scenarios, number_modifications As Integer, ByVal sheet)
Dim fleet_volume As Integer 'counts the number of aircrafts of the same model and affected by the same scenario

    If scenario.type = "Cabin Conversion for Narrow-bodies on Operating Lease" Or scenario.type = "Cabin Conversion for Wide-bodies on Operating Lease" Then
        Call compute_modification_lease(aircraft, scenario, number_modifications) ' compute the number of modification for aircrafts on operating lease
    End If
    If scenario.type = "Overall Redesign of Domestic Cabins" Or scenario.type = "Overall Redesign of International Cabins" Then
        Call compute_fleet_volume(ByVal sheet, aircraft, fleet_volume) 'compute the number of aircrafts of the same operator
        Call compute_total_duration(scenario, ByVal fleet_volume) 'compute the program duration for the entire fleet
        Call compute_modification_normal(aircraft, scenario, number_modifications) ' compute the number of modification for the other aircrafts
        'MsgBox ("aircraft: " & aircraft.model & Chr(13) & "fleet volume: " & fleet_volume & Chr(13) & "number modif: " & number_modifications)
    End If
    If scenario.type = "No Modification Scenario" Then
        number_modifications = 0
    End If
End Sub

Sub compute_modification_lease(aircraft As aircrafts, scenario As scenarios, number_modifications As Integer)
Dim end_computation As Boolean
Dim date_modification As Date 'indicates the date of the current forecast modification
end_computation = False 'command the exit of the loop
date_modification = aircraft.lease_termination 'the first modification will happen at the date of lease termination

If scenario.date_limit > Date Then 'if aircraft is not yet phased-out then modifications should be planned
    number_modifications = 0
    Do While (end_computation = False)
        number_modifications = number_modifications + 1
        date_modification = date_modification + scenario.frequency * 31 + scenario.duration 'computation of the date of the next modification
        If date_modification > scenario.date_limit Then 'if the date of the next modification exceed the upper limit, no more modification will be planned
            end_computation = True
```

```
      End If
   Loop
Else 'if the aircraft is already phased-out, no more modification will be planned
   number_modifications = 0
End If
End Sub

Sub compute_fleet_volume(ByVal sheet, aircraft As aircrafts, fleet_volume)
Dim row As Integer
row = 18
fleet_volume = 0

      Do While sheet.Cells(row, 3) <> "" 'scan all the rows until the end of the sheet
         If aircraft.lease_termination = "00:00:00" Then 'if the aircraft is not on operating lease
            If aircraft.freighter = False Then 'if the aircraft is not a freighter
               If aircraft.operator = sheet.Cells(row, 6) Then 'if the aircraft belongs to the same operator
                  fleet_volume = fleet_volume + 1 'count the fleet volume
               End If
            End If
         End If
         row = row + 1
      Loop
End Sub

Sub compute_total_duration(scenario As scenarios, ByVal fleet_volume)
scenario.tot_duration = scenario.equ_duration * fleet_volume 'compute the duration of the whole program (in days)
End Sub

Sub compute_modification_normal(aircraft As aircrafts, scenario As scenarios, number_modifications)
Dim end_computation As Boolean
Dim date_modification As Date 'indicates the date of the current forecast modification
end_computation = False 'command the exit of the loop
date_modification = Date 'the first modification will happen at the date of today

If scenario.date_limit > Date Then 'if aircraft is not yet phased-out then modifications should be planned
   number_modifications = 0
   Do While (end_computation = False)
      number_modifications = number_modifications + 1
      date_modification = date_modification + scenario.frequency * 31 + scenario.tot_duration 'computation of the date of the
next modification
      If date_modification > scenario.date_limit Then 'if the date of the next modification exceed the upper limit, no more
modification will be planned
         end_computation = True
      End If
   Loop
Else 'if the aircraft is already phased-out, no more modification will be planned
   number_modifications = 0
End If
End Sub

Sub write_number_modifications(ByVal number_modifications, ByVal row, ByVal sheet)
sheet.Cells(row, 31).Value = number_modifications
End Sub
```

Sub project_commercial_airplanes_total_modifications() 'compute and write the number of modifications for each region and each scenario

```
Dim region As String
Dim scenario_type As String
Dim sheet As Worksheet 'describes the worksheet we work on
Dim row As Integer 'describes the row of this worksheet we work on
row = 18 'row gives the number of the current row. Information begins at row number 18.
Dim number_modifications As Integer 'gives the number of modifications of a specific aircraft
Worksheets("Forecast").Range("D32:U34").ClearContents

For Each sheet In Worksheets
   If ((sheet.Name = "Forecast") Or (sheet.Name = "Aircrafts") Or (sheet.Name = "Airlines") Or (sheet.Name = "ExecutiveJets")
Or (sheet.Name = "Freighters")) Then
   Else 'scan only the worksheets about commercial airplanes
      row = 18
      Do While sheet.Cells(row, 3) <> "" 'scan all the rows until the end of the sheet(we consider only one aircraft each time)
         number_modifications = 0 'before the computation there is no modification for this aircraft
         Call read_region(region, ByVal row, ByVal sheet) 'scan the world region where this aircraft is based
         Call read_scenario(scenario_type, ByVal row, ByVal sheet) 'scan the modification scenario of this aircraft
         Call read_number_modifications(number_modifications, ByVal row, ByVal sheet) 'scan the number of modifications for
this aircraft
         Call compute_detailed_modifications(ByVal number_modifications, ByVal scenario_type, ByVal region) 'compute and
write the number of modifications for each region and each scenario
         row = row + 1 'goes to the next row
      Loop
   End If
Next sheet
Call compute_total_modifications   ' compute and write the total amount of modifications for each scenario
End Sub

Sub read_region(region As String, ByVal row, ByVal sheet)
region = sheet.Cells(row, 7)
End Sub

Sub read_scenario(scenario_type As String, ByVal row, ByVal sheet)
scenario_type = sheet.Cells(row, 30)
End Sub

Sub read_number_modifications(number_modifications As Integer, ByVal row, ByVal sheet)
number_modifications = sheet.Cells(row, 31)
End Sub

Sub compute_detailed_modifications(ByVal number_modifications As Integer, ByVal scenario_type As String, ByVal
region As String)
If scenario_type = "Overall Redesign of International Cabins" Then
      If region = "Western Europe" Then
         Worksheets("Forecast").Cells(32, 5) = Worksheets("Forecast").Cells(32, 5) + number_modifications
      End If
      If region = "Eastern Europe" Then
         Worksheets("Forecast").Cells(32, 6) = Worksheets("Forecast").Cells(32, 6) + number_modifications
      End If
      If region = "China" Then
         Worksheets("Forecast").Cells(32, 7) = Worksheets("Forecast").Cells(32, 7) + number_modifications
      End If
      If region = "Asia Pacific" Then
```

```
        Worksheets("Forecast").Cells(32, 8) = Worksheets("Forecast").Cells(32, 8) + number_modifications
    End If
    If region = "Africa" Then
        Worksheets("Forecast").Cells(32, 9) = Worksheets("Forecast").Cells(32, 9) + number_modifications
    End If
    If region = "Middle East" Then
        Worksheets("Forecast").Cells(32, 19) = Worksheets("Forecast").Cells(32, 19) + number_modifications
    End If
    If region = "Latin America & Caribbean" Then
        Worksheets("Forecast").Cells(32, 20) = Worksheets("Forecast").Cells(32, 20) + number_modifications
    End If
    If region = "North America" Then
        Worksheets("Forecast").Cells(32, 21) = Worksheets("Forecast").Cells(32, 21) + number_modifications
    End If
End If

If scenario_type = "Overall Redesign of Domestic Cabins" Then
    If region = "Western Europe" Then
        Worksheets("Forecast").Cells(33, 5) = Worksheets("Forecast").Cells(33, 5) + number_modifications
    End If
    If region = "Eastern Europe" Then
        Worksheets("Forecast").Cells(33, 6) = Worksheets("Forecast").Cells(33, 6) + number_modifications
    End If
    If region = "China" Then
        Worksheets("Forecast").Cells(33, 7) = Worksheets("Forecast").Cells(33, 7) + number_modifications
    End If
    If region = "Asia Pacific" Then
        Worksheets("Forecast").Cells(33, 8) = Worksheets("Forecast").Cells(33, 8) + number_modifications
    End If
    If region = "Africa" Then
        Worksheets("Forecast").Cells(33, 9) = Worksheets("Forecast").Cells(33, 9) + number_modifications
    End If
    If region = "Middle East" Then
        Worksheets("Forecast").Cells(33, 19) = Worksheets("Forecast").Cells(33, 19) + number_modifications
    End If
    If region = "Latin America & Caribbean" Then
        Worksheets("Forecast").Cells(33, 20) = Worksheets("Forecast").Cells(33, 20) + number_modifications
    End If
    If region = "North America" Then
        Worksheets("Forecast").Cells(33, 21) = Worksheets("Forecast").Cells(33, 21) + number_modifications
    End If

End If
(….)
End Sub

Sub compute_total_modifications()
Dim index As Integer

  For index = 5 To 21
  Worksheets("Forecast").Cells(32, 4) = Worksheets("Forecast").Cells(32, index) + Worksheets("Forecast").Cells(32, 4)
  Next index
  For index = 5 To 21
  Worksheets("Forecast").Cells(33, 4) = Worksheets("Forecast").Cells(33, index) + Worksheets("Forecast").Cells(33, 4)
  Next index
  For index = 5 To 21
```

```
   Worksheets("Forecast").Cells(34, 4) = Worksheets("Forecast").Cells(34, index) + Worksheets("Forecast").Cells(34, 4)
   Next index
End Sub
```

Sub project_freighter_conversion()

```
 Call compute_fleet_distribution 'compute and write the freighter world fleet
 Call compute_conversion_volume 'compute and write the total volume of freighter conversion
 Call write_conversion_distribution 'compute and write the world distribution of freighter conversions
End Sub
```

Sub compute_conversion_volume()

```
Dim index As Integer
   Worksheets("Freighters").Cells(13, 5).Value = Worksheets("Freighters").Cells(13, 3) * Worksheets("Freighters").Cells(13, 4).Value 'multiplies the freighter fleet forecast with the freighter conversion proportion
   Worksheets("Forecast").Cells(35, 4) = Worksheets("Freighters").Cells(13, 5).Value 'write the total amount of conversions
End Sub
```

Sub compute_fleet_distribution()

```
Dim region As String
Dim sheet As Worksheet 'describes the worksheet we work on
Dim row As Integer 'describes the row of this worksheet we work on
Dim index As Integer 'useful for the distribution of the fleer (at the end)
row = 18 'row gives the number of the current row. Information begins at row number 18.
Dim fleet_volume As Integer 'counts the freighter world fleet volume
fleet_volume = 0
Worksheets("Freighters").Range("C18:J18").ClearContents

For Each sheet In Worksheets
   If ((sheet.Name = "Forecast") Or (sheet.Name = "Aircrafts") Or (sheet.Name = "Airlines") Or (sheet.Name = "ExecutiveJets") Or (sheet.Name = "Freighters")) Then
   Else 'scan only the worksheets about commercial airplanes
      row = 18
      Do While sheet.Cells(row, 3) <> "" 'scan all the rows until the end of the sheet(we consider only one aircraft each time)
         If sheet.Cells(row, 5) = 1 Then 'considers only freighters
            fleet_volume = fleet_volume + 1 'counts the freighter fleet
            region = sheet.Cells(row, 7) 'scans the world region where this aircraft is based
            If region = "Western Europe" Then
               Worksheets("Freighters").Cells(18, 3) = Worksheets("Freighters").Cells(18, 3) + 1 'counts and write the freighter fleet of Western Europe
            End If
            If region = "Eastern Europe" Then
               Worksheets("Freighters").Cells(18, 4) = Worksheets("Freighters").Cells(18, 4) + 1
            End If
         (……)
         End If
         row = row + 1 'goes to the next row
      Loop
   End If
Next sheet
Worksheets("Freighters").Cells(18, 2) = fleet_volume ' write the freighter fleet volume
For index = 3 To 10
   Worksheets("Freighters").Cells(18, index) = Worksheets("Freighters").Cells(18, index) / fleet_volume ' compute and write the distribution of the fleet
Next
```

```
End Sub

Sub write_conversion_distribution()
Worksheets("Forecast").Cells(35, 5) = CInt(Worksheets("Freighters").Cells(18, 3) * Worksheets("Freighters").Cells(13, 5))
'multiplies the total number of conversion by the fleer proportion of that region and converts the result into an integer.
Worksheets("Forecast").Cells(35, 6) = CInt(Worksheets("Freighters").Cells(18, 4) * Worksheets("Freighters").Cells(13, 5))
(…)
End Sub
```

Sub project_VIP_modification()

```
Dim duration As Integer 'contains the duration of a VIP modification
Dim frequency As Integer 'contains the time between two modifications
Dim time_available As Integer 'contains the the period within which VIP modifications will be undertaken
Dim number_modification_aircraft As Long 'contains the amount of VIP modifications for one business aircraft
Dim total_modifications As Long 'contains the total amount of VIP modifications in the world
Dim aircraft_volume As Long 'contains the amount of business aircraft deliveries

duration = Worksheets("Forecast").Cells(17, 6) 'read the duration of a VIP modification in days
frequency = Worksheets("Forecast").Cells(17, 5) * 31 'read the frequency of VIP modifications in months and convert it in days
time_available = Worksheets("Forecast").Cells(17, 9) * 365 'read the time available for VIP modifications during the aircraft useful life (in years) and convert it in days
number_modification_aircraft = time_available / (duration + frequency) 'compute the number of modifications for one aircraft during its useful life
aircraft_volume = Worksheets("ExecutiveJets").Cells(13, 2) 'read the business aircraft fleet in the sheet ExecutiveJets
total_modifications = number_modification_aircraft * aircraft_volume 'compute the total amount of VIP modifications
Worksheets("Forecast").Cells(36, 4).Value = total_modifications 'write this result in the sheet Forecast
End Sub
```