Hochschule für Angewandte Wissenschaften Hamburg
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Bachelorarbeit

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The Process Chain for Private Jet Cabin Refurbishment

Fakultät Technik und Informatik
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Faculty of Engineering and Computer Science
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The Process Chain for Private Jet Cabin Refurbishment

Bachelorarbeit eingereicht im Rahmen der Bachelorprüfung

im Studiengang Kabine und Kabinensysteme
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Abteilung CAMO
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Summary

Nouran Hossameldin

Theme of the Bachelor Thesis

The Process Chain of Private Jet Cabin Refurbishment

Keywords

Interior, Modification, Refurbishment, Airworthiness, Approvals, Release, High utilization, downtime, and other interesting words describe the whole process.

Description

This thesis aims to investigate the process chain of refurbishing the private jet interior and discuss its Procedures not only for a better modification but also for avoiding every complexity in the management and delay in the downtime of the Jet. Additionally, process analysis techniques and flow chart methods will be discussed as a methodology for the process chain improvements.

Abstract

The thesis is accomplished in cooperation with “Air Hamburg Luftverkehrsgesellschaft” and carried out at “HAW Hochschule”. This paperwork concentrates on the refurbishment projects of the private jets to provide a comprehensive overview of the procedures in a simplified way for better improvement in the future to reach the optimal workflow strategy. The main challenges of the project will be investigated in detail, also solutions will be discussed to avoid the problems, which affect the business aviation (BA) industry.

In addition, a structured analysis technique is described and can be used as a functional analysis tool for the refurbishment project, which gives airlines and new employees, who are taking on the process, a better understanding of how the process is running and how it can be improved.

The downtime of the aircraft, costs, and unplanned tasks are also some of the main challenges spotted by the private jet airlines and some of the main reasons why the refurbishment project could be improper. That is why an optimal project procedure is investigated to improve the workflow in the BA industry.

Kurzreferat

Die Bachelorarbeit wird in Zusammenarbeit mit „Air Hamburg Luftverkehrsgesellschaft“ erstellt und an der „HAW-Hochschule“ durchgeführt. Die Thesis soll einem umfassenden Überblick über die Kabinen Überholungen sowie deren Probleme und mögliche Optimierungen aufdecken. Außerdem, wird eine strukturierte Analysetechnik beschrieben, den als Funktionsanalyse-Tool für die Kabinen Überholungen verwendet werden.

Die neuen Methoden des Projekts unterstützt die Fluggesellschaften und den neuen Ansprechpartnern, die das Projekt übernehmen, um ein besseres Verständnis von dem Prozessverlauf zu geben und wie der Prozess verbessern zu können.

Die Ausfallzeit des Flugzeugs, die Kosten und ungeplante Aufgaben des Projekts sind die wichtigsten Herausforderungen, die von den Privatjet Fluggesellschaften erkannt wurden. Darüber hinaus wird ein optimaler Projektverlauf mit neuen Methoden untersucht, um den Arbeitsablauf in der Business Aviation (BA) zu verbessern.

Hochschule für Angewandte Wissenschaften Hamburg
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FAKULTÄT TECHNIK UND INFORMATIK
DEPARTMENT FAHRZEUGTECHNIK UND FLUGZEUGBAU
Professor Gordon Konieczny.

Scope of the thesis

Name: Nouran Hossameldin

Theme: The Process Chain for Private Jet Cabin Refurbishment

Introduction

Cabin-related modifications and upgrades, especially on private jets, are some of the critical projects, that influence the present economy and growth of airlines worldwide. Private Jet Airlines need to convert and modify its fleet from time to time once required. This thesis will investigate the whole process behind the refurbishment of the private jet cabin and discuss the solutions, which reduce the downtime for the project. A great number of configuration parameters and criteria need to be handled and followed according to the standards of the European Aviation Safety Agency (EASA).

In Order to simplify the complicated process, some methodologies will be discussed to easily understand and track the whole process of the project life cycle. Additionally, solutions will be optimized for the difficulties occurring during the refurbishment project.

The way to handle the process and optimize it is essential for the aviation industry and interior stakeholders, this will lead to:

- utilize the thesis as a "Manual" for the refurbishment process when introducing new aircraft interior modification/retrofit projects.
- review the procedures and challenges for a better modification.
- Avoid any complexity and delay until release.

- Avoid the reasons, that lead to requiring a new refurbishment in a short period

And that's what the Thesis aims to.

During the thesis the following working points are considered:

- General concepts of the private jets business
- Initial consideration and requirements of the owner
- Major project challenges and their modifications
- Materials used for VIP cabin
- Engineering tasks and EASA certifications
- Methodologies for solving main challenges
- Implementation of the refurbishment until release to the customer

This Bachelor Thesis will be handled in cooperation with "Air Hamburg Luftverkehrsgesellschaft mbH., Hamburg". The industrial supervisor is:

Herr. Johannes Schmechel
CAMO Fleet Director

Hamburg
September 27, 2022

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List of Abbreviations

PAX	Passengers
A/C	Aircraft
HU	High Utilization
BA	Business Aviation
IBAC	The international Business Aviation Council
MRO	Maintenance, Repair and Overhaul
NBAA	National Business Aviation Association
EBAA	European business aviation association
DLR	Deutsches Zentrum für Luft-und Raumfahrt
GVA	Gross Value Added
IFE	Inflight Entertainment
AI	Artificial Intelligence
IPC	Illustrated Part Catalogs
CMM	Component Maintenance Manual
FTP	Flammability Test Plan
AMM	Aircraft Maintenance Manual
MX	Maintenance
DOA	Design Organizational Approval
EASA	European Aviation Safety Agency
OEM	Original Equipment Manufacturer
DO	Design Organizational
CS	Certification Specification
NAA	National Aviation Authorities

MOA	Maintenance Organization Approval
POA	Production Organization Approval
STC	Supplemental Type Certificate
ETSO	European Technical Standard Order
TC	Type Certificate
EB	Engineering Bulletin
HIC	Head injury criteria
CVE	Compliance Verification Engineer
IPC	Illustrated Parts Catalogue
FTP	Flammability Test Plan
MOC	Means Of Compliance
FAA	Federal aviation administration
FH	Flight Hours
FC	Flight Cycles
HU	High Utilization
AI	Artificial Intelligence
KBE	Knowledge Based Engineering
SOW	Scope of Work
PN	Part Number
SN	Serial Number

1 Introduction

1.1 Motivation

Aviation is more than airplanes, technology, and approvals. It is also about the people who use and work with them. During the pandemic of COVID-19, a great number of flights on commercial airlines were cancelled, which also altered the travel mode preferences. A shift from commercial aviation to private aviation increased during the pandemic, which lead a category of passengers (PAX) to prefer travelling privately to avoid the contact between people in crowded commercial aircraft (Sobieralski 2021).

Replacing a commercial flight with a private flight is high expensive. That is why the category of PAX, who book these types of private flights, are usually groups of first-class friends and family members travelling on vacations as well as Entrepreneurs, who are travelling for business and whose work or meetings can not be cancelled. Therefore, the work on cabin refurbishment is highly increased to satisfy every PAX and Private Jet owner's requirements. They must get the best customer experience through the luxury, comfort, and safety in the cabin (Parker 2021).

The first sight for the customers in business aviation is the cabin, it also influences their feedback/review after landing. A high quality, optimally managed process chain, and operational excellence are the key factors for a good refurbishment project.

1.2 Keywords definitions

The title of the thesis is "the Process Chain of Private Jet Cabin Refurbishment", a detailed definition of some keywords will be as following described:

Process Chain

What is meant by process chain, is the sequence of the procedures which lead at the end to the completed refurbishment of the cabin (SAP 2022).

Refurbishment

Refurbishment is the interior services performed inside the aircraft and the process of modification, which renews the cabin. It has two ways whether a whole new design is required for the cabin with

new replacements or just modifying the old interior without buying new parts. Some of these services are like (ACM 2022):

- Interior design
- Upholstery
- Leather repair and recoloration
- Veneering / Varnishing / Revarnishing
- New carpets
- Lighting

Private Jet

A private Jet or business Jet is a jet aircraft designed for customers of high-end travel, who want to travel on their own alone or with a small group to their own destination with the highest luxurious and comfortable feeling (Parker 2021).

Downtime

A downtime of an aircraft is the scheduled time interval from the arrival until the next departure. It means the exact period when the aircraft is on the ground, which must be in all cases as short as possible to release the aircraft and be able to fly again.

1.3 Objectives

During the Thesis, the whole process chain of the cabin refurbishment is clarified from the beginning of the project until the last step which is releasing the aircraft to fly. A comprehensive overview of the cabin project is an analysis for every person involved in the BA industry to improve the procedures and avoid any complexity or failures in the project. Therefore, aims this work to:

- Create a process summary of the refurbishment
- Review all the failures and main challenges
- Identify solutions, that help to improve the project life cycle
- Present methodologies of managing and tracking the project through workflow strategy

- Discuss all the certifications and approvals taken to do the refurbishment and how this can influence the project
- Discuss the materials used for the high-quality and luxury targets
- Identify the benefits by reaching the optimal workflow of the cabin retrofit

1.4 Structure

The work will be structured and investigated in the following chapters:

Introduction in the VIP aircrafts	⇒ As an introduction, this shows up the importance of the private jets, different kind of them and their cabins and how the modification affects the market ⇒ VIP A/C. growth during the pandemic of COVID-19
Requirements	⇒ This chapter investigates how the requirement's procedure is taken and which considerations should be involved ⇒ Different types of refurbishment / modification ⇒ Selection of providers ⇒ The criteria of the selection phase ⇒ Offers from suppliers and comparison awareness for the best selection ⇒ In addition how the decision of the selection is taken
Engineering tasks and approvals	⇒ Identifying the main certifications and approvals needed to proceed the whole project of cabin refurbishment in according to EASA part 21J ⇒ Part 21G for productions and manufacturing ⇒ Part 145 for installation and removal ⇒ Also the Impact of the Engineering tasks on the process chain
Project main challenges	⇒ Factors, which drive the cabin to be refurbished ⇒ Down Time needed for the A/C on different tasks as well as for the refurbishment ⇒ Costs/Budgets in the business aviation industry ⇒ Occured unplanned tasks and their effectiveness ⇒ Companies competition

Required materials in business aviation (BA)	⇒ Discussing the different materials used in business jets ⇒ Flammability and approvals ⇒ Different methods for tests
Methodologies and improvements	⇒ Describing the High Utilization (HU) concept ⇒ Workflow Strategy ⇒ Discussing methods for manage, flow and track the process chain for better improvements
Implementation phase	⇒ How the refurbishment project is implemented ⇒ Before / After refurbished cabin examples ⇒ Quality control
Benefits and conclusion	⇒ Spotting the benefits of the improvements on the process chain ⇒ At the end a brief summary is indicated to give the reader an overview on the main points of the thesis

Table 1: Chapters of the thesis

2 Business / Private Jets

2.1 Introduction

Since the rate of travel highly increased worldwide, the need for business jets also increased and became more important. BA differs from the scheduled services airlines like Lufthansa, Air France, etc. It facilitates the travel for some PAX, who need to travel to their own destination when time matters most. They have full control over their schedule and more availability for airports other than scheduled airlines. Private jets travel to at least 3 times more destinations in one country in Europe than scheduled ones, which attracts more PAX and improves connectivity across Europe. It is a dynamic sector, which can be used for also medical transport or as a tool to help governments and businesses generate local economic development (Oxford 2012).

Compared to commercial airlines, not all kinds of PAX can travel with private jets. They are commonly used by business leaders, enabling entrepreneurs and wealthy people to travel whether for business or leisure.

The international business aviation Council (IBAC) has classified BA operators into three categories:

- Commercial
- Corporate
- Owner operated

One of the major companies that are defined under corporate type is BMW. A Commercial BA side is known as “Air charter”, where in Germany there are more than 60 air charter companies for example “Air Hamburg airline”. This kind of BA is probably the easiest and most economical way to shift from scheduled services and facilitate the customer’s journey.

Stakeholders in the BA systems are:

- Aircraft owners
- Maintenance, repair and overhaul (MRO) firms
- Fixed-base operators (FBO)
- Airports and airfields with a BA focus

- Air charter brokers
- Consultants and market intelligence
- Manufacturers of business jets and parts
- Airworthiness authorities

The definition of BA, according to the national business aviation association (NBAA), is all the non-scheduled and non-military flying for business purposes.

As the business aviation sector growing up also man crafts and job opportunities are increasing as shown in figure 2-1, in 2017 a case study is done by Deutsches Zentrum für Luft-und Raumfahrt (DLR), which shows up the number of employees in the business aircraft operators in Europe (EBAA 2018).

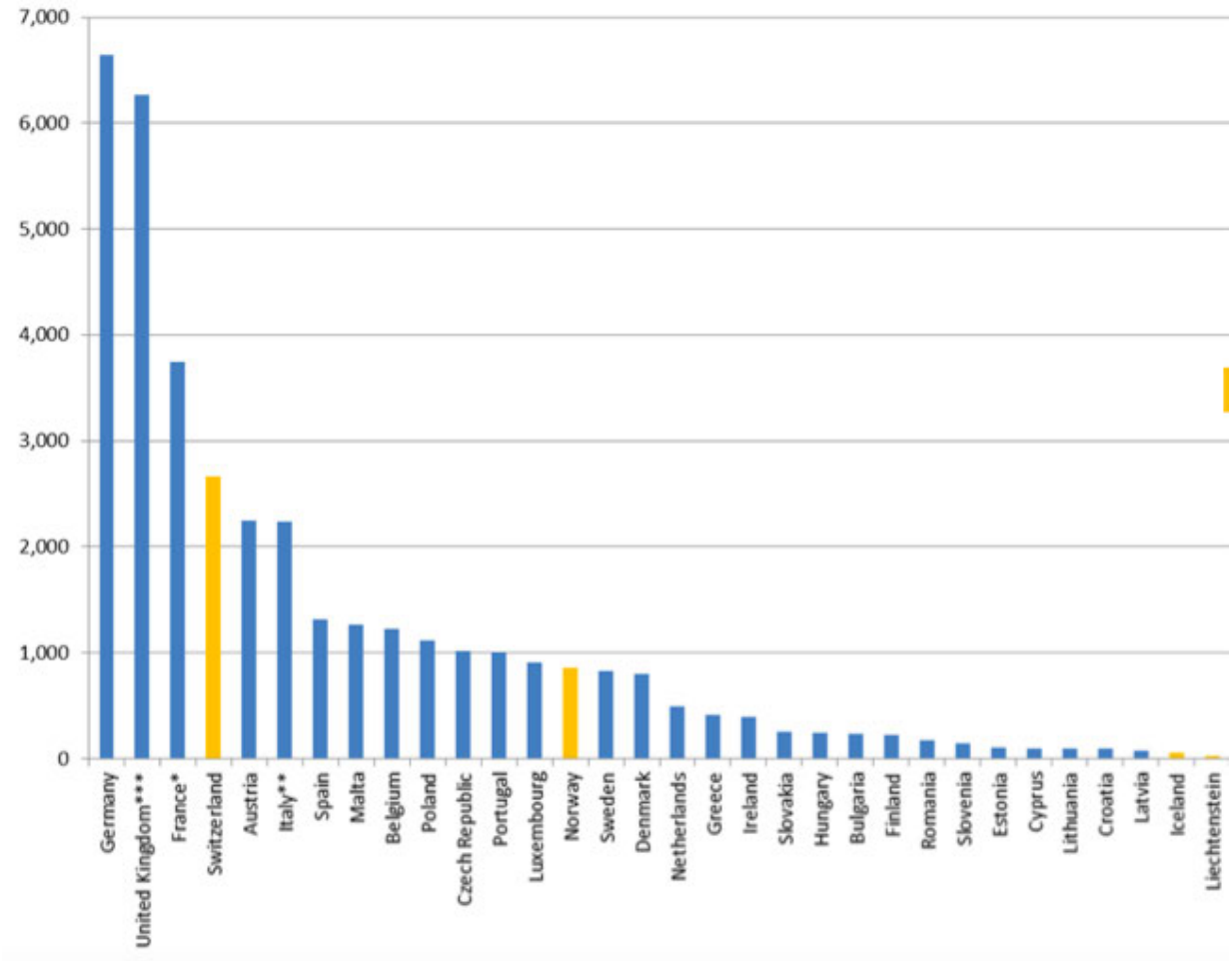


Figure 2-1: Direct employment of Business aircraft operators (DLR 2019)

Germany, the UK, France and Switzerland are the main players in this sector, producing 76% of the total gross value added (GVA) of the industry. Otherwise, according to the DLR research case in 2017, France is leading in BA manufacture, while Germany and the UK have higher shares in employment for operations.

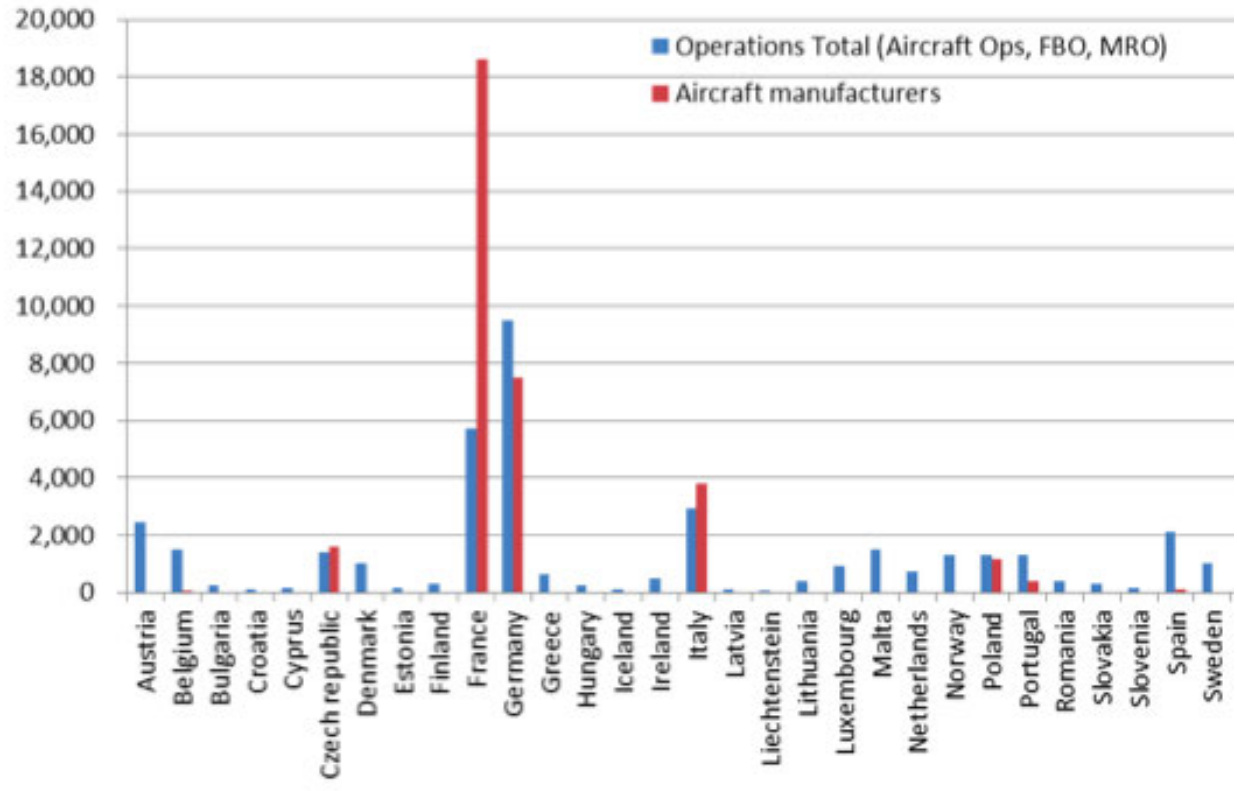


Figure 2-2: Total direct employment in the European business aviation sector (DLR 2019)

The business sector is also defined as a travel solution, which provides travel benefits that help in the improvement of the aviation industry. For many PAX, time is their priority while travelling. According to a study case, Private jet flights save an average of 127 minutes over commercial travel by scheduled airlines. Figure 2-3 shows the difference and the average time saved:

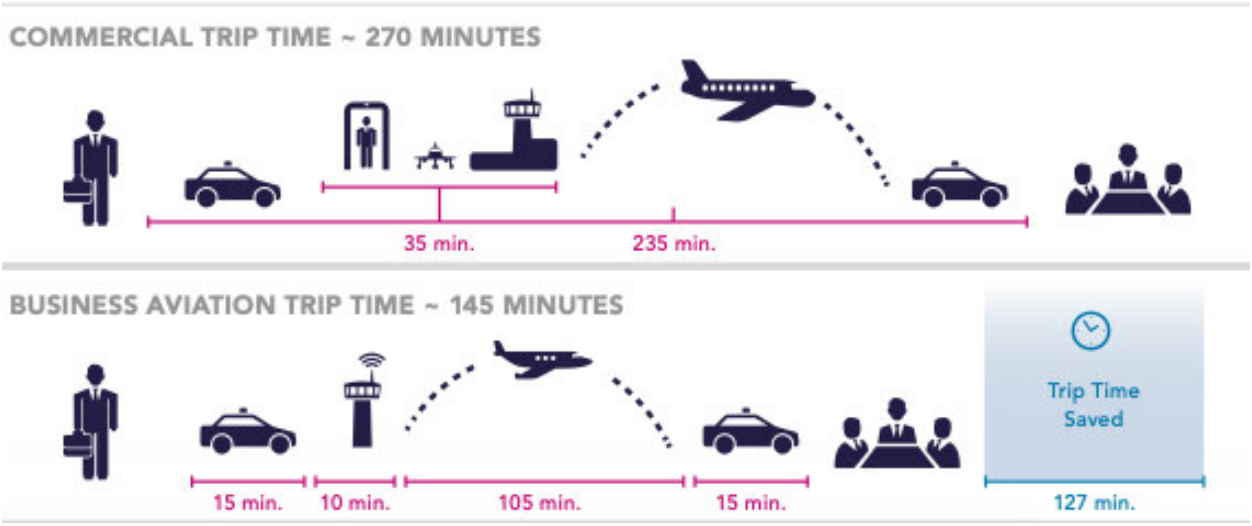


Figure 2-3: Average time saved for Business and Commercial Aviation (EBAA 2018)

Although the pandemic of COVID-19 had a huge impact on the commercial airline industry, the BA increased more at the beginning of 2021. The reason behind that can be clarified under three main facts, that PAX concentrated about:

1- Less crowded terminals, private check-ins, and a healthier atmosphere
2- Faster and fewer transfers as well as avoiding contact with others
3- Private and comfort flights on smaller planes

The high peak travel times fall especially in the summer and on major holidays. According to the WINGX weekly BA bulletin, May 2022 was the strongest month for recording the BA flights since the middle of 2021 as shown in figure 2-4. Global Charter, fractional, and private flights flew in May 2022 are 30% more sectors than in pre-pandemic May 2019, which confirms the growth of the Private jet airlines around the world (Sobieralski 2021).

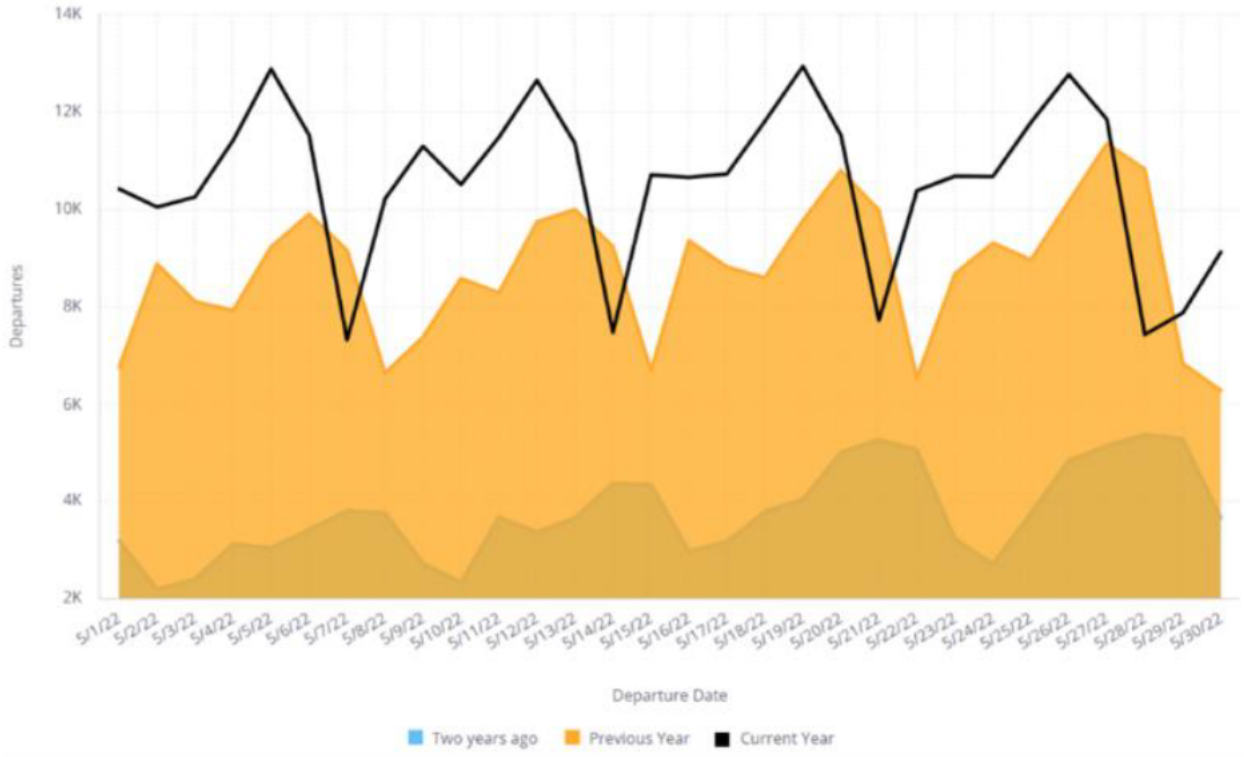


Figure 2-4: Comparable business jet activity in May 2022, 2021, and 2020 (WINGX 2022)

2.2 Private jet categories and markets

There are dozens of private jet models and each one has its kind of cabin. This leads to defining the different types of jets, that the current market has.

Jet Models	Examples and cabin growth
Very light	• Cessna Citation Mustang and Embraer Phenom 100 • Carries 4-6 PAX
Small light	• Embraer Phenom 300 and Cessna Citation XLS • Carries 6-8 PAX
Midsize cabin	• Embraer Legacy 450 and 500 • Carries 5-10 PAX

Super midsize cabin	• Embraer Legacy 600 and Hawker Beechcraft 4000 • Carries 8-13 PAX
Heavy	• Dassault Falcon 7x and Gulfstream G500 • Carries 10-18 PAX
Ultra-long range heavy	• Gulfstream G600 and G700 • Up to 19 PAX
Executive airliners	• BBJ (Boeing Business Jet) • The interiors of these jets vary frequently since they are all custom ordered

Table 2: Private jet categories (Claiborne 2022)

Each cabin of these models differs in capacity, dimensions, inflight entertainment (IFE), and design. There are no two business jets alike, which makes a detailed analysis and knowledge of the cabin on each aircraft a must for the refurbishment project. The reason behind that is the diversity of business jet owners. Each person has his individual needs in the cabin, which makes business aviation more interesting and attractive day by day.

The private jet interior must suit the personality of the owner, while the cabin is the place to work for some PAX, thus it must investigate the owner's desires to offer the concentration and environment needed. A business jet can be a flying meeting room, sometimes it is used to hold meetings and meet business partners, thus this environment should be reflected in the interior design. As well as the aircraft models differ, also the needs of customers in the cabin differ from type to type. Mainly this can be summed up in three categories:

- For some PAX, a cabin is a place for working productively while flying from point A to point B
- For others, it is an area for doing meetings
- It is also a comfortable place of retreat while travelling as a family or group of friends, in that case, perhaps more IFE is needed, a bed to lie on and a warm carpet to let the owner feels like in his living room (ACS 2021)

After knowing the desires of private jet owners, the modification/refurbishment of the cabin takes place when needed. The life of the private jet cabin is always variable, cabins are redesigned, refurbished, and converted from time to time. For this reason, the cabin modification market is growing fast. The interior of a business jet is like a car or an apartment which has two dimensions of focus:

- Form and function, or
- Aesthetic and pragmatic

At the end of the process, the refurbished cabin must satisfy the owner or the user visually and practically. While buying new private jets is very expensive, most of the owners prefer interior refurbishment to bring old aircraft into a new one. Even when a downturn Economic existed, the cabin market has recovered quickly and is growing continuously as shown in figure 2-5 (Scholz 2010).

Figure 2-5: Aircraft Cabin Interiors Market (Market 2020)

3 Cabin Refurbishment Requirements

3.1 Requirement Characteristics

Private Jets owners are different persons. They might be investors, private customers, which are the PAX themselves, or even a private jet airline like a charter airline. In some cases, the private jets are owned by the customer, but they are being operated by a subcontractor company (e.g., a charter airline), which is working on the customer's behalf to take care of the private jet and perform his requirements and all the needs whether a refurbishment or a Maintenance (MX). Depending on the aircraft situation and age, the owner or the CEO of a charter airline requests whether a refurbishment for the cabin or a whole design conversion besides the MX inspection. Whole cabin conversion scenarios are managed within a completion centre. This completion centre is responsible to complete all the desired changes, components, and approvals including weight, durability, appearance, and EASA regulations until the delivery to the customer.

The reason behind the refurbishment requested by a charter airline is different from a normal request by a private owner. Charter airlines concentrate not only on the cleanness and comfortable cabin experience but also on increasing their revenues. The purpose is to keep the cabin value as high as possible. Thus, they invest high expenses in the refurbishment of cabins to achieve their goals. Refurbishments are carried out to improve the saleability of an aircraft, it enhances the aircraft's resale value as well as the customer experience. In addition, a full refurbishment for the VIP cabins could generate 50% more return on costs. Therefore, a VIP cabin should be continuously retrofitted.

Once the request is out, the owner and the refurbishment centre will conduct a kick-off meeting. In this Meeting, all the details, downtime, and costs of the project will be discussed and determined.

In the refurbishment project, all the requests from the customer must be realistic as well as approved under EASA regulations. VIP cabin refurbishing is a project, which refers to a new development for the interior while removing the old one; such a process involves:

- Veneering
- Varnishing/Revarnishing
- Soft coverings of the seats, and carpets

- An upgrade in the lighting, displays, Headsets, etc.

The operators in this market segment have very challenging work and processes, from perfect appearance to safety and from custom artwork to high-quality special materials, like Vinyl leather or Ceramic coating. Engineers must consider all the developments under the certification constraints, which also must be clarified to the customer at the very beginning of the process. A set of boundaries are then conducted in the requirements phase, in order to extract and define the desires of the customer in technical terms (Nita 2009).

Existing Refurbishment Centres, like AeroVisto in Staad, Switzerland undertakes especially VIP Refurbishments, as this market field is continuously growing. The legal frame for dealing with such a Refurbishment centre is that they must hold a Design Organizational Approval (DOA) as well as a MOA (Maintenance Organizational Approval), issued by (EASA). DOA allows the environment for conducting an airworthy design, as it will be shown later (Nita 2009).

Once the owner decides on a refurbishment for the cabin, an interior survey must be performed, which is an inspection report to record the existing state of the entire cabin and give a potential analysis. This survey shows all the cabin components, which must be repaired, refurbished, or replaced.

The purpose of this analysis is to perform an inspection of the aircraft's interior (Galley, Passenger Cabin, Lavatory, etc.). According to the customer’s impressions and feelings, pictures and descriptions are provided within the survey. Although this task shows only areas where the refurbishment is needed, it does not assess the technical/Airworthiness condition of the aircraft. As follows is an example of defect areas in figure 3-1, which is detected in the main entry door of a private legacy jet.

Figure 3-1: Main Entry Door cutout on private Legacy

For the process chain of the project, it is very important to discuss the aircraft situation with the customer at least six months before the project starts, which is the optimal timeline. This permits the development of full work scope, determining the project period, costs, and having enough time to search for the best offer between the different Interior services companies. One of the parameters that should be determined in the requirement phase of the process chain is the selection of materials and colors.

Some customers prefer to change the interior color of the sidewall panels, ceiling, or even seats. While every single change in the cabin can affect the jet, an earlier visualization of the desired change in the VIP cabin is highly needed. Here comes the need for solutions based on Artificial Intelligence (AI), which will be explained as a methodology in the next chapters to improve the process chain of the project. Furthermore, if the project is being performed in cooperation with a subcontractor charter airline and the customer, then the layouts should be considered as shown in figure 3-2 (Nita 2009).

Materials Selection is one of the main challenges for the project, due to the Approvals needed for the different and various kinds of materials, which will be later explained. During the requirement

phase, the customer needs to specify which parts of the cabin, they want to refurbish or if there is any change in the design itself. Additionally, if the project is carried out on behalf of an operator, thus the downtime and the budget should be determined before sending the request to the refurbishment centre. Most of these requirements are determined in documents and discussed first with the Interior service facility to get at the end the best offer/quote, but this way of working can be optimized to facilitate the process and perform it faster and easier (Gregolin 2016).

Normally reporting the defects in the cabin are documented with photos and then summarized in the survey, which is the report, but this approach has several negative consequences on the whole process, some of them are as follows:

- Missing data about the defects (e.g., unclear photos)
- Inaccurateness of the place, where the defect occurs
- Took too much time to analyze and report the survey

To avoid those problems a better method will be later discussed under the “Methodologies” chapter to improve the process and perform it faster.

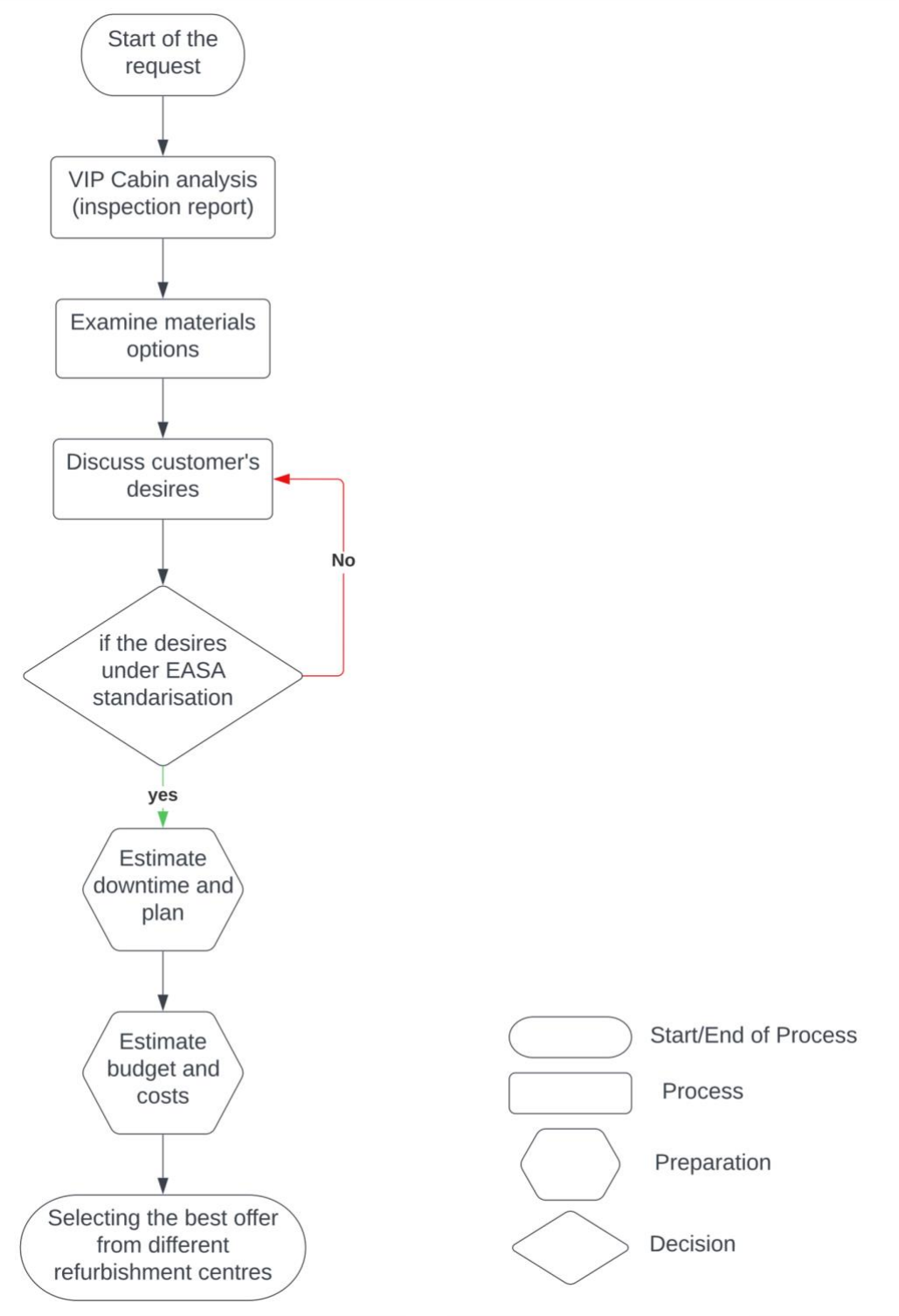


Figure 3-2: Flowchart of Requirement Phase, by Lucidchart

3.2 Selection of Service Providers

After discussing the design, Materials, and the required refurbished parts in the cabin with the customer, the project is being analyzed and prepared for the next step, which is the selection of the refurbishment centre. To answer the question of who can undertake the cabin refurbishment, the following three main criteria should be considered:

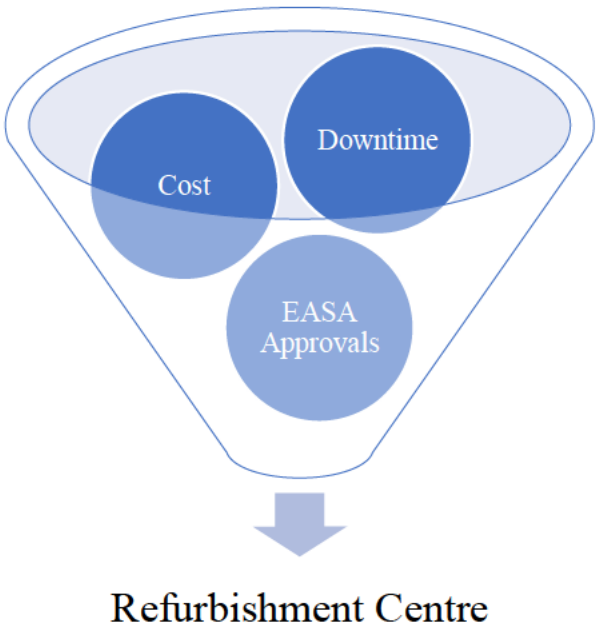


Figure 3-3: Major criteria for the selection of providers

One school of thought prefers using the aircraft's Original Equipment Manufacturer (OEM) to handle the completion work. As they believe that the original manufacturer is the best centre that knows every detail in the A/C. They also believe that with the OEM it is much easier to have the knowledge and all needed documentation of the aircraft that need to gain approval from the regulatory authority (Szasz 2009).

Nevertheless, while this field is growing too fast, there is a lot of approved service centres built up in the last years and that is why there is another school of thought, that prefers to let such a certified service centre perform the compliance on the private jets. Companies that specialize in some specific elements in the cabin have their advantages and disadvantages, but in the meantime, operators/customers always search for a company that handles all the requested refurbishment in the same place. As an example, some companies renew the carpet, others manufacture the seats and divans, others the galley or entertainment systems and in the end, they collect all the parts

together again. On the other hand, there are interior service centres, which have sufficient technicians to do all these tasks at the same place, which is more preferred (Szasz 2009).

These centres must provide customers with three major fundamentals as shown in figure 3-3. First, they should be able to perform the service in the shortest time possible depending on their capacity peaks because the downtime of the aircraft is always one of the criteria that provides negative consequences when it gets longer than requested. It also reflects the scope and the quality of the work ahead. Second, there is always competition between the companies to provide the best possible refurbishment and gain the customer's trust for future deals, which makes the offer an attractive factor for the selection.

Furthermore, every refurbishment project focuses on both the scope of cabin changes and the total costs. The status of the current cabin, which is called (Before Modification), and the requested future cabin status (After Modification) need to be documented and compared to each other. These documents will be then collected and identified by the refurbishment centre to estimate the costs needed as shown in the following figure (Szasz 2009).

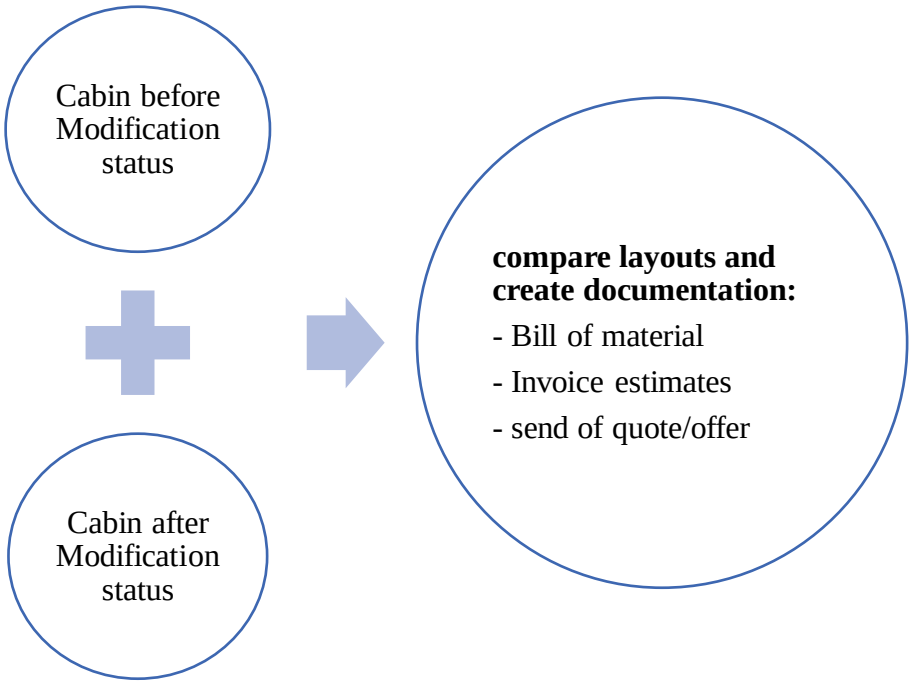


Figure 3-4: Concept of Invoice Statement (Szasz 2009)

The last factor, which is the certification phase is a must to start the refurbishment. Thus, a completion centre can not perform any changes on the A/C without EASA approvals inside Europe. As a result, the selection of a service provider is considered in accordance with:

- The time attractiveness
- High quality
- Technical feasibility and regulations
- The high performance within the intended cost bracket

The design and appearance of the cabin play a big role in the process as it reflects the customer's character. It allows creating and showing of objects and spaces in a way that suits the owner's tastes or to create a personal statement. Meanwhile, with the growth of individualization, companies are making a big effort to show their business premises in a special and recognizable look and feel, to inspire customers in order to remain in their memory. Although the new cabin should reflect the style of the owner or the ambiance of several business jets of a charter airline, it should also reflect the high quality of the completion centre's work (Hindawi 2021).

Once an interior-service facility is certified to develop an airworthy design, the requirements of the customer become the main priority and focusing point for the engineers. Thus, the reported survey plays a big role to identify the tasks, then the fact-finding and analysis phase begins in the company before signing the contract with the customer. In this phase, the company's capacity is evaluated, and the estimated cost is added. If the refurbishment takes longer than the requested time by the customer, then a re-evaluating downtime must be discussed (Nita 2009).

In addition to the Maintenance Repair and Operation's costs (MRO), all the certifications' costs must be taken into consideration to evaluate the pricing quote. These tasks include all the tests (e.g., Burn tests for materials), Design approvals according to EASA, Weight & Balance (W&B) of aircraft, and additional costs. The following summarized process in figure 3-5 clarifies the different phases before signing the contract with the customer:

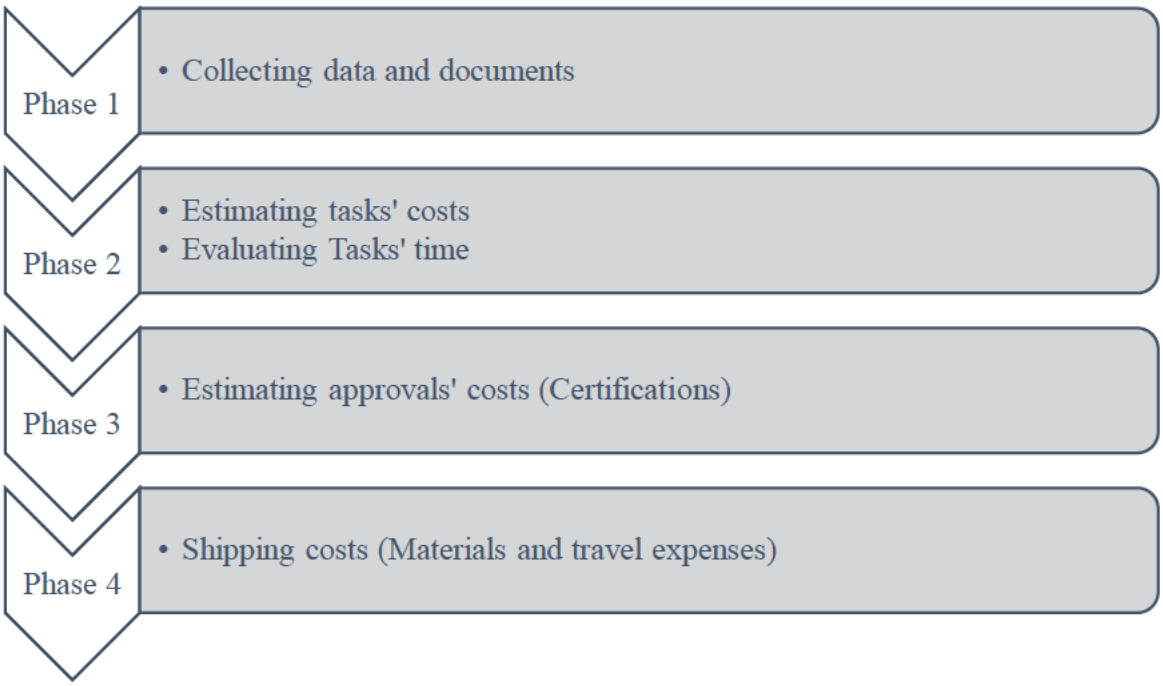


Figure 3-5: Company's Pricing Quote analysis

As mentioned above, EASA Approvals/Certifications are one of the main important factors that affect the whole process chain of the project and without them, the refurbishment can not be performed by any interior-service company (facility). To hold these certifications, a detailed description of the engineering tasks will be in the next chapter clarified.

4 Engineering Tasks

4.1 Certifications and types of organization

Once an offer from the customer is published and accepted by the completion centre (refurbishment facility), a certification procedure is handled for the cabin interior's modification. the Design Organisation (DO) controls the regulations of the A/C type under EASA standardization with the applicable Certification Specifications (CS) also referred to as Airworthiness Codes, which can be estimated under two types:

CS 23	For small, normal, utility, aerobatic, and commuter categories of airplanes
CS 25	For large and turbine-powered A/C.

Table 3: Certification Specification types (EU Parliament 2018)

The CS describes the minimum requirements, that must be fulfilled to meet the certifications and approvals for an aircraft. Each approval for any task in the cabin can affect the process chain of the whole project. Some refurbishment companies aren't allowed to perform all work needed on the A/C; they don't have the EASA certification/approval for all tasks. That's why they collaborate with other design organizations to handle the remainder of the work. In instances where many companies are working on the same project a type of homogeneity and precise time management must be established to ensure the cabin is refurbished on schedule, with high safety and quality. To achieve the safety requirements needed for this alteration, three main entities interact together. They are as follows (EU Parliament 2018):

Entities	Tasks
The regulator	Sets the rules and certifies the products in the cabin
The designer	Establishes and maintains an airworthy design
The operator	which is in this case the "refurbishment centre". takes care of the modification and maintenance within the procedures and limits specified by the regulator and the designer

Table 4: Entities types and tasks

Inside Europe, the regulator is represented by the certification agency which is EASA and there are several authorized companies to conduct the certified new products. Another term is being used by EASA to designate the organizations, which comprise the design activities for developing products and this term is called Design Organization (DO) as mentioned above. As next, the contribution case between the DO and the refurbishment centre will be discussed in detail (Nita 2009).

Normally the cabin refurbishment certification process can take from 2 to 4 weeks, but sometimes it takes up to 6 weeks depending on the project volume and what exactly will be re-designed/refurbished. Input for achieving this objective was given directly from the DO, through the company QCM design GmbH. As follows is a timeline to recognize the process until the release of the A/C to fly again.

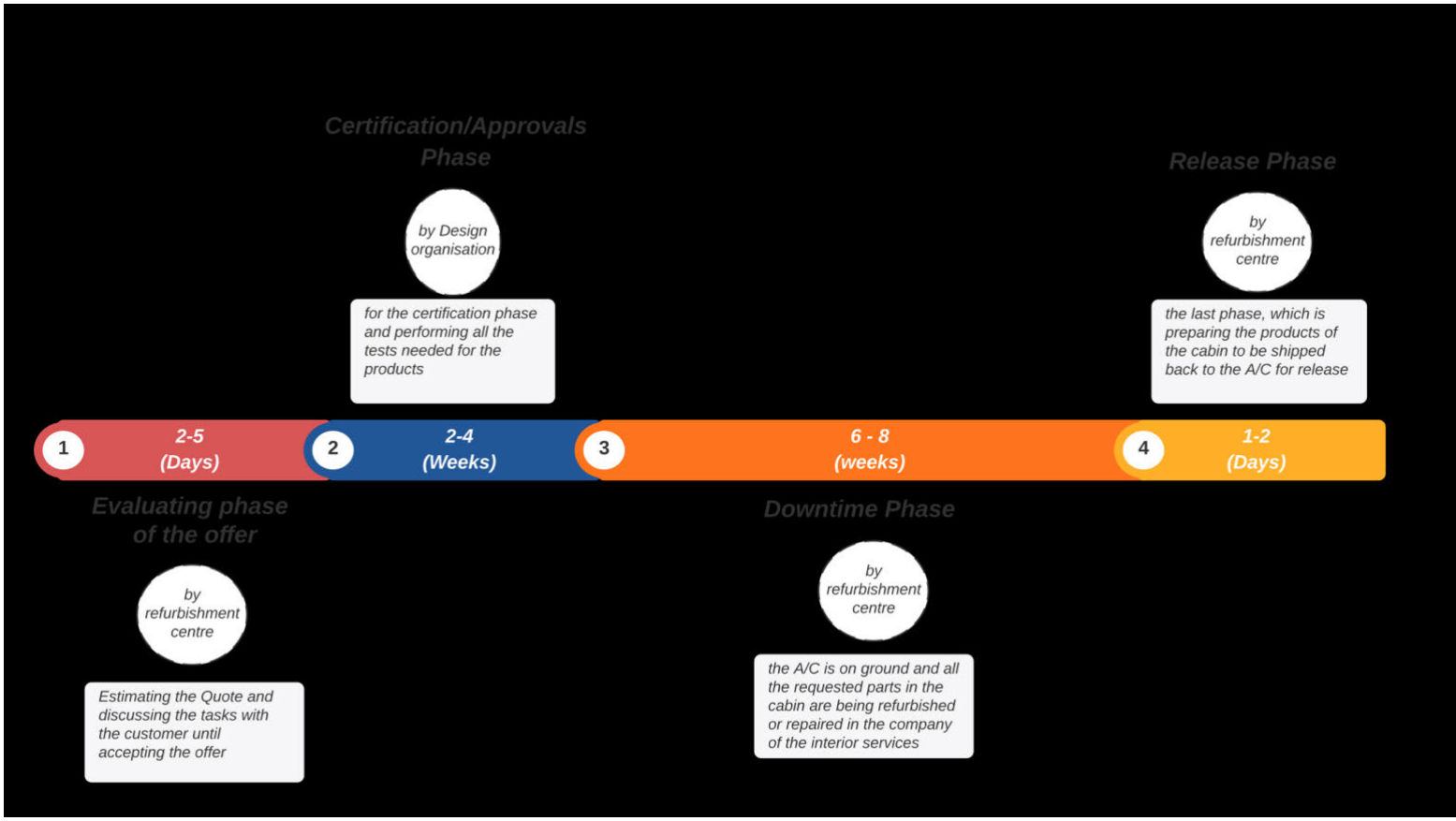


Figure 4-1: Timeline of the Refurbishment project, by Lucidchart

To understand better the consequences of the engineering tasks on the whole process and why an improvement of the process chain should be designated, the importance and idea of regulations according to EASA will be explained. For a refurbishment project, three main approvals are mostly required:

- EASA Part 145 Maintenance Organization Approval (MOA)
- EASA Part 21G Production Organization Approval (POA)
- EASA Part 21J Design Organization Approval (DOA)

The implementing rules and requirements from the basic regulations of EASA are classed as “Hard Law”. The implementing rules are divided into many different rules, as next is a simplified chart to understand the main two rules and their functions as well as their subfunctions.

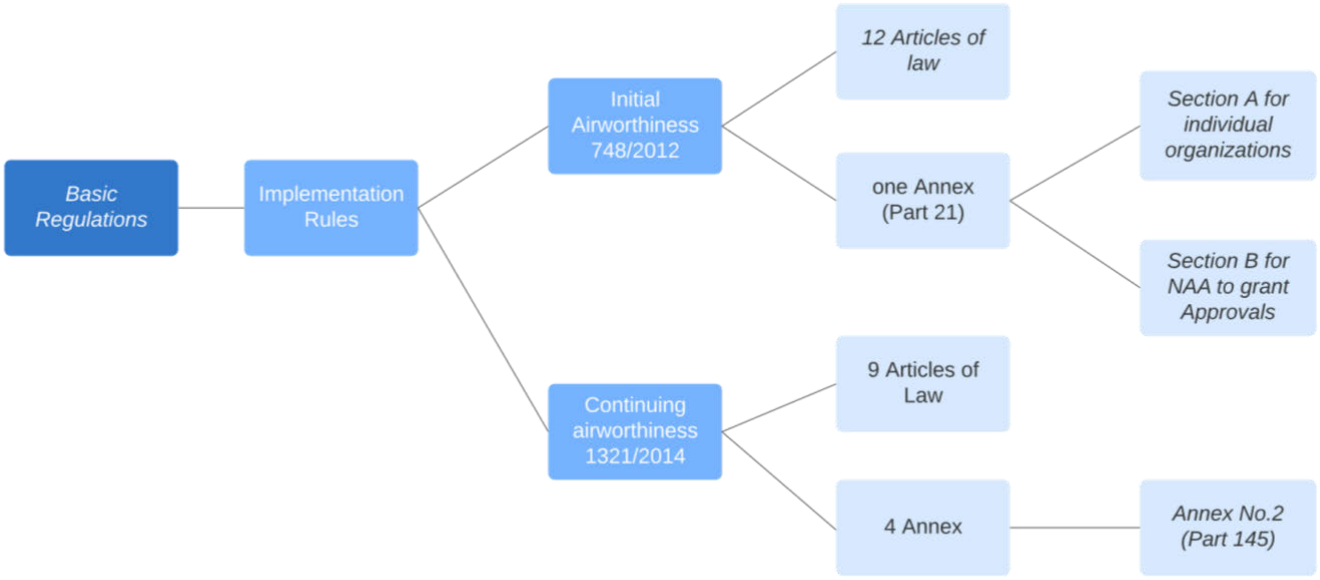


Figure 4-2: Functions of the implementation rules of EASA, by Lucidchart

Each Annex of the Implementation rules is broken down into section A and section B. Section A deals with the requirements to be met by the individual organizations. Section B covers the requirements of the National Aviation Authorities (NAA) to grant approvals. As it is shown in the chart, continuing airworthiness covers 4 Annex, where Annex No. 2 includes Part 145 requirements for organizations wishing to carry out and certify aircraft maintenance. As an

example, seats are one of the main components in the VIP cabins, which are often included in the project to be refurbished. PAX/Crew seats are not only refurbished as shown in figure 4-3 but also, might be repaired, thus the company must have such approval to perform this MX before the retrofit (EASA Part 21, 2020).

Figure 4-3: Cessna citation XLS Passenger seats after repair and upholstery, (AeroVisto 2022)

EASA Part 21 contains different subparts as shown in figure 4-4. Subpart "G" organization is an organization that has the approval to manufacture aircraft parts and appliances according with approved data. Subpart "J" is also defined as called; it details the elements required of a design organization (DOA) (EASA Part 21, 2020). Privileges of a DOA holder are as follows:

- Perform design activities within the scope of approval
- Have compliance documents accepted by the Agency (EASA) without further verification
- Perform activities independently from the Agency

As mentioned before the implementation rules are classed as Hard Laws, there are also separate documents containing Accepted Means of Compliance (AMC) and Guidance Material (GM), these are classed as "Soft laws". Since they are non-binding, regulated persons may choose another alternative means to comply with the rule. In this case, they still have to demonstrate how they meet the requirements.

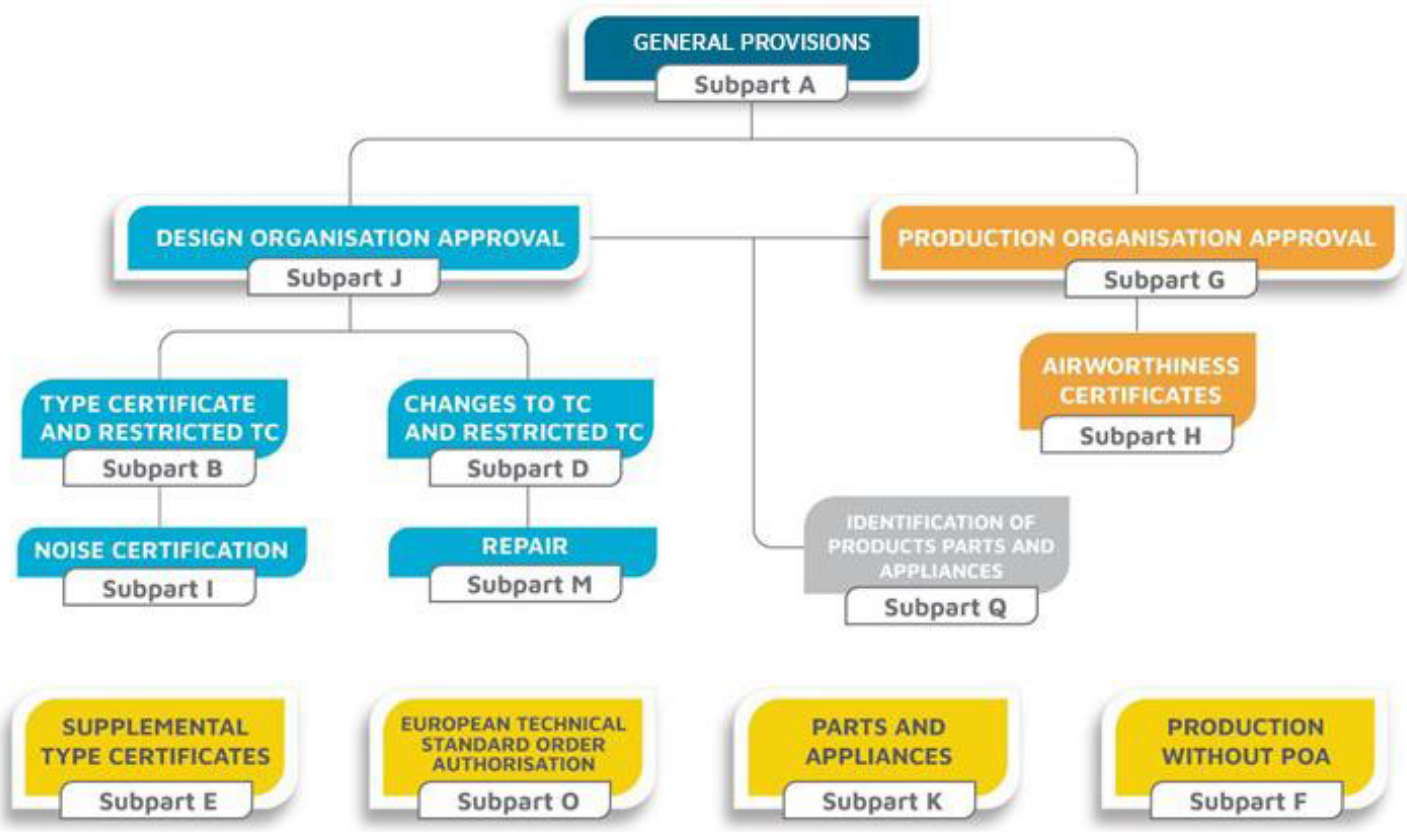


Figure 4-4: Subparts classifications of EASA Part 21, (SOFEMA)

To summarize, the subpart "J" together with the AMC and GM specify the requirements of EASA for a design organization in order to receive the approval to perform the refurbishment design.

4.2 Classifications of change

To ease the procedures of the refurbishment, EASA classifies the alteration in the cabin into two categories:

- Minor change
- Major change

These two categories are set according to the tasks done in the cabin. No matter if the change is for transforming a whole large aircraft e.g., from PAX to PAX or cargo to PAX, or even modifications in the VIP cabin, the processes are the same, they go all through the same steps and way to be handled. In figure 4-5, the flowchart shows how the decision is taken and how the

changes are classified according to EASA. The Interior-service company, which holds a DOA, has the privilege to classify the changes in the cabin under the specifications of EASA (Nita 2009).

Mostly all the refurbishment projects of the VIP jets are titled under “minor change” unless any factor occurred from the major aspects. Thus, if it is a major change, a request must be added to a third-party for a Supplemental Type Certificate (STC). The STC Holder is responsible not just for the modification but also for the interface, which means the impact on the original Type Certificate (TC). As it adds to the existing TC, it is deemed “Supplemental” (EASA CM 2021).

Minor Change has no effects on the mass, balance, structural strength, reliability, operational characteristics, or other characteristics affecting the airworthiness of the product. Any change has to be substantiated regardless of classifying the change as minor or major; the responsibility is on the European Technical Standard Order (ETSO). As a general criterion, a change is classified as “minor” if it does not require a complete reinvestigation for compliance assessment to the applicable requirements. Thus, an ETSO holder can perform the minor changes too, but for major change, that could lead to a new ETSO authorization. For the efficiency of the process chain, if the project includes a DOA, thus an early contribution should start between both the DO and the refurbishment centre to support the customer and finish the tasks in the scheduled time (EASA CM 2021).

Starting the certification process in parallel to the pricing-quote phase helps to reduce time and errors and to avoid any unplanned tasks, that could occur in the middle of the implementation phase. Mainly the steps are:

- Establishing contacts with the authorities and company responsible for the refurbishment
- Preparing certifications for the tests (flammability, heat release, smoke emissions, etc.)
- Preparing the Engineering Bulletin (EB)
- Creating certification documentations
- Signing the declaration of compliance

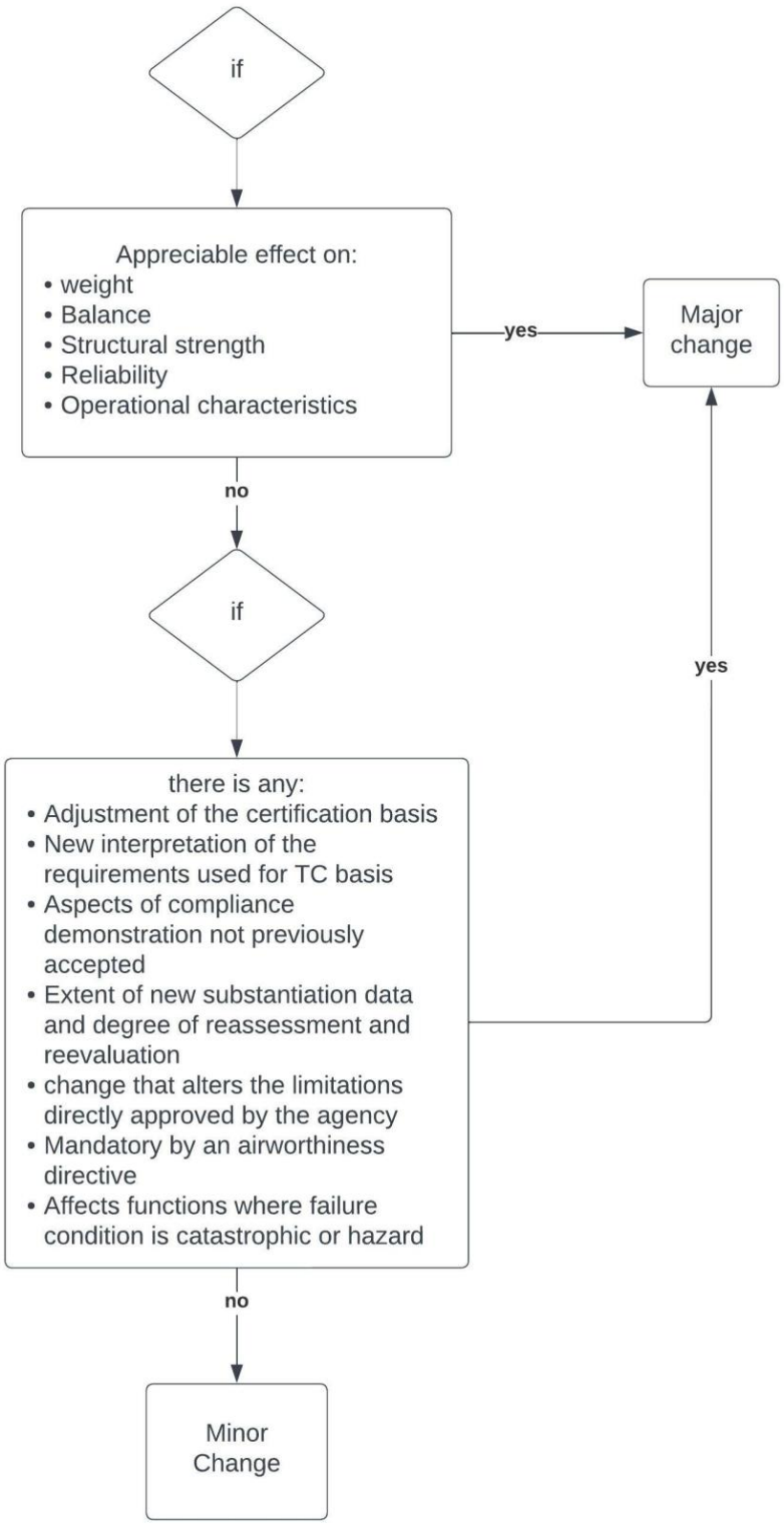


Figure 4-5: Classification process of Minor and Major changes, by Lucidchart

4.2.1 Examples of major change for cabin safety

Examples
⇒ 16G Seats: which are dynamic standards for all PAX and cabin crew seats protection against serious head injury (HIC), where head contact with seats or other structures occurred.
⇒ Changing cabin layout, which affects the emergency evacuation or access to exits
⇒ Installation of new avionics
⇒ Pressurization control system
⇒ Low heat/smoke release tests, which is depending on used materials in the cabin
⇒ Installation of new design elements for dividers (Partitions)
⇒ Installation of new toilets or wardrobes

Table 5: Examples of major change for cabin safety (Maurine 2019)

During a refurbishment project in November 2017 for a Bombardier Global Express, the customer required some new designs in the cabin. The project was sent to the DO (QCM GmbH) to approve and create the certifications. In the analysis phase of the design, the DO came out with two tasks, that were affecting the safety in the cabin, and they could not provide the approval for these two tasks. As shown in figures (4-6 and 4-7) this is the 3D model of the new required design by the customer:

Figure 4-6: Central cabin view for new design, (QCM design GmbH).

As shown in figure 4-6 through the data input received from the company "QCM design GmbH"; the customer requested a divider between two areas in the middle of the cabin to separate the aft part from the middle one. The problem occurred because the PAX seats are located exactly in front of the divider door. Thus, a 16G requirement could not be fulfilled in this case. In addition, the bulkhead standards were missing, as the safety requires curvy bulkheads in the corners, which is not the case in these PAX seats, to prevent any critical injuries during emergency landings. Therefore, the DO could not provide the refurbishment facility with the needed certification for these elements, and they discussed together a new improvement for the bulkheads. The consequences for this case were:

- Negative results on the time of the project, because the required design did not fit with the downtime period
- Negative effects on the costs

Therefore, it is always preferable for the DO to be notified of the project request before the refurbishment facility accepts the offer and sends the quote. This ideal procedure, while possible in theory, does not work in practice, as it is always difficult to achieve this coordination between the DO and the refurbishment centre (QCM 2022).

Figure 4-7: Rear powder room view for new design, (QCM design GmbH)

The most challenging part of the refurbishment project for the VIP Jets compared with the large aircraft for commercial airlines is that the customer needs have no limits, and everything can be requested, which complicates the achievement of the new design.

In the aft lavatory of the cabin, as shown in figure 4-7, the customer wanted to design a bronzed mirror along the whole door. the DO could not accept the request because of the following reasons:

- Does not fit with safety requirements; the mirror must not touch the ground and designed along the whole door
- The excessive length of the mirror produces negative results in the flammability test
- Safety effects during the emergency landing, because of the weight

The alternative idea for this design was to produce a shorter mirror in the middle of the door instead of producing it too long. Thus, the mirror would not touch the ground and would comply with safety standards while also decreasing the weight of the door and avoiding an overconsumption of material (QCM 2022).

4.2.2 Documentations and procedures

The flow of the processes and documents for the VIP cabin refurbishment project should be organized in a method, that reduces the parameters like time, costs, efforts, and errors. The path of the process starting from the offer till the certification phase will be presented below.

The first phase to define is the customer requirements made in the offer phase. It starts with the customer request, which is formalized into preliminary documents, describing in detail the owner's requirements and the implications within the DO. At the same time, a feasibility study should be created by the engineering office, to compare if it is a benefit for the company to accept the proposed task or not. As shown in the last example of the Bombardier Global Express, it would be quite difficult to comply with the requirements from the customers, when it comes with products, which are not conforming to the type certification standards. Thus, if each task process ends with a “yes” to all the standards specifications, then the process enters the next phase as shown in figure 4-8 (Nita 2009).

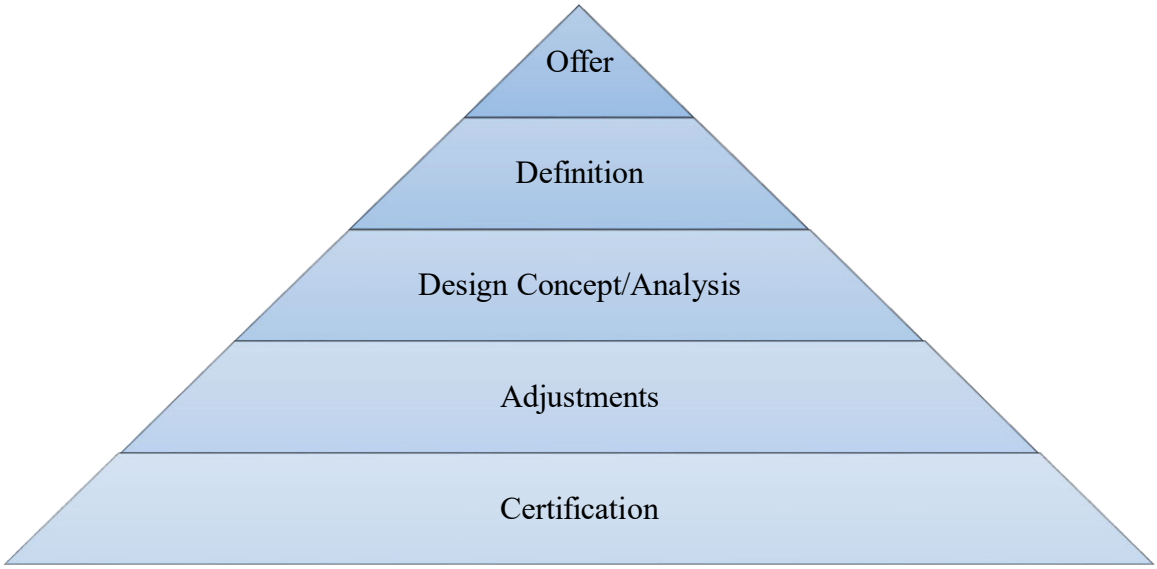


Figure 4-8: Process chain concept up to the certification phase

1) **Offer Phase**

It is the first phase for accepting the project from all the companies working on it. The actions required at the beginning of the project should be followed by the refurbishment company as below:

- Understanding and filtering the customer requirements
- Evaluating and filtering the certifications and tests needed
- Creating an internal feasibility study
- Considering the design possibilities
- Organizing the workflow
- Organizing the preliminary design

2) **Definition Phase**

Coming up with the definition phase means approaching the same tasks of the offer phase but more in-depth and under the DO's supervision, with the aim of achieving the final version of the design.

- Receiving the aircraft documents, which are:
    - Illustrated Parts Catalogue (IPC)
    - A/C Survey, detailed pictures of parts to see which parts will be refurbished beside the required materials for each product
    - Component Maintenance Manual (CMM)
- Defining the certification standards
- Defining the means of compliance
- Creating the Engineering Bulletin (EB) as a first version, which means not fully completed version
- Defining the process steps of certification
- Creating the engineering team
- Analyzing the different parameters between components
- Performing material tests
- Validating the design concept

3) **Design Concept Phase**

The design phase includes the responsibility of 5 main persons, which are:

1- Head of the DO

2- Head of the office of airworthiness
3- Compliance Verification Engineer (CVE)
4- Design Engineer
5- Quality management engineer

The work within this phase is based on the cooperation of the team mentioned above. Mainly during this phase, it is required to:

- Perform the design according to the standards elaborated during the earlier phases
- Verify the last update of the design
- Give feedback on the project

4) Adjustment Phase

It defines a summarized phase of the activities, to prove that the company is able to deliver the cabin modifications certification. Some of the processes during this phase are as follows:

- Getting feedback from the engineers
- Comparing the weakness point with other projects
- Proposing points of improvement

5) Certification Phase

The last phase is approving all the required modifications to the products and proving that the design complies with all the requirements stated in the specifications emitted by the authority. Thus, the refurbishment facility takes over and begins with the implementation tasks. At this time all the required documentation will be sent to the other partner, the main documents are:

- EB as a draft for proofing, to check affected parts with assigned materials
- Means Of Compliance (MOC)
- Flammability Test Plan (FTP) with the materials requested or surrogate panels, which will be presented in the next chapters
- Performed Burn Tests

5 Challenges of the VIP Cabin Refurbishment

5.1 Materials Approval

The first challenge, that faces the cabin refurbishment project is choosing the right and acceptable materials according to the regulations. One of the difficulties, which often occurs by the refurbishment companies, is that they do not consider early the exact time needed for the approvals of materials, which affects later the downtime of the A/C. If the materials have been selected after signing the refurbishment project, the facility would be facing multiple charges and longer downtime, which should be prevented from the start. That's why it is always preferable to discuss the material selections and approvals with the customers before the "offer" phase to get an accurate timeline from the refurbishment facility. This management will also help to create a realistic budget according to the cost of materials testing and based on the design.

Furthermore, all the materials must be tested before the installation to get the approvals in order to be used in the cabin, which is an intensive and expensive scope of work. The main four tests applied to the materials are as follows:

- Flammability test
- Heat Release
- Smoke emissions
- Toxicity

Private jet fires are more critical than big aircrafts as the cabin space is smaller and there are no immediate means of escape when in flight. The ability to resist fire is one of the important properties of materials. The severity of materials depends on some factors, which are the minimum heat, temperature, and time required for the material to ignite. In addition, the rapidity of the flame once ignited, the tendency of the flame to be self-extinguishing after removing the ignition source, and the toxicity of the gases produced by the burning materials. As next, the flammability factor will be discussed in detail to investigate its importance among the other factors (John 1964),

A flammability test is a test performed under the agency regulations, which is EASA in Europe or Federal Aviation Administration (FAA) in the USA. Both agencies have similar conditions and standards for these flammability tests. Refurbishing cabin interiors of existing VIP jets often includes replacing the finish on existing parts and creating a new composite build-up that must be

tested to determine its flammability characteristics and has to match the flammability requirements (FAA 2006).

Each material has a finish, which can be a paint, stain, varnish, laminate, or other combination. This finish is applied on the panel, which is the substrate element, which means the layer(s) of the whole material, that will be reused in the A/C. Panels are like Nomex honeycomb-core construction and wood paneling used in partitions, sidewalls, or ceilings, as well as veneered plywood and hardwood used in cabinets and furniture as shown in figure 5-1.

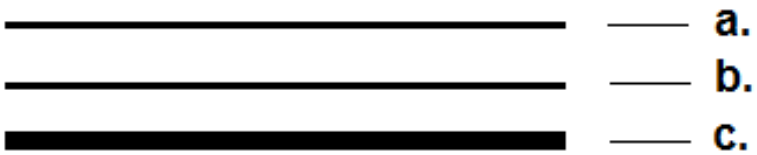


Figure 5-1: Cross section view of different layers for a material combination, QCM design GmbH

The composite build-up term means the configuration representative of the final material that will be installed in the aircraft. It will normally consist of the original panel of the A/C, and the new finish. The flammability standards according to the regulations specify that the certified laboratory should test the panel and the finish together as a unit specimen to check for any synergistic effects among the panel components when exposed to fire. Therefore, materials must be tested as a section cut from the fabricated part as installed in the A/C, which is called “Test Specimen Configuration” (FAA 2012).

When more than one material (i.e., leather & foam on a Window-liner, or lacquer & veneer on a bulkhead) is used to refurbish the same part in the cabin, a combination specimen is also taken into consideration and this unit is been tested as a “combination configuration” to show the effects when it is exposed to fire and build up an equivalent level of safety (FAA 2022).

This composite unit “combination configuration” of materials can also be a challenge for the design organization as it might have problems and cause unknown flammability behaviours, that is why it must be tested when combined (in the ‘as installed’ configuration).

5.1.1 Methods of testing

There are different methods of testing the specimens. Each method has its own procedures and criteria. The test procedures can be performed at different angles, to analyze the behaviour of the

specimen. Some tests are performed vertically, which are called “Vertical Bunsen Burner Tests” and they have two different time lengths. The first one is for 60-second length and the other one for 12-second length. Other procedures are done horizontally, at Forty-five degrees or even at sixty degrees.

There are several factors, that can affect the flammability test results. In order to prevent that, some factors need to be taken into consideration as follows:

- **Conditioning degree:** each specimen must remain in the conditioning environment until being tested under the flame
- **Specimen Thickness:** This must not be thicker than the minimum thickness approved to be qualified for use in the aircraft. As an example, test specimens of thick foam parts, such as seat cushions, must be ½ inch in thickness
- **Cut-out selection:** It is also a factor that influences the result in the end. It must be based on standards, otherwise such as sandwich panels may not be separated for the test.
- A minimum of three specimens must be tested and then the average result of them is taken

5.1.2 Different burn lengths of Tests

1) 60-second Vertical Test

In this kind of procedure, the specimen is aligned vertically and exposed to a Bunsen Burner flame at its lower edge in the centre. The test length means the distance from the original edge to the farthest evidence of damage to the test specimen due to flame impingement including areas of partial or complete consumption but not including areas stained or discoloured, nor areas where the material has melted away from the heat source. The 60-second vertical test according to (FAA 2006) can be performed on materials for:

- Interior ceiling panels
- Interior wall panels
- Partitions
- Galley structure
- Large cabinet walls
- Structural flooring

- Materials used in the construction of stowage compartments

2) 12-second Vertical Test

On the other hand, the 12-second vertical test is performed on the following materials:

- Floor covering
- Textiles (including draperies and upholstery)
- Seat cushions
- Padding
- Decorative and non-decorative coated fabrics
- Leather, trays, and galley furnishings
- Electrical conduit
- Air ducting, joint and edge covering

This test is also performed vertically on the specimen but for only 12 seconds and then removed. If the material could react differently depending, on which direction it is cut, it must then be tested in two different directions, e.g., vertically, and horizontally. In praxis woven materials like carpets must be tested with 3 samples “cut up” the roll and 3 samples “cut across” the roll (AeroBlaze 2022).

As shown below in figure 5-2 and 5-3, the sample is tested in a certified laboratory under a Vertical Bunsen Burner test for 60 or 12 seconds along.

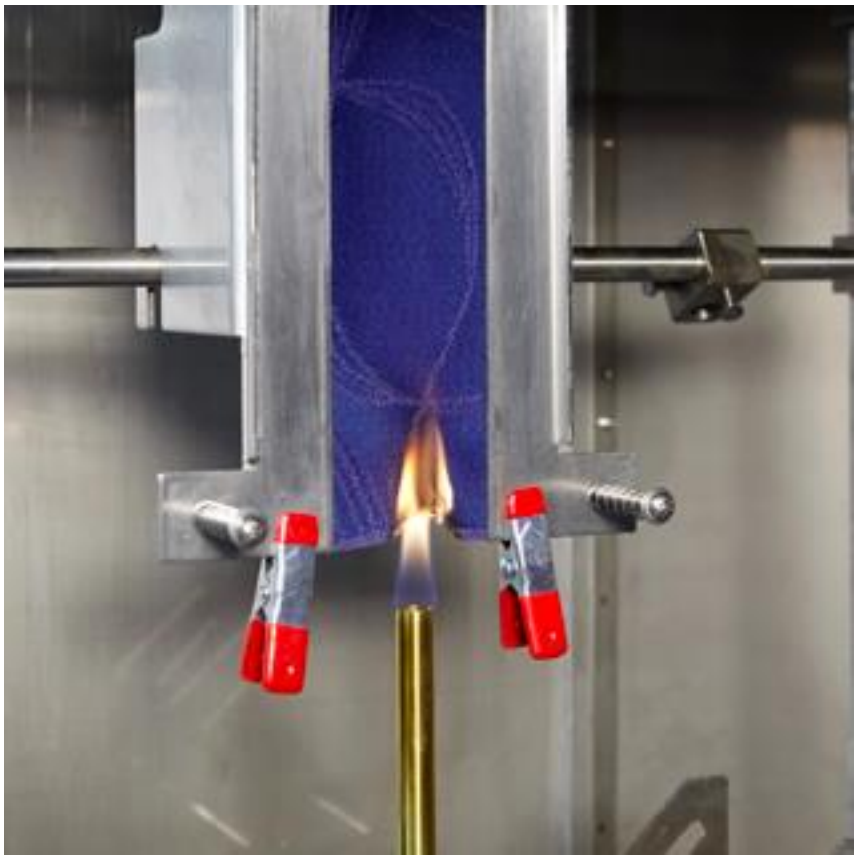


Figure 5-2: Vertical Bunsen Burner Test for 60/12 seconds, (AeroBlaze 2022)

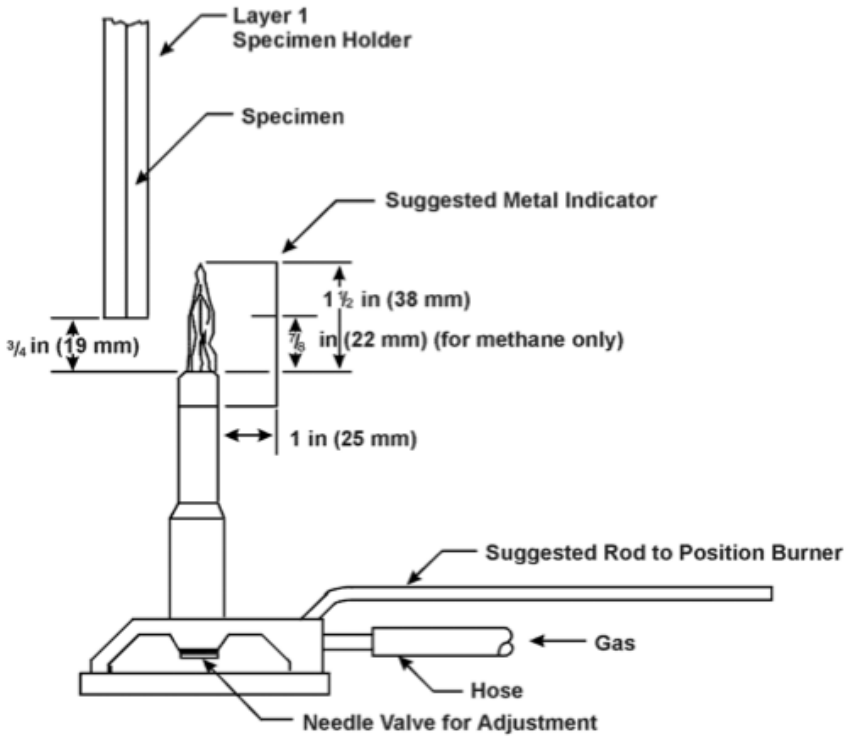


Figure 5-3: Burner Plumbing and Burner Flame Height Indicator, (FAA 2021)

A summary of the applicable requirements for JAR/FAR: 25.853 / Appendix F (a)(1)(i) & (ii) is shown below:

Specimen Test Quantity	Flame Applied (Seconds)	Max After-flame (Seconds)	Max Dripping (Seconds)	Max Burn Length (Inch / mm)
3	60	15	3	6 / 152
3	12	15	5	8 / 203

Table 6: Applicable requirements for Tests under JAR/FAR: 25.853, (FAA 2022)

5.1.3 Surrogate Panels for Flammability Testing

A major challenge is associated with the renovation of the interior cabin components, which is the difficulty in conducting certification tests that would determine if the refurbished component is still compliant with the heat release, smoke, and flammability certification requirements.

Therefore, the international "Aircraft Materials Fire Test Working Group" and the FAA Technical Centre investigated a similar but nonidentical panel, known as a surrogate panel, which may be used in place of the original base panel composite build-up for flammability testing of renovated aircraft interiors. Mostly the surrogate panel is used in case, that the company for testing the materials does not always have the exact identity of each material used in the original panel (such as core brand or veneer). For this reason, they have to create a replaced material composite, which has the same basic construction and build-up as the original panel, and any differences in these basic constructions could lead to erroneous results. For example, if the original panel is constructed with a cherry wood veneer that will be used again in the cabin after refinishing, thus it is reasonable and acceptable to construct a surrogate panel with a cherry wood veneer of the same thickness (Marker 2001).

All surrogate panels shall represent the configuration of the old ones, including:

- Core type
- Resin and adhesive type
- Thickness, number, and type of pre-preg or non-pre-preg plies
- All old finishes that will not be removed before applying the new finish

5.1.4 Materials selection and alternatives for refurbishment

Material selection is one of the challenges, that faces the refurbishment facility with the customer during picking up the preferred material in the interior. Analyzing the characteristics and strategies of the materials to the design through the years; helps investigate more environmentally sustainable products in the future. The more sustainable the product is, the less repair is required. In addition, it will reduce the cost efficiency if the product is sustainable enough to service until the next refurbishment interval. Thus, instead of replacing the whole material composite, it requires only small alterations like varnishing, veneering, etc. but this depends on the time and costs boundaries (Gregolin 2016).

A private jet should always feel unique even for those who use them regularly. The benefit of the private jet is not only the privacy gained from it but also the luxurious it has. One of the main factors in building up this high-class image is the interior design. High-quality material is the key to reach the perfection in a business or private jet interior. Therefore, each detail in the cabin affects the final design result as shown in figure 5-4 (AeroVisto 2022).

Figure 5-4: Cessna XLS Cabin Interior after upholstered seats, (AeroVisto 2022)

5.1.4.1 Upholstery as an alternative method

Upholstery is one of the solutions, which renews the components in a short time with lower costs rather than selecting new material. Comfort is one of the most important factors, that can increase the flight experience. Therefore, upholstery has a great effect on the PAX's experience, as an example is the work done on the PAX seat, where the layers are shown in figure 5-5. In Addition, focusing on upholstery remains a constant task for the refurbishment companies.

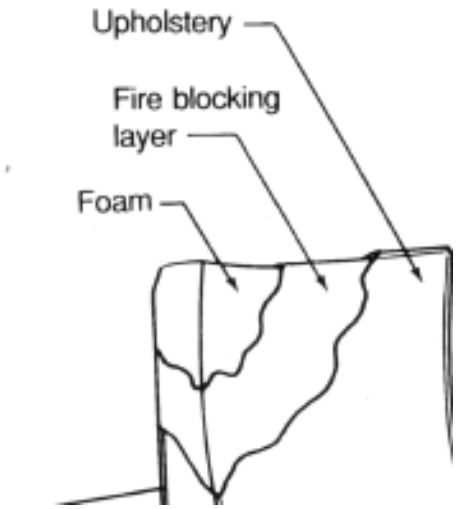


Figure 5-5: Typical PAX seat installation, (FAA Appendix C)

Upholstered seats lead to an enjoyable flight; in other words, the combination of high-quality materials and comfort is the main challenge for any company when the time comes to renew the components of the cabin interior. There are two ways of restoring the cabin in private jets:

- Whether just restoring the old visual appearance with the same materials, that have the same form and functions
- Or changing the material itself, which depends on the customer desires as well as time and costs boundaries

When the time and budget do not matter to the customer, the existing surfaces can be completely reveneered with new materials. Otherwise, other solutions occur to reduce the duration of the refurbishment. as mentioned above upholstery can be a solution, that can be performed on:

- PAX Seats
- Divan (s. figure 5-6)
- Lower sidewalls

- Window-liner
- Valance panels and headliner

Figure 5-6: Embraer legacy 600 divan upholstery, (AV 2022)

5.1.4.2 Décor film application method

On the other hand, limited deadlines and budgets of the projects lead the refurbishment centre to perform other solutions beside upholstery, that facilitate the renewal of components in the cabin interior. When it comes to the refurbishment project of charter airlines as their aircrafts are regularly used and time is a critical factor, then the easiest and fastest way of alteration should be followed. The modification of surfaces in the interior plays a big role in the project, which leads to the modification idea of decor film application. This method is a visual renewal, it is also used in the refurbishment projects of vehicles whether for the interior or the exterior look as well as buildings (interior designs). Such a method provides a lot of benefits (AV 2020):

- Protecting the surfaces with a high-quality appearance and finish (figure 5-7)
- High durability and strength
- Long-lasting quality

- Lower costs compared with revarnishing or reveneering of surfaces, as it reduces the cost of material used
- Protecting from corrosion
- Quick to apply
- Easy in cleaning and maintaining
- Reducing downtime of the aircraft by at least 50%
- Increasing the creativity in designs

Figure 5-7: Table film application on Embraer Legacy 600, (AV 2022)

5.1.4.3 Recoloring and repairing of leather

Another method, which is applied to reduce the time and budget challenges, is the recoloring and repairing of leather instead of using new leather material. This method is performed in some cases of refurbishing projects, as it refreshes the leather instead of replacing it by painting it in the preferred color by customers. In this case, the components such as seats do not need to be disassembled. Recoloring is also a fast change method, which greatly impacts the project's time and budget (AV 2020).

As next is a study case performed in cooperation with the company AeroVisto to compare the decor film application method with revarnishing and reveneering on different types of aircrafts in according to various criteria such as:

- Time
- Costs
- Maintainability
- Appearance
- Certification/approvals

Category	Criteria	A/C Category	Décor Film Apllication	Revarnishing	Reveneering
Financial	Investment in (EUR)	Small jets (e.g. Cessna XLS)	35,000	70,000	120,000
		Mid-Size Jets (e.g.Legacy 450)	80,000	160,000	240,000
		Heavy Jets (e.g.Dassault Falcon 7X)	140,000	220,000	350,000
	Aircraft Downtime in (Weeks)	Small jets (e.g. Cessna XLS)	2	4	6
		Mid-Size Jets (e.g.Legacy 450)	3	6	9
		Heavy Jets (e.g.Dassault Falcon 7X)	4	8	12
	Business distruption		Minimized	Significant	Very significant
Design and Appearance	Design Creativity		Very high	None	Very high, if budget has no boundaries
	Visual Renewal and fresh look		Yes	No	Limited

	Brand identity input		Many signature options possible	No	Many signature options possible
	Attractive to customers		Yes	Yes	Yes
Certification and Approvals	Burn-testing FAR 25.853		Yes	Yes	Yes
	EASA Approval: Part 145, Part 21G, Part 21J		Yes	Yes	Yes
Maintainability	Durability		Long-term solution	Long-term solution	Long-term solution
	Risk of cracking		No	Yes	Yes
	Weight-saving	Small jets (e.g. Cessna XLS)	Estimated 20 kg	No saving	No saving
		Mid-Size Jets (e.g.Legacy 450)	Estimated 40 kg	No saving	No saving
		Heavy Jets (e.g.Dassault Falcon 7X)	Estimated 90 kg	No saving	No saving
	Easy to clean		Yes	Yes	Yes
	Easy to repair		Yes	No (downtime required)	No (downtime required)

Table 7: Study-case overview for decor film application on different aircrafts

5.2 Private Jet Downtime

Cabin refurbishment is considered as a huge project, which needs a great planning program to deliver the aircraft on time. Due to the short downtime in the most projects, it is more efficient for the operator to perform two projects at the same time. Thus, a maintenance program is mostly being processed at the same time as the refurbishment project. This developed planning program for the refurbishment is balancing the time spent and costs incurred with A/C fleet maintenance. Thus, the whole project is performed one time instead of planning to leave the A/C on the ground twice for two separate projects. The planning of the downtime depends on some criteria as follows:

- Customer's requirements
- Technician's skills / MX company's performance
- Hours of work to perform MX tasks
- Costs related to the facilities

Reducing A/C downtime is one of the main challenges of the process chain, it must be followed by applying maintenance work scheduling methodologies to reduce MX costs and to create new strategies to improve the process chain of the refurbishment. These methodologies will be explained in the next chapters in detail (Pereira 2021).

As a solution, all maintenance requirements are planned according to phase packages (timeline) to facilitate MX planning, which will also include the refurbishment project when needed to face the downtime challenges. Each phase package is defined into different time intervals, which have been developed in coordination between the operators and the manufacturers (e.g., Air-Hamburg btw. Embraer). Embraer recommends adapting the MX program according to two utilizations which are as follows (AMP AH):

- High utilization > 500 Flight Hour (FH) and 250 Flight Cycle (FC)
- Low utilization < 500 FH and 250 FC

The intervals used for the MX program including the refurbishment or the inspection requirements are established in FH or FC or calendar time. The criteria to choose the interval to be used is "Whichever occurs first" between the available proposed intervals. The table below contains the different intervals of high utilization (HU) depending on the FH and FC (s. table 8):

PHASE PACKAGE	INTERVAL [+/- 15 days]	INTERVAL [+/- 20 FH]	INTERVAL [+/- 20 FC]
HU6	6MO	500 FH	not applicable
HU12	12MO	1000 FH	not applicable
HU24	24MO	2000 FH	1000 FC
HU48	48MO	4000 FH	2000 FC
HU72	72MO	6000 FH	3000 FC
HU96	96MO	8000 FH	4000 FC
HU144	144MO	12000 FH	6000 FC
HU192	192MO	16000 FH	8000 FC

Table 8: Phase packages depending on FH and FC, (AMP AH)

An aircraft age is a mix of flown hours and landing cycles issued by aviation authorities, and engineering analysis. These data are important to plan the MX package. If the operator decides to perform a high utilization program for an aircraft, it sends the A/C to the MRO, which is the organization specialized in performing **M**aintenance, **R**epair, and **O**verhaul on an A/C and components demanding a minimal cost and improved reliability. The downtime period is decided depending on the heavy level of MX tasks and if it includes a cabin refurbishment or not (Pereira 2021).

Therefore, an MRO must have efficient and effective management to plan all the tasks at the same time without any delay in the release. Another challenge is to find the best balance between the budget and the downtime, as the cost gets higher proportionally with the A/C downtime. Costs depend on different criteria such as (Pereira 2021):

- MX cost including direct labor and materials needed for tasks
- Cabin refurbishment budget if required
- Maintaining cost of equipment, tools, and building facilities
- Man-hour
- Virtual disbursement due to the number of days, where the A/C is out of service

In addition, a delay in the downtime can lead to a great loss up to $25.000 per aircraft. Therefore, the planning of an aircraft MX program including the refurbishment project is always a competition that impacts the whole process chain and needs to be managed in the earliest phase of

the project. In addition, any unplanned tasks added in the middle of the project's interval should be prevented, as it leads to the delay of the release date. The Project's tasks can be planned and unscheduled but not the other way around. That is why each refurbishment company tries to avoid the additional tasks added spontaneously.

As shown in the following table, a risk analysis has been performed in cooperation with AeroVisto to recognize the occurrence probability of each risk, their potential causes, and the preventive actions required.

Risks	Probability of occurrence	Expected reasons	Preventive actions
Downtime	High	Delay of release date	Time management, project monitoring/tracking
Unplanned tasks	Middle	Additional non-approved tasks during the project's interval	Planning extra time included in downtime
Costs	High	Unexpected costs due to unexpected tasks	• Provision for extra budget • Bundling more than one refurbishment project during a single request, which decreases distribution costs
Transportation	Low	Damage or loss of components during transportation	Good packaging/Spare parts
Planning	High	Unrealistic plan due to unplanned tasks	Time management, project monitoring/tracking
Assembly	High	Removal/Installation damages	Qualified technicians and employees
Delivery	Low	Unexpected delay	Contractual commitment of delivery

Table 9: Risk analysis of refurbishment project

6 Process Chain Optimization and Structure Methodology

6.1 Inspection Report Optimization Concept

In order to optimize the process chain of the refurbishment project and reduce the major challenges, some methodologies will be explained to decrease the risks facing the project and facilitate the work scope done by the different companies. With new methods for VIP cabin modification, the aviation industry will continue to change and grow. As technology keeps expanding day by day, the need of using paper documents is decreasing. Thus, engineers started developing applications and websites, that simplify daily work and help to reduce human failures.

As mentioned above, first when the refurbishment project starts; and the aircraft's operator requests a refurbishment for the VIP cabin, an inspection report is needed to know exactly what should be performed and modified. This report includes the small scratches in the cabin up to a whole new design for a component. Therefore, searching for a new method that facilitates the project management and the reporting process will help the airline charter (owner) to know in detail the status of the private jet. Unfortunately, a manual inspection report takes too much time to be done including too many emails and dozens of phone calls besides personally supervising tasks on site (Craker 2022).

A digital method instead of paper works is being used in the construction field to perform the building's inspection. This idea of "Digital Project Inspection" in form of an application would also help in the aviation field to report the cabin status and upload all the needed data for the inspection. In addition, it also gives access to the owners to do the inspection by themselves, whenever a defect is detected (PlanRadar 2022).

Unfortunately, such a methodology is not being used by many refurbishment and MX facilities but recently some companies in the aviation field (e.g., W5 Aviation and AeroVisto) started to digitize the workflow for the survey. This application improves the process for surveying the interiors of VIP jets, especially in refurbishment projects. As follows is some examples of the benefits:

Benefits
⇒ Delegate tasks efficiently without the need of making phone calls or writing emails, as the entire team has access to the application
⇒ Mark the defects on the uploaded photos/plan and detect the exact locations of them to provide an overview of the current status of the cabin
⇒ Add notes or comments to unclear failures detection
⇒ Easily create digital documentation
⇒ Save up to 80% of the work time, due to the fast and automatic generation of documents instead of spending hours writing notes and findings in the office
⇒ Facilitate preparing memos and photographic documentation
⇒ Filter the detected faults according to the status, priority, and category
⇒ Generate an inspection report, which is ready to be handed to the owner to show up the current status
⇒ Create templates, which contain everything necessary to carry out a fast and efficient inspection of a private jet
⇒ Reduce costs and decrease downtime of infrastructure assets

Table 10: Benefits of digitizing the inspection reports (PlanRadar 2022)

Therefore, the inspection's application is a useful method to be used for surveying the aircraft interiors during the project acquisition phase. As follows are the steps to create the report and digitize the work:

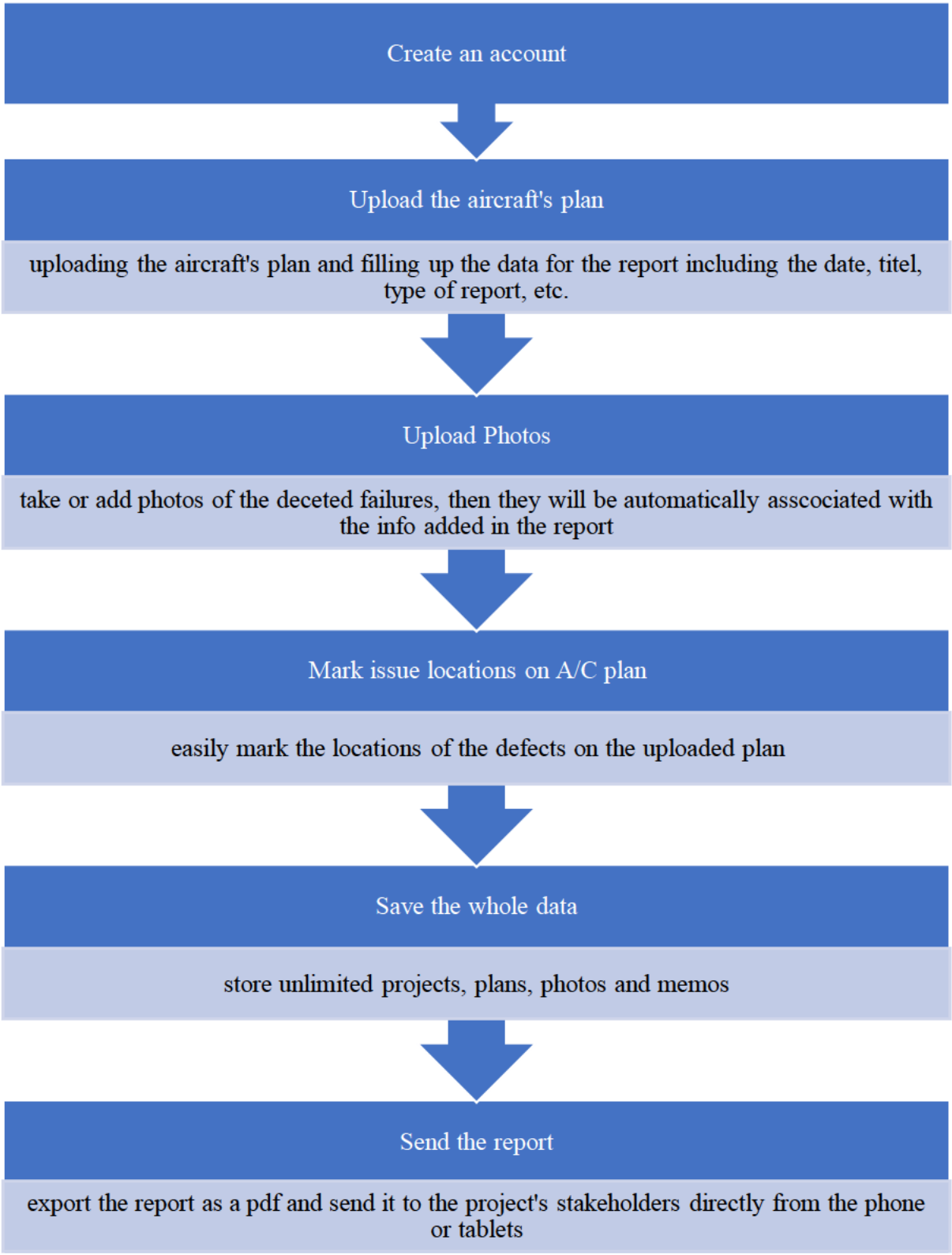
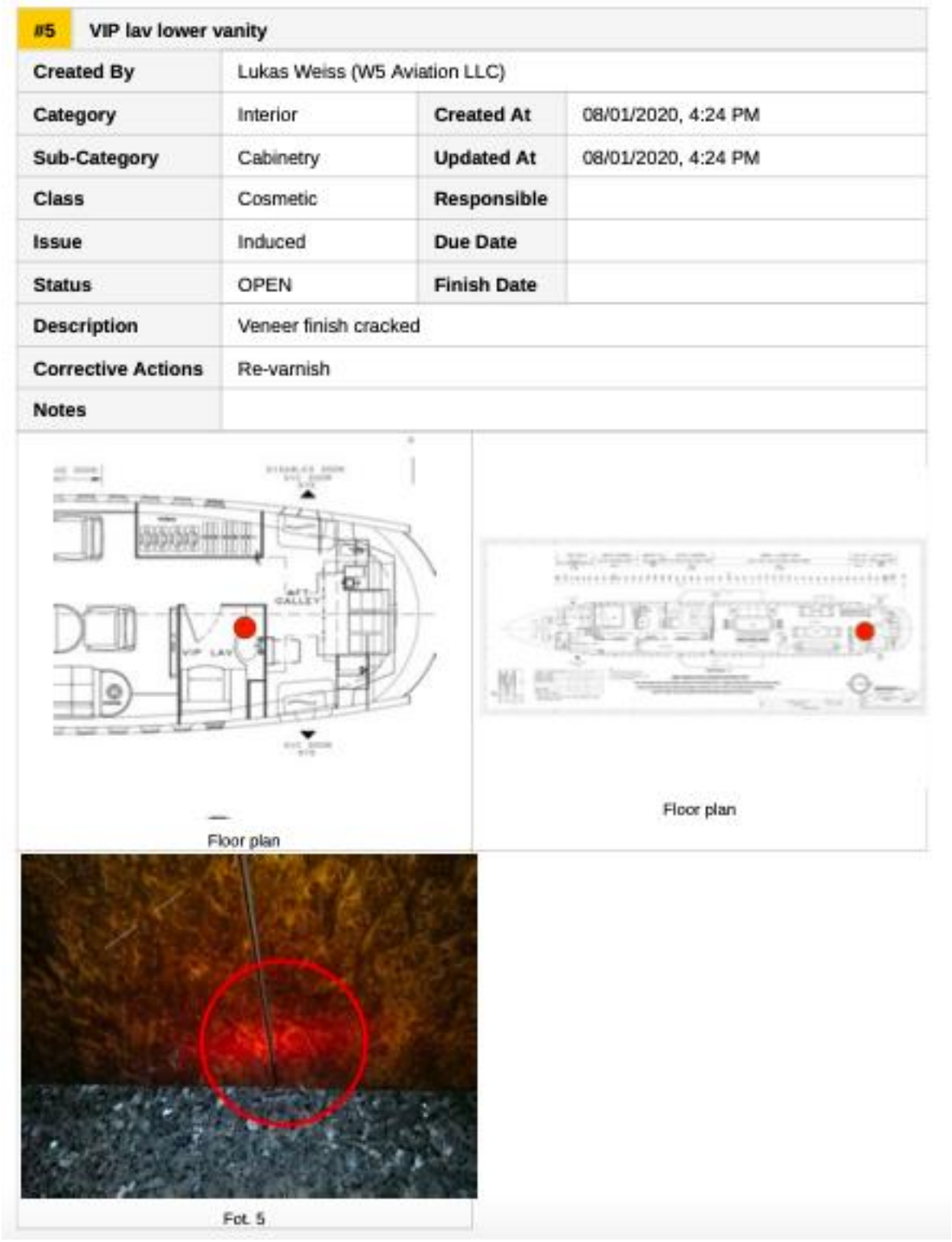


Figure 6-1: Project inspection report's steps (W5 2020)

According to the workflow of the company W5 Aviation, an example of inspection report's page on the application is designed as the following figure:



#5	VIP lav lower vanity		
Created By	Lukas Weiss (W5 Aviation LLC)		
Category	Interior	**Created At**	08/01/2020, 4:24 PM
Sub-Category	Cabinetry	**Updated At**	08/01/2020, 4:24 PM
Class	Cosmetic	**Responsible**	
Issue	Induced	**Due Date**	
Status	OPEN	**Finish Date**	
Description	Veneer finish cracked		
Corrective Actions	Re-varnish		
Notes			

Figure 6-2: Aircraft Preliminary DEMO Survey (W5 2020)

The application's powerful functions as mentioned above solve many challenges, the most important of them is time. In addition, such an optimization gives the customers:

- A quick overview of the cabin's status
- It helps to eliminate any ambiguity by providing a detailed issue description supported by images and a plan view
- It clarifies the interior's condition and shows only the areas that concern the customer.

According to a refurbishment company's experience with this methodology, it saves up to 2-5 hours per inspection, which is a great rate that affects the rest of the process chain (W5 2020).

It is an easy way for optimization to end up with planning failures and gaps in information due to the paper documents. Particularly, when it comes to defect management, the whole process fails, the project participants do not get a plan to stay on it, and in the worst-case loss of data. That is why an applied digitalization method is used during the project management of the cabin refurbishment (Craker 2022).

For the application's upgrade, some options could be added to improve the workflow as follows:

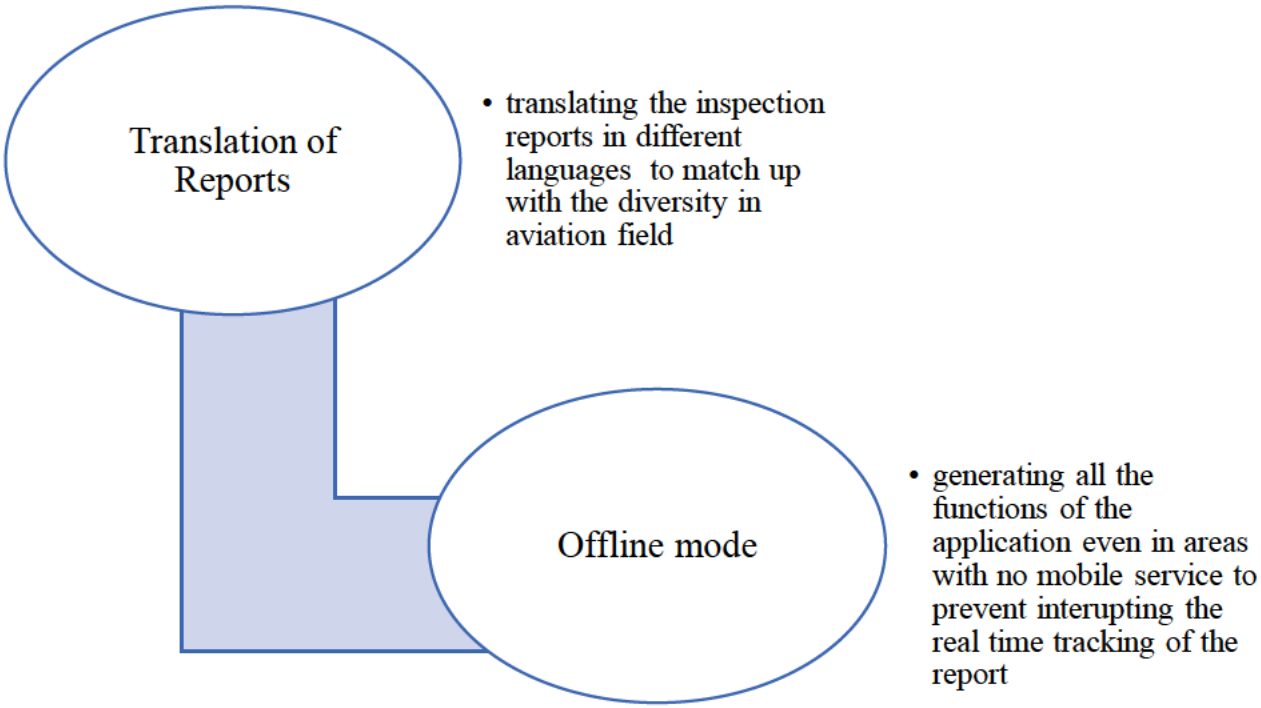


Figure 6-3: Application's upgrade options for improvements

6.2 Artificial Intelligence (AI) in Refurbishment Project

After evaluating the inspection report for the aircraft's interior, the next phase in the process chain begins by determining the customer's modification requests with the completion centre. Whether the completion centre performs the refurbishment and the certifications together or they perform only the refurbishment tasks and cooperate with a third party, which is a design organization authority to perform the approvals. In this paperwork, the concentration will be on the second case, where the main factors are:

- The customer as a charter airline to operate the business jet
- A refurbishment company to perform the tasks
- A design organization authority to perform the certification and approvals needed

Over the last years, Computer-aided Design (CAD) has added a huge development in the design field. It facilitated the visualization of the new design, new products, and parts before implementing them. CAD helped to design new models that meet the design specification. A new feature in modern CAD is founded, which is called Knowledge Based Engineering (KBE). This feature could be very helpful for achieving the customer's modification requests in the cabin, as it supports the diagnosis, selection, and monitoring of tasks (Scholz 2010).

In addition, a related technology to KBE is Artificial Intelligence (AI) which also supports problem-solving, as it is based on rules which determine how decisions are made. Each industry, right from designing the product and turning it into usability, needs AI for better performance of the products. The traditional tools of the CAD do not contain any feasible analysis and conditions for the airworthiness standardizations. Therefore, the idea is to integrate AI into 3D CAD modelling, where the AI analyzes all the airworthiness requirements of the new interior.

On one hand, some "VIP" refurbishment companies use the 2D and 3D CAD tools to implement multidisciplinary design optimization in analyzing complex new projects like the Bombardier Global 5000 as shown in the figures below (6-4/6-5), but on the other hand, such a methodology of adding the AI concept of EASA requirements to the program is still not being used as needed. Therefore, the integration of AI would help to:

- Facilitate the workflow strategy
- Minimize the workload performed for the certifications and approvals during the project

- Increase the chances of accuracy in the design
- Decrease the expected errors in modelling
- Automate the repetitive human tasks
- Support conceptual design activities
- Support the investigation of multiple “what-if” concepts in the design, which is the most important strategy for the airworthiness authorities
- Parallelization of the refurbishment tasks and the approvals as the rules added in CAD are based on the certifications supported by the AI

An example for the design modelling is shown in the next figures, to show up how the cabin components are being designed:

Figure 6-4: Designing the Bombardier Global 5000 Seat, (Cases 2022)

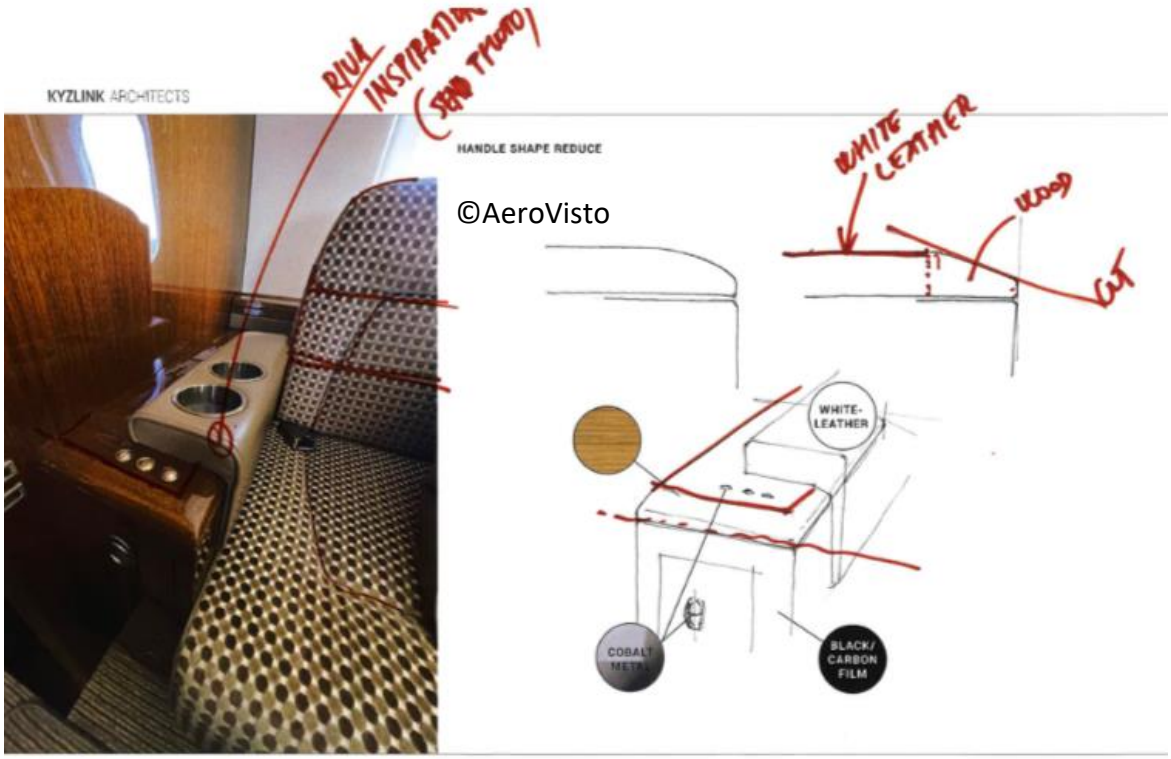


Figure 6-5: Hand-rest sketch Bombardier Global 5000, (Cases 2022)

Some of the driving characteristics of the 3D visualization concept are:

- Early design and refurbishment reviews
- Software tools, allowing enhancements of the design in an early phase
- Good communication between the engineering team and the customer

In order to achieve the above results during the design phase, it is necessary to create a specific design model using CAD tools integrated with the AI. The methodology will be performed according to the approvals data and regulations, which are supported by the design authority. Such a facility will reduce:

- The downtime
- Costs
- Engineering tasks that any refurbishment project needs, as it is very important during the negotiation phase to create a fast cabin layout and show to the customer the modification possibilities

The integration of AI in CAD modelling, where the rules are gathered into a knowledge database, allows the development of configuration systems. The main purpose of such a method in the refurbishment project's case is to solve the challenge and difficulty of configuring a cabin's new layout according to the owner's requirements and the restrictions of the design authority at the same time.

The customers will be able to see in advance what the new interior will look like and how it will fit with the existing aircraft cabin. In addition, it would help to investigate if the new interior is airworthy and meets all the requirements for the approvals or if there are additional tests that must be performed. Such an integration would influence the whole process chain in the future (Nita 2009).

6.3 Web-based Methodology for Project Modification

6.3.1 Main problems affecting the project

Searching for a new method to manage the process chain for a refurbishment project is a challenging work, that needs a planned, executed, and controlled system. Such a system facilitates the workflow to the main stakeholders to be able to deliver a fully refurbished private jet according to the customer's desires in the required lead time without any delays or added costs. As shown in figure 6-6, the main stakeholders in this case are the refurbishment company (B) and the engineering office (C), who are responsible to perform all the tasks needed for the refurbishment. The customer (A) in this case of study is referring to an airline charter, which is responsible to operate the A/C on behalf of the owner or the airline owns the private jet by itself.

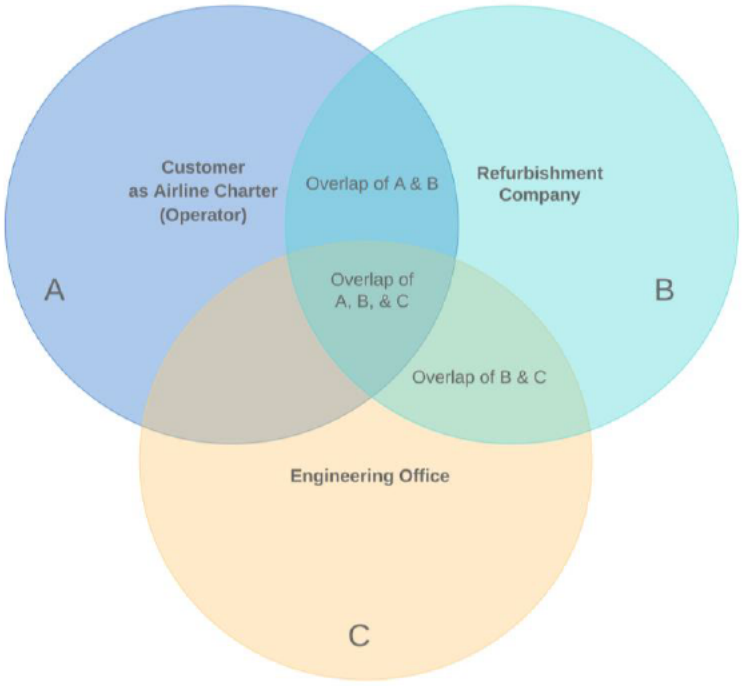


Figure 6-6: Three-set diagram for the organizations concept, by Lucidchart

The main problems facing the refurbishment project of a VIP cabin need to be managed and solved through the enhancement methodology of the process chain. According to a study case performed with the three organizations during the training phase, the main problems recognized by the stakeholders and the customer are as follows:

From the point of view of	Problems	Explanations
Customer	Monitoring/tracking the process	Gap of having a real-time overview on the process flow until releasing the jet
	Delays	Timeline delays due to different reasons interrelated with different stakeholders
	Additional costs	Increasing the budget plan due to unexpected delays or additional tasks

Engineering office	Late receive of full documents	Late or delay in receiving all the A/C documents needed, to perform the approvals and certification due to interrelated sharing between stakeholders
	Unscheduled material tests	Unexpected additional tests must be performed, which are not planned or required early from the refurbishment company
Refurbishment company	Late receive of full documents	Late or delay in receiving all the A/C documents needed, to perform the approvals and certification due to interrelated sharing between the customer and the company
	Misalignment between stakeholders and their business objectives	While each stakeholder is working internally alone on the project, thus there are communication issues due to different internal objectives and unshared data. Gaps must disappear and objectives must be aligned between the three stakeholders
	Dependency conflicts	Most of the tasks are interrelated and shared with many persons. These dependencies mean that a single task delay has a significant ripple effect on other related processes in the chain and disrupts schedules
	Overlapping tasks	Overlapping of tasks causing time conflicts and triggering expensive in the project

Table 11: Problems facing the three main companies

6.3.2 Project monitoring supported by a Web-based system

A Web-based platform is a concept to solve the problems mentioned above. It supports managing the project between the different stakeholders. The aim of such a platform is to:

- Satisfy the customer by having real-time tracking for the process chain until the release
- As well as to facilitate sharing of information and data between groups “B” and “C” as shown in figure 6-6 without any delays or unexpected additional costs.

Each group from figure 6-6 has some common tasks to perform with each other. These common tasks will be explained below in order to model/build a Web-based system to track the refurbishment project and optimize the process through better communication between companies.

Common work between A&B	Common work between B&C	Common work between A,B&C
• Applying for the project • Sending A/C survey (which parts will be refurbished) • Sharing A/C documents (IPC, CMM, etc.) • Discussing Quote and offer • Setting the deadline	• Receiving SOW as early as possible • Sending and receiving documents related to the A/C approvals (EB, PLA, FTP, etc.) • Sending all required flammability test results and "Weight and Balance" report • Setting deadlines for new material tests (if required) • Building, sharing and discussing CAD model for new designs (if required)	• Receiving additional unplanned tasks during the timeline • Discussing the new design (Accept or Deny) • Monitoring time slots and discussing for extend (if needed) • Sending all required A/C release docs

Table 12: Main common points between stakeholders

6.3.3 Workflow strategy on the platform

Based on the common tasks and problems, an information system is needed to facilitate the project management. The platform typically involves:

- Competing demands for: scope, time, cost, risk, and real-time tracking
- One place for all required documents
- Identified requirements
- Stakeholders with differing needs and expectations

Such a project management platform is an information system consisting of the tools and techniques used to gather, integrate, and disseminate the outputs of the process chain. Organizations performing projects like VIP cabin refurbishment will usually divide each group of tasks into several project phases to improve management control and provide ongoing operations. These project phases are known as "project life cycle". The customers benefit from the platform because they have access to track the project phases and monitor the tasks by completion. On the other side, the engineering office and the refurbishment company will be able to work on the same platform as they share, integrate, and communicate on a controlled, organized web-based system (Guide 2005).

To do this, the flow of information between the different parties involved in the project is mapped out as shown in the next table (13). Such a platform will store all the documentation of the project from the beginning of applying to the refurbishment until the release throughout the life cycle of the process chain. Finally, the system will demonstrate to all the participants that a good project management is a basic for the fulfillment of the project objectives. In addition, such a platform gives the customer an overview of the completion percentage for each phase in the process chain, thus the owner is able to investigate early delays (Forcada 2005).

Figure 6-7: Real-time monitoring for the project phases, by Lucidchart

1. Phase	1.1	Assign project leader
	1.2	Applying for cabin refurbishment through the Web-based system
	1.3	Uploading the inspection report for the cabin performed by an application
	1.4	Analyze request
	1.5	Contact customer and set first meeting through the platform
	1.6	On the first meeting: initiate discussions and negotiations
	1.6.1	Estimate design effort, time, and costs
	1.7	Conceive preliminary solutions for the required modifications
	1.8	Negotiate solutions with the engineering office
	1.9	Create preliminary representation of the solutions found to the customer

	1.10	Refurbishment company creates feasibility study to:
	1.10.1	Analyze expected results
	1.10.2	Identify required resources
	1.10.3	Estimate profit
	1.11	Decision of accepting or denying the project
	1.12	Sign agreement through shared documents on the platform
2. Phase	2.1	Upload A/C documents
	2.2	Initiate team organization between engineering, design, and certification
	2.3	Plan the certification process
	2.4	Request preliminary material approvals from engineering office
	2.5	Conceive the procedures to be followed
	2.6	Perform 2D and 3D representations for cabin model (new design/modification)
	2.7	Uploading completed 3D model with all specifications
	2.8	Discussing the 3D modified model with the customer
	2.9	Send last results for the next implementation
	2.10	Receive engineering bulletin and other approvals required from the design office
3. Phase	3.1	Add additional unplanned tasks if required
	3.2	Reanalyze downtime and costs
	3.3	Begin with the implementation phase (receiving parts, veneering, varnishing, etc.)
	3.4	Perform quality control on the whole components
	3.5	Prepare all release documents in the form required by the customer
	3.6	Upload all data on the platform
	3.7	Deliver all the refurbished/modified parts
	3.8	Close the project

Table 13: Workflow of the process chain through the web-based platform

The purpose of this platform strategy is to digitalize all the process chain of the project and to offer one place of work to the three stakeholders, thus they can communicate, share data, and perform tasks on the same web-based system. First by performing the inspection report through an application. Second by applying for the refurbishment with the desired company on the website and modelling the modifications needed on CAD. Finally, performing the refurbishment on site while in parallel sharing the updates to the customer on the platform until the release of the aircraft.

6.3.4 Implementation phase

Once all needed documents and data are fully received, begins the phase of the implementation on site as shown in figure 6-8.

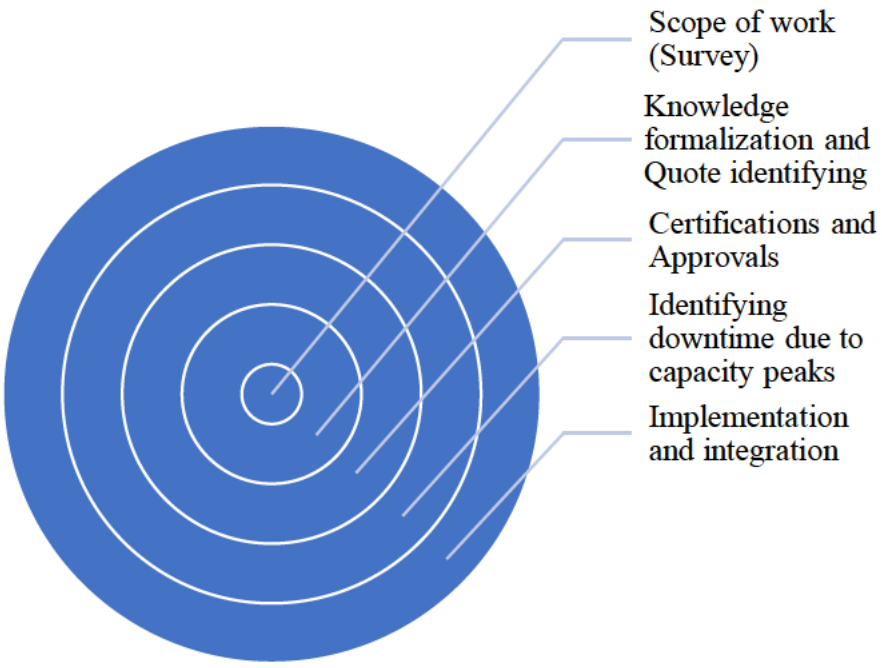


Figure 6-8: Process chain until Implementation

Starting with the implementation phase, the refurbishment company receives all the interior components to begin the work. All item 's part numbers (PN), and serial numbers (SN) must match with the "IPC" document, that involves effort and time if the incoming items are not titled. Parts are then disassembled, stripped of the existing materials, and rebuilt to design specifications. During this process, the team works to verify the design, functionality, and any upgrades to update the components for a newer/modifier cabin (Craker 2022).

Another area of risk regarding the process chain is related to the performance and success of the implementation. As the service centre often receive additional unplanned tasks during the implementation phase, these tasks must be handled to help mitigate delays. This includes ensuring a clear understanding of the process and responsibilities related to finding of regulatory compliance. That is why communication and coordination through a common web-based system is a key factor to success in order to prevent any risks to the project (Craker 2022).

Figure 6-9: Installed sideledges in Cessna XLS after refurbishment, (Air Hamburg Technik)

In parallel with the retrofit of the interior, most of the companies perform quality control during the work stages instead of waiting until the last stage. Finally, all the refurbished components are installed in the cabin as shown in figure 6-9, whether the A/C is in the refurbishment centre itself or it is in another hangar, where other maintenance work is performed. Thus, in such a case all parts need to be highly packaged and delivered within the timeline planned.

6.3.5 Benefits of the process chain optimization

Every aspect of the process chain will have some level of risk inherent within the scope. That is why an optimization is needed to analyze progress in overcoming the risk areas. Everything is currently performed electronically, even in the aviation field. Therefore, managing the refurbishment project digitally has a lot of benefits for the whole process chain. As follows are the advantages of using the three main apps within the project (Murray 2001):

Apps	Benefits for the process chain
Inspection Application	Improve downtime in the whole process due to faster inspection
	Remove data inconsistencies and rework, like issues discovered until late in the cycle
	Find defects earlier in the lifecycle
	Archive the survey for further needs
	Clear documentation with pictures and better understanding
	Easier shared documents
	Access to add notes/comments in the document for a better communication
	Reduce costs in the project, while the inspection is performed by one person
CAD supported by AI technology for design	Reduce negotiation and discussion time with customer
	Reduce work progress for certification standards
	Identifying the certification requirements for engineering through AI
	Facilitate the related tasks for the engineering office
	Give the customer a better visualization for the modified cabin
	Estimate the obstacles that could delay the project
	Estimate time and efforts needed
	Better follow-up tool for new employees taking the project
	Easily prioritise tasks
	Identify which tasks are hindering the process and should be refused
	Better communication tool to discuss the design between the stakeholders

"Website" Platform	It can easily, quickly, and inexpensively set up
	Reduce timeline of the whole process
	Quick tool for sharing documents and updates between stakeholders
	All teams will have instantaneous and continuous access to information
	Eliminating wasteful paper flow
	Reducing the number of inefficient meetings
	Better tracking method for the customer
	Moreover, when these actors are working with a web-based platform sharing documents all the stakeholders should have the same working standards
	It unifies the different working processes of all the companies involved in the project
	Facilitate project complexity, size, and duration
	Publication dates are clearly determined
	Continous control on documentation
	Preventing double work from different persons, as the completion of tasks is published
	Better management on additional added tasks

Table 14: Benefits affecting the process chain

7 Conclusion

The necessity of optimizing the process chain of VIP cabin refurbishment is a key factor in the aviation industry. Private jets industry is growing day by day gaining more customers and passengers. Therefore, modifying a private jet is one of the factors that affect the industry, and that is why it must be managed and proceed in a good way.

This thesis showed the processes of the project from the beginning of the customer's request until the release of the aircraft. In addition, it has spotted the different challenges affecting the whole procedure. Estimating downtime, costs, and searching for service providers; were the main challenges that should be managed and controlled to prevent any delays or increase in the budget. Therefore, managing the project as easily as possible helps to improve the process chain.

On the other hand, digitalization and artificial intelligence are the key factors for the new methodologies of the project, as they would aid to optimize the process chain. First, the inspection report methodology showed how a simple application facilitates the work with fewer failures, efforts, and time. Furthermore, AI is one of the main important improvements that minimize the work done by hundred persons in an easy technological way. The aim of such a development in the CAD system would be to shrink the repetitive engineering tasks in order to create a fully accepted and certified design in a short timeline.

Finally, the web-based platform is explained as a methodology to combine all the procedures and tasks in one place to facilitate sharing documents with different stakeholders as well as tracking the whole process for a better management and a great customer experience.

Competitive products are the key to the success of every company. To resist the pressure of high competition, companies must also optimize their processes to an even greater extent. That is why the concept of the paperwork is to digitalize each process in the project, as it has a great impact and benefits for all stakeholders as well as for the customer.

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Erklärung zur selbstständigen Bearbeitung der Arbeit

Hiermit versichere ich,

Name: Hossameldin

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dass ich die vorliegende Bachelorthesis die entsprechend gekennzeichneten Teile der Arbeit mit dem Thema: The Process Chain for Private Jet Cabin Refurbishment

ohne fremde Hilfe selbständig verfasst und nur die angegebenen Quellen und Hilfsmittel

benutzt habe. Wörtlich oder dem Sinn nach aus anderen Werken entnommene Stellen sind unter

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Hamburg den, 27.09.2022