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OEM'S PRACTICES TO ACT AS AN EFFECTIVE THIRD PARTY FACILITATOR IN AIRCRAFT REDELIVERY PROCESSES

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"Per ardua ad astra".

(Official motto of the Royal Air Force)

Resumo

Processos de *redelivery* normalmente ocorrem com o encerramento de um contrato de arrendamento (*leasing*). Este procedimento, que se trata do processo de retornar uma aeronave, envolve estreita colaboração entre duas partes: o proprietário (*lessor*) e o operador (*lessee*). Tendo em vista que uma aeronave é um equipamento composto por vários componentes em um sistema complexo; e que o processo de *redelivery* requer compromisso e extenso conhecimento das partes envolvidas; alguns problemas podem surgir, comprometendo o cronograma de devolução e elevando os custos estimados. O principal objetivo desta pesquisa é desenvolver um modelo prescritivo especificando as categorias de problemas mais significativas que ocorrem durante o *redelivery* e que podem ser solucionadas pelo Fabricante do Equipamento Original (*OEM*) – sobretudo ao considerar um quadro estratégico de redução de custos e tempo. Duas análises foram conduzidas neste projeto. A primeira se refere a uma Análise de Conteúdo, que se baseia em uma revisão de literatura e visa classificar a frequência de cada problema. A segunda análise trata do Método Delphi, que, por meio de um questionário aplicado a um painel de especialistas, gera uma resposta consensual, permitindo classificar a relevância de cada problema. A fim de assegurar a consistência dos resultados, ambas abordagens foram mutuamente aplicadas, visando o mesmo propósito – *i.e.*, identificar os obstáculos mais críticos encontrados durante a entrega de uma aeronave. A partir dos resultados deste estudo, o leitor dispõe de procedimentos para envolver o fabricante no *redelivery*, permitindo, assim, a criação de diretrizes para *OEM*s. O modelo prescritivo resultante desta dissertação mostra que a participação da *OEM* no processo de retorno de uma aeronave pode ser vantajosa, sobretudo ao considerar as seguintes categorias: *Reconfiguração de interiores*; *Procedimentos e planejamento de manutenção*; *Suporte de Engenharia*; *Suporte a dados técnicos, ordens, publicação e documentações*; *Requisitos de aeronavegabilidade*; *Certificação aeronáutica*; e *Gerenciamento de suporte de produto*. O envolvimento de *OEM* em tais procedimentos pode resultar em *redeliveries* eficientes, o que beneficia os proprietários e os operadores de aeronaves. Além disso, *OEM*s podem encontrar oportunidades de mercado de alto valor, ao mesmo tempo em que fornecem serviços certificados de pós-venda aos seus próprios produtos.

Palavras-chave: Arrendamento, Manutenção, Certificação, Método Delphi, Análise de Conteúdo.

Abstract

Aircraft redelivery processes usually occur during the closure of an aircraft leasing agreement. This procedure, which refers to the process of returning an aircraft, involves close cooperation between two parties: the owner (lessor) and the operator (lessee). Given the fact that an aircraft is an asset – that is, an equipment composed by many components in a complex system; and that the redeliver requires full commitment and an extensive knowledge of both parties, some issues may arise, compromising the return time schedule and increasing estimated costs. The main objective of this research is to develop a prescriptive model specifying the most significant categories of problems, which occur throughout redelivery processes and which may be tackled by the Original Equipment Manufacturer (OEM) – especially considering a strategic framework of cost and time-consuming reduction. Two different analyses are performed in this project. The first one refers to the Content Analysis (CA), which is based on a literature review to classify the frequency of each problem. The second one is the Delphi Method (DM) that, by means of a questionnaire applied to a panel of experts, generates a group response that enables the classification of the relevance of each problem. In order to assure the consistency of results, both approaches were mutually applied towards the same purpose – *i.e.*, identifying the most critical obstacles encountered during the handover of an aircraft. From the results of this study, the reader is provided with practices of means of including the manufacturer in the redelivery, and thus, creating a guideline to the OEMs. The prescriptive model achieved in this thesis shows that participation of the OEM during the handover of an aircraft may be beneficial considering the following categories: *Interior reconfiguration*, *Maintenance procedures and planning*, *Sustaining engineering support*, *Support for technical data, orders, publications and documentations*, *Airworthiness requirements*, *Aeronautical certification* and *Product support management*. The involvement of the OEM in such operations may result in efficient redelivery processes, which benefits owners and aircraft operators. Moreover, OEMs may find high-value business opportunities meanwhile providing certified after-sales services to their own products.

Keywords: Leasing; Maintenance; Certification; Delphi Method; Content Analysis.

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List of Acronyms

ACMI	Aircraft with Crew, Maintenance and Insurance
AD	Airworthiness Directives
AFM	Aircraft Flight Manuals
AIPC	Aircraft Illustrated Parts Catalog
AMM	Aircraft Maintenance Manuals
ANAC	Brazilian National Civil Aviation Agency
AOG	Aircraft on Ground
APU	Auxiliary Power Unit
BiT	Built in Test
CA	Content Analysis
CAAC	Civil Aviation Administration of China
CoA	Certificate of Airworthiness
CPCP	Corrosion Prevention and Control Procedures
DM	Delphi Method
EASA	European Aviation Safety Agency
EFH	Engine Flight Hours
EGT	Exhaust Gas Temperature
FAA	Federal Aviation Authority
FC	Flight Cycles
FH	Flight Hours
FIM	Fault Isolation Manual
HTC	Hard Time Components
IATA	International Air Transport Association

IBA	International Bureau of Aviation
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ILS	Integrated Logistic Support
LOPA	Layout of Passenger Accommodations
MPD	Maintenance Planning Document
MRO	Maintenance, Repair and Overhaul
OCCM	On-Condition and Condition-Monitored
OEM	Original Equipment Manufacture
SARP	Standards and Recommendations Practices
SB	Service Bulletin
SRM	Structural Repair Manual
SHM	Structural Health Monitoring
STC	Supplementary Type Certificate
TC	Type Certification
TCCA	Transport Canada Civil Aviation
TSN	Time Since New
VFR	Visual Flight Rules

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1 Introduction

Given the high acquisition costs, airlines are choosing leasing operations as means of acquiring aircraft. In this way, airlines can compose their aircraft fleets without large initial investment. In addition, leasing also provides flexibility to operators to increase or decrease their fleets according to the market demand. Throughout the years, the rate of leased aircraft has been increasing in the world, expanding the airlines' leased fleet from almost zero to 35% between 1990 and 2010 (Gomes *et al.*, 2013). Leasing processes, which are becoming a consolidated market with strong growth forecast, are characterized by the rental (lease) of an airplane from a leasing company (lessor) to an operator (lessee). These processes are regulated by a formal contract and have four main stages: pre-delivery, delivery, operation and redelivery, which can assume a cycle form. The core of this study is the redelivery. The redelivery process (henceforth mentioned purely as "redeliver") is the act of returning an aircraft from the operator (lessee) to the owner (lessor) – or to another operator (next lessee), employing the lessor as moderator. This stage is characterized by auditing the aircraft and all its existing records.

Given the fact that an aircraft is an equipment composed by many components in multiple systems; redelivery requires full commitment of both parties (lessor and lessee) and once the redelivery is only part of the end of the leasing process (either by the end of a leasing contract period or by any form of leasing disruption, *e.g.* due to an eventual airline financial bankruptcy), a long period (usually more than eight years) separates the agreement and the return of the aircraft (IATA, 2015). In addition, operating an aircraft is a logistic challenge, composed by many factors and requirements, such as: preventive and corrective maintenance, aircraft modifications and repairs, crew hiring and training and the involvement of aviation authorities and suppliers. The combination of this long period of operations and the complexity of the asset and its operation may contribute to increased costs, delays and disruptions along the closing contract. In general, an inefficient redeliver is a burdensome issue to the lessee and lessors. According to the IBA (2015), in 2015, the overpayments resulted from inefficient redelivery were about $1.65 mi (US dollars) per single aisle aircraft.

Considering the high likelihood of occurring many causes that lead to an onerous process of returning an aircraft to its owner, this research addresses the main problems encountered during the redelivery. This analysis is directly linked to understanding the commercial aviation scenarios and the leasing process in a bigger picture.

The understanding of the root causes of redelivery issues is a key tool towards an efficient and lean process. Literature references on this subject are mostly present in white papers, magazine articles, industry reports and guidebooks (ACKERT, 2012a; 2012b; 2014; AIRCRAFT COMMERCE, 2017; IBA, 2015; 2016; IATA, 2015; GOMES *et al.*, 2013). Thus far, when considering scientific publications, issues associated to the return of an aircraft have not been covered in any peer reviewed paper, with exception of Burhani *et al.* (2016), who have analyzed aircraft documentations and proposed a compliance model to assist during the handover of aircraft in a leasing process. The lack of scientific literature on redelivery justifies further development on the subject.

1.1 Objectives

The main objective of this research is to develop a prescriptive model specifying the most significant categories of problems, which occur throughout redelivery processes and in which the aircraft manufacturer (OEM) may act as a facilitator – especially considering a strategic framework with cost and time-consuming reduction.

Initially, this project intends to investigate, in detail, the main reasons and the root causes for complications in the redelivery. With that in mind and based on the issues detected, this study aims at suggesting different practices in which the manufacturer is able to assist and act as an effective third party facilitator within the redelivery process. The secondary objectives are sequentially listed as follows:

- Introducing the concepts of redelivery in the academic context, especially considering the lack of studies in the field of aircraft redelivery;
- Analyzing the essential academic and practical references on the matter;
- Investigating the opinion of experts in the field of aircraft leasing (airlines and leasing companies), manufacturers and aviation consultants;
- Investigating the problems – faced by lessees, lessors and eventually other stakeholders; that affect the return of the aircraft, in terms of due time and costs;
- Listing the main problems in aircraft redelivery, considering a strategic viewpoint of including the manufacturer as an assisting ally;
- Generating a prescriptive final model containing the categories of areas to be tackled when solving the most relevant redelivery problems;

- Suggesting practices to involve OEMs in redeliveries taking into account an empirical approach in the viewpoint of the author.

1.2 Overall structure of the manuscript

This Master Thesis is divided into five chapters, including this first one, which delineates the problem and the objectives of this research. The second is the literature review, which covers the technical and methodological background required for this research. The third chapter outlines the proposed methodology, including both followed approaches: Content Analysis and interviews using the Delphi Method. The fourth chapter presents the methodology application, results, the prescriptive final model and a discussion on potential practices to involve OEMs in the redelivery. Finally, the fifth chapter provides the conclusions of this thesis.

2 Literature Review

The Literature Review is subdivided into three main sections: Technical Background on Aircraft Redelivery, Technical Background on the Commercial Aviation Industry and Methodological Background. These sections provide the reader with information to properly assimilate the concepts and the steps followed in this thesis. The bibliographical references are summarized in Table 2-1 and Table 2-2, considering the assessed content for the Technical and the Methodological Background.

Table 2-1 – Summary table of the references used in the Technical Background (Technical Background on Redelivery and on the Commercial Aviation Industry) and their assessed content

Author	Year	Type	Content of the publication
ATA Specification	2004	Specification	Current specification on technical publications
Gavazza	2010	Research Paper	Aircraft leasing concepts – Content Analysis
TCCA	2012	Advisory Circular	Aeronautical requirements and regulations
Gomes *et al.*	2013	Guidebook	Aircraft leasing concepts – Content Analysis
Ackert	2014	Guideline report	Redelivery concepts – Content Analysis
IATA	2015	Guidebook	Leasing guidebook – Content Analysis
IATA	2015	Guidebook	Leasing focused on redelivery
IBA	2015	White paper	Redelivery complications - Content Analysis
De Florio	2016	Published book	Aviation history and ICAO information
SX000i	2016	Guide report	Concepts of the Integrated Logistic Support
Burhani *et al.*	2016	Research Paper	Pioneering research paper on redelivery - Content Analysis

IBA	2016	White paper	Redelivery complications – Content Analysis
Bourjade *et al.*	2017	Research Paper	Aircraft leasing concepts
Aircraft Commerce	2017	Article	Redelivery concepts – Content Analysis
FAA	2019	Digital publication	Aeronautical requirements and regulations
EASA	2019	Digital publication	Aeronautical requirements and regulations
ICAO	2019	Digital publication	ICAO history and annexes
Ackert	2012a	Guideline report	Maintenance reserve concept – Content Analysis
Ackert	2012b	Guideline report	Aircraft market concepts – Content Analysis

Table 2-2 – Summary table of the references used in the Methodological Background and their assessed content

Author	**Year**	**Type**	**Content of the publication**
Dalkey and Helmer	1963	Research Paper	One of the first publications concerning the Delphi Method
English and Kernan	1976	Research Paper	Pioneering application of the Delphi Method to aircraft researches
McCarty and Moore	1977	Master Thesis	Pioneering application of the Content Analysis to aircraft maintenance
Weber	1990	Published Book	Reference on the Content Analysis
Abrahão	1998	Master Thesis	Content Analysis and Delphi Method
Neuendorf	2002	Published Book	Reference on the Content Analysis
Patankar *et al.*	2003	Conference Paper	Maintenance and Content Analysis
Lattanzio *et al.*	2008	Research Paper	Maintenance and Content Analysis
Linz *et al.*	2011	Research Paper	Delphi Method in aircraft researches
Yu *et al.*	2011	Conference Paper	Maintenance and textual data mining

Bowyer and Davis	2012	Research Paper	Expert interviews for aircraft acquisition
Linz	2012	Research Paper	Delphi Method in aircraft researches
Duncan	2013	PhD Dissertation	Delphi Method in aircraft researches
Romero and Vieira	2014	Conference Paper	MRO and Content Analysis
Bevilacqua *et al.*	2015	Research Paper	Delphi Method in aircraft researches
Lan *et al.*	2016	Conference Paper	Delphi Method in aircraft researches

2.1 Technical background on aircraft redelivery

This section begins with an introduction of Aircraft Redelivery. The following section includes information about aviation and logistic matters, as a brief explanation of the creation and importance of the International Civil Aviation Organization (ICAO), aviation authorities, aeronautical certification, airworthiness, aircraft maintenance, technical publications and Integrated Logistic Support (ILS), which are the foundation to building a lean redelivery process, meanwhile considering the involvement of the OEM.

Considering the high costs and responsibilities for the acquisition of aircraft, airlines and operators are choosing to rent or lease airplanes, characterizing the leasing process (IATA, 2015). Leasing companies, also called lessors, are the owners of aircraft, negotiating directly with the manufacturers to acquire these products and leasing them to so-called, lessees, who are the operators. With a market already consolidated and strong growth forecast, leased aircraft represent more than 35% of all operational aircraft worldwide (Gomes *et al.*, 2013). Figure 2-1 presents the number and the percent of airplanes under leasing contract in the world.

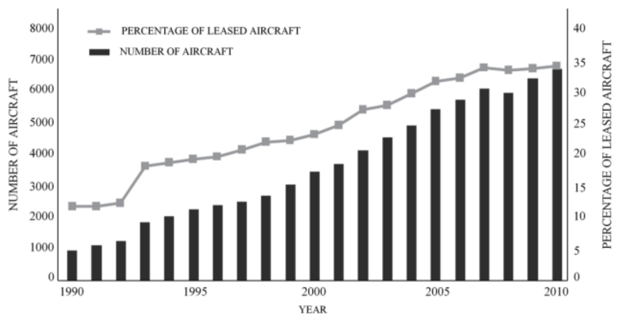


Figure 2-1 – Number and percent of airplanes under leasing contract in the world. Adapted from Gomes *et al.* (2013).

Two types of leasing contracts are usually conducted. The dry-lease and wet-lease are the means that the lessor offers its aircraft to the next operator. In both cases, the lessor grants the lessee exclusive use of its aircraft for a pre-agreed period, known as the lease term. Dry-lease is a lease where the lessee provides crew, maintenance and insurance. The wet-lease, on its turn, consists of the lessor providing an Aircraft with Crew, Maintenance and Insurance (Bourjade *et. al*, 2017), also known as ACMI. A wet-lease is typically conducted for a short term. Specific situations motivate wet-leasing practices, which include: (1) mechanical failure of an operator's fleet, known as "aircraft on ground" (AOG); (2) replacement in cases of hull loss or damaged aircraft; (3) heavy maintenance checks of fleet aircraft; (4) introducing a new route; and (5) seasonal demands (Bunker, 2000). In the case of a dry-lease, for a brand new aircraft, this term is often extended between eight to twelve years for a Narrow-Body and up to twelve years for a Wide Body (IBA, 2015). A monthly rental fee is charged to the operator for the aircraft use and an additional fee may also be charged for the maintenance reserve. Therefore, the lessor is able to guarantee that the maintenance and conservation of its aircraft is carried out, even if the operator does not plan for it. This maintenance reserve rate is heavily used for maintenance and heavy checks (IATA, 2015).

Even with the monthly payment for the use of the aircraft (leasing cost), together with the maintenance reserve, operators may identify advantages in aircraft leasing. The clearest one is that the operator avoids any large initial financial investment and, thus, the risk of the residual value of the aircraft continues with the lessor. A lease contract may also provide flexibility to optimize the operator's fleet capacity, including seasonal demands (Gomes *et al.*, 2013).

Besides, the leasing process of aircraft is the main source of income for any leasing company. Therefore, a lessor seeks to maintain its net worth by specifying how the aircraft should be used by contract, ensuring that this agreement is strictly followed by means of aircraft audits, documentations and records. In this way, leasing contracts are extremely complex agreements. These contracts cover aviation regulatory regimes and legal jurisdictions, incorporating protection mechanisms such as pre-mitigation for adverse events and airline failure, for example (IATA, 2015).

Given this scenario and according to IATA (2015), leasing processes can be divided into four steps: a) Pre-delivery; b) Delivery; c) Operation; d) Redelivery. This segmentation covers the whole process of aircraft leasing. Pre-delivery consists of the lessor formulating the contract and the lessee approving it. The next steps follow the delivery of the aircraft (Delivery), the operation (Operation) and the return of the aircraft after the period of operation (Redelivery) (IATA, 2015). The mentioned steps are detailed in the following paragraphs.

Leasing can be a cumbersome process once it involves an expensive product with a complex integrated system. Given the importance of the agreement for both parties, it is necessary that both the lessor and the lessee allocate time and effort to ensure the clarity and adequacy of the structure that will be leased. In this way, both the owner and the operator protect themselves from any problems during the agreed leasing period.

Therefore, the Pre-delivery process is characterized by the contact of an operator with the owner with the intention of renting one or more aircraft, followed by a pre-contract of the lease, which is usually made by the lessor itself, and concluded with the agreement signed by both parties involved (IATA, 2015).

The Delivery condition consists of handing over the aircraft to the operator. In this way, the operator considers and accepts the legal aspects for his involvement in the leasing process, such as the airworthiness condition in which the aircraft is to be delivered. Technical aspects are evaluated more deeply, especially in order to take into consideration most relevant items, such as engines, landing gear and APU (Auxiliary Power Unit), for example. Physical inspections on the aircraft and revisions of the records are also carried out, in order to certify that the aircraft complies with the conditions agreed in the contract. Finally, if the aircraft is in accordance with the return conditions, the operator signs the contract and receives the aircraft, concluding the process known as Delivery (IATA, 2015).

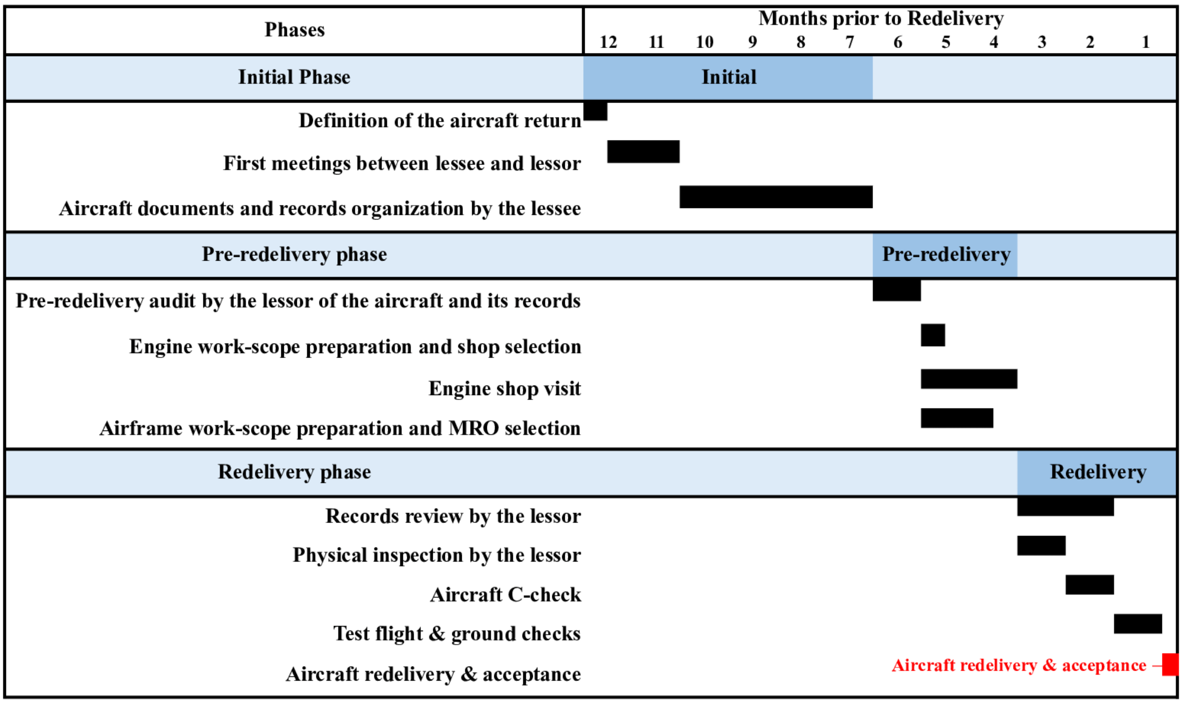
Throughout the operation, the closer contact and communication between the lessor and the lessee arise from maintenance and conservation activities. As it involves high costs and in order to maintain the value of the asset, the lessor has a great concern for the conservation and maintenance of its aircraft. In this way, many lessors impose contractually the maintenance reserve. This reserve guarantees a cashier so that there are always financial resources to pay for the required maintenance tasks (ACKERT, 2012).

Furthermore, the lessor may require, during the leasing period, audits and consultations of the documents and records to monitor the state in which his aircraft is. Failure to comply with these rules, imposed by contract, or non-payment of the maintenance reserve, may result in a breach of the leasing agreement (IATA, 2015).

As it composes the last leasing phase, the redelivery is further explored in the next paragraphs. In this process, the lessee returns the leased aircraft to the lessor. In this way, the conditions under which that airplane is to be returned and the date on which that process will occur are agreed in the leasing contract. As the aircraft is likely to be transferred to another operator, the timeframe and return condition must be followed strictly by the lessee and may suffer severe penalties in case of delays or disruptions during this process (IATA, 2015).

At the end of the leasing period, the redelivery may start, for instance, twelve months before the aircraft return. During this period the lessee must provide to the lessor many types of information about the involved aircraft. The whole redeliver process contains several distinct activities organized in phases. Figure 2-2 presents a diagram that outlines a typical redelivery timeline.

Figure 2-2- Typical redelivery timeline



During the approximately twelve months prior to redelivery, the lessee is expected to provide to the lessor several information about the condition of the aircraft and its records. As formerly presented, distinct activities may compose the entire redeliver, such as inspections, maintenances, shop visits, checks and audits. Those activities enable maintaining the aircraft in accordance with the lessor's and the applicable aviation authority requirements (ACKERT, 2014).

Lease agreements usually describe the conditions, which an airplane should be returned to the lessor, by a given date, at the end of the lease period. These are known as Technical Redelivery Requirements (ACKERT, 2014). The redelivery conditions should be negotiated during the pre-delivery period, where the lease contract is generated, avoiding any unexpected event at the end of the lease term (IATA, 2015). According to Ackert (2014), the requirements could be separated in four categories: a) physical; b) records; d) performance; and d) certification. Table 2-3 presents the aim of each category.

Table 2-3 – Objective of each category of the technical redelivery requirements usually evaluated by the lessor

Category	Technical Redelivery Requirement (Actions)
Physical	Evaluating the physical condition of the airframe, cabin interior, components and systems.
Records	Auditing all the aircraft records to ensure and guarantee that they fit with the lease terms and the regulatory authorities’ requirements.
Performance	Performing an Engine Power Assurance Run, functional and operational check of the components and a final Aircraft Acceptance Flight.
Certification	Guaranteeing compliance with local authorities’ requirements; Guaranteeing compliance with the next authorities’ requirements (cross-border transfer).

If the aircraft status is not compliant with the redelivery conditions, at the end of the lease period, the lessee not only needs to solve the defect at its own cost, but also needs to cover the rental payment of the aircraft. In case of a late redelivery and under the terms of the contract, the cost of this rental is expected to be even higher and, thus, the rent price increases. It usually increases more than one hundred percent of the contracted and agreed price (IATA, 2015).

The whole redelivery process can be divided into three stages, the initial, the pre-delivery and the redelivery stage. The redelivery process starts with the initial stage months before the redelivery event. In this stage, the lessee organizes the required aircraft documents and records in order to meet the redelivery conditions. The period of this planning phase is associated with the complexity and the duration of the lease term. Considering scenarios with possible needs for major checks and engines shop visits, it may be common that this initial phase starts six to twelve months before the redelivery.

At the pre-redelivery stage, the lessee – in cooperation with the lessor; creates a relevant maintenance work-scope. The lessor may assign an inspector to evaluate the aircraft condition and records. The integration between the lessor and the lessee, during the pre-redelivery period, is essential to avoid discussions during the redelivery. According to IATA (2015), the pre-redelivery stage generally includes the following elements:

- Pre-redelivery audit by the lessor of the aircraft and records;
- Designing an engine work-scope and seeking the lessor’s endorsement;
- Selecting the engine shop and allocating the slot to ensure timely return of the engine, if applicable;

- Creating an airframe work-scope and selecting the Maintenance, Repair and Overhaul organizations (MRO);
- Provide initial discussions with the lessor on planning, records standard, and other requirements.

The final stage is the redelivery itself. In this stage, the lessee focuses efforts on the aircraft records and checks procedures. The lessee's staff work together with the lessor's inspectors to check and approve all the aircraft records by monitoring the aircraft through a final major check - including a C-check and flight tests. By following check procedures and fulfilling leasing agreements and authority requirements, the aircraft is apt to be returned to the lessor (IATA, 2015).

In general, all the lease agreements specify the maintenance and condition in which the aircraft must be returned to the lessor. Typical return requirements (agreed in contract) define the components, engines, interior and airframe. Three return conditions for components are usually practiced. The first is related to FH (Flight Hours), FC (Flight Cycles) and Hard Time Components (HTC), specifying minimum levels of remaining utilization. The next condition concerns the calendar-limited component, which requests that these categories of calendar-limited components must not require a removal for the next 12 months. The last one involves the OCCM components (On-Condition and Condition-Monitored), which must be serviceable and the accumulated flight time since new (TSN) must not exceed 110% of the airframe accumulated flight time (IBA, 2015).

Regarding the engines, IBA (2015) also identifies three typical redelivery clauses. First one, minimum levels of remaining utilization, which must not exceed 6,000 engine flight hours (EFH) until the next scheduled removal. The second one is that, for each engine, a complete check must be run, including a hot and cold section video borescope inspection, and engine Run-Up according to an Original Equipment Manufacture's (OEM) maintenance manual procedure. Lastly, it is required to avoid any condition or defect that compromises the remaining life of the engine's constituent parts, also in accordance with authority airworthiness requirements and OEM recommendations.

With respect to the interior, that is, the most tangible part of the aircraft for the passengers; the lessors place great emphasis on it during the redelivery process to maintain the value of their aircraft. In general, the lessee may modify any original element of the cabin design. However, the lessors usually require that the aircraft returns with the same equipment that was first delivered. The conditions of its elements are also important, carpets, seats, cabin celling, sidewalls and overhead bins are expected to be clean and serviceable (AIRCRAFT COMMERCE, 2017).

In relation to the aircraft airframe, which involves fuselage, wings, empennage and corrosion issues; the IBA (2015) reveals that the aircraft structure should be free of major dents and abrasions; loose, pulled or missing rivets. In addition, the requirement that all structure repairs occurred during the aircraft operation should be permanent and in accordance with the structural repair manual (SRM) or any OEM approved documentation.

With respect to the corrosion issues, the redelivery conditions stipulate that the aircraft should be inspected and evaluated in accordance with the approved corrosion prevention and control procedures (CPCP).

Some variations of the redelivery conditions could be applicable given the length of lease, age and type of the aircraft. According to Aircraft Commerce (2017):

> "The term of the lease often changes expectations of return conditions, both during the lease and upon the aircraft's return. All things being equal, a longer lease term typically means a lower lease rate and a softening of return conditions. A long lease may see an aircraft make the transition from a marketable commodity to one destined for teardown. There is little sense in drafting onerous return conditions for an aircraft that may not fly again at the end of the lease".

2.1.1 Redelivery complications

Due to its structure and complexity, the redelivery process can be a major problem for lessees and lessors. The first issue is related to the redelivery conditions, which can be unclear and imprecise, leaving the return requirements open to misinterpretation. The poor contract of the redelivery conditions is one of the main challenges during the redelivery, since it may create disputes involving lessees and lessors (IBA, 2015). The IATA (2015) defines some elements of the redelivery conditions as 'almost always left vague'. One of the vaguest redelivery elements are the interiors, considering the evaluation of cosmetic and subjective terms, which are open to several misinterpretations. Expressions as 'fair wear and tear' are one term that can lead to disputes during lease returns. Aircraft Commerce (2017) defines the expression 'fair wear and tear' as a normal deterioration which causes furnishing, fittings, trim, panels, bulkheads, doors, floor panels, ceilings or other interior equipment to be worn or to have such level of deterioration which is consistent with normal operational use. This concept allows some level of degradation to be acceptable (AIRCRAFT COMMERCE, 2017).

Interiors are not the only concern that can cause discussions between lessee and lessor, given the poor contract resolutions regarding the redelivery conditions. The definitions of the "Replacement Parts" can also lead to confusion among the entities, for example.

"A 'Replacement Part' means a part, component, furnishing, appliance, module, accessory, instrument or other item of equipment and shall include the APU: (i) That is in the same operating condition as, and has a utility at least as equal to the part replaced (assuming that the replaced part was in the condition and repair in which it is required to be maintained under this agreement)" (AIRCRAFT COMMERCE, 2017).

Some clauses present conditions to protect the aircraft against devaluation due the amount of older parts incorporated. However, some words and expressions may cause subjective interpretations, such as the expression: 'at least equal'.

Other complication is often encountered with the fact that, in most cases, the original authors of the leasing terms, that is, the former representatives of lessors and lessees are not the same with the expiration of the term, especially due the long-term contracts. This situation could create, during the end of the lease term, contradictory points of interpretation between lessors and lessees. The use of outdated terms can also leave some clauses open to misinterpretation. For example, a return clause, which specifies that the aircraft should be returned with a late 'D check'; however, the term 'D check' is no longer clearly defined, affirms Aircraft Commerce (2017).

According to IBA (2015), a typical single aisle aircraft (737/A320) has an average additional cost of $1.65m per redelivery process, considering a six-year lease period. This value is based on the return complications. Some examples of return clauses are presented in the following sub items, together with the respective involved issues.

- **Clause (a):** "*The aircraft will be in good operating condition and be clean by scheduled passenger airline standards, and all structural shall have been repaired to a permanent standard*" (IBA, 2015).

  Involved issue: The terms 'good' and 'clear' could lead to confusion, even if the aircraft is subject to a C-check in order to return to the lessor, the condition of some items may not be acceptable. Generally, the structural condition and repairs could demand considerable efforts by the operator to achieve the lessor's requirements, generating high costs and delays to the lessee.

- **Clause (b):** "*The aircraft will have installed the full complement of equipment, components, accessories, furnishings and loose equipment as when originally delivered to lessee and, the aircraft (including the aircraft Documents and Records) shall be in a condition suitable for immediate operations under EASA EU-Ops 1, or FAR Part 121*" (IBA, 2015).

Involved issue: The full complement of equipment, components, accessories, furnishings and loose equipment, including the aircraft documents and records and its concern to the dual EASA and FAA requirements could provoke unexpected costs.

- **Clause (c):** "*The aircraft will have in existence a valid Certificate of Airworthiness (C of A) (or if required by lessor, a valid export certificate of airworthiness) with respect to the aircraft issued by the Air Authority*" (IBA, 2015).
  Involved issue: If necessary, the emission of a Certificate of Airworthiness could generate an additional cost.

- **Clause (d):** "*The aircraft will comply with the OEM's original specifications as at the Delivery Date*" (IBA, 2015).
  Involved issue: The lessee often applies modifications in the aircraft during the lease term. These modifications (Service Bulletin (SB), Supplementary Type Certificate (STC), etc.) can alter the final aircraft configuration from the OEM's original specification. Therefore, the lessee could spend time and money to remove the certain modifications or provide the modification certification.

- **Clause (e):** "*The aircraft will have undergone, immediately prior to redelivery, the next relevant C-check in block format so that all airframe inspections, falling due within the C-check interval, as defined in Manufacturer's Maintenance Planning Document (if lessee's Maintenance Program does not comply with the requirements of the Manufacturer's Maintenance Planning Document), have been accomplished*" (IBA, 2015).
  Involved issue: inside the lessee's Maintenance Program, some specific lessee tasks and requirements should be re-align with the OEM's Maintenance Program. Usually, airliners also operate out of phase tasks, requiring some modifications, so that these tasks fall within the C-check.

- **Clause (f):** "*The aircraft will have had accomplished all outstanding Airworthiness Directives (AD) affecting that model of aircraft issued by the Federal Aviation Authority (FAA) or European Aviation Safety Agency (EASA) which, if the aircraft were registered with the FAA or EASA, would have to be complied with during the term and for a period of 180 days after redelivery*".

Involved issue: The applicability of an Airworthiness Directives (AD) could be open to misinterpretation. The operator is susceptible to wrongly opt not to apply an AD, according to a subjective analysis of the AD compliance.

- **Clause (g):** "*The aircraft will be in external livery as provided by the lessor 90 days prior to redelivery to meet the next lessee's required paint scheme. If less than 90 days notice is provided, the aircraft will be redelivered with the fuselage and tail having been fully stripped, re-primed and painted white*" (IBA, 2015).
Involved issue: the lessee is expected to perform a completely new livery (next lessee's livery) painting-work or provide a fully stripped, re-primed and white painting of the fuselage and tail.

- **Clause (h):** "*The aircraft will have no open, deferred, continued, carry over or placarded log book items*" (IBA, 2015).
Involved issue: In case the operator finds several defects in the C-check, before the redelivery date, there is an obligation to fix each one, which generates additional costs.

- **Clause (i):** "*Each Flight Hour and Cycle controlled Hard Time Component (HTC) shall have not less than the 3,000 Flight Hours and/or the 3,000 Cycles of life remaining to the next scheduled removal, and shall be supported by appropriate certification documentation such as EASA Form 1 / FAA form 8130-3*" (IBA, 2015).
Involved issue: The poor documentation of each component may affect its traceability and management, generating additional costs due to the replacement or repair of parts, even in good conditions and serviceable.

- **Clause (j):** "*The installed components as a group will have an average of total flight time since new of not more than 110% of that of the Airframe*" (IBA, 2015).
Involved issue: This clause is set to avoid that old components may be installed in newer aircraft, devaluing the asset. Usually, the same operator with older aircraft could exchange components with newer aircraft in this fleet.

- **Clause (k):** *"Each engine will have not less than 6,000 Flight Hours expected life remaining to the next scheduled removal and the life limited components shall have not less than the 6,000 Cycle life remaining. The expected life remaining will be determined by a review by lessor and lessee of the engine in-service operating history, in-flight monitoring (particularly in respect of Exhaust Gas Temperature (EGT) and any abnormal trends), work scopes accomplished during the Term (particularly EGT margin and borescope* *findings), such information to be utilized in reference to industry experience, the engine manufacturer and the average deterioration rate of similar engines in lessee's fleet in assessing the expected remaining life of the engine*" (IBA, 2015).

Involved issue: One of the most expensive issues involving the engines. As the remaining life to the next schedule remove is estimated by a review of the engine, the lessee could chose to send the engines to the shop visit much earlier than necessary to avoid any considerable problem, but wasting money and lifetime of the engines.

- **Clause (l):** "*The fuselage will be free of major dents and abrasions, lose or pulled or missing rivets and all structural repairs shall be permanent standard repairs performed in accordance with the SRM or Manufacturer's Approved Data*" (IBA, 2015).

  Involved issue: During the operation, the aircraft may suffer damages and any other structural deterioration (major dents, abrasions). The repair must be permanent and with an acceptable finishing. However, the repair documents at some operators are not usually satisfactory and the quality and finish could take the lessor's evaluation open to misinterpretation.

- **Clause (m):** *"The landing gear and wheel wells will be clean, free of leaks and repaired as necessary; Each installed landing gear shall have not less than the 10,000 Flight Hours and/or the 10,000 Gear Cycles and/or the 36 months Calendar Time (whichever is the more limiting) to the next scheduled removal in accordance with the MPD (Maintenance Planning Document); and the wheels and brakes will have not less than half of their useful life remaining"* (IBA, 2015).

  Involved issue: Life limitations may provoke early shop visits of the wheels, tires, brakes, driving and landing gears (prior to the determinate MPD life).

To complement the list above, the IBA (2016) asked the lessors two questions about the most commons issues, biggest challenges and reasons for a late and costly redelivery process. The presented issues reveal the complications and pitfalls of the redelivery process according to the lessor's answers (IBA, 2016). The main root causes are mentioned as:

- Lack of lessee planning;
- Early engagement with the lessor;
- Inadequate focus on assets during operation;
- Lessee operational demands consuming redelivery resources;
- Decentralized, missing or incorrectly completed records;

- Underestimation of the total workload;
- Lead times and lessor expectations;
- Discovery of additional work required during the redelivery maintenance input;
- Lack of lessor appetite for the returned aircraft;
- Engines failing final borescopes.

The complications above could lead to main delays and additional costs during the lease transactions. In addition, lessors are in general more rigid, powerful and expert than the lessee. These characteristics are not usually demonstrated by the lessee, especially considering small airlines. The consequences of a redelivery process between a lessor – who has a good expertise; and a lessee – who has not enough experience; may create additional issues, causing delays and increasing costs to the lessee (IATA, 2015).

2.2 Technical background on the commercial aviation industry

In order to provide to the reader a broader vision about of some aspects and in order to base the forthcoming methodological applications, result discussions and further author's recommendations, this present subsection introduces a brief explanation of some elements that compose the commercial aviation industry.

As the redelivery is a process inserted in some other scenarios, it is important to present and explain each one. The first point is to clarify how and why the aviation has become one of the most regulated systems in the world. This may be achieved by starting with the introduction of the ICAO, followed by the creation of the aviation authorities and then, by the aeronautical regulations and requirements. The second issue treated here is the aeronautical technical publications and maintenance that must be introduced to base redelivery explanations. Then, the third concept presented in this technical background section is the ILS development, that brings to the reader a broad vision of how the relationship between the involved parties may occur (*e.g.* OEMs, lessees, lessors, suppliers), considering logistic activities during the entire life cycle of the aircraft, from its concept until its disposal.

2.2.1 The ICAO (International Civil Aviation Organization)

The introduction of the ICAO in this study aims at explaining how the aviation requirements and regulation have been developed. In addition, this concept is crucial to understand the establishment and the relevance of aviation authorities, which is presented in this thesis within several redelivery analyses.

The increase in the demand for civil air transportation was the main motivation to set a group of 55 allied countries, in order to establish world air rules. The Convention of International Civil Aviation took place in Chicago in November 1944, aiming at first initiatives to consolidate the International Civil Aviation Organization (ICAO), which was officially implemented in 1947 (FILIPPO DE FLORIO, 2016). The objectives of the ICAO are to consolidate Standards and Recommendation Practices (SARPs) and policies to support the civil aviation regarding the following aspects: safety, efficiency, security, economical sustainability and environmental responsibilities. Currently, ICAO works with 193 members and industry groups. Since its creation, the technical standardization (aviation international standards) has been ensuring high levels of quality in several civil aviation sectors, including aircraft, facilities, crews and general services (ICAO, 2019).

The international standards guide each member of the ICAO towards its particular aeronautical requirements administration. In the case of a noncompliant member (unapt to comply with the aviation standards), the ICAO may impose restrictions associated with any aircraft registered in its respective country.

Unlike the standards, the recommended practices, however, are not essential, but desirable. Therefore, the basic premise of each Contracting State (member) is to be engaged with the standards, aiming to assure the worldwide civil aviation standardization, regarding the previously mentioned aspects (FILIPPO DE FLORIO, 2016).

The Standards and Recommendations Practices (SARPs) are divided in 19 Annexes, as follows:

- *Annex 1. Personnel Licensing provides information on licensing of flight crews, air traffic controllers, and aircraft maintenance personnel, including medical standards for flight crews and air traffic controllers.*
- *Annex 2. Rules of the air contain rules relating to visual- and instrument-aided flight.*
- *Annex 3. Meteorological Service for International Air Navigation provides meteorological services for international air navigation and reporting of meteorological observations from aircraft.*

- *Annex 4. Aeronautical Charts contains specifications for the aeronautical charts used in international aviation.*
- *Annex 5. Units of measurement to be used in air and ground operations list dimensional systems to be used in air and ground operations.*
- *Annex 6. Operation of Aircraft enumerates specifications to ensure a level of safety above a prescribed minimum in similar operations throughout the world.*
- *Annex 7. Aircraft Nationality and Registration Marks specifies requirements for registration and identification of aircraft.*
- *Annex 8. Airworthiness of Aircraft specifies uniform procedures for certification and inspection of aircraft.*
- *Annex 9. Facilitations provides for the standardization and simplification of border-crossing formalities.*
- *Annex 10. Aeronautical Telecommunications Volume 1 standardizes communications equipment and systems, and Volume 2 standardizes communications procedures. •*
- *Annex 11. Air Traffic Services includes information on establishing and operating air traffic control (ATC), flight information, and alerting services.*
- *Annex 12. Search and Rescue provides information on organization and operation of facilities and services necessary for search and rescue.*
- *Annex 13. Aircraft Accident and Incident Investigation provides uniformity in notifying, investigating, and reporting on aircraft accidents.*
- *Annex 14. Aerodromes contain specifications for the design and equipment of aerodromes.*
- *Annex 15. Aeronautical Information Services includes methods for collecting and disseminating aeronautical information required for flight operations.*
- *Annex 16. Environmental Protection Volume 1 contains specifications for aircraft noise certification, noise monitoring, and noise exposure units for land-use planning and Volume 2 contains specifications for aircraft engine emissions.*
- *Annex 17. Security-Safeguarding International Civil Aviation against Acts of Unlawful Interference specifies methods for safeguarding international civil aviation against unlawful acts of interference.*
- *Annex 18. The Safe Transport of Dangerous Goods by Air specifies requirements necessary to ensure that hazardous materials are safely transported in aircraft while providing a level of safety that protects the aircraft and its occupants from undue risk.*

- *Annex 19. Reinforces the role played by States in managing aviation safety, stressing the concept of overall safety performance in all domains in coordination with service providers.*

2.2.2 Aviation authorities and airworthiness

The annexes above do not have power of law enforcement; however, the grounds presented by the ICAO Annexes support and guide the aviation authorities, for each different member, to create and maintain the aviation regulations. In this way, each country (ICAO member) through its aviation authority has the responsibility to regulate, supervise and audit its aviation system. Given that, some terms have been established. The definition of Airworthiness enables indicating whether an aircraft or aircraft component is allowable to operate in accordance with the authority regulations:

"For an aircraft, or aircraft part, (airworthiness) is the possession of the necessary requirements for flying in safe conditions, within allowable limits" (RAI ENAC Italian Technical Regulations *apud* FILIPPO DE FLORIO, 2016).

This definition is based on three conditions: Safe conditions, possession of necessary requirements and allowable limits:

- Safe conditions: Any aircraft or aircraft component that is capable to make a complete flight without endangering the crew, passengers, equipment, properties and environment.
- Possession of the necessary requirements: Any aircraft or aircraft component must be designed, built and tested in accordance with the airworthiness regulation criteria.
- Allowable limits: Any aircraft or aircraft component is projected to operate within a flight envelope and some conditions previously defined. Therefore, some operational limits must be ensured, such as speed and structural load factors limits and flight rules (e.g. VFR – Visual Flight Rules and IFR – Instrument Flight Rules).

Airworthiness enables aviation authorities to classify, according to their regulations, if an aircraft or aircraft component is able to operate in the same condition that were established as safety and proper to operate. In this way, the main responsibilities and tasks of an aviation authority are (FILIPPO DE FLORIO, 2016):

- To define airworthiness requirements. These requirements are essential to establish the procedures and rules, so that aviation organizations are able to comply with the ICAO standards. Each aviation authority may create their own requirements or may adopt requirements already validated from another ICAO member.
- To advise and notify the involved organizations about the regulations. This can be accomplished by several types of publications, such as circulars, technical regulations and airworthiness directives.
- To supervise and audit aeronautical material (aircraft and aircraft components) and organizations based on the previously defined airworthiness requirements.

Table 2-4 presents different worldwide aviation authorities. The presentation of such entities; especially the Federal Aviation Administration (FAA) and European Union Aviation Safety Agency (EASA); is essential to understand redelivery clauses, which are presented in the sequence of this study.

Table 2-4 – Example of aviation authorities

Name	**Country**
FAA - Federal Aviation Administration	USA
EASA* - European Union Aviation Safety Agency	Europe Union
ANAC – Brazilian National Civil Aviation Agency	Brazil
TCCA - Transport Canada Civil Aviation	Canada
CAAC - Civil Aviation Administration of China	China

*EASA - The European Union Aviation Safety Agency is an agency of the European Union, established in 2002, that represents 32 European countries (EASA, 2019).

2.2.3 Aeronautical requirements and regulations

The aeronautical requirements and regulations and their respectively certificates are the foundation of some redelivery concerns. The following explanation presents particular certificates that are essential and part of the redelivery. As previously mentioned, the ICAO standards are guidelines to implement the respective aeronautical requirements and regulations created by an aviation authority. The requirements and regulations are based on the ICAO

Annexes 6 and 8 and the aim to establish procedures and rules to the aviation organization (ICAO, 2019).

Given that they aim to cover several types of aviation operations and services, the aeronautical requirements are used separately in distinct areas. The FAA (Federal Aviation Administration) has divided the requirements in specific parts related with the aircraft, airman, airspace, operation (general and air carriers), certificated agencies (schools and maintenance stations), airports and others (FAA, 2019).

To exert aeronautical activities, OEM's, operators and any other organization must comply with the applicable aeronautical requirements, thus, the aviation authorities issue some statements to certify their activities. The preliminary statement documentation that certifies if an OEM complies with the regulations imposed by the aviation authority is described Type Certification (TC). The TC is a documentation issued by the aviation authority to certify a model of product (aircraft) in accordance with the applicable aeronautical requirements. Therefore, the OEM must keep each aircraft, of the same model produced, in the same specifications certified and described in the TC (FAA, 2019).

The whole certification process, which culminates with the issue of the TC, is generally conducted by the same aviation authority of the OEM's country. But, bilateral agreements between aviation authorities of distinct countries may guarantee a simpler certification process after the first TC delivered (EASA, 2019).

The FAA briefly describes the certification process:

"The FAA's aircraft certification processes are well established and have consistently assured safe aircraft designs. As part of any certification project, we conduct the following:

- *A review of any proposed designs and the methods that will be used to show that these designs and the overall airplane complies with FAA regulations;*
- *Ground tests and flight tests to demonstrate that the airplane operates safely;*
- *An evaluation of the airplane's required maintenance and operational suitability for introduction of the airplane into service; and*
- *Collaboration with other civil aviation authorities on their approval of the aircraft for import".*

The registration of any aircraft requires that the aircraft's TC be issued by the Aviation Authority of the corresponding country. However, other significant statement is essential to operate each aircraft, the Certificate of Airworthiness (CoA). A certificate also issued by the Aviation Authority that certifies if the aircraft is in the same condition that is described in the aircraft TC (FAA, 2019). A CoA remains valid as long as the aircraft is in a condition for safe operation, maintenance, preventative maintenance, and alterations are performed in accordance with the applicable requirements (FAA, 2019).

As the aim of the CoA is to guarantee that the operators are maintaining the aircraft in safe conditions, the operators must keep it onboard the aircraft and present to the Aviation Authority representative if necessary (FAA, 2019).

2.2.4 Technical publications, aircraft records and documentations

In additional of the TC and CoA, other relevant aspects for this study are the technical publications, a set of technical to support and assist the airliners, operators and owners during the entire aircraft life cycle. This set may contain, and others: Aircraft Maintenance Manuals (AMM), Aircraft Flight Manuals (AFM), Aircraft Illustrated Parts Catalog (AIPC), Fault Isolation Manual (FIM), Services Bulletins (SB), Airworthiness Directives (AD) and Supplementary Type Certifications (STC), being the last three the focus of this study (EASA, 2019).

The Services Bulletin (SB) is a publication issued by OEMs, approved by its aviation authority and due bilateral agreements, others authorities, which have as main objective the aircraft modifications. Due to economic, market or safety reasons, is desirable from the operators some upgrades to maintain its aircraft economically efficient, profitable or to increase performance, change the cabin lay-out and others types of modifications. These improvements may support the fleet along the years and may be an essential business for the OEMs (FAA, 2019). Service Bulletins are not mandatory, in terms of incorporations. But, when the Service Bulletin affects flight safety, the aviations authorities may issue an Airworthiness Directives (AD) to alert the owners and operators. The incorporation is mandatory if the aviation authority of the registered aircraft or the aviation authority of the OEM issued an AD. If the owner or operator does not comply with the incorporation of the applicable AD, the aircraft CoA expires, being prevented to fly. The other relevant document for this study is the STC. The STC is an approved document issued by the OEM, MRO and any other aeronautical company with the aim to alter or repair an aircraft, engine or propeller. The STC is adding to the aircraft TC and its main difference to the SB is that the approval is not included in bilateral agreements. Therefore, if a company develops and applies an STC, this company must certify the modification to its aviation authority and to any other authority that has the intention to register the aircraft (TCCA, 2012).

The main purposes of these three types of Technical Publications, (SB, AD and STC), presented below, are further explored in this Master Thesis (ATA SPECIFICATION - iSpec 2200, 2004):

- *Modifications to the aircraft, engine or accessory including embedded software.*
- *Modifications, which affect performance, improve reliability, increase safety of operation, provide improved economy or facilitate maintenance or operation.*
- *Substitution of one part with another superseding part only when it is not completely interchangeable both functionally and physically, or when the change is considered to be sufficiently urgent or critical that special scheduling or record of accomplishment will be required.*
- *Substitution of one embedded software program by another which change equipment function and the part number of the programmed memory device, requiring a record of accomplishment.*
- *Special inspections/checks required to maintain the aircraft, engine, or accessories in safe operating condition.*
- *One-time inspections/checks to detect a flaw or manufacturing error.*
- *Special inspections/checks required to be performed until a corrective action can be taken. (e.g., an inspection to detect cracks in a radius until the radius can be ground out.) The modification information may be issued as a revision to the same Service Bulletin that transmits the inspection instructions.*
- *Special functional checks of an urgent nature required to detect an incipient failure, such as pressure checks, functional checks, etc.*
- *Reduction of existing life limits or establishment of first time life limits for components.*
- *Conversions from one engine model to another.*
- *Changes affecting the interchangeability or intermixability of parts.*

Moreover, with regard to the mentioned technical publications, aircraft records and documentations are part of the entire life cycle of the aircraft, by registering, tracing and documenting any significant activity performed in the aircraft. The importance of such technical publications is associated with registering, tracing and documenting any significant activity performed in the aircraft (AIRCRAFT COMMERCE, 2017).

In addition, these records and documentations enable proving and certifying whether investigated actions have been implemented. Therefore, they may be requested by the applicable aviation authority and by the lessor in eventual audits. Particularly, during the redelivery, audit practices are commonly more frequent and strict. Considering this, the lessee must create and preserve aircraft records and documentations in good conditions. The most common document types required by the lessors during the redelivery are (ACKERT, 2014):

- Status List (*e.g.* Certified Airworthiness Directive Status; Certified Modification Status);
- Certificates (*e.g.* Certificate of Airworthiness; Noise Limitation Certificate);

- Statements (*e.g.* Major and Minor Modification Statements; Accident/Incident Statement);
- Records (*e.g.* Airframe Logbook; AD Records; Hard Time Part Records);
- Drawings (*e.g.* LOPA; Emergency Equipment Layout);
- Manuals (*e.g.* Last revision of the applicable Flight Manual; Aircraft Maintenance Manual - AMM);

The poor conservation or even the lack of proper documentation lies at the root of disputes between lessees and lessors during the redelivery. In this case, usually, the lessor may request the lessee to execute the involved action (*e.g.* the replacement of a component, whose installation has not been properly registered) to certify that the aircraft meets its requirements and the aviation authority's requirements. In addition, since many aircraft records and documentations are in paper media, its organization and conservation become a challenge, especially considering long term negotiations (BURHANI *et al.*, 2016).

One of the main sources of the records and documentations issues is the aircraft maintenance activity, which is presented in the sequence of this literature review. These two aspects (aircraft records/documentations and aircraft maintenance) are strongly demanded during the redeliver considering the lease agreements' compliance and may be potential concerns to the lessees and lessors (IATA, 2015).

2.2.5 Aeronautical maintenance

In order to keep the aircraft in a safe condition and to meet the applicable aeronautical authority's requirements, it is essential to assure the proper maintenance along its life cycle. In addition, lessors consider this aspect as one of the most important to keep its asset (aircraft) economically valued. Therefore, during the redelivery, the lessor may put effort to audit the significant maintenance activities performed and their related records (ACKERT, 2018).

In general, there are two types of aircraft maintenance: preventive and corrective. The preventive maintenance encompasses tasks and their receptivity intervals (*e.g.* flight hours, flight cycles, months) which are pre-defined in accordance with the maintenance document planning (MPD) issued by the OEM or in accordance with the lessee's approved maintenance planning document. In turn, the corrective maintenance comprises the required tasks to amend eventual issues and corrections, which were not planned, but may regularly occur (ACKERT, 2018).

The preventive maintenance tasks are usually grouped in "maintenance packages" which have the objective of minimizing maintenance costs and maximizing the aircraft availability, taking advantage of specific and defined periods of implementations. Thus, some aircraft parameters must be strictly controlled, in order to schedule the maintenance package application. These parameters are usually flight hours and cycles, but it is common to meet some maintenance packages that are controlled by period, as months and years. The most common packages are known as "A-Check" and "C-Check", which may be understood – by the aeronautical industry in terms of amount and the complexity of the tasks; as minor and major checks respectively. In general, as the C-check is a maintenance package – which covers several essential areas of the aircraft, through replacements of parts, inspections and tests; this procedure is expected to be required by the lessor during the redelivery. Furthermore, the preventive maintenance may be beyond the scope of maintenance packages. For instance, it may be needed to perform isolated schedule tasks, overhaul and shop visits of some components, as landing gears, APU (auxiliary power unit) and engines may be needed (ACKERT, 2018).

In parallel, the corrective maintenance acts to support the lessee in case of any non-routine event, such as an unexpected component failure or an airframe structural damage. These types of maintenances are, usually, out of the lessee's control and may be requested in distinct situations, such as at airports with sufficient maintenance resources availability or in the worst-case scenario, airports without the necessary infrastructure and resources (*e.g.* lack of manpower, parts, tools, ground support equipment) to perform the demanded task (ACKERT, 2018).

One example of the importance of maintenance tasks during the leasing period is the provision of financial resources by the lessor, under the lessee's payment, in order to guarantee that the major maintenance activities are performed. This is known as Maintenance Reserves and many of leasing agreements bring this payment obligation along with other leasing expenditures. The non-payment of the maintenance reserves may be reason for breaching leasing agreements (ACKERT, 2012).

However, the lessee's concerns that involve maintenance are not exclusive about the maintenance actions; lessees may also find some difficulties and pitfalls during the planning and management of the aircraft maintenance. In general, the operator has to manage not only one aircraft, but rather a fleet of aircraft. This scenario creates a logistic challenge, which may be composed by several distinct areas, such as the management of flight operations, parts and components, personal resources and others (AIRCRAFT COMMERCE, 2017).

This brief overview on aeronautical maintenance is essential to guide upcoming methodological applications and further discussions in this master study. Many of the lessees and lessors' disruptions during the redelivery may be grounded in maintenance issues.

2.2.6 ILS (Integrated Logistic Support)

The aspects mentioned above in the technical background provide a concise vision of the aviation regulation as its ramifications, since the creation of the ICAO. The leasing process, which encompasses the redelivery, has been introduced with these concepts. However, as the objective of this study is to investigate the potential involvement of aircraft OEMs during the redeliver, by assisting aircraft lessees and lessors; one more concept must be introduced. Considering redelivery concerns, this section starts presenting a developed logistic process that may work as baseline to future method applications and several discussions and results.

Based on logistics activities, the ILS (Integrated Logistics Support) is an integrated and interactive process to assist manufactures and their stakeholders to minimize and optimize the production life cycle costs (DAU-MIL, 2020). The following paragraphs explain and clarify the ILS term and how the industry takes advantage of this process.

The first point that should be quoted is the product life cycle phase. Considering that aircraft are complex products, its entire life cycle may be divided into distinct phases (SX000i, 2016):

- Preparation phase: Definition of the product concept and requirements;
- Development phase: Detailed product design and development process;
- Production phase: Product manufacturing and final assembly;
- In service phase: Entry in service and operational phase;
- Disposal phase: Product retiring and recycle.

These definitions may guide each involvement between manufacturers and their stakeholders for future analysis. Despite the redelivery is inserted in the "in service phase", the other phases are also relevant for this study, given that the decisions during the "concept, development and production phases" may affect the "in service phase". The ILS process may be applied in each of the mentioned phases; it is a technical and a management process, which brings the logistic concepts and elements to the life cycle phases, aiming to develop a support solution to optimize and minimize the life cycle costs.

The main objectives of the ILS are: 1) Support the product design, focusing on minimizing maintenance, operational and training costs, while increasing operation readiness; 2) Develop the required support for the design, funding and test resources; 3) Provide the required assistance, from the beginning to the end (disposal phase), ensuring that the support solution and physical deliveries are updated with new technologies and operational requirements (SX000i, 2016).

The complete ILS process is divided in twelve distinct elements of different fields of study. Such distinct elements promote the understanding and the application of the process. According to the SCX000i international guide (2016), the following list presents each ILS element:

- **Maintenance Procedures and Planning:** This element covers the maintenance concepts and maintenance requirements to support the product along its life cycle. It is included analyses, optimizations and improvements of the applicable maintenance procedures, planning and resources. The main activities of Maintenance Procedures and Planning are developing the maintenance concept and plan; performing Level of Repair Analysis (LORA); and conducting Maintenance Task Analysis (MTA).

- **Technical data, orders and publications:** The objectives of this ILS element are to identify, plan and test potential resources to acquire and store technical information and publications, as operational records, maintenance manuals and technical certificates. The main activities of Technical data, orders and publications are: to develop and promote a Technical Data Package (TDP) that may include engineering drawings, standards and performance requirements; to create and provide technical publications in accessible medias, as electronic devices.

- **Training and training support:** Training and training support aims to identify, plan and provide the necessary personnel training to operate and maintain the product. The main activities of Training and training support are to provide Training Needs Analysis (TNA) and a training plan.

- **Design influence:** Design influence is an element to support the system engineering to analyze and explore the potential impacts of the conceptual design and development process along the product life cycle. This element utilizes interactive and quantitative parameters, as Reliability, Availability, Maintainability and Testability (RAMT) and Supportability to drive these analyses. The main activities of design influence are to perform life cycle cost, RAMT and logistic support analyses.

- **Product support management:** The product support management consists of preparing the ILS plan and the support concept; and providing the obsolescence report. The main activities of the Product support management are: Studying and determining the high level requirements to support the product; Managing the agreements and contracts; Developing and keeping ILS plan updated; and finally, Providing an obsolescence management.

- **Supply support:** Supply support consists of the identification, study and analysis of the required suppliers to support the product since its conception until its disposal. This element covers the management and plan for spare and repair parts, Ground Support Equipment (GSE) and any other material supplied from third parts. The main activities of supply support are to perform material supply; and to provide provisioning data.

- **Packaging, Handling, Storage and Transportation (PHS&T):** This element is associated to any kind of logistics activities to support the products, their GSE, spare and repair parts and any other additional material throughout their life cycle. These logistic activities may encompass handling aspects, *e.g.*: Transportation, towing, recovery, load and unload. Also, may encompass storage, transportation and packaging aspects, such as: Conservation, lifting, container concept, packing and unpacking. The main activity of PHS&T is to analyze and develop PHS&T demands and requirements in order to support the product and its applicable support equipment.

- **Sustaining engineering:** The aim of the sustaining engineering element consists of the engineering assistance to maintain the product inside its operational and safety requirements. During the lifetime, the product also may require some updates and corrective actions to keep it economically viable and safe. The main activities of Sustaining engineering are to perform engineering activities, *e.g.* technical analysis and scientific studies; and to provide engineering assistance for modifications and design changes.

- **Computer resources:** This element covers the software, hardware, facilities and the required manpower in order to operate and support the computer systems. The main activities of computer resources are to provide computer resources and perform computer analysis during the entire product life cycle to keep the product updated and inside its requirements.

- **Facilities and infrastructure:** Consist of the study of the required facilities, infrastructure to operate, integrate and support a product. For this element, there is also a need to consider training places, equipment storages and any other property asset to compose the entire product support network. The main activities of Facilities and Infrastructure are to provide Facilities and Infrastructure analysis, with the considerations described above, at each product phase, since its preparation phase (*e.g.* development rooms, laboratories) until its disposal phase (*e.g.* recycle or cannibalization places).

- **Manpower and personnel:** The aim of the Manpower and personnel element is to identify, analyze and plan the required personnel resources. This element also encompasses the proper study of the required qualifications and skills to operate, maintain and support the product. The main activities of Manpower and Personnel are: Establish and analyze the applicable manpower (that is, the recommended number of personnel to accomplish the demand tasks) and personnel (the recommended level of qualification, skills, knowledge and abilities of each professional, crew member and staff).

- **Support equipment:** This element consists of the study and planning of the required equipment to support the product. Such equipment may include special GSE, common tools, expendable and durable items. The main activities of Support equipment involve analyzing the product requirements to acquire and maintain the applicable support equipment.

The presented twelve elements are an overview of the ILS process, which combines several logistic activities, in order to optimize and minimize the total aircraft life cycle cost. OEMs and their stakeholders should conduct an interactive and integrated process. Thus, a consistent collaboration between all the parties is fundamental to create a robust and mature process, hence, increasing the product efficiency and effectiveness. From that perspective, this master study brings the ILS concept for further applications. The ILS elements are a baseline to support and determine the methodological aspects.

2.2.7 Technical background considerations

The Technical Background on the Commercial Aviation presents an introduction about some civil aviation concerns, as aeronautical requirements, aviation authorities, technical publications and aircraft maintenance. In addition, a logistic framework (ILS) has been introduced, in order to guide the involved parties during the product (aircraft) life cycle, minimizing potential issues and extra expenditures. With it and as the aim of the present master thesis is to study the OEM’s involvement as an effective third party facilitator in the aircraft redelivery, the main proposal of this master thesis is to identify and list the most critical redelivery issues, which concern the aircraft manufacturers.

For this purpose, along the Technical Background on Aircraft Redelivery it was introducing several complications of the redelivery process, in general, without any segregation between issues that may involve or not the OEM. Thus, the complications presented in the Section 2.1.1. are the main complications of the entire redelivery process, many of them, lessors and lessee’s internal problems or organizational and cultural issues that are out of the OEM's work scope.

The Technical Background on Aircraft Redelivery also reveals that the main studies and surveys about redelivery issues are more punctual than overarching, denoting problems that are not clearly targeted for a solution or that may not address their root causes. Therefore, this study also performs a low-level analysis of redeliveries issues, illustrating some concepts for logistics and supportability to enable the standardization and evaluation of possible root causes, in consideration of the OEM’s involvement as an effective third party facilitator. In sequence, even if the solutions of the problems are not the core of this study; a set of recommendations is provided to allow the OEMs assisting lessors and lessees with the most significant issues during the handover of aircraft.

2.3 Methodological background

One of the purposes of this thesis is to gather information of the existing literature and the knowledge of experts on the field of maintenance and/or aircraft leasing to identify different categories to be tackled in the process of returning the aircraft, using Content Analysis and the Delphi Method.

Traditional Content Analysis is a quantitative approach that enables summarizing messages using scientific concepts (replicability, validation and hypothesis testing). The method enables analyzing interpretations in different units or formats from those originally presented in the assessed text (NEUENDORF, 2002). Hence, the Content Analysis enables reducing the information of texts into fewer content categories (WEBER, 1990).

In the field of Aircraft Maintenance, Yu *et al.* (2011) explored a different type of procedure to derive information from large quantities of textual content. The authors conducted a textual data mining to capture historical data from Maintenance Repair and Overhaul (MRO) Engineer's reports to provide an efficient job quotation. Textual Data Mining allows words in the text to be classified and counted; however, the use of a computer-aided Content Analysis to categorize engineering activities does not need to face problems related to misinterpretations, as the text provides straightforward and precise information. Contrary to this context, the present thesis encounters issues associated to different professional judgments concerning the relevance of redelivery activities.

Bowyer and Davis (2011) conducted face-to-face interviews to explore participant's perspective and experience in aircraft acquisition. Given the complexity of leasing agreements, the authors have also used textual data mining on lease terms and conditions to compare to the findings from the expert's interviews. The authors identified that the acquisition decision involves the cost and availability of maintenance as one primary concern that is associated to aircraft type but not necessarily connected to the issues of its price and financing (BOWYER and DAVIS, 2011). This finding highlights the need to explore different measures to provide efficient maintenance, aiming at cost and time-consuming process reductions.

Also in the context of Maintenance and Content Analysis, Lattanzio *et al.* (2008) and Patankar *et al.* (2003) analyzed procedural errors (errors involving Maintenance Manuals, Service Bulletins, Workcards, Jobcards, Maintenance Tips and Illustrated Parts Catalog, *e.g.*)

in aircraft maintenance by dividing incident reports into two error groups, Document Deficiencies and User Errors. Patankar *et al.* (2003) list several computer-aided coding schemes in aviation maintenance, especially concerning the identification of procedural errors in narrative sections of Aviation Safety Reporting System (ASRS) reports, such as MEDA (1994), NASA (1996), QUORUM (MCGREEVY, 1997), FRANCIE (OSTROM *et al.*, 1997), HFACS-ME (SCHMIDT and WATSON, 2002) and a tool developed by Hobbs and Williamson (2002).

Despite the computing advances in machine learning, that have been showing reasonable interpretation of word senses and texts, a standard content analysis is considered sufficient to conduct this present research, ensuring the correct analysis of syntactic structures and referentially integrated semantic representations.

Also, in the context of aircraft maintenance, McCarty and Moore (1977) conducted a semantic content analysis to reduce both data volume and semantic bias and to provide a key list of “in-use” aircraft maintenance cost information.

Considering the scarce literature concerning the relationship of Product Lifecycle Management (PLM) and MRO, Romero and Vieira (2014) proposed a Content Analysis using different sources of information (research papers, academic documents, white papers, industrial documents and news) in order to investigate how PLM system could be improved to better support MRO services. Given that for the purpose of the present research, the scientific literature in aircraft redelivery and maintenance is also limited, different sources of information are considered.

The method applied in this thesis, that proposes to analyze aspects of the redelivery, was inspired on the study conducted by Abrahão (1998), who performed a multi-technique model to detect issues associated with Aircraft Battle Damage Repair (ABDR). Abrahão (1998) draw upon a Content Analysis and a Delphi Method to collect a ranked list of categories to validate the proposed ABDR model and to, finally, suggest recommendations for the Brazilian ABDR Program.

The Delphi Method was originated at the RAND Corporation (DALKEY and HELMER, 1963), which develops researches and analyses for the United States Department of Defense. Thereby several researches, especially the ones that first mentioned the Delphi approach, are inserted on the military context. The main objective of the method is to provide the most reliable opinion consensus of a group of professionals. In order to do so, the experts respond to several rounds of questionnaires until their ideas converge (DALKEY and HELMER, 1963).

One of the first scientific research papers published on the matter of Aircraft studies and the Delphi method intended to predict air travel and air traffic technology to the year 2000 (ENGLISH and KERNAN, 1976). According to the experts at that time, supersonic flights would not be allowed to overfly the United States nor European countries, which in fact occurred. However, the experts have wrongly predicted that the development of a more advanced supersonic aircraft would go into production and that sonic boom could not be reduced. The outcome from this research enables concluding that forecasting technological aircraft developments for long-term periods may not provide accurate estimates. This thesis, in turn, proposes assessing the experts' viewpoint for present judgments and experiences. This framework avoids creating more deviation between the experts' responses.

Different authors (LINZ *et al.*, 2011; LINZ, 2012; DUNCAN, 2013; BEVILACQUA *et al.*, 2015; LAN *et al.*, 2016) have recently explored the Delphi method in aircraft researches.

Linz *et al.* (2011) and Linz (2012) have conducted a Delphi exercise to project future scenarios for the business aviation industry. As opposed to English and Kernan (1976), Linz *et al.* (2011) and Linz (2012); Bevilacqua *et al.* (2015) combined a Delphi methodology with discrete event simulation and integration definition methods for process modeling to predict future scenarios of air traffic operations. It can be noted that with new advances on computer modeling, the forecasts are becoming more reliable, as researchers are able to combine and validate historical data and experts' opinions into different analytical models.

On the context of aircraft Maintenance using the Delphi approach, Lan *et al.* (2016) explored professionals' viewpoints on critical components for the environmental control system of aircraft. The historical data of the key factors – indicated by the experts during the Delphi exercise; were considered as input in a neural network. The authors have then built an optimal prediction model to come up with a maintenance strategy of critical components. Given the scarce literature references on the use of Content Analysis and the Delphi Method to maintenance case studies, this thesis provides not only methodological contributions, as it gathers the existing literature content, but also provides recommendations for redelivery procedures that are, thus far, not content of any scientific publication.

3 Methodology

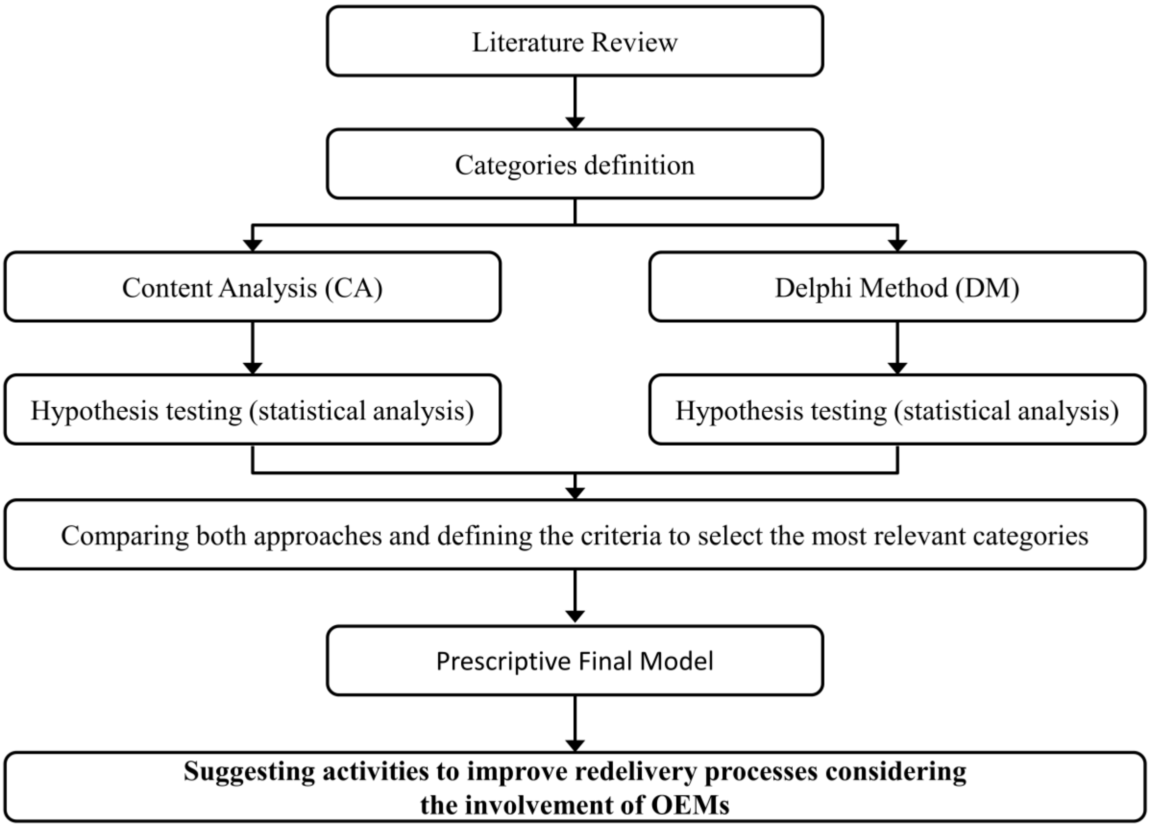
This study aims at assessing redelivery processes and, then, identifying and listing the most critical issues which concern aircraft manufacturers. Thereby, the main objective is to provide the manufactures with some recommendations to assist lessors and lessees, based on the detected redelivery issues.

Given the objectives of this thesis, the present research proposes to firstly investigate the problems involving the redelivery. The starting point of the investigation of the redelivery problems is by a straightforward literature review, considering that articles may provide valuable insights of particular problems. Academic researchers, in turn, may struggle to explore such particular problems, as they are more likely to be associated to extensive industrial practices. Therefore, it becomes necessary to delineate a new interpretation of the redelivery issues, by subdividing into “studyable” categories, associated to frequent redelivery issues. The connection between the valuable insights of the literature (academic) review and the working practices are addressed in this study by a Content Analysis (CA) and by a Delphi Method (DM), respectively. The application of the mentioned approaches is explained in Subsections 3.1 and 3.2. The outcome of both approaches, added to statistical analyses, enable deducing a Final Model, which may provide the reader with the issues associated to the redelivery process and their respective relevance, according to their cost and time expenditures. The closing part of this study is to detect the categories that may be associated to manufacturer activities and recommend different practices to improve the redelivery process, considering an innovative strategic plan for manufacturers. Thus, Figure 3.1 summarizes the methodology proposed in this study.

This research is mainly separated into a Literature Review to delineate the important categories, two distinct exploratory approaches (CA and DM), the definition of a Final Model and the study of manufacturer practices towards redelivery processes.

Both exploratory approaches enable investigating different views for the redelivery problems. The first approach refers to the Content Analysis (CA), which is based on the literature review. The second approach is the Delphi Method (DM), which is based on experts’ evaluations. Subsections 3.1 and 3.2 describe both approaches. Subsection 3.3 describes the statistical validation for the definition of relevant categories and their respective group of similarity.

Figure 3-1 – Flowchart of the proposed method for this Master Thesis



3.1 Content Analysis

The Content Analysis is a research technique that uses the literature review to identify words, phrases, ideas or other patterns and, then, categorizes them into distinct subjects. The technique allows the researcher to count the frequency that each category is mentioned, followed by a table with the references chosen, categories and their frequencies. The results from the quantitative Content Analysis present the most frequent subjects on the literature (NEUENDORF, 2002).

The first step to conduct human-coded or interpretive modes of text analysis is to define each reference that should be considered. In order to do it, the researcher starts a review of all the literature that involves the main issues of the research. The researcher may also explore references that go beyond the main subject to create an extensive view about the proposal (CAMPOS, 2004).

The second step of the Content Analysis consists of defining which unit or pattern the researcher should adopt. Words, words senses, sentences, themes, ideas or any other pattern may be chosen. The researcher must carefully read and gather the references to create enough sensitivity about how the subjects are treated on the literature (WEBER, 1990).

The third step of the Content Analysis is the definition of the categories. The categories may be previously defined by the researcher, according to the experience or even the interest of the study (CAMPOS, 2004). Weber (1990) argues that some investigators have counted by hand a few words or phrases, while others have carried on a computer aided based analysis.

The following step of the Content Analysis is once again reading all the references. However, now, the main goal is to count how many times each category occurs, based on the unit previously defined. In summary, this calculated measure indicates the intensity of concern with each category (WEBER, 1990). The last step is to prepare a table that comprises all the results, the references versus the categories and how many times they occur (CAMPOS, 2004).

In this study, the results for the Content Analysis are subject to a non-parametric statistical hypothesis testing, described in Section 3.2.

3.2 Delphi Method

The Delphi Method (DM) is a technique that allows the researcher to consult a panel of experts to obtain a group response (BROWN, 1968). The purpose of applying this analysis to this research is to create a fundamental list of categories of the main relevant problems involving redelivery procedures.

The first step of the approach, which is also mentioned in the literature as the Delphi exercise, consists of defining a heterogeneous group of experts, in order to preserve the validity of the results (LINSTONE and TUROFF, 2002). The criterion consists of selecting professionals who have extensive knowledge with the associated areas of the research. The second step of the Delphi Method starts with the elaboration of a primary list of categories. The same list used on the Content Analysis may support the categories on the Delphi Method. This wide approach, even covering matters outside the redelivery subjects' core, may create an ample discussion and diversity of content (ABRAHÃO, 1998). The second step is to provide the experts with the complete list of selected items and allow them to fill, add, eliminate or modify the categories. Thereafter, with the experts' feedback, another list is created and once again forwarded. This cycle is only closed with the consensus among the experts about the list, ensuring the most reliable outcome (DALKEY and HELMER, 1963). Several rounds may be required in order to achieve consensus and to finally come up with an agreed list. The last step starts with the final adjusted list after all the required interactions. Hence, the author sends the list back to the experts for them to rank the categories, according to each professional judgment. Given the classification, the researcher, then, gathers the results of each professional and evaluates the result of the Delphi Method (ABRAHÃO, 1998).

Meanwhile the Content Analysis provides us with an enumeration of the number of times each analyzed category is mentioned throughout a reference text, the Delphi Method, on its turn, results in a ranked list indicating the relevance of each category. The rank ranges from *1* to *N* (in case of no ties), with *1* being the most relevant category and *N* the least one – where *N* is the number of categories. The expert may also opt to set out tied rankings.

In this study, the results for the Delphi Method are subject to a non-parametric statistical hypothesis testing, described in Section 3.2.

3.3 Statistical hypothesis testing

In this study, the objective is to evaluate the hypothesis test considering a scenario of data not belonging to any particular probability distribution. In statistics, such tests are part of non-parametric analyses.

The most popular non-parametric tests in the literature are the Mann-Whitney, Wilcoxon, Friedman and Kruskal-Wallis. The former two tests, Mann-Whitney and Wilcoxon enable analyzing two different independent conditions. On the other hand, the Friedman and the Kruskal-Wallis are usually applied to dependent variables (Field, 2013).

The Friedman test aims at testing the differences between related groups, *i.e.*, testing different assessments of the same individuals to equal situations/categories. The first step of the analysis is to set scores for each category at each observation of the sample.

Since the outcome of both analyses here to be tested (CA and DM) provide different measures, the scores will be set as follows, similarly to a Wilcoxon test (Wilcoxon, 1945):

- For the Content Analysis, the observations list the number of times each category is mentioned. That is, the greater the number, the greater its relevance. For this situation, the researcher needs to organize the data in ascending order, set a value of *1* to the first category and increase the rank up to the total number of categories. In case of tied values, the scores are set as the average rank.
- The Delphi Method is applied in the opposite manner. Since the data is already a rank, where *1* is the most relevant and so forth, the researcher needs to organize in descending order and set inverse scores.

The following steps involve organizing the records into columns, where each column gathers the information of each analyzed category in different observations. In this study, the observations of the Content Analysis gather information of a number of literature references meanwhile the Delphi Method lists the responses of different experts.

The calculation of Friedman's statistics is shown in Equation 3.1.

$$F_R = \left[\frac{12}{Nk(k+1)}\sum_{i=1}^{k} R_I^2\right] - 3N(k+1) \quad (3.1)$$

Where R_i is the sum of scores for each category and *N* is the total number of observations of the sample. In the present study, *N* is the number of references in the Content Analysis and the number of experts who responded the questionnaire in the Delphi Method. When the number of *N* is large (greater than 20), the statistical test is distributed as chi-square (Field, 2013). *k* is the total number of categories assessed (17 in this study). Hence, the degrees of freedom are (k-1), 16.

In order to assess whether the hypothesis test may be accepted, a *p-value* is determined from the critical value table for the Friedman Test. Considering that this study finds relevant a level of confidence of 95% (significance level of 5%), the critical value F is 26.3 (with 16 degrees of freedom) (Martin *et al.*, 1993). This means that in order to reject the null hypothesis and accept that the categories differ from each other, the calculated statistic F should not be lower than 26.3.

The statistical analysis for the results of both Content Analysis and the Delphi Method enable defining similarity groups that may outline the handling approaches to treat groups of most and least relevant subjects in the redelivery. The results of the similarity between both approaches provide tools for the researcher to create a Final Model.

4 Results and Final Model

The following subsections present the results of the method, described in five parts. As one important objective of this study lies on finding the relevant categories associated to the redelivery process, the first outcome is gathered from the literature review, and then presented in Subsection 4.1. The reason for this preliminary investigation is to be able to detect the root causes that are consuming money and time during the redelivery procedures.

In Subsection 4.2, the references and results of the Content Analysis are shown, along with the statistical test and the conclusions on the evaluated categories' relevancies in similarities.

Subsection 4.3 presents the results of the ranks of each analyzed category in the Delphi Method. This subsection also provides the reader with a statistical analysis and a resulting framework of similar groups of categories.

Subsection 4.4 gathers the outcome of both research approaches (Content Analysis and Delphi Method) and summarizes the relevance of each category, grouping them according to the similarity of their relevance. In this subsection, a Final Model is set and a discussion is provided to exploit the relation between the statistical results and the aviation practices. Subsection 4.4 also contributes with some insights and recommendations – coming from experts in the field (using the literature review, the Content Analysis and the results from the questionnaire of the Delphi Method); to be able to come up with suggestions about how the OEM's may be involved on the redelivery process, creating a guideline to lessors and lessees and also promoting a business opportunity to the OEM's.

4.1 Setting the categories from the literature review

The first step towards the Content Analysis and the Delphi Method is to set the categories to be evaluated, according to the groups of the Integrated Logistic Support (ILS) elements and others significant aeronautical topics. This definition is based on the grounds that the ILS elements can cover almost the entire involvement that a manufacturer could provide to its customers and stakeholders, from the development of the product to its disposal (SX000i, 2016). Added to that, some categories are also considered, as they are more specific to aeronautical topics and may not be approached into the ILS elements, as aeronautical certification and airworthiness. It is also important to reinforce that the first defined categories may cover all the redelivery issues, meaning that, some categories may be added, modified or excluded to fit the scope of this study.

Table 4-1 displays the 17 categories selected in the present thesis.

Table 4-1 – Selected categories associated to the redeliver

<table>
<tr><td rowspan="17">Categories</td><td rowspan="5" colspan="1"></td><td>1</td><td>Interior reconfiguration</td></tr>
<tr><td>2</td><td>General reconfiguration</td></tr>
<tr><td>3</td><td>Instruction for Continuous Airworthiness (ICA)</td></tr>
<tr><td>4</td><td>Aeronautical certification - requirements and regulations</td></tr>
<tr><td>5</td><td>Spare and repair parts</td></tr>
<tr><td rowspan="12">ILS Elements</td><td>6</td><td>Maintenance procedures and planning</td></tr>
<tr><td>7</td><td>Technical data, orders and publications</td></tr>
<tr><td>8</td><td>Training and training support</td></tr>
<tr><td>9</td><td>Design influence</td></tr>
<tr><td>10</td><td>Product support management</td></tr>
<tr><td>11</td><td>Supply support</td></tr>
<tr><td>12</td><td>Packaging, handling, storage and transportation</td></tr>
<tr><td>13</td><td>Sustaining engineering</td></tr>
<tr><td>14</td><td>Computer resources</td></tr>
<tr><td>15</td><td>Facilities and infrastructure</td></tr>
<tr><td>16</td><td>Manpower and personnel</td></tr>
<tr><td>17</td><td>Support equipment</td></tr>
</table>

4.2 Content Analysis

As the aim of the Content Analysis is to present the most frequent subjects on the literature, the method application starts with the definition of each reference to be contemplated. This decision incorporates all references that the researcher considers the most relevant about the redelivery. In the case of this thesis, the literature is about redelivery processes and also some subjects that may involve redelivery, such as aircraft leasing and aeronautical finances. In addition, given the non-academic development about the redelivery process, the chosen references cover not only academic articles, but also white papers, magazine articles, industry reports and guidebooks. Table 4-2 presents the references considered for the Content Analysis.

Table 4-2 – References from the literature review used for the Content Analysis

ID	Literature Reference
1	Ackert, S. (2012a). Basics of aircraft maintenance reserve development and management. Forming a Policy to Identify Ideal Assets for Long-term Economic Returns. Aircraft Monitor, v. 1.0, August 2012.
2	Ackert, S. (2012b). Basics of aircraft market analysis. A lessor's Perspective of Maintenance Reserve Theory and Best Practices. Aircraft Monitor, v.1.0, March 2012.
3	Ackert, S. (2014). Redelivery Considerations in Aircraft Operating Leases. Guidelines and best practices to ease transferability of aircraft. Aircraft Monitor, v. 1.0, October 2014.
4	Aircraft Commerce (2017). Best industry practice for aircraft lease transitions. Aircraft trading and the aftermarket, n. 110, February-March 2017.
5	Burhani, S.; Verhagen, W. J.; Curran, R. (2016). Measuring compliance during aircraft (component) redeliveries at KLM Engineering & Maintenance. Proceedings of the 23rd International Conference on Transdisciplinary Engineering (ISPE), Curitiba, Parana, Brazil, October 3-7.
6	Gavazza, A. (2010). Asset liquidity and financial contracts: Evidence from aircraft leases. Journal of financial Economics, v. 95, n. 1, p. 62-84.
7	Gomes, S. B. V.; Fonseca, P. V. D. R.; Queiroz, V. D. S. (2013). O financiamento a arrendadores de aeronaves: modelo do negócio e introdução à análise de risco do leasing aeronáutico. BNDES Setorial, n. 37, mar. 2013, p. 129-172.
8	IATA - International Air Transport Association (2015). Guidance Material and Best Practices for Aircraft, 2nd ed., May 2015. In.: http://www.iata.org.
9	IBA - International Bureau of Aviation (2015). Redelivery expenditure – minimising surprises and maximising cashflow, October 2015, United Kingdom.
10	IBA - International Bureau of Aviation (2016). Redeliveries revisited closing the perception gap between lessors and Lessees, October 2016, United Kingdom.

In the second step, the researcher defines the unit or pattern and studies all the references in order to create enough perception about how the subjects are presented on the literature. The general Content Analysis considers that words, phrases, ideas or any other pattern are acceptable as an option of unit or pattern. In this thesis, only phrases are considered as pattern/unit. This is due to the dissimilarity of the adopted references (Table 4-2). Scientific and commercial white papers create a diversified sample of references that demand a refined analysis; hence, phrases may be considered the most convenient unit to fulfill the study expectations.

Considering the categories set in Subsection 4.1, the following step of the Content Analysis is to count how many times each category is mentioned, based on the unit previously defined. The last step is to prepare a table that comprises all the results, the references versus the categories and how many times they occur (Campos, 2004). Table 4-3 presents the descriptive statistics of the resulting Content Analysis here conducted.

Table 4-3 – Descriptive statistics for the Content Analysis

Category	**Average**	**Std. dev.**	**Min**	**Max**
Interior reconfiguration	1.8	1.9	0	5
General reconfiguration	1.2	1.4	0	4
Instruction for Continuous Airworthiness (ICA)	1.1	1.5	0	4
Aeronautical certification - requirements and regulations	1.8	2.6	0	7
Maintenance procedures and planning	3.6	4.7	0	15
Technical data, orders and publications	2.9	3.1	0	7
Spare and repair parts	0.9	1.1	0	3
Training and training support	0.6	0.7	0	2
Design influence	0.3	0.7	0	2
Product support management	2.3	3.2	0	9
Supply support	1.0	1.6	0	5
Packaging, handling, storage and transportation	0.1	0.3	0	1
Sustaining engineering	1.8	2.2	0	5
Computer resources	0.1	0.3	0	1
Facilities and infrastructure	0.2	0.4	0	1
Manpower and personnel	0.7	1.2	0	3
Support equipment	0.0	0.0	0	0

Table 4-3 provides information to conclude that all categories were mentioned at least once, with exception of the *Support equipment*, which was not cited in any of the analyzed papers. The most discussed category was the *Maintenance procedures and planning*, which was mentioned 15 times in IBA (2015). Table 4-4 shows the respective average score for each category in descending order and the results of the Friedman Test.

Table 4-4 – Average score for each category applying the Content Analysis

Category	**Score***
Maintenance procedures and planning	13.25
Interior reconfiguration	11.90
Technical data, orders and publications	11.60
Product support management	10.85
Sustaining engineering	10.50
Aeronautical certification - requirements and regulations	10.40
General reconfiguration	9.70
Spare and repair parts	9.30
Training and training support	8.65
Instruction for Continuous Airworthiness (ICA)	8.60
Supply support	8.40
Manpower and personnel	8.15
Design Influence	7.45
Facilities and infrastructure	6.45
Packaging, handling, storage and transportation	6.20
Computer resources	5.95
Support equipment	5.65

*Test statistic (Friedman) of 50.355 and *p-value* of 0.000 (*N*=10)

The non-parametric analysis was held to evaluate whether the group of categories present similar significance. *I.e.*, the evaluated hypothesis may be set as:

H_0 (null hypothesis) – the categories ranks are equally likely.

H_1 (alternative hypothesis) – the categories ranks are not equally likely.

Considering a level of significance of 5% and that the model resulted in a smaller probability value (*p-value* of 0.000), the null hypothesis is rejected in favor of the alternate hypothesis. Thus, the relevance of the categories is more likely to be distinct. In order to further assess the differences between the categories, the Friedman test was also applied considering a pairwise analysis. Appendix A contains the complete outcome of the Friedman pairwise analysis for the Content Analysis, which showed that only the following category scores are likely to be considered distinct (Table 4-5).

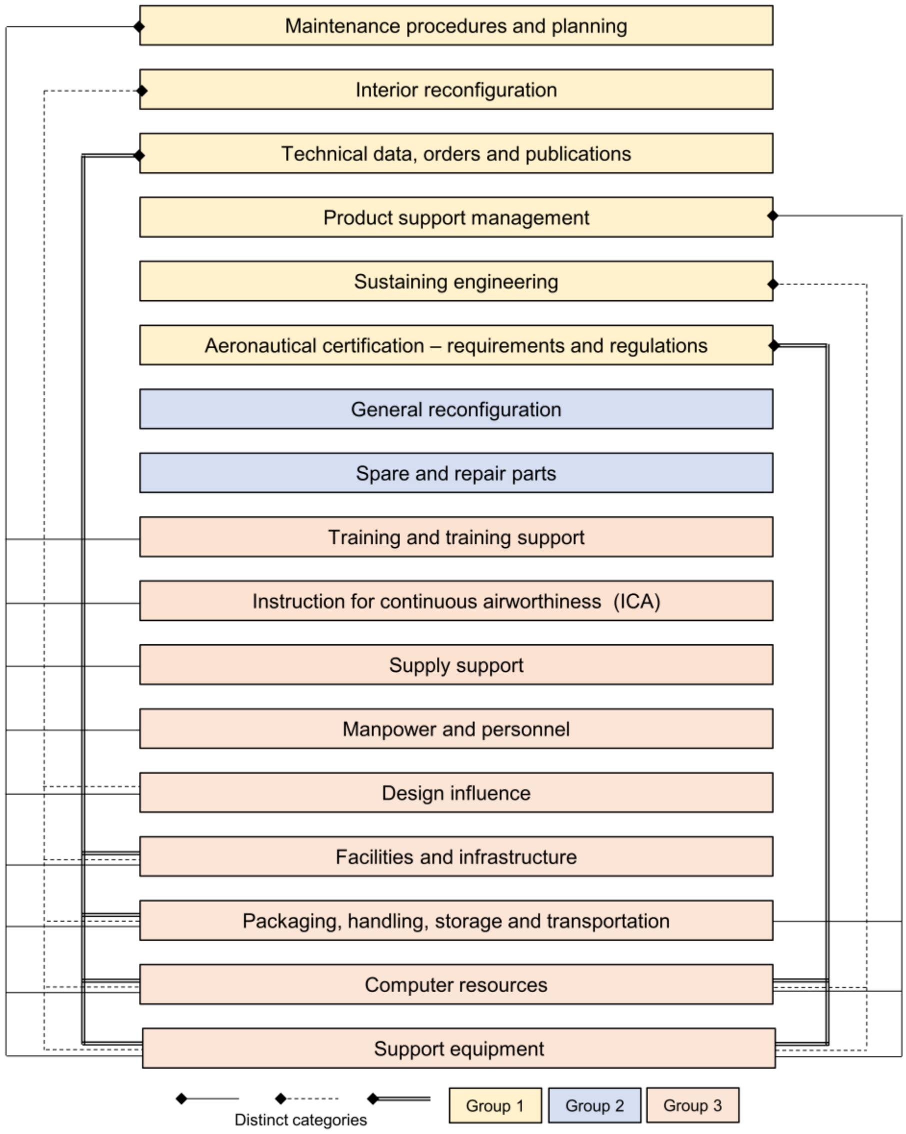
Table 4-5 – Pairwise comparisons (Friedman) of the significant categories scores (CA)

Category 1	Category 2	Test statistic	p-value
Support equipment	Maintenance procedures and planning	7.600	0.001
Computer resources	Maintenance procedures and planning	7.300	0.001
Packaging, handling, storage and transportation	Maintenance procedures and planning	7.050	0.002
Facilities and infrastructure	Maintenance procedures and planning	6.800	0.003
Support equipment	Interior reconfiguration	6.250	0.006
Support equipment	Technical data, orders and publications	5.950	0.008
Computer resources	Interior reconfiguration	5.950	0.008
Design influence	Maintenance procedures and planning	5.800	0.010
Packaging, handling, storage and transportation	Interior reconfiguration	5.700	0.012
Computer resources	Technical data, orders and publications	5.650	0.012
Facilities and infrastructure	Interior reconfiguration	5.450	0.016
Packaging, handling, storage and transportation	Technical data, orders and publications	5.400	0.017
Support equipment	Product support management	5.200	0.021
Facilities and infrastructure	Support for technical data, orders, publications and documentations	5.150	0.023

Manpower and personnel	Maintenance procedures and planning	5.100	0.024
Computer resources	Product support management	4.900	0.030
Support equipment	Sustaining engineering	4.850	0.032
Supply support	Maintenance procedures and planning	4.850	0.032
Support equipment	Aeronautical certification - requirements and regulations	4.750	0.035
Packaging, handling, storage and transportation	Product support management	4.650	0.039
Instruction for Continuous Airworthiness (ICA)	Maintenance procedures and planning	-4.650	0.039
Training and training support	Maintenance procedures and planning	4.600	0.042
Computer resources	Sustaining engineering	4.550	0.044
Computer resources	Aeronautical certification - requirements and regulations	4.450	0.049
Design influence	Interior reconfiguration	4.450	0.049

According to the results shown previously, one may define different groups of similarity between the analyzed categories. Three groups are defined, considering the categories assessed at the Content Analysis. The first step is to list the categories, according to the scores (Table 4-4). Thereafter, using the pairwise Friedman Test results (Table 4-5), one may detect the categories that are distinct from one another. Using this straightforward method, three groups are defined for the 17 categories. Figure 4-1 illustrates the definition of the groups. Group 1 was set as the most relevant one and the connectors show that they comprise categories distinct to categories in Group 3. Group 2 comprises the categories that do not precisely fit within Group 1 or 3.

Figure 4-1 – Illustration of the definition of group of categories for the Content Analysis



4.3 Delphi Method

The Delphi Method (DM) is a technique that allows the researcher to consult a panel of experts to obtain a group response (Brown, 1968). The purpose of this analysis is to create a fundamental list of categories of the main relevant problems involving redelivery procedures. Thus far, it can be noted that the literature on redelivery is scarce and few scientific papers have been found published. This corroborates the need for consulting experts to support this thesis.

The selection of experts to take part into the research consisted of inviting five professionals with strong knowledge in aircraft leasing, finances and maintenance.

The first round consisted of a questionnaire mailed to each professional. The responses provided by the experts did not reach a consensus at the first round, demonstrating the need for a second round. However, only at a third round a consensus was achieved. Appendix B presents the categories defined at each of three rounds of survey and Appendix C contains the final ranks outlined by the experts during the Delphi exercise (maintaining the confidentiality of each individual).

Table 4-6 presents the descriptive statistics of the Delphi Method. It can be noted that the most relevant category is the *Interior reconfiguration*, as the average rank is 3.2. On average, the least relevant category is *Facilities and infrastructure*, however, considering a consensus, the category that ranges at lower ranks (from the 9th to the 13th position in all responses) is *Training and training support*.

Table 4-6 – Descriptive statistics for the Delphi Method

Category	**Average**	**Std. dev.**	**Min**	**Max**
Interior reconfiguration	3.2	2.7	1	7
External reconfiguration	8.2	1.5	6	10
Airworthiness requirements	5.2	3.9	1	9
Aeronautical certification	7.6	4.3	2	13
Maintenance	4.8	6.3	1	16
Support for technical data, orders, publications and documentations	6.6	3.3	3	11
Spare and repair parts	7.6	3.6	3	12
Training and training support	11.2	1.8	9	13
Design to redelivery	6.8	1.9	4	9
Product support management	9.0	5.1	3	14
Supply support	6.6	3.4	3	12
Packaging, handling, storage and transportation support	9.4	5.4	3	17
Sustaining engineering support	4.6	3.2	2	10
Computer resources	11.2	5.5	2	16
Facilities and infrastructure	12.0	5.2	3	15
Manpower and personnel	11.8	5.3	3	17
Support equipment	9.4	5.4	3	14

Table 4-7 presents the score for each category, where, conversely to what the panel of experts responded in the questionnaire, the most relevant category is represented with a higher value and the least important with a lower value. Table 4-4 also indicates the results of the Friedman Test.

Table 4-7 – Average score for each category applying the Delphi Method outcome

Category	**Score***
Interior reconfiguration	14.70
Maintenance	12.50
Sustaining engineering support	12.40
Airworthiness requirements	12.20
Support for technical data, orders, publications and documentations	10.50
Design to redelivery	10.40
Supply support	10.30
Aeronautical certification	9.50
Spare and repair parts	9.50
External reconfiguration	8.70
Product support management	8.50
Packaging, handling, storage and transportation support	7.10
Support equipment	6.90
Training and training support	5.50
Computer resources	5.30
Manpower and personnel	4.60
Facilities and infrastructure	4.30

*Test statistic (Friedman) of 29.983 and *p-value* of 0.018 (*N*=5)

The non-parametric analysis (Friedman Test) was held to evaluate whether the group of categories present similar significance. Considering the same analysis conducted in the Friedman Test for the Content Analysis, the hypothesis were set as:

H_0 (null hypothesis) – the categories ranks are equally likely.

H_1 (alternative hypothesis) – the categories ranks are not equally likely.

The null hypothesis may be rejected in favor of the alternate hypothesis, since the *p-value* is 0.018 (that is, lower than the level of significance of 0.05). Thus, the relevance of the categories is more likely to be distinct. Appendix D contains the complete outcome of the Friedman pairwise analysis for the Delphi Method, which showed that only the following category scores are likely to be considered distinct (Table 4-8).

Table 4-8 – Pairwise comparisons (Friedman) of the significant categories scores (DM)

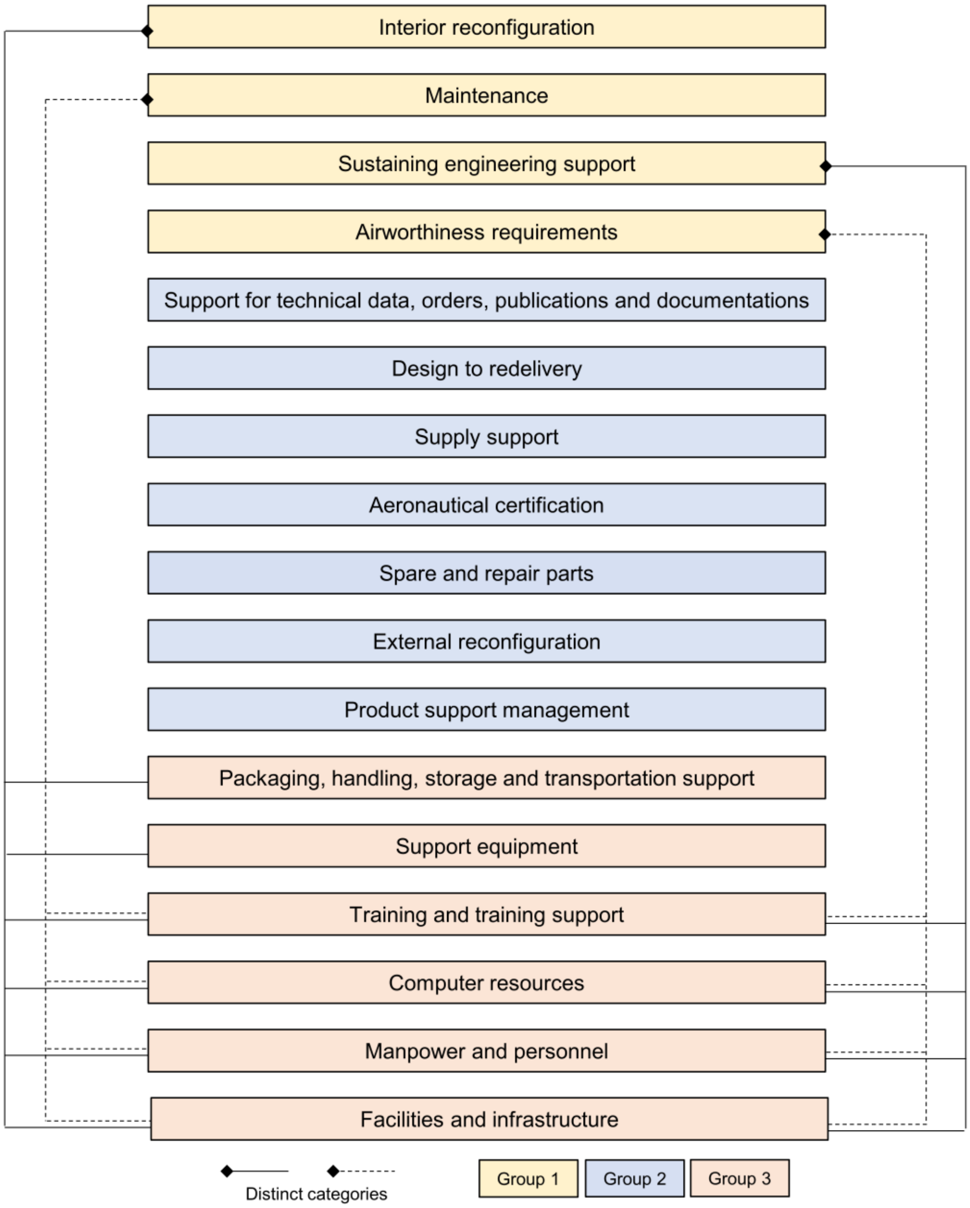
Category 1	**Category 2**	**Test statistic**	**p-value**
Facilities and infrastructure	Interior reconfiguration	10.400	0.001
Manpower and personnel	Interior reconfiguration	10.100	0.002
Computer resources	Interior reconfiguration	9.400	0.003
Training and training support	Interior reconfiguration	9.200	0.004
Facilities and infrastructure	Maintenance	8.200	0.010
Facilities and infrastructure	Sustaining engineering support	8.100	0.011
Facilities and infrastructure	Airworthiness requirements	7.900	0.013
Manpower and personnel	Maintenance	7.900	0.013
Manpower and personnel	Sustaining engineering support	7.800	0.015
Support equipment	Interior reconfiguration	7.800	0.015
Manpower and personnel	Airworthiness requirements	7.600	0.017
Packaging, handling, storage and transportation support	Interior reconfiguration	7.600	0.017
Computer resources	Maintenance	7.200	0.024
Computer resources	Sustaining engineering support	7.100	0.026
Training and training support	Maintenance	7.000	0.028
Computer resources	Airworthiness requirements	6.900	0.031
Training and training support	Sustaining engineering support	-6.900	0.031
Training and training support	Airworthiness requirements	6.700	0.036

According to the results shown in Tables 4-7 and 4-8 and the same methodology applied in Section 4.1, three groups are identified, considering the categories evaluated by a panel of experts in the Delphi Method.

Figure 4-2 illustrates the definition of the groups. Group 1 was set as the most relevant one and the connectors show that they comprise different categories in comparison to Group 3. Group 2 comprises the categories that do not precisely fit within Group 1 or 3.

In comparison to the groups defined for the Content Analysis, it can be noted that the most relevant group identified by the Delphi Method is smaller, as the former contains 6 categories and the latter 4 categories. Moreover, Group 2 is larger for the Delphi Method, indicating lesser consensus for the definition of the relevance of the categories in the Delphi Method than in the Content Analysis. That is, the bibliographic references have more convergent views than the experts' opinions on redelivery matters.

Figure 4-2 – Illustration of the definition of groups of categories for the Delphi Method



4.4 Final Model

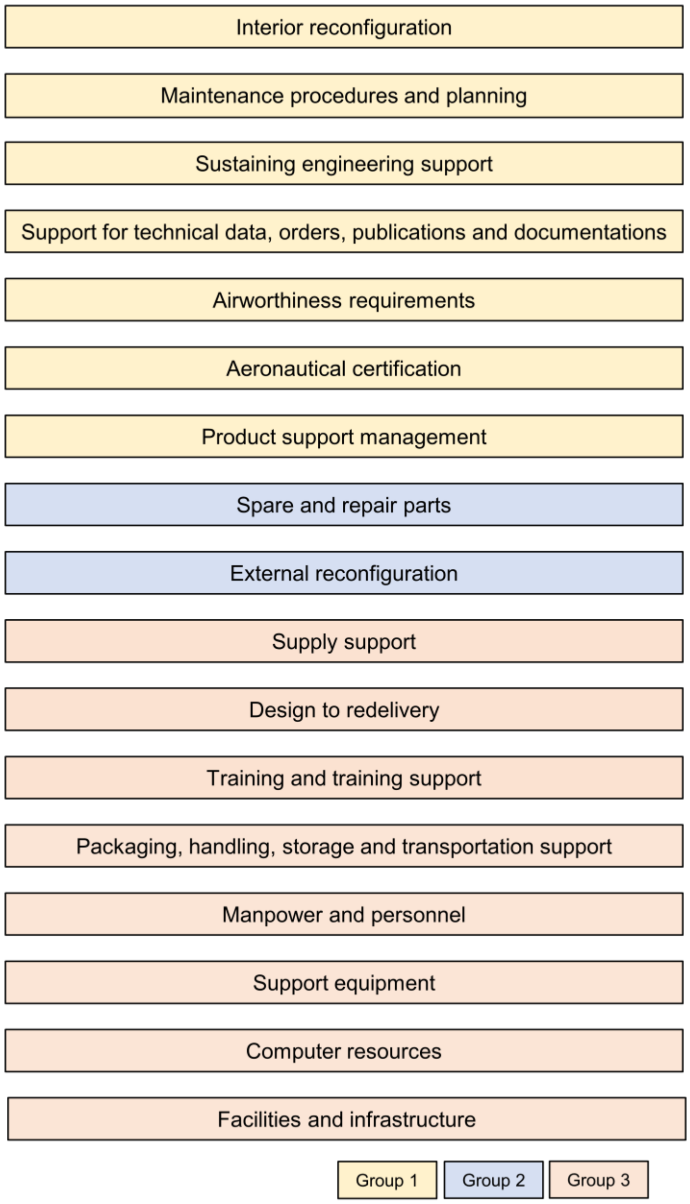
A Final Model containing the relevance of each category may be inferred from both approaches (CA and DM). Table 4-9 displays the average scores from both approaches, in order to infer the Final Model.

Table 4-9 – Average scores for the Final Model

Category	**Av. Score***
Interior reconfiguration	13.30
Maintenance	12.88
Sustaining engineering support	11.45
Support for technical data, orders, publications and documentations	11.05
Airworthiness requirements	10.40
Aeronautical certification	9.95
Product support management	9.68
Spare and repair parts	9.40
Supply support	9.35
External reconfiguration	9.20
Design to redelivery	8.98
Training and training support	7.08
Packaging, handling, storage and transportation support	6.65
Manpower and personnel	6.38
Support equipment	6.28
Computer resources	5.63
Facilities and infrastructure	5.38

The final model may be inferred considering the intersection between both approaches and that the category must fit into the most relevant group for at least one approach (CA or DM). *I.e.*, the categories of *Interior reconfiguration*, *Maintenance procedures and planning*, and *Sustaining engineering support* are part of the most relevant group (Group 1) in both the CA and the DM. Meanwhile, the categories *Support for technical data, orders, publications and documentations*, *Airworthiness requirements*, *Aeronautical certification* and *Product support management* were referred as being part of the most relevant group for at least one approach. On the other hand, *Supply support*, *Design to redelivery*, *Training and training support*, *Packaging, handling, storage and transportation support*, *Manpower and personnel*, *Support equipment*, *Computer resources* and *Facilities and infrastructure* are part of the least relevant group (Group 3). The Final Model shows that the intermediate categories (*External* *reconfiguration* and *Spare and repair parts*) are, for both approaches, uncertain in terms of their relevance.

Figure 4-3 – Illustration of the Final Model



The Final Model provides a rank of categories in order to expose the distribution of relevancies of the redelivery issues. This result supports future discussions, which are held in detail, in this study. However, before presenting the detailed discussion, it is important to present a conceptual and technical explanation about the resulting list and the impact of dividing the categories in three groups.

The intersection between the results for the CA and the DM reveals the most relevant issues. This result may be elucidated using some literature observations and the commentaries provided by the consulted experts. Hence, the next paragraphs present conclusions drawn from the study and how these conclusions may correspond to the final result.

Firstly, it is important to add that the discussions of the final result have some premises that must be addressed. The clarification of these premises aims to create a clear result and may give to the reader a broad vision of the redelivery issues. It is more usual to recognize, in the practical aeronautical environment, common problems than to explore their roots causes. For instance, considering both applied methods, CA and DM, the category *Design influence* resulted in a lower relevance than *Maintenance Procedures and Planning.* This outcome exposes that there are more burdensome redelivery issues associated with maintenance than with the design of the aircraft. However, a diverse number of maintenance features are defined during the conceptual and development product phase, which are based on *Design Influence* activities. The same context may occur with other pair of categories, *e.g*. *Computer Resources,* when compared with *Support for Technical Data, Orders, Publications and Documentations*, results in less relevance. In this situation, some issues associated with technical data, orders, publications and documentations may have their root causes in the lack of computer resources. Therefore, it is essential to note that the categories are not completely independent and that the final result depends on the level of analysis carried out for each reference.

The 17 categories were divided into three groups, according to their relevance. The most common issues are comprised in Group 1. The categories of Group 3 may be considered the least relevant issues. Meanwhile, Group 2 holds categories with an average relevance. The previous explanation about the correlation between the elements and the level of analysis carried out may base another point of attention: Group 1 delineates the categories that are more exposed to general analysis and studies, whilst Group 3 exposes the issues that are more difficult to be identified in a narrow analysis. Therefore, the results also depend on the level of analysis of the problem, considered by the assessed references and by the experts' feedbacks.

The next paragraphs present the discussion about the categories of Group 1 selected by the adopted criteria to compose the final model. In addition, each discussed category is followed by the author's recommendations on how the OEMs may participate as a third party collaborator, aiming at more efficient and effective redelivery.

The following sub items explore the OEM's capabilities and present how they may be implemented and adopted in the redelivery. Compared to lessors and lessees, OEMs usually hold competitive advantages, which may be considered in further redelivery activities. These main competences include extensive knowledge on the aircraft design, as the ownership of the engineering parameters, databases and the domain of the technical publications. In addition, due to the aircraft certification efforts, OEMs, in general, may have more ability than lessors and lessees to conduct eventual discussions with aviation authorities.

The mentioned advantages support the following discussions and recommendations. It is important to note that the recommendations are not the complete solution for the subsequent redelivery issues. These recommendations are based on the author's observations and conclusions exploited from the literature review and methodology application.

4.4.1 Interior Reconfiguration

Interior reconfiguration consists of the most important challenges to the Redelivery, as airlines are focusing on interiors with more quality, comfort and connectivity technologies. Moreover, the interior has becoming the tangible part of the aircraft by the passenger’s view, as an important point to evaluate and choose the airline (AIRCRAFT COMMERCE, 2017). In general, as return conditions, the lessee must provide to the lessor – or to the next operator; a complete or partial reconfiguration of the aircraft interior (depending on the leasing agreement); as the operators hold distinct brands (*e.g.* seat color, fabric) and may require different Layout of Passenger Accommodations (LOPA). In addition, the aircraft interior has several items, whose condition is subjectively evaluated. This qualitative judgment provokes disagreements between the lessor and Lessee. The following list presents some typical interior redelivery conditions described in leasing agreements; according to Ackert (2014):

> *“i. Interior panels (including overhead bins, sidewall and ceiling panels, bulkheads and cargo compartment panels), and related seals (including window seals) shall be clean and newly painted if discolored or stained and free of holes, cracks, temporary repairs and dents. All interior panels will meet EASA and FAA fire resistance regulations.*
>
> *ii. Passenger service units (PSUs) will be serviceable and in good condition*
>
> *iii. Passenger seats will be serviceable, in good condition, secure & clean*
>
> *iv. Carpets, seat covers & cushions will be serviceable, in good condition, secure, clean, free of tears and stains and will meet EASA and FAA fire resistance regulations.*
>
> *v. All external placards, signs and markings will be properly attached, free from damage, clean and legible.*

vi. All galley catering inserts including trollies, containers, ovens, hot cups, coffee makers and water boilers shall be serviceable and in good working condition.

vii. All cabin emergency equipment (including but not limited to, life vests, life rafts and emergency slides) and loose equipment shall be fully operational.

viii. If so equipped, the cargo loading system shall be demonstrated to be fully functional. Cargo linings shall be free of holes, dents, gouges. Cargo nets will be in good condition with no tears or frayed areas.

ix. All in-flight & audio entertainment systems shall be fully operative and all IFE seat functions will be serviceable."

Many of the redelivery clauses involve *good condition* as a return requirement. The term "fair wear and tear" is commonly used to describe this situation as an acceptance condition, when the component (or equipment) has a natural wear but is still operational and in working condition. In parallel, each new interior equipment or component must be certificated in accordance with the applicable requirements (as the material burn certificate). In case the aircraft is transferred to other aviation authority, it becomes necessary to set the interior in order to meet potential advanced requirements (ACKERT, 2014).

Understanding the importance of the aircraft interior is the basis to set the following recommendations. In general, lessors are not exclusively concerned about meeting the applicable aviation authority requirements towards the interior reconfiguration. Instead, they also take into consideration the interior configuration in the viewpoint of the passenger. Hence, airlines are setting a good interior condition as one of their priorities. Thus, lessors who are aiming to maintain their aircraft as attractive assets, have been putting effort during the redelivery to acquire higher aircraft interior conditions. This presented context leads to many disputes between lessees and lessors during the redelivery (AIRCRAFT COMMERCE, 2017).

The aircraft interior has several components, whose evaluation is treated in a qualitative scenario. The term previously cited as "fair wear and tear" is not enough to conduct an object evaluation about the interior components' condition. Hence, OEMs are able to provide (to the lessees and lessors) a technical and clear definition about what is considered a normal wear along the utilization years.

In addition, a common activity during the redelivery as a next lessee requirement is the modification or alteration of some interior components. Distinct airlines may have different LOPA's (*e.g.* number of seats, galleys and closets may change) and their brands have distinct visual identities (*e.g.* colors, symbols, materials, fabrics may be different). Therefore, during the redelivery, it may become necessary to perform a reconfiguration of some interior components and because of it, lessees and lessors face several complications.

The interior reconfiguration may require an engineering involvement, to develop the solution and create a valid and approved document to support the modification, such as a SB or STC. Usually, OEMs provide to the lessee the demanded solutions, but in most cases, OEMs may not comply with the required deadline. The late engagement with redelivery procedures and the focus on the operation by the lessee, along with the delay on setting the next leasing agreement (with the subsequent lessee) are the main reason to this short available period. Hence, OEMs could provide to the lessee and lessor an expeditious solution and the applicable technical publications for several types of interior configuration. This may be achieved by studying (in advance) about the required potential interior configurations and, thus, developing interior reconfigurations SBs or STCs. In addition, during the aircraft conceptual and preliminary design, the OEMs could adopt high-level requirements to guide the development teams to create an aircraft easy to reconfigure. For instance, installing structural supports and provisioning electrical cables in advance might facilitate eventual reconfigurations (*e.g.* from an interior without In-Flight Entertainment to an interior with In-Flight Entertainment or from a cabin with only economic class to a cabin with two classes, business and economic class).

Furthermore, lessees have also the challenge to provide to the lessor the Interior Burn Certification. If a carpet, seat cover, cushion or any panel was replaced during the lease period, the lessee must provide the burn certification of each replaced component. Thus, due to their expertise about certification processes and the close involvement with distinct aviation authorities, OEMs could support and assist the lessee to accomplish this return condition.

Commonly, an interior reconfiguration is a maintenance activity, and this is another significant redelivery aspect. The following analyzed category is the *Maintenance*; and, so, the following paragraphs present the discussions and recommendations to this relevant redelivery aspect.

4.4.2 Maintenance

Maintenance is an essential category, which is the source of many redelivery issues. Usually, a typical return condition requirement implies that the aircraft must be free of major maintenance for a time period after the return closure. This period is defined on the leasing agreement. In addition, many other return conditions demand a set of inspections, checking procedures and audits that may lead to a maintenance intervention (IBA, 2015).

A typical return condition may include the structural check of the airframe and overhaul of some components, as landing gears, APU and engine modules, in accordance with the aircraft OEM's Maintenance Planning Document (MPD) or an approved Lessee maintenance program. The following paragraph presents a typical redelivery conditions (Involving maintenance aspects) described in leasing agreements (ACKERT, 2014):

> *"The Airframe shall be returned to lessor fresh out of the Redelivery Check such that the Aircraft is clear of all tasks and other items for not less than 24 months, 6,000 Flight Hours and 4,500 Cycles, all in full accordance with the MPD. Lessee must remove the Aircraft from any customized maintenance program and reintegrate the Aircraft back into the latest version of the MPD by carrying out any required block check/s required at that time".*

In addition to the required MPD activities, the lessor may inspect and test the aircraft, searching for any type of crack, damage, corrosion, leaking and any other evidences that may indicate a failure. Historically, there are some areas of the aircraft in which lessors put more effort during inspection. For instance, galleys and lavatory regions, doors, cargo compartments, fuel tanks, floor supports and undercarriage bays are more likely to present corrosions issues and the landing gear, wing spars and ribs, pressure bulkhead, attach points (engine, wing, empennage) and skin doublers are more likely to present cracks issues (IBA, 2015). These inspections and checks demand maintenance activities not only if a fault is found, but to perform the inspections, in most cases, it is necessary to disassemble parts and components to get access to the inspection area, consuming time and resources during the redelivery process (AIRCRAFT COMMERCE, 2017). The following paragraph presents a typical redelivery contract wording describing a required inspection; according to Ackert (2014):

> *"The Aircraft inspection shall commence after its last revenue flight and continue until the date on which the Aircraft is returned to lessor in the condition required by this Lease.*
> *During the Aircraft inspection lessor and/or its representatives will have an opportunity to observe functional and operational system checks, perform a visual inspection of the Aircraft (taking into account the Aircraft type, age, use and other known factors with respect to the Aircraft), and have the right, to the extent necessary in their reasonable opinion, to have additional panels or areas opened in order to allow further inspection by any inspecting party".*

Finally, the lessor may audit maintenance registrations, engineering orders, task cards, logbooks and any other documentation that record maintenance activities along the lease period. The objective is to figure out whether the lessee fulfilled the required preventive maintenance described in the OEM's MPD, corrective maintenance and applied the applicable Airworthiness Directives (AD) and Service Bulletins (SB). This master study provides a specific discussion topic about documentations and records, but the lack of maintenance registrations or the quality of these registrations may lead to extra maintenance activities during the redelivery process (AIRCRAFT COMMERCE, 2017). The following paragraphs present a typical return condition about the Airworthiness Directives status, described in leasing agreements; according to Ackert (2014):

" i. All Airworthiness Directives applicable to the aircraft issues during the lease term requiring compliance either (a) before the redelivery date or (b) within 24 months after the redelivery date shall be accomplished on a terminating action basis.

ii. No inspection shall be due under any Airworthiness Directive within 24 months after redelivery or, if shorter, a full inspection period under the relevant Airworthiness Directive".

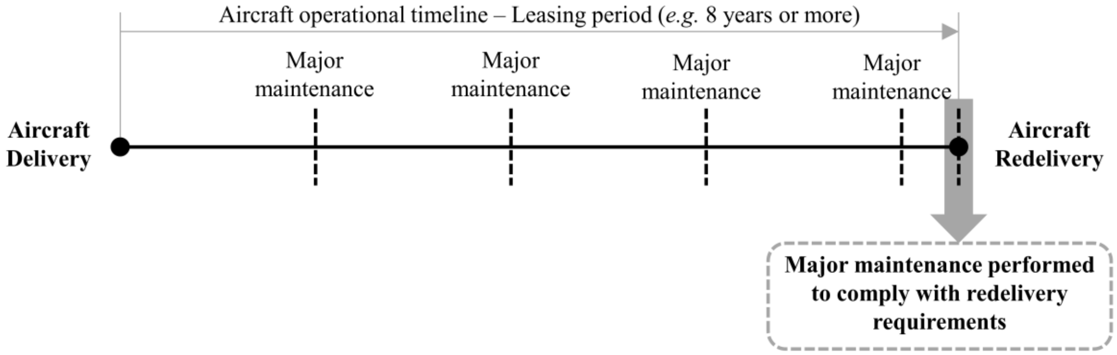
Maintenance is one of the most important activities during the operation of an aircraft. The high costs, frequency, regulation and complexity involved are attributes that put the maintenance to the core of many disputes between lessee and lessor during the redelivery. Essentially, the lessor expects, at the end of the leasing period, outstanding aircraft conditions during the return; meanwhile the lessee, on its turn, is purely attempting to meet the return conditions, without extra expenditures (AIRCRAFT COMMERCE, 2017).

The aforementioned approach guides the following recommendations. As general return condition, the aircraft must be free of major maintenance for a time period after the return closure; a full C-check interval (considered a major maintenance) is settled as reference. This period depends on the type of the aircraft and its utilization, but on several times the lessee faces the necessity to apply an exceptional C-check just to comply this return condition. Therefore, one of the redelivery activities is the C-check, which generates extra expenditures to the lessee. The involved issues are that the lessee may finish running a complete check close to when the redelivery begins, having the necessity to repeat this major check as a return condition. Figure 4-4 illustrates a sequential diagram of major maintenance (C-Checks) during the leasing period.

Hence, this exceptional C-check may generate additional costs and time (a major maintenance may last few weeks) during the redelivery. The optimal scenario is to meet the

MPD C-check simultaneously with the redelivery C-check. However, this situation would demand a huge planning and logistic effort by the lessee, which may not cause a sustainable action. Therefore, OEMs could assist lessees with a customized maintenance planning bearing in mind the entire leasing period and the required redelivery major check. The support provided by the OEM may include the study of lessee's operations and the eventual adequacy (increasing) of the interval of some components’ maintenance, according to applicable aviation authorities.

Figure 4-4 – Major maintenance (C-Checks) during the leasing period



In parallel with the major check, the lessor usually performs its own physical inspection of the aircraft, searching for failures or signs for failures. Even in a generic and broad perspective, these inspections focus on specific areas and components, as aforementioned. Thus, extra maintenance tasks may be generated in order to get access to the inspection area (*e.g.* aircraft interior removal), especially considering the lessor’s requirements for specific inspections. Accordingly, the OEM could provide to the lessee (and lessor) some predefined redelivery inspection tasks (*e.g.* using the format of a conventional Aircraft Maintenance Manual - AMM) relating the areas which usually generate more disputes between lessee and lessors. With it, the lessor has the opportunity to focus its inspections on predetermined areas and the lessee might be conveniently prepared to avoid any ungrateful surprise.

The maintenance activities aim to preserve the aircraft safe, available and cost-efficient. In addition, the lessor sees the maintenance as an essential aspect to keep its asset valuable. With that in mind and as the aircraft is considered a complex equipment, it is crucial that the Lessee receives the necessary engineering support along the leasing period and evidently, during the redelivery. The next analyzed category is the *Sustaining engineering support*; the following paragraphs present the discussions and recommendations to this relevant redelivery aspect.

4.4.3 Sustaining engineering support

In general, the engineering support comes from OEMs or the Lessee may constitute its own engineering team to support its fleet. The Lessee may also subcontract an engineering support from specialized companies. In that context, the engineering support is an expensive concern to the lessee who aims at maintaining its fleet profitable and in accordance with the airworthiness requirements and leasing contractual agreements (IATA, 2015).

The aim of an engineering team is to provide assistance to the lessee. Specifically, during the redelivery process, the magnitude of engineering support may increase, given the fact that the lessee must provide to the lessors several number of information about the aircraft. Furthermore, the lessor may require to the lessee the mandatory reconfigurations or maintenance activities to meet the applicable authority certification specifications and the contracted return conditions (AIRCRAFT COMMERCE, 2017).

The most common activities of an engineering team are to provide technical support for repairs, drawings and eventual engineering solutions. For instance, in case the lessor finds corrosion area during the airframe inspections, the lessee is more likely to provide the definitive and approved (by the next authority) repair of the affected region. Even typical repairs that are described in the OEM’s Structural Repair Manual (SRM) may demand engineering teams to develop and support the required restoration. The following paragraph present a typical return condition about repairs, described in leasing agreements (ACKERT, 2014).

> *“There will be no temporary, time limited or interim repairs on the Aircraft unless Manufacturer specifically recommends such repair. All repairs to the Aircraft will be accomplished in accordance with Manufacturer's Structural Repair Manual or:*
>
> - *EASA-approved data supported by EASA Repair Design Approval Sheets or its EASA equivalent.*
> - *FAA-approved data supported by an FAA Form 8110-3 or FAA Form 8100-9”.*

Several other situations may require an engineering support to develop and support the aircraft, as a new interior configuration, or if the lessor demand the implementation of a modification. This may be accomplished by a Service Bulletin implementation; therefore, the engineering of the OEM may be requested.

These presented scenarios reveal a wide field of opportunities to the OEM’s engineering teams to assist the lessees and lessors. Usually, OEM's concentrated engineering teams with extreme expertise on their aircraft design, holding all the aircraft engineering parameters and databases. In addition, the proximity and credibility with aviation authorities enable the OEMs to conveniently assist redelivery processes, given the engineering demands.

Therefore, it is interesting to establish, by OEMs, specific areas to attend the redeliveries' engineering requirements from the lessee and lessor. These areas may have as main purpose the prompt provision of:

- Engineering repair data;
- SB's and AD's reference documents;
- Aircraft drawings (*e.g.* Layout of Passenger Accommodation – LOPA, emergency equipment layout and galley drawings);

In addition, the OEM's engineering team should be able to make available several types of technical disposition, according to the lessee or the lessor's necessities. One of the most common demands may be the evaluation of the components and parts status. Even if a component or part appears in good condition, the lessor may ask for an engineering approval and release.

The engineering involvement in the redelivery may minimize subjective and open to interpretation issues, decreasing, in most of the scenarios, the doubts that generate improper replacements and repairs of parts and components.

In order to provide the mentioned engineering support and to meet the aviation authorities' requirements, assistances from OEMs to the lessees and lessors are usually made by official technical documentations, which are the next subject of this study. This relevant category, according to the final developed model, is the *technical data, orders, publications and documentations supporting*. Hence, the next paragraphs present the discussions and recommendations to this relevant redelivery aspect.

4.4.4 Technical data, orders, publications and documentations supporting

One of the most common practices during the redelivery process is to audit and analyze the aircraft records, current status of components, logbooks and any kind of documentation that may indicate and trace significant events along the leasing period.

To support an aircraft, the lessee must generate and preserve a high quantity of documentation to register, for instance, preventive and corrective maintenance actions, modifications and repair activities. Therefore, along an extensive leasing period (in general, more than eight years) and given the fact that an aircraft is a complex system, the quantity of demand records is vast. Consequently, lessees usually face issues to manage and store such records in good conditions. The following paragraph presents a typical contract wording on aircraft records, usually described in leasing agreements; according to Ackert (2014):

> *"For a period commencing three (3) months, but not earlier than one (1) month, prior to the proposed redelivery date and continuing until the date on which the Aircraft is returned to lessor in the condition required by this Lease, Lessee will provide for the review of lessor and/or its representative all of the Aircraft records and historical documents in one central room with access to telephone, photocopy, fax and internet connections at the Aircraft return location".*

Therefore, the Lessee must provide to the lessor records and documents usually described in leasing agreements. The most common requested documents and records are indicated in the list below:

- Airworthiness Directive Status: The status of ADs must present, in a chronological sequence, a summary of the applicable ADs. In parallel, the lessor may request for the compliance paperwork (*e.g.* task card, dirty fingerprints) to certify that the AD's incorporations were completed according to the applicable aviation authority requirements and lease conditions (ACKERT, 2014).

- Service Bulletin Status: Similar to the AD's status, the lessee must provide to the lessor a summary, in a chronological sequence, of the status of the applicable manufactures service bulletins (SB's). In addition, the lessor may audit engineering orders or any other document related to the SB's accomplishments (ACKERT, 2014).

- Serialized Component Status List: This list provides to the lessor the status (*e.g.* time since new, time since shop visit) of the serialized components, which do not demand regular maintenance intervals or replacements (ACKERT, 2014).

- Maintenance Program Compliance: A document to verify the compliance of the required maintenance activities in accordance with the OEM's or Lessee approved maintenance program (IATA, 2015).

- Modifications and Alterations: This documentation presents the status of any applied modification and alteration. These eventual modifications and alterations must be in accordance of the aviation authority requirements (*e.g.* FAA, EASA) and any other lease agreement. For instance, Supplemental Type Certificates (STC) and Service Bulletins may be considered approved data (ACKERT, 2014).

- Repairs: The lessee must present to the lessor the aircraft repair records, which, in general, are called repair logbook. The repair status must be in accordance with the approved OEM's Structural Repair Manual (SRM) or, if not accomplished in accordance with the SRM, the repair must be approved by the aviation authority (*e.g.* FAA Form 8110-3) (ACKERT, 2014).

The remainder of the following documents are commonly requested by the lessor: the Certified Life-Limited Parts Status List; Hard-Time (HT) Component; Engine Summary Data; APU Summary Data; Landing Gear Overhaul Data; Interior Arrangement and Emergency Equipment List and Interior Burn Certification. This list of documents and records are essential to trace the aircraft condition during the lease period. Therefore, the lessor puts a lot of effort to audit and analyze such documentation ACKERT, 2014).

In addition, the lessee depends on several documentations from the OEM to support and guide the required actions to maintain the aircraft – as the Aircraft Maintenance Manuals (AMM), Structural Repair Manuals (SRM) and Service Bulletins (SB). For instance, a reconfiguration to meet the next aviation authority or to meet the return requirements may be necessary during the redelivery process. The OEM’s service bulletin implementation is the most common practice towards such reconfiguration. Thus, the OEM must provide to the lessee and lessor this essential documentation (AIRCRAFT COMMERCE, 2017).

The following recommendations cover the potential involvement of OEMs while assisting lessees to generate and maintain aircraft records. The following recommendations also include documentations, which are usually responsibility of OEMs (*e.g.* manuals, orders, instructions, catalogs and guides) aiming to decrease the redelivery disputes between lessees and lessors.

Due to usual long leasing periods, one of the main challenges faced by the lessee is to generate, store and maintain in good conditions an enormous number of documents and records. These documentations and records are, in general, sheet papers – which are signed by technicians, inspectors, and engineers; to formalize veracities. Therefore, under the applicable lessees' operational certification, the aircraft records may prove and indicate, to the lessor, every accomplished activity performed in the aircraft. In case of an eventual loss or deterioration of a record, the lessor may request to the lessee the new accomplishment of the involved task or a release of a new documentation.

To avoid eventual disputes and their rough consequences along the redelivery, the OEMs could help guiding the lessees and lessors by building a different record registration framework; for instance, by utilizing digital records combined with digital signatures. Even though the digital and computerized technology has been extensively and widely accepted nowadays, the implementation of a digital system may encounter difficulties to be approved by the aviation authorities. Thus, OEMs may work together with the lessees and lessors to develop and approve (under the aviation authorities' requirements) these new records and documentations improvements.

In the same line of reasoning, OEMs could develop and provide distinct manners to present their own technical publications, considering maintenance, repair, operating manuals and service bulletins. For instance, the development of interactive maintenance manuals, which may include virtual reality or any other groundbreaking technology applied to redelivery concerns.

In addition, OEMs could implement self-testing technologies in their aircraft. New technologies, as Structural Health Monitoring (SHM) and Built-in Test (BIT) are bringing information and data of the condition of structural parts and components to the aircraft itself, decreasing the necessity of physical inspections and their respective documentations. However, same as digital records, the tests, which are performed directly on the aircraft, must be approved in advance by the applicable aviation authorities, creating a barrier to their utilization.

This new technological perspective of information not only facilitates any eventual maintenance or modification action during the redelivery, but also creates better maintenance and modification scenarios, enabling lessees to maintain and operate the aircraft during the leasing period, minimizing future issues and disputes with the lessors.

Finally, the leasing contract itself is a document that may be considered the root cause of many redelivery issues. It is not unusual to see contract terms completely unreachable from a technical point of view, given distinct reasons (*e.g.* replacement of an entire structural part of the aircraft instead of its repair). Considering this, OEMs are able to assist the lessees and lessors during the development of the leasing contract by carrying out its customization according to each type of aircraft.

The previous paragraphs presented several relevant aspects of the redelivery process according to the methodology application. In general, the given concerns about each redelivery are associated with the compliance of the aviation authority's requirements. Therefore, the remained categories refer to the *Airworthiness requirements* and *Aeronautical certification*. The following paragraphs present the discussions and recommendations to these relevant redelivery aspects.

4.4.5 Airworthiness requirements and Aeronautical certification

Many demanded activities during the redelivery process occur to meet the authority requirements – in general, the subsequent aviation authority (the aviation authority in which the aircraft will be registered after the delivery process) (AIRCRAFT COMMERCE, 2017).

These requirements may be divided into certification and airworthiness requirements, being these two aspects relevant concerns during the redelivery process. All kinds of modification or repair must be certificated and the respective records in accordance with the authority required condition. In addition, the aircraft must hold a valid certificate of airworthiness (CoA) (ACKERT, 2014). Most redelivery conditions encompass certifications or airworthiness requirements. The following paragraphs present a typical contract wording that involves certification or airworthiness requirements; according to Ackert (2014):

i. Parts fitted to the aircraft that are controlled by both part number and serial number shall have EASA Form One or FAA 8130-3 certification.

ii. All time controlled and Life Limited Parts (LLPs) shall have EASA Form One or FAA Form 8130-3 certification and where applicable, traceability back -to-birth (although not FAA, EASA or ICAO required it is generally good policy to obtain back-to-birth records.)

iii. Have been deregistered from all relevant aircraft registries and notice of deregistration by the Aviation Authority shall have been sent to an aviation authority designated by lessor

iv. Be in a condition suitable for issuance of an EASA or FAA Standard Certificate of Airworthiness for transport category aircraft and commercial passenger operations

vi. Have a valid certificate of airworthiness for export issued by the Aviation Authority, provided the accomplishment of such modifications will not result in a delay in the redelivery of the aircraft to lessor. In *the event such modifications to the Aircraft are required by lessor, and such modifications are not a requirement of this Lease, lessor shall reimburse for the accomplishment of such modifications."*

The non-issued or non-approved certificate (by the applicable aviation authority) mentioned above is critical to the redelivery, as that the lessor is prohibited to transfer the aircraft to the next lessee. This interdiction is based on the fact that the aircraft is not allowed to fly without meeting the applicable aviation authority's requirements. Therefore, lessors usually put considerable efforts to work with the lessee focusing on the mentioned issues and approvals. The certification process may depend on physical and records' inspections. Therefore, due to extensive experience with certification processes, OEMs may work with lessees and lessors, aiming to assist them.

The other attention point is that distinct aviation authorities may have distinct requirements for the same type of aircraft. This characteristic implies another concern to lessees and lessors, which in general, must adapt the aircraft to meet the next lessee aviation authority's requirements. Usually, these arrangements involve interior reconfiguration (*e.g.* placards) and eventual additional systems, thus, the OEM may provide to the lessee and lessor the applicable support, developing the reconfiguration and supporting the subsequent aviation authority approval.

The next analyzed aspect involves the management of the aircraft throughout the leasing period. In general, airlines compose a fleet with more than one type of aircraft. This scenario brings some challenges to manage each one in terms of configuration and records.

4.4.6 Product support management

The last aspect here considered, by the adopted criteria, as a category in which are concentrated several relevant redelivery issues is the *Product Support Management.* In this way, along the lease period, an appropriate management of the aircraft and the applicable documents and records are essential for a further smooth redelivery process.

The *product support management* involves aspects as the configuration management of an aircraft and the management of the documentation and records. Thus, this management may support some aspects cited in the paragraphs above, as interior reconfiguration, maintenance, technical data, documentations and records. For instance, during preventive or corrective maintenance activities, several parts may suffer changes, bringing the challenge of managing each one aiming to trace them along their operational time. In general, this management comprises specific objective indicators, which are not open for subjective interpretation about the status of each component. The most common indicators are Flight Cycles (FC), Flight Hours (FH), Calendar time (*e.g.* Months, Years), and even Time Since New (TSN), Time Between Overhaul (TBO) and others. The following paragraph presents a typical contract wording that describes the importance of the product management; according to Ackert (2014):

> *"All hard time components shall have remaining to the next limiting factor for maintenance at least: (i) for items the subject of an hour limit, 6,000 Flight Hours; (ii) for items the subject of a cycle limit, 4,500 Cycles; or (iii) for items the subject of a calendar limit, 24 months interval. In the event that such hard time components have an interval of less than 6,000 Flight Hours, 4,500 Cycles or 24 month interval (as the case may be), they shall have 100% of life remaining."*

The lessee must maintain considerable control of the aircraft components. However, even if a component is in a good condition (operational and functional) but its applicable records of installation (*e.g.* dirty fingerprint, task card) are not available or in good condition, the lessor may find the components unacceptable. Hence, in parallel with the management of the aircraft configuration, the lessee must manage all applicable documentation and records, especially ensuring adequate paper document storage.

This lack of a satisfactory management generates several disputes between lessees and lessors during the redelivery. It is common to occur extra replacement of aircraft parts due to the lack of applicable documentation or traceability. Therefore, OEMs are able to work with lessees, throughout the leasing period to assist them – in order to improve the configuration management of the aircraft parts and components. This management may be performed by strictly controlling each part number and the most common parameters (*e.g.* FH, FC).

During the production phase, the aircraft material (consumable, expendable or repairable) may be serialized. Those serialized components are not necessarily monitored; neither must the records be generated or traceable. However, in general, leasing agreements enclose generic terms that demand (from the lessee) a control of all serialized parts. Thus, OEMs are able to assist the lessee by developing a guide-list of the parts and components, which must be controlled or traced. This action aims to concentrate the configuration management effort on essential parts and components and hence, minimizing disputes between lessees and lessors.

4.4.7 Final model discussion considerations

The last subsections clarify the results and present examples on how the categories are expressed in terms of the redelivery concerns. In addition, the author performed some recommendations about how the OEM might be involved in the redelivery, based on the experience acquired during the methodology application. Table 4-10 gathers the recommendations provided.

Table 4-10 – Recommendations to OEMs towards redelivery assistance practices

Involved category	Author's Recommended Practices for OEM's
Interior reconfiguration	Provide to the lessees and lessors a technical and clear definition about normal wear throughout the utilization years of the interior parts and components.
	Provide to the lessee and lessor an expeditious solution and applicable technical publications for several types of interior configuration.
	Adopt high-level requirements of interior design to guide the development teams to create an aircraft easy to reconfigure
	Support and assist the lessee to accomplish the "Interior Burn Certification" process.
Maintenance	Assist lessees with a customized maintenance planning and take into account the entire leasing period and the required redelivery major check.
	Provide to the lessee and lessor predefined redelivery inspection tasks, identifying the areas, which usually generate more disputes between lessee and lessors.
Sustaining engineering support	Support specific areas to attend the redeliveries’ engineering requirements from the lessee and lessor, such as: Engineering repair data; SB’s and AD’s reference documents; Aircraft drawings (*e.g.* Layout of Passenger Accommodation – LOPA, emergency equipment layout and galley drawings);
Technical data, orders, publications and documentations supporting	Assist lessees and lessors by building a different record registration framework; for instance, by utilizing digital records combined with digital signatures.
	Develop distinct manners to present and provide their own technical publications (*e.g.* OEM's manuals, service bulletins).
	Implement self-testing technologies in their aircraft
	Assist lessees and lessors during the development of the leasing contract, customizing the leasing contract to each type of aircraft.

Airworthiness requirements and Aeronautical certification	Support and assist lessees and lessors with physical and records' inspections by the aviation authorities.
	Provide to the lessee and lessor the demanded aircraft reconfiguration and support its subsequent aviation authority approval.
Product support management	Work with lessees in order to improve the configuration management of the aircraft parts and components. This management may be performed by strictly controlling each part number and the most common parameters (*e.g* FH, FC).
	Assist the lessee by developing a guide-list of the parts and components which must be controlled or traced.

5 Conclusions

One of the purposes of this thesis was to gather information of the existing literature and the knowledge of experts on the field of aircraft leasing to identify different categories to be tackled in the process of returning the aircraft (redelivery), using Content Analysis and the Delphi Method. This study brings forward the concept of including the OEM, which is the main expert of its product, to work together in the process of evaluating and solving non-conformities during the handover of an aircraft. In addition, the involvement of the OEM may result in more efficient processes, considering the maintenance, repair, overhaul and all kind of supports. Besides, with this proposed strategy, it is expected to occur reduction in the costs and length of the entire redelivery process.

The main objective of this research is to develop a prescriptive model specifying the most significant categories of problems, which occur throughout redelivery processes and in which the aircraft manufacturer may act as a facilitator – especially considering a strategic framework with cost and time-consuming reduction. The prescriptive model achieved in this thesis shows that participation of the OEM during the handover of an aircraft may be beneficial considering the following categories:

- *Interior reconfiguration,*
- *Maintenance procedures and planning*,
- *Sustaining engineering support,*
- *Support for technical data, orders, publications and documentations*,
- *Airworthiness requirements*,
- *Aeronautical certification* and
- *Product support management*

The involvement of the OEM in such operations may result in efficient redelivery processes. On its turn, an aircraft encompassing higher liquidity is more attractive in view of an investor's perspective. Moreover, OEMs may find high-value market opportunities meanwhile providing certified after-sales services to their own products.

The gap between manufacturing (and certificating) – which is the field of expertise of the OEM; and operating an aircraft – competence of the airlines; is one of the greatest challenges to persuade OEMs to become involved in the redelivery. This barrier is, however, intensified by volatile cultural operating systems and political barriers that may differ from the original OEM-headquarters.

The result achieved in this thesis shows that the OEM may participate by being involved in the redelivery. Despite the difficulties, the involvement of the OEM during the redeliver has shown that the process may have increased the efficiency, minimizing extra expenditures and wasted time. The categories, which compose the final model, concentrate the most relevant redelivery issues. Therefore, OEMs may concentrate their efforts on supporting and assisting lessees and lessors with the aforementioned categories.

At the end of the discussion section, the author provided some recommendations on practices that the OEM may participate in the redelivery (Table 4-9). However, such recommendations have not been validated and are only empirical assumptions.

5.1 Further researches

It becomes essential to delineate topics that may be further developed in order to contribute with the progress of the research on aircraft redelivery, especially with the consideration of the practical viewpoint. Real and significant earnings for the aviation industry may be achieved with academic studies on the matter, as this present thesis has corroborated.

As these earnings may be measured by financial matters, the development of researches focused in on aviation economic concerns is an important stage for the validation and implementation of the presented recommendations and any other potential recommendation that may be elaborated. These studies may quantify the eventual benefits of the involvement of the OEM in the redelivery, being a fundamental tool for the industry's decision makers.

In parallel, the provided final model with the most relevant categories may be studied in detail, by breaking down each category, in order to investigate and create more recommendations to OEMs. Also, taking advantage of new technologies and Engineering concepts, as the methodology of System Engineering, and economic matters, the author’s recommendations may be tested, integrating interdisciplinary areas, aiming to create financial earns for the entire aviation industry.

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Appendices

Appendix A – Friedman Pairwise Comparisons (Content Analysis)

Category 1	Category 2	Test statistic	p-value
Support equipment	Maintenance Procedures and Planning	7.600	0.001
Computer resources	Maintenance Procedures and Planning	7.300	0.001
Packaging, handling, storage and transportation support	Maintenance Procedures and Planning	7.050	0.002
Facilities and infrastructure	Maintenance Procedures and Planning	6.800	0.003
Support equipment	Interior reconfiguration	6.250	0.006
Support equipment	Technical data, orders and publications	5.950	0.008
Computer resources	Interior reconfiguration	5.950	0.008
Design Influence	Maintenance Procedures and Planning	5.800	0.010
Packaging, handling, storage and transportation support	Interior reconfiguration	5.700	0.012
Computer resources	Technical data, orders and publications	5.650	0.012
Facilities and infrastructure	Interior reconfiguration	5.450	0.016
Packaging, handling, storage and transportation support	Technical data, orders and publications	5.400	0.017
Support equipment	Product support management	5.200	0.021
Facilities and infrastructure	Technical data, orders and publications	5.150	0.023
Manpower and personnel	Maintenance Procedures and Planning	5.100	0.024
Computer resources	Product support management	4.900	0.030
Support equipment	Sustaining engineering	4.850	0.032
Supply support	Maintenance Procedures and Planning	4.850	0.032
Support equipment	Aeronautical Certification - Requirements and Regulations	4.750	0.035

Packaging, handling, storage and transportation	Product support management	4.650	0.039
Instruction for Continuous Airworthiness (ICA)	Maintenance Procedures and Planning	-4.650	0.039
Training and training support	Maintenance Procedures and Planning	4.600	0.042
Computer resources	Sustaining engineering	4.550	0.044
Computer resources	Aeronautical Certification - Requirements and Regulations	4.450	0.049
Design Influence	Interior reconfiguration	4.450	0.049
Facilities and infrastructure	Product support management	4.400	0.051
Packaging, handling, storage and transportation	Sustaining engineering	-4.300	0.057
Packaging, handling, storage and transportation	Aeronautical Certification - Requirements and Regulations	4.200	0.063
Design Influence	Technical data, orders and publications	4.150	0.066
Support equipment	General reconfiguration	4.050	0.073
Facilities and infrastructure	Sustaining engineering	4.050	0.073
Facilities and infrastructure	Aeronautical Certification - Requirements and Regulations	3.950	0.080
Spare and repair parts	Maintenance Procedures and Planning	3.950	0.080
Computer resources	General reconfiguration	3.750	0.097
Manpower and personnel	Interior reconfiguration	3.750	0.097
Support equipment	Spare and repair parts	3.650	0.106
General reconfiguration	Maintenance Procedures and Planning	-3.550	0.116
Packaging, handling, storage and transportation	General reconfiguration	3.500	0.121
Supply support	Interior reconfiguration	3.500	0.121
Manpower and personnel	Technical data, orders and publications	3.450	0.127
Design Influence	Product support management	-3.400	0.132
Computer resources	Spare and repair parts	3.350	0.138
Instruction for Continuous Airworthiness (ICA)	Interior reconfiguration	3.300	0.144
Facilities and infrastructure	General reconfiguration	3.250	0.150
Training and training support	Interior reconfiguration	3.250	0.150
Supply support	Technical data, orders and publications	3.200	0.156
Packaging, handling, storage and transportation	Spare and repair parts	3.100	0.170
Design Influence	Sustaining engineering	-3.050	0.177

Support equipment	Training and training support	3.000	0.184
Instruction for Continuous Airworthiness (ICA)	Technical data, orders and publications	-3.000	0.184
Support equipment	Instruction for Continuous Airworthiness (ICA)	2.950	0.191
Design Influence	Aeronautical Certification - Requirements and Regulations	2.950	0.191
Training and training support	Technical data, orders and publications	2.950	0.191
Facilities and infrastructure	Spare and repair parts	2.850	0.207
Aeronautical Certification - Requirements and Regulations	Maintenance Procedures and Planning	-2.850	0.207
Support equipment	Supply support	2.750	0.223
Sustaining engineering	Maintenance Procedures and Planning	2.750	0.223
Computer resources	Training and training support	2.700	0.232
Manpower and personnel	Product support management	2.700	0.232
Computer resources	Instruction for Continuous Airworthiness (ICA)	2.650	0.241
Spare and repair parts	Interior reconfiguration	2.600	0.250
Support equipment	Manpower and personnel	2.500	0.268
Computer resources	Supply support	2.450	0.278
Packaging, handling, storage and transportation	Training and training support	2.450	0.278
Supply support	Product support management	2.450	0.278
Packaging, handling, storage and transportation	Instruction for Continuous Airworthiness (ICA)	2.400	0.288
Product support management	Maintenance Procedures and Planning	2.400	0.288
Manpower and personnel	Sustaining engineering	2.350	0.298
Spare and repair parts	Technical data, orders and publications	2.300	0.308
Design Influence	General reconfiguration	2.250	0.319
Manpower and personnel	Aeronautical Certification - Requirements and Regulations	2.250	0.319
Instruction for Continuous Airworthiness (ICA)	Product support management	-2.250	0.319
Computer resources	Manpower and personnel	-2.200	0.330
Packaging, handling, storage and transportation	Supply support	2.200	0.330
Facilities and infrastructure	Training and training support	2.200	0.330
Training and training support	Product support management	-2.200	0.330
General reconfiguration	Interior reconfiguration	2.200	0.330

Facilities and infrastructure	Instruction for Continuous Airworthiness (ICA)	2.150	0.341
Supply support	Sustaining engineering	-2.100	0.352
Supply support	Aeronautical Certification - Requirements and Regulations	2.000	0.376
Packaging, handling, storage and transportation	Manpower and personnel	-1.950	0.388
Facilities and infrastructure	Supply support	1.950	0.388
Instruction for Continuous Airworthiness (ICA)	Sustaining engineering	-1.900	0.400
General reconfiguration	Technical data, orders and publications	-1.900	0.400
Design Influence	Spare and repair parts	1.850	0.413
Training and training support	Sustaining engineering	-1.850	0.413
Support equipment	Design Influence	1.800	0.425
Instruction for Continuous Airworthiness (ICA)	Aeronautical Certification - Requirements and Regulations	-1.800	0.425
Training and training support	Aeronautical Certification - Requirements and Regulations	1.750	0.438
Facilities and infrastructure	Manpower and personnel	-1.700	0.452
Support equipment	Maintenance Procedures and Planning	1.650	0.465
Manpower and personnel	General reconfiguration	1.550	0.492
Spare and repair parts	Product support management	-1.550	0.492
Computer resources	Design Influence	1.500	0.507
Aeronautical Certification - Requirements and Regulations	Interior reconfiguration	1.500	0.507
Sustaining engineering	Interior reconfiguration	1.400	0.535
Interior reconfiguration	Maintenance Procedures and Planning	-1.350	0.550
Supply support	General reconfiguration	1.300	0.565
Packaging, handling, storage and transportation	Training and training support	1.250	0.580
Design Influence	Training and training support	1.200	0.595
Spare and repair parts	Sustaining engineering	-1.200	0.595
Aeronautical Certification - Requirements and Regulations	Technical data, orders and publications	-1.200	0.595
Design Influence	Instruction for Continuous Airworthiness (ICA)	1.150	0.611
Manpower and personnel	Spare and repair parts	1.150	0.611
General reconfiguration	Product support management	-1.150	0.611
Instruction for Continuous Airworthiness (ICA)	General reconfiguration	1.100	0.626

Spare and repair parts	Aeronautical Certification - Requirements and Regulations	1.100	0.626
Sustaining engineering	Technical data, orders and publications	1.100	0.626
Training and training support	General reconfiguration	1.050	0.642
Product support management	Interior reconfiguration	1.050	0.642
Facilities and infrastructure	Design Influence	1.000	0.658
Design Influence	Supply support	-0.950	0.674
Supply support	Spare and repair parts	0.900	0.690
Support equipment	Facilities and infrastructure	0.800	0.723
General reconfiguration	Sustaining engineering	-0.800	0.723
Product support management	Technical data, orders and publications	0.750	0.740
Design Influence	Manpower and personnel	-0.700	0.757
Instruction for Continuous Airworthiness (ICA)	Spare and repair parts	-0.700	0.757
General reconfiguration	Aeronautical Certification - Requirements and Regulations	-0.700	0.757
Training and training support	Spare and repair parts	0.650	0.773
Support equipment	Packaging, handling, storage and transportation	0.550	0.808
Computer resources	Facilities and infrastructure	-0.500	0.825
Manpower and personnel	Training and training support	0.500	0.825
Manpower and personnel	Instruction for Continuous Airworthiness (ICA)	0.450	0.842
Aeronautical Certification - Requirements and Regulations	Product support management	-0.450	0.842
Spare and repair parts	General reconfiguration	0.400	0.859
Sustaining engineering	Product support management	0.350	0.877
Support equipment	Computer resources	0.300	0.894
Support equipment	Interior reconfiguration	0.300	0.894
Computer resources	Packaging, handling, storage and transportation	0.250	0.912
Packaging, handling, storage and transportation	Facilities and infrastructure	-0.250	0.912
Manpower and personnel	Supply support	0.250	0.912
Supply support	Instruction for Continuous Airworthiness (ICA)	0.250	0.912
Supply support	Instruction for Continuous Airworthiness (ICA)	0.200	0.929
Aeronautical Certification - Requirements and Regulations	Sustaining engineering	-0.100	0.965
Instruction for Continuous Airworthiness (ICA)	Training and training support	-0.050	0.982

Appendix B – Categories defined at three rounds of the Delphi Method

Round 1	Round 2	Round 3
Interior reconfiguration	Interior reconfiguration	Interior reconfiguration
General reconfiguration	General reconfiguration	External reconfiguration
Instruction for Continuous Airworthiness (ICA)	Instruction for Continuous Airworthiness Definition of components regards content of records versus airworthiness Engines definition and support regards airworthiness and limits of operation	Airworthiness requirements
Aeronautical certification - requirements and regulations	Aeronautical certification - requirements and regulations	Aeronautical certification
Maintenance procedures and planning	Maintenance procedures and planning Engineering support for repair maps Definition and support for structural repairs versus leasing agreement terms	Maintenance
Technical data, orders and publications	Technical data, orders and publications Contract analysis (redelivery conditions) Support for general terms used in the leasing agreement which is unreachable Recovery of delivery documents loosing during operation	Support for technical data, orders, publications and documentations

Spare and repair parts	Spare and repair parts Support for PMA and/or DER repairs and parts	Spare and repair parts
Training and training support	Training and training support	Training and training support
Design influence	Design influence Definition of parts with serial must be controlled	Design to redelivery
Product support management	Product support management	Product support management
Supply support	Supply support	Supply support
Packaging, handling, storage and transportation	Packaging, handling, storage and transportation	Packaging, handling, storage and transportation support
Sustaining engineering	Sustaining engineering Back to birth definition and support for recovery records for components Clear of definition of term (normal wear)	Sustaining engineering support
Computer resources	Computer resources	Computer resources
Facilities and infrastructure	Facilities and infrastructure	Facilities and infrastructure
Manpower and personnel	Manpower and personnel	Manpower and personnel
Support equipment	Support equipment	Support equipment

Appendix C – Final ranks outlined by the experts during the Delphi exercise

id	Final Category	Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp. 5	Sum
1	Interior reconfiguration	7	1	2	5	1	16
2	External reconfiguration	6	8	8	10	9	41
3	Airworthiness requirements	1	9	7	8	1	26
4	Aeronautical certification	2	10	5	8	13	38
5	Maintenance	3	16	1	1	3	24
6	Support for technical data, orders, publications and documentations	6	11	4	9	3	33
7	Spare and repair parts	5	12	9	3	9	38
8	Training and training support	9	13	10	11	13	56
9	Design to redelivery	8	7	4	6	9	34
10	Product support management	11	14	3	4	13	45
11	Supply support	12	5	6	7	3	33
12	Packaging, handling, storage and transportation support	17	6	9	12	3	47
13	Sustaining engineering support	10	3	5	2	3	23
14	Computer resources	16	2	11	14	13	56
15	Facilities and infrastructure	15	15	12	15	3	60
16	Manpower and personnel	14	17	13	12	3	59
17	Support equipment	13	4	14	13	3	47

Appendix D – Friedman Pairwise Comparisons (Delphi Method)

Category 1	Category 2	Test statistic	p-value
Facilities and infrastructure	Interior reconfiguration	10.400	0.001
Manpower and personnel	Interior reconfiguration	10.100	0.002
Computer resources	Interior reconfiguration	9.400	0.003
Training and training support	Interior reconfiguration	9.200	0.004
Facilities and infrastructure	Maintenance	8.200	0.010
Facilities and infrastructure	Sustaining engineering support	8.100	0.011
Facilities and infrastructure	Airworthiness requirements	7.900	0.013
Manpower and personnel	Maintenance	7.900	0.013
Manpower and personnel	Sustaining engineering support	7.800	0.015
Support equipment	Interior reconfiguration	7.800	0.015
Manpower and personnel	Airworthiness requirements	7.600	0.017
Packaging, handling, storage and transportation	Interior reconfiguration	7.600	0.017
Computer resources	Maintenance	7.200	0.024
Computer resources	Sustaining engineering support	7.100	0.026
Training and training support	Maintenance	7.000	0.028
Computer resources	Airworthiness requirements	6.900	0.031
Training and training support	Sustaining engineering support	-6.900	0.031
Training and training support	Airworthiness requirements	6.700	0.036
Facilities and infrastructure	Support for technical data, orders, publications and documentations	6.200	0.052
Facilities and infrastructure	Design to redelivery	6.200	0.052
Product support management	Interior reconfiguration	6.200	0.052
Facilities and infrastructure	Supply support	6.000	0.060
External reconfiguration	Interior reconfiguration	6.000	0.060
Manpower and personnel	Design to redelivery	5.900	0.065
Manpower and personnel	Support for technical data, orders, publications and documentations	5.900	0.065
Manpower and personnel	Supply support	5.700	0.074
Support equipment	Maintenance	5.600	0.080
Support equipment	Sustaining engineering support	5.500	0.085
Packaging, handling, storage and transportation	Maintenance	5.400	0.091
Support equipment	Airworthiness requirements	5.300	0.097
Packaging, handling, storage and transportation	Sustaining engineering support	-5.300	0.097
Facilities and infrastructure	Spare and repair parts	5.200	0.103
Facilities and infrastructure	Aeronautical certification	5.200	0.103

Computer resources	Design to redelivery	5.200	0.103
Computer resources	Support for technical data, orders, publications and documentations	5.200	0.103
Spare and repair parts	Interior reconfiguration	5.200	0.103
Aeronautical certification	Interior reconfiguration	5.200	0.103
Packaging, handling, storage and transportation	Airworthiness requirements	5.100	0.110
Computer resources	Supply support	5.000	0.117
Training and training support	Support for technical data, orders, publications and documentations	5.000	0.117
Training and training support	Design to redelivery	-5.000	0.117
Manpower and personnel	Spare and repair parts	4.900	0.125
Manpower and personnel	Aeronautical certification	4.900	0.125
Training and training support	Supply support	-4.800	0.133
Facilities and infrastructure	External reconfiguration	4.400	0.168
Supply support	Interior reconfiguration	4.400	0.168
Facilities and infrastructure	Product support management	4.200	0.188
Computer resources	Spare and repair parts	4.200	0.188
Computer resources	Aeronautical certification	4.200	0.188
Design to redelivery	Interior reconfiguration	4.200	0.188
Support equipment	Interior reconfiguration	4.200	0.188
Manpower and personnel	External reconfiguration	4.100	0.199
Training and training support	Aeronautical certification	4.000	0.210
Training and training support	Spare and repair parts	4.000	0.210
Product support management	Maintenance	4.000	0.210
Manpower and personnel	Product support management	3.900	0.222
Product support management	Sustaining engineering support	-3.900	0.222
External reconfiguration	Maintenance	-3.800	0.234
Product support management	Airworthiness requirements	3.700	0.247
External reconfiguration	Sustaining engineering support	-3.700	0.247
Support equipment	Support for technical data, orders, publications and documentations	3.600	0.260
Support equipment	Design to redelivery	3.600	0.260
External reconfiguration	Airworthiness requirements	-3.500	0.273
Computer resources	External reconfiguration	3.400	0.287
Support equipment	Supply support	3.400	0.287
Packaging, handling, storage and transportation	Design to redelivery	3.400	0.287
Packaging, handling, storage and transportation	Support for technical data, orders, publications and documentations	3.400	0.287
Computer resources	Product support management	3.200	0.316
Training and training support	External reconfiguration	3.200	0.316
Packaging, handling, storage and transportation	Supply support	3.200	0.316
Training and training support	Product support management	-3.000	0.348
Aeronautical certification	Maintenance	-3.000	0.348

Spare and repair parts	Maintenance	3.000	0.348
Spare and repair parts	Sustaining engineering support	-2.900	0.364
Aeronautical certification	Sustaining engineering support	-2.900	0.364
Facilities and infrastructure	Packaging, handling, storage and transportation	2.800	0.381
Spare and repair parts	Airworthiness requirements	2.700	0.398
Aeronautical certification	Airworthiness requirements	2.700	0.398
Facilities and infrastructure	Support equipment	-2.600	0.416
Support equipment	Spare and repair parts	2.600	0.416
Support equipment	Aeronautical certification	2.600	0.416
Manpower and personnel	Packaging, handling, storage and transportation	2.500	0.434
Airworthiness requirements	Interior reconfiguration	2.500	0.434
Packaging, handling, storage and transportation	Aeronautical certification	2.400	0.452
Packaging, handling, storage and transportation	Spare and repair parts	2.400	0.452
Manpower and personnel	Support equipment	-2.300	0.471
Sustaining engineering support	Interior reconfiguration	2.300	0.471
Supply support	Maintenance	2.200	0.491
Maintenance	Interior reconfiguration	2.200	0.491
Supply support	Sustaining engineering support	-2.100	0.511
Product support management	Design to redelivery	2.000	0.531
Product support management	Support for technical data, orders, publications and documentations	2.000	0.531
Design to redelivery	Maintenance	2.000	0.531
Support for technical data, orders, publications and documentations	Maintenance	2.000	0.531
Supply support	Airworthiness requirements	1.900	0.552
Design to redelivery	Sustaining engineering support	-1.900	0.552
Support for technical data, orders, publications and documentations	Sustaining engineering support	-1.900	0.552
Computer resources	Packaging, handling, storage and transportation	1.800	0.573
Support equipment	External reconfiguration	1.800	0.573
Product support management	Supply support	-1.800	0.573
External reconfiguration	Support for technical data, orders, publications and documentations	-1.800	0.573
External reconfiguration	Design to redelivery	-1.800	0.573
Support for technical data, orders, publications and documentations	Airworthiness requirements	1.700	0.595
Design to redelivery	Airworthiness requirements	1.700	0.595
Computer resources	Support equipment	-1.600	0.616
Training and training support	Packaging, handling, storage and transportation	-1.600	0.616
Support equipment	Product support management	1.600	0.616

Packaging, handling, storage and transportation	External reconfiguration	1.600	0.616
External reconfiguration	Supply support	-1.600	0.616
Training and training support	Support equipment	-1.400	0.661
Packaging, handling, storage and transportation	Product support management	1.400	0.661
Facilities and infrastructure	Training and training support	1.200	0.707
Facilities and infrastructure	Training and training support	1.000	0.754
Product support management	Aeronautical certification	1.000	0.754
Product support management	Spare and repair parts	1.000	0.754
Aeronautical certification	Design to redelivery	-1.000	0.754
Aeronautical certification	Support for technical data, orders, publications and documentations	-1.000	0.754
Spare and repair parts	Support for technical data, orders, publications and documentations	1.000	0.754
Spare and repair parts	Design to redelivery	-1.000	0.754
Manpower and personnel	Training and training support	0.900	0.778
External reconfiguration	Spare and repair parts	-0.800	0.802
External reconfiguration	Aeronautical certification	-0.800	0.802
Spare and repair parts	Supply support	-0.800	0.802
Aeronautical certification	Supply supp1ort	-0.800	0.802
Manpower and personnel	Computer resources	0.700	0.827
Facilities and infrastructure	Manpower and personnel	-0.300	0.925
Airworthiness requirements	Maintenance	-0.300	0.925
Computer resources	Training and training support	0.200	0.950
Support equipment	Packaging, handling, storage and transportation	0.200	0.950
Product support management	External reconfiguration	0.200	0.950
Supply support	Design to redelivery	0.200	0.950
Supply support	Support for technical data, orders, publications and documentations	0.200	0.950
Airworthiness requirements	Sustaining engineering support	-0.200	0.950
Sustaining engineering support	Maintenance	0.100	0.975
Aeronautical certification	Spare and repair parts	0.000	1.000
Support for technical data, orders, publications and documentations	Design to redelivery	0.000	1.000

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5. TÍTULO E SUBTÍTULO:

OEM’S practices to act as an effective third party facilitator in aircraft redelivery processes.

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8. PALAVRAS-CHAVE SUGERIDAS PELO AUTOR:

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11. RESUMO:

Aircraft redelivery processes usually occur during the closure of an aircraft leasing agreement. This procedure, which refers to the process of returning an aircraft, involves close cooperation between two parties: the owner (lessor) and the operator (lessee). Given the fact that an aircraft is an asset – that is, an equipment composed by many components in a complex system; and that the redeliver requires full commitment and an extensive knowledge of both parties, some issues may arise, compromising the return time schedule and increasing estimated costs. The main objective of this research is to develop a prescriptive model specifying the most significant categories of problems, which occur throughout redelivery processes and which may be tackled by the Original Equipment Manufacturer (OEM) – especially considering a strategic framework of cost and time-consuming reduction. Two different analyses are performed in this project. The first one refers to the Content Analysis (CA), which is based on a literature review to classify the frequency of each problem. The second one is the Delphi Method (DM) that, by means of a questionnaire applied to a panel of experts, generates a group response that enables the classification of the relevance of each problem. In order to assure the consistency of results, both approaches were mutually applied towards the same purpose – *i.e.*, identifying the most critical obstacles encountered during the handover of an aircraft. From the results of this study, the reader is provided with practices of means of including the manufacturer in the redelivery, and thus, creating a guideline to the OEMs. The prescriptive model achieved in this thesis shows that participation of the OEM during the handover of an aircraft may be beneficial considering the following categories: *Interior reconfiguration*, *Maintenance procedures and planning*, *Sustaining engineering support, Support for technical data, orders, publications and documentations*, *Airworthiness requirements*, *Aeronautical certification* and *Product support management*. The involvement of the OEM in such operations may result in efficient redelivery processes, which benefits owners and aircraft operators. Moreover, OEMs may find high-value business opportunities meanwhile providing certified after-sales services to their own products.

12. GRAU DE SIGILO:

(X) OSTENSIVO **( ) RESERVADO** **( ) SECRETO**