Nicolas Fernandez

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Finnair Technical Operations (FTO) is an organization that provides maintenance and repair services for Finnair's aircraft. Currently FTO provides line maintenance services for Finnair's fleet of Airbus 350, Airbus 330, Airbus 32s, Embraer 190 and ATR-72 aircraft. The main responsibility of FTO is to ensure the continuous airworthiness of the Finnair fleet.

Aircraft maintenance is divided into two categories: Line maintenance and base maintenance. Line maintenance is considered every day maintenance required for operating the aircraft consisting of daily, weekly and monthly checks, and the rectification of defects as well. Base maintenance, also referred to as heavy maintenance, is an extensive check carried out once in two years or sometimes in three years. In the past Finnair has performed base maintenance in Helsinki for all Finnair fleet.

The objective of this study was to research FTO's current capability to perform base maintenance in Helsinki. The main objective was to study what investments FTO must make to perform base maintenance. This involves materials, tools, equipment and personnel needs.

This study was based on Embraer's manuals mainly the maintenance planning document (MPD). Data was also collected by studying several sources and by interviewing Finnair personnel. Finnair has kept a very good record of maintenance history performed in Helsinki and abroad. Embraer provided data on the experiences of other companies.

According to the study FTO has good facilities and basic equipment for performing base maintenance. As FTO already provides line maintenance services for Embraer 190, most special tools are already available. The largest investments would consist of maintenance platforms and employing more personnel. There are several possibilities on how to keep investment cost low. Using a mix of contractors and own employees would keep risks lower.

Keywords	

Tekijä Otsikko Sivumäärä Aika	Nicolas Fernandez Tutkimus Perushuoltojen Suorittamisesta Embraer 190 Lentokoneille 34 sivua + 2 liitettä
Tutkinto	Insinööri (AMK)
Koulutusohjelma	Konetekniikka
Suuntautumis-vaihtoehto	Koneautomaatio
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Finnairin tekniset palvelut (FTO) on organisaatio joka tuottaa teknisiä palveluja Finnairille. Tällä hetkellä FTO tarjoaa linjahuoltoa Finnairin Airbus 350-, Airbus 330-, Airbus 32-, Embraer 190- ja ATR-72-lentokoneille. FTO:n päävastuu on varmistaa Finnairin laivaston jatkuva lentokelpoisuus.

Ilma-alusten huoltotoiminta jaetaan linjanhuoltoon ja perushuoltoon. Linjahuolto on koneen päivittäistä huoltoa. Se koostuu päivittäin, viikoittain ja kuukausittain suoritettavista tarkastuksista sekä vikojen korjaamisista. Perushuolto, jota kutsutaan myös raskaaksi huolloksi, on laaja tarkastus kerran kahdessa vuodessa tai joskus kolmessa vuodessa. Aikaisemmin Finnair on tehnyt perushuoltoja Helsingissä kaikille koneilleen.

Tämän tutkimuksen tavoitteena oli tutkia FTO:n nykyistä kykyä suorittaa perushuoltoja Helsingissä. Päätavoitteena oli selvittää, mitkä investoinnit FTO:n on tehtävä, jotta perushuoltoja voidaan suorittaa. Investoinnit koskevat materiaaleja, työkaluja, laitteita ja henkilöstötarpeita.

Tutkimuksen perustana olivat Embraerin käsikirjat, erityisesti maintenance planning document (MPD). Tietoa kerättiin myös tutkimalla muita lähteitä ja haastattelemalla henkilökuntaa. Embraer toimitti tietoa muiden yhtiöiden kokemuksista.

Tutkimuksen mukaan FTO:lla on hyvät tilat ja resurssit perushuoltojen tekemiseen. FTO tuottaa linjahuolto palveluja Embraer 190 laivastolle, joten suurin osa erikoistyökaluista on jo saatavilla. Suurimmat kustannukset muodostuvat telakoiden hankkimisesta ja työntekijöiden palkkaamisesta. Investointikuluja ja -riskejä voidaan alentaa käyttämällä vuokratyövoimaa sekä yhtiön omia työntekijöitä.

Keywords	

Contents

List of Abbreviations

MRBR	Maintenance Review Board Report
MPD	Maintenance Planning Document. A tool or manual used for planning of maintenance.
AMM	Aircraft Maintenance Manual. A manual which has description of all aircraft systems and instructions for accomplishment of maintenance tasks.
MPP	Maintenance Procedures
IPC	Illustrated parts catalogue.
SRM	Structural repair manual.
ERJ	Embraer regional jet
GSE	Ground support equipment
ITEM	Illustrated tools and equipment manual. Present the ground support equipment (GSE) used for accomplishment of maintenance tasks.
MRO	Maintenance repair and overhaul. An organization that provides maintenance, repair and overhaul services for aircrafts.
TC	Task card. Describes a certain maintenance task.
FH	Flight hours, hours the aircraft is airborne.
FC	Flight cycles, one take-off and landing is one cycle.
Mechanic	A person the performs maintenance on aircraft
B1	A mechanic with license to do maintenance on mechanical systems.
B2	A mechanic with license to do maintenance on electrical and avionics systems.
C	A mechanic with license to do heavy maintenance.
A/C	Aircraft
GVI	General visual inspection. Visual inspections made at one arm’s length
DVI	Detailed visual inspection. Visual inspection performed with a magnifying class.
SDI	Special detailed inspection. Inspections using special devices including nondestructive testing.
NDT	Nondestructive testing. Special inspections of structures. Eddy current, rotating probe, FPI, x-ray.

CAA FI	Finnish Transport Agency
FTO	Finnair Technical Operations
MOE	Maintenance Organization Exposition

1 Introduction

1.1 Finnair Technical Operations and Aircraft Maintenance

Finnair Technical Operation (FTO) is an organization that provides maintenance and repair services for Finnair's aircraft. Currently FTO provides Line maintenances services for Finnair's fleet of Airbus 350, Airbus 330, Airbus 32s, Embraer 190 and ATR-72 aircraft. Finnair Technical Operation consists of maintenance control, maintenance planning, engineering, aircraft maintenance, material management and compliance & development. The main responsibility of FTO is to ensure continuous airworthiness of the Finnair fleet.

Aircraft maintenance is divided into two categories: Line maintenance and Base maintenance. Line maintenance is considered as every day maintenance required for operating the aircraft. It consists of daily, weekly, monthly checks and rectification of defects. Base maintenance also referred to as heavy maintenance is an extensive check carried out once in two years or sometimes in three years. Depending on the aircraft type and long-term maintenance planning, Base maintenance takes from 1 to 3 weeks. During base checks, the aircraft is under intensive checks consisting of structural inspections.

1.2 Objective

The objective of this study was to research and perform a capability check for Base maintenance on Embraer 190. This thesis examines the technical aspects and investments required to perform maintenance in Helsinki. The biggest investments would be hangar space and working platforms. A major challenge would be the recruitment of staff and policy on whether to employ the company´s own staff or to use contractors. Other less significant investments would be special tools, spare parts and materials used for Base maintenance. Basic tools for performing Base maintenance are the same as in Line maintenance and are left outside this study.

1 Embraer 190 introduction

1.1 Embraer S.A.

Embraer is a Brazilian aerospace conglomerate founded in 1969 by Ozires Silva, a famous Brazilian entrepreneur and former military pilot. Embraer started the production of Embraer E-Jet family in 2002, and the first E190 flew its first flight in March 2004. The E-jet family consists of E170, E175, E190 and E195.

The Embraer 190 is a narrow-body medium-range twin-engine commercial jet as seen in picture 1. The aircraft is designed to carry 124 passengers with a range of 4,537 km. It is mostly used by regional airlines to fly short distance flights. It is powered by two General Electric GE CF34-10E turbo fan engines.

Picture 1 Embraer 190 in factory livery.

1.2 Finnair ERJ 190 Fleet and Age

Finnair's fleet of E190 consists of 12 aircraft. The oldest aircraft was delivered in 2006 and the newest was delivered in 2009. The age and flight cycles/ flight hours can be seen in table 1.

A/C Register	A/C Serial No.	MFG Date	Flight Cycles	Flight Hours
OH-LKE	00059	13.Dec.2006	17221	26125
OH-LKF	00066	26.Nov.07	16723	25631
OH-LKG	00079	08.May.2007	16610	25074
OH-LKH	00086	26.Jun.2007	16062	24226
OH-LKI	00117	11.Oct.2017	16119	24309
OH-LKK	00127	19.Nov.2007	15945	23966
OH-LKL	00153	26.Feb.2008	15596	23600
OH-LKM	00160	24.Mar.2008	15252	23313
OH-LKN	00252	10.Feb.2009	13890	21543
OH-LKO	00267	20.Nov.09	13796	21240
OH-LKP	00416	14.Nov.11	10999	17097
OH-LKR	00436	19.May.2011	10529	16354

Table 1 Finnair ERJ190 fleet.

Finnair's fleet of Embraer 190's is reaching their midlife according to flight cycles and flight hours.

Picture 2 Finnair Embraer 190 taxing to runway.

2 Aviation Authorities

2.1 Authorities

Likenteen Turvallisuusvirasto, Trafi (CAA FI) is the local aviation authority in Finland. Finland is a member state of EASA (European Aviation Safety Agency). As a member state, all EU regulations in the aviation act regulations apply directly to it. Trafi cooperates with other member states and ensures that regulations are implemented according to agreed timetables. Trafi also issues more detailed legislation based on international standards and recommendations. Most of the regulative power has been transferred away from local authorities to the European Union. This allows for a uniform and high standards of flight safety across Europe. (EASA, 2003)

3 ERJ 190 Maintenance Requirements

3.1 Maintenance Steering Group

In the 1970s an industrial team called Maintenance Steering Group (MSG) was established for the analyses and determination of a maintenance program for a new aircraft type. MSG is also referred to as an industry steering group (ISC). In this process, the team would analyze which components or structures were the most likely to cause malfunctions. The team was provided with information of the aircraft and based on this they would develop maintenance procedures and determine the intervals of tasks that are acceptable for the authorities. (MRBR, 2017)

MSG-1 was later developed into MSG-2 and then later to MSG-3. MSG-3 approach to determining the maintenance program was divided into airframe system tasks, structural tasks and zonal tasks. The main purpose of MSG-3 process is to identify unnecessary maintenance tasks and increase efficiency. Maintenance requirements and the maintenance program are developed according to these categories. (MRBR, 2017)

3.2 Maintenance Review Board Report

When the ISC reports results of the detailed analysis to the maintenance review board (MRB) for approvals, MRB issues the maintenance review board report, which includes the minimum maintenance or inspection requirements to be used in a maintenance program. This report issues the minimum requirements, but as the operator gathers more experience these can be adjusted. If an operator adjusts or makes deviations in the maintenance program from the MRBR, it shall inform Embraer and the maintenance review board. (MRBR, 2017)

The responsible local authorities inspect the program to ensure that all MRB tasks are included in the maintenance program.

3.3 Maintenance Program Document MPD

The aircraft manufacturer provides maintenance requirements for operators. To make the procedures easier for operators, a single tool was developed, called the maintenance program description (MPD). The MPD is a list of all tasks that affect a certain aircraft type. It is basically a description of all the maintenance tasks and their relevant thresholds and intervals to be performed. There are some requirements that local authorities require and these are included in the MPD. MPD also includes additional data on the following: the source of the task, information on relevant access panels needed to gain access, description of the task, man hours needed to perform the task and the number of personnel needed.

All tasks in the MPD are not mandatory, and airlines can choose which tasks they want to implement on their aircrafts. Below in table 2 there is a list of sources in the MPD. Tasks recommended by manufacturers are not mandatory and operators can choose which tasks to implement. The airlines can also follow up on tasks and findings and choose to tighten or escalate intervals. Usually when a certain task is repeatedly performed with little or no findings, airlines choose to escalate intervals. However, if findings are frequent or certain systems or structures cause disruptions in the operations of an aircraft, airlines can tighten the interval or choose to do non-mandatory tasks.

Source	Descriptions
MRB	Maintenance Review Board Report
CMR	Certifications Maintenance Requirements
ALL	Aircraft Component Life Limit
ALI	Airworthiness Limitation Item
REC	Manufacturer´s recommendations
CMP	Configurations, Maintenance and Procedures - Extended Range Operation
NR	National Regulations in country of origin of airplane
AD	Airworthiness Directives
FSIL	Fuel System Limitation

Table 2 List of sources in the MPD

It is the responsibility of the airlines to build a maintenance program based on the MPD and get approval from local authorities.

3.4 Maintenance program

The aircraft maintenance program is a document approved by CAA and all maintenance performed by FTO should be performed in accordance with it. Deviations from intervals may be temporarily approved by the operator and authorities.

3.5 ATA-100 numbering system

The ATA-100 numbering system or code table is a numbering system for all commercial aircraft documentation. In Table 3 we can see a list of all ATA chapters and their relevant systems. (Federal Aviation Administration, 2008)

ATA#	Description
05	Time Limits/ Maintenance Checks
06	Dimensions and areas
07	Lifting and shoring
08	Leveling and weighing
09	Towing and taxiing
10	Parking, storage and return to service
11	Placards and markings
12	Servicing
20	Standard Practices Airframe
21	Air Conditioning
22	Auto Flight
23	Communications
24	Electrical Power
25	Equipment/Furnishing
26	Fire Protection
27	Flight Control
28	Fuel
29	Hydraulic Power
30	Ice and Rain Protection
31	Indicating/ Recording System
32	Landing Gear
33	Lights
34	Navigation
35	Oxygen
36	Pneumatic
38	Water/Waste
44	Cabin System
49	Airborne Auxiliary Power
50	Cargo and Accessory Compartment
52	Doors
53	Fuselage
55	Stabilizers
56	Windows
57	Wings
71	Powerplant
72	Engine
73	Engine Fuel and Control
74	Ignition
75	Air
78	Exhaust
79	Oil
80	Starting

Table 3 ATA-100 chapters relevant in Embraer 190 AMM.

3.5.1 System and Powerplant Maintenance Requirements

System maintenance requirements consist of tests and part replacements or inspections on various system components. Replacements can also involve the cleaning or restoration of parts. Operational tests are performed on systems and are usually performed using the aircraft´s own equipment. These can be returned to service test using the aircraft´s own computers. Functional tests are more extensive checks of systems and are often performed using external testing devices. (MPD, 2017)

System tasks are numbered as per ATA-100 numbering system as XX-XX-XX-XXX. For example, 27-11-00-003, is a detailed inspection of aileron control cables. The first identifier 27 determines that the task is performed on the flight controls. (MPD, 2017)

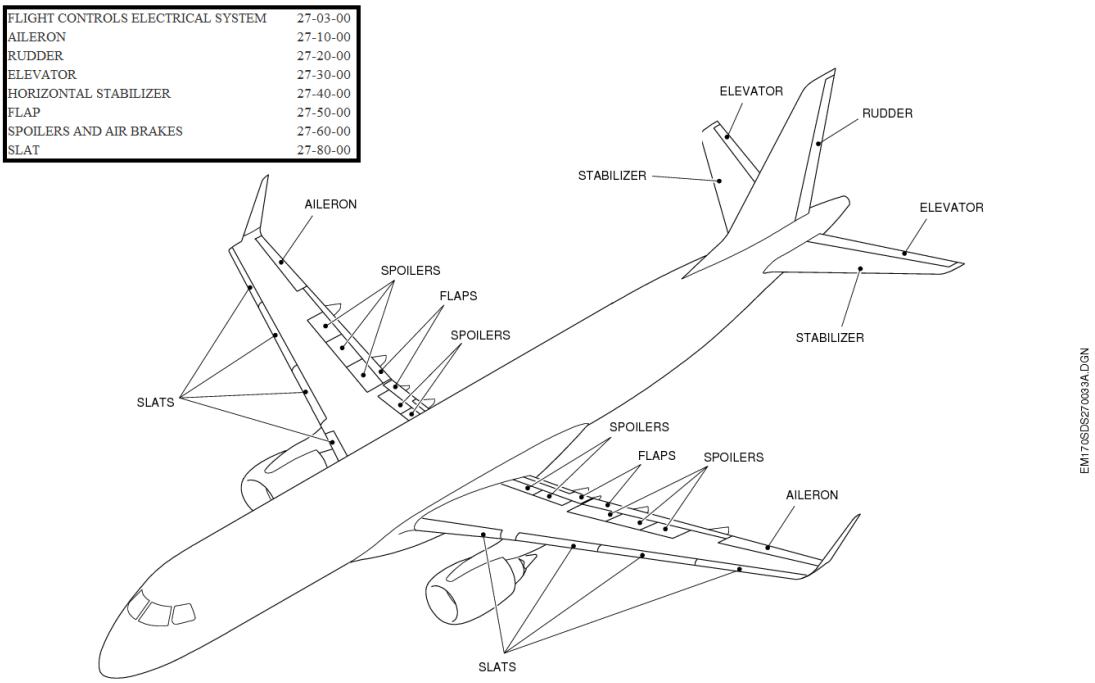

Figure 1 ATA-100 numbering of control surfaces (SRM, 2017)

3.5.2 Structural Maintenance Requirements

Structural maintenance requirements consist of inspections of specific structural parts. These inspections can be divided into visual, general visual or special detailed inspec-

tions. Special detailed inspections (SDI) are usually either nondestructive testing or inspections with a borescope. Borescope inspections are used in internal inspections of structures and areas where the access is limited and visual inspections are needed. There are various NDT inspections on aircraft. The most common inspections are eddy current and FPI inspections. On 40000 flight cycle thresholds, there are also x-ray inspections on some parts of the aircraft. (MPD, 2017)

Structural inspection tasks often require gaining access to the specific area. For example, internal inspections of the fuselage may require removing everything from the cabin. This would include the wall lining, overhead stowage bins, galleys, lavatories or floor panels. For this, the structural inspection tasks require many man hours. It is practical to plan all cabin inspections on the same check. (MPD, 2017)

Structural maintenance requirements include ATA chapter 32,52,53,54,55,56,57,71 and 78. Structural tasks are numbered differently than system task. Systems task numbering is XX-XX-XXX-XXXX. For example, a general visual inspection of the forward pressure bulkhead is 53-10-001-0919. (MPD, 2017)

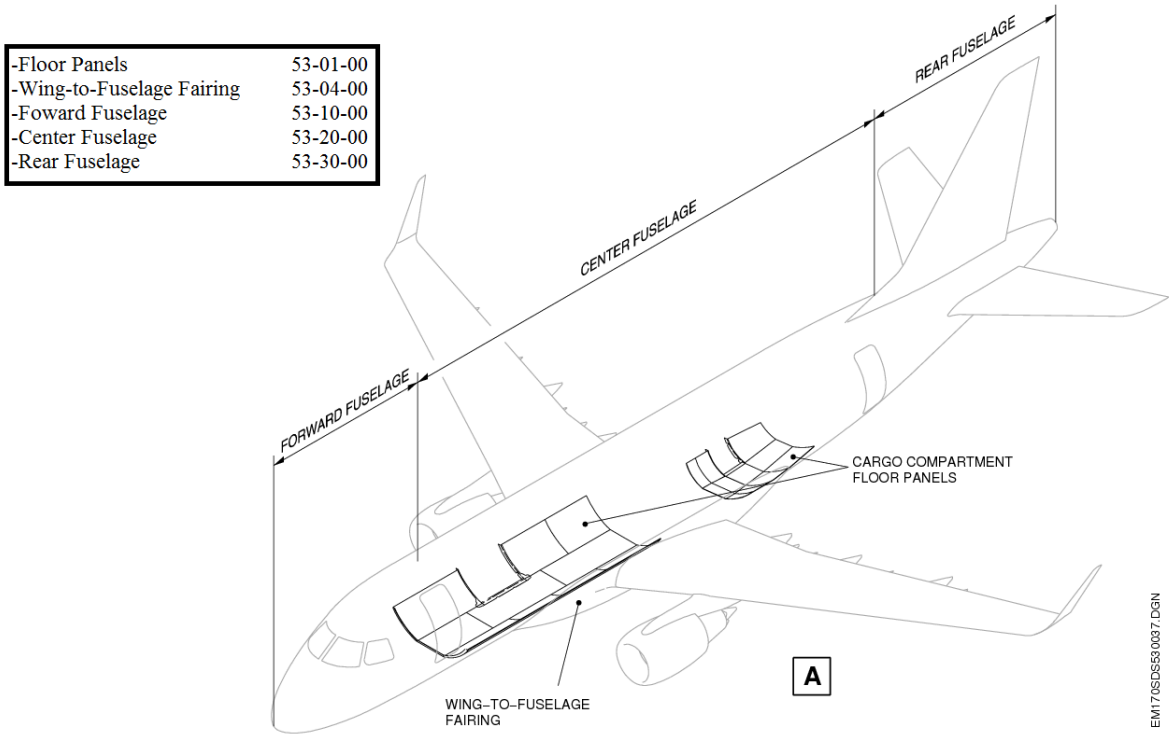

Figure 2 ATA-100 numbering of fuselage sections. (SRM, 2017)

3.5.3 Zonal Maintenance Requirements

Zonal maintenance requirements consist of inspections of an area or zone. Zonal tasks are performed for detecting unsatisfactory conditions of any system or structures. The Embraer 190 family uses Enhanced Zonal analysis in accordance with MSG-3. (MPD, 2017)

Zonal inspections are performed in all ATA chapters. They can include inspections of structures, examinations of components, inspections of electrical harnesses or inspections of flight controls. Zonal tasks are numbered as Zxxx-xxx. For example, Z190-001 is a GVI of wing to fuselage fairings. (MPD, 2017)

3.6 Thresholds and intervals

Threshold is the time when a task should be performed for the first time. Interval is when to repeat a task after it was performed for the first time. In table 4 is a list of periodicities that tasks should be performed in. (MPD, 2017)

Acronym	Description
FH	Flight Hour
FC	Flight Cycle
MO	Month
DY	Day
AH	Auxiliary Power Unit Hour

Table 4 List of periodicities for task thresholds and intervals.

3.6.1 Base maintenance Tasks

Many tasks in the MPD are for Line maintenance and are performed on a daily, weekly and monthly basis. Base maintenance tasks are threshold or intervals greater than 6,250 FC, 7,500 FH or 36 MO. Although it is common to put Line maintenance tasks with Base maintenance work packages. (MPD, 2017)

According Embraer's assumption, the aircraft utilization is 2,000 to 4,000 FH/year and flight hours are gathered 1.33 (FH) per flight cycle (FC). According to these figures Finnair will perform the basic check 5.

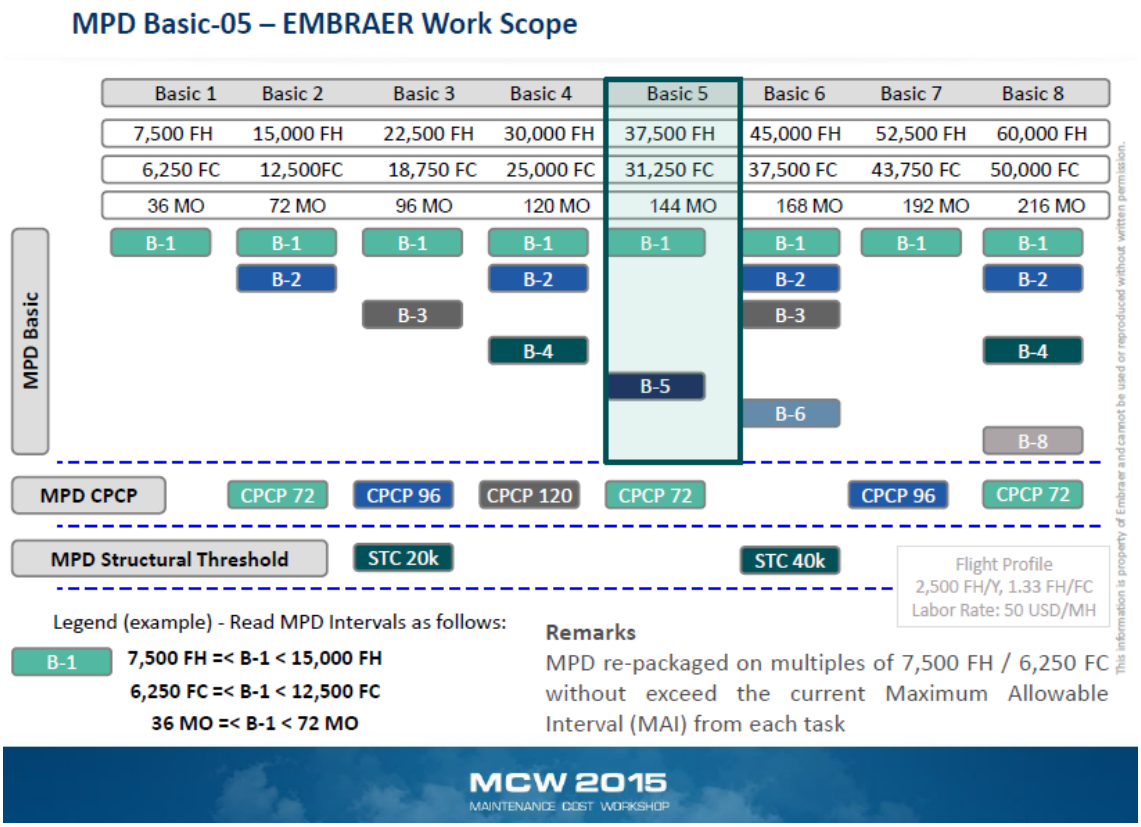

Figure 3 Excerpt from the maintenance cost workshop 2015 (Blue, 27)

On table 5 is an explanation of MPD packages with their relevant thresholds and intervals.

Package	Threshold/ Interval >=
B-1	7,500 FH & 6,250 FC >= 15,000FH & 12,500FH
B-2	15,000FH & 12,500FH >=22,500FH & 18,750FC
B-3	22,500FH & 18,750FC >=30,00FH & 25,000FC
B-4	30,00FH & 25,000FC >= 37,500FH & 31,250FC
B-5	37,500FH & 31,250FC >= 45;00FH & 37,500FC
B-6	45;00FH & 37,500FC

Table 5 Basic check packages.

In table 6 is the recommended structural inspection program. STC packages are inspections of structures. Usually they are either GVI or DVI inspections. They can also be SDI

or NDT inspections. STC packages are performed to inspect unsatisfactory condition of structures, caused by fatigue or damage. The CPCP (Corrosion Prevention and Control Program) is a part of the structural maintenance program. The purpose of CPCP is to keep control of corrosion levels caused by chemical or environmental interaction. (MPD, 2017)

MPD Structural Checks	
STC Package	**Threshold**
STC 20k	20000FC
STC 40k	40000FC
CPCP	**Threshold/ Interval >=**
CPCP 72	72 Month
CPCP 96	96 Month
CPCP 120	120 Month

Table 6 Structural inspection program.

4 Research

The main research was performed using the manuals and technical publications on Embraer's home site. AMOS was used for gathering info on Finnair's work pages and aircraft data. A wide variety of excel worksheets were used for studying the relevant data obtained from MPD and AMOS. Rules and regulations were studied from Finnair's MOE and EASA regulations.

4.1 AMOS Aviation Software

The research was performed by using AMOS Aviation Software and Embraer manuals. AMOS is a Swiss made computer software or aviation maintenance management system. There are many features in AMOS that are available for use in an MRO or airline. AMOS has built in programs. Each program has a distinctive number and a name. This enables a faster use of the whole program. In this study, the main programs used were the maintenance forecast and check control system.

APN 25 is a maintenance forecast and in here are listed all work orders, task cards, service bulletins etc. The maintenance forecast can be regarded as a queue for all work

on a selected aircraft that are planned to be implemented. APN: 1488 is a newer version of maintenance forecast. It has some additional features. This program was used for gathering work packages for the future basic checks. All data can be extracted in several formats, in this work excel was used for analyzing the data.

A check control system is used for making groups of tasks that have the same threshold and interval. Finnair uses this feature and most groups are named RPxxxxx. In table 07 is an example of RP19747, a group of structural tasks.

RP19747/(13300FH/10000FC) STRUCTURAL INSPECT
Task Number and Description
53-22-008-0002 CF II AFT PRESSURE BULKHEAD
53-22-010-0001 CENTER FUSELAGE II LONGITUDINAL SPLICES - INTERNAL
53-22-015-0002 CF II CIRCUMFERENTIAL SKIN SPLICES
55-20-002-0001 ELEVATOR HINGES AND ACTUATORS FITTINGS ON THE ELEVATOR FRONT SPAR.
55-40-002-0002 RUDDER HINGE AND ACTUATOR FITTINGS
57-50-022-0001 FLAP TRACK SUPP. 02
57-60-001-0001 AILERON HINGE FITTINGS AND ACTUATOR FITTINGS AT AILERON AND WING - INT

Table 7 Example of a group of tasks.

This program was used to extract data in Excel format to be analyzed and compared to MPD and ITEM.

There is a program to access and view the maintenance program and all task cards. With this program, one can add new task cards, view or edit old tasks. This program was used to make an Excel table of all the tasks in the maintenance program. This list also included material information on some tasks.

4.2 Tools

Embraer has published an Illustrated Tool and Equipment Manual (ITEM). It has a description of all tools and equipment needed for performing maintenance tasks for E190 aircraft. Each tool is identified by a Ground Support Equipment (GSE) number. ITEM does not contain tools used for performing tasks related to the engine. Engine related GSE can be found in the engine publications. As engines are overhauled at a workshop outside Finnair, no special tools are needed. ITEM includes a part number index, cross-

reference table and a list of manufacturers of all the GSE tools. In the AMM with each task is a list of all GSE's needed for performing the task. (ITEM, 2017)

Each task in the MPD has a list of all the tools needed for accomplishing it. The MPD is built in such a way that there is a direct link to the equivalent GSE in ITEM. By going through all the tasks, a list of all the required tools was made.

Embraer has also provided a list of all the GSE's used in specific base checks. This list is based on what other airlines and MROs have used in the past. This has also been studied and is part of the research results.

4.3 Hangar and Facilities

Per EASA, AMC 145.A.25(a) regulations Base maintenance must be performed inside a hangar and shall be protected against weather and the environment. According to these rules, all Base maintenance is to be performed inside a hangar. Finnair has the required facilities for Base maintenance and this is necessary to gain approvals from the authorities. (EASA, 2003)

As a good practice Base maintenance, should be performed separated from Line maintenance so they don't interfere with each other. (Siren, 2017)

During Embraer base checks, it is necessary to remove heavy parts such as rudder, flaps and sometimes stabilizers. It is recommended to have a lifting crane for heavy equipment and aircraft parts. A crane can also be used for moving brakes and other heave equipment to make maintenance safer and faster. It is possible to rent one, but in the long run this could become more expensive. (Siren, 2017)

4.4 Platforms

Many tasks involve work in high places and maintenance platforms are necessary. Finnair has a nose platform suitable for E190. It is recommended to get platforms for working under the wing and in the tail of the a/c. Small ladders are adequate for working under the wing in Line maintenance. During Base maintenance technicians work long periods

of time under the wing and open and close access panels. Having a platform where a technician is not required to walk down and move platforms when moving to next area, saves a lot of time.

Some MRO's use construction platforms on Base maintenance. The advantage of construction platforms is that they are cheaper, customizable and storage is easier. Large custom-made platforms are very expensive to manufacture and they take a lot of space for storage. Many times, platforms are stored outdoors and this requires some additional durability and protection from the environment. Due to strict worker safety regulations, construction platforms should only be used for short periods and not continuously. Construction platforms do not fulfill all the safety standards. For this reason, manufactured platforms are appropriate for Base maintenance. (Skogberg, 2017)

Finnair has also used rented platforms in the past. Rented platforms are usually built by the rental company after the plane is in the hangar. This usually takes several hours and therefore time is wasted in the beginning. (Skogberg, 2017)

4.4.1 Tail Dock

The most important platform needed in Base maintenance would be the tail dock. There are many inspections in the tail section of the aircraft. These include inspections of the vertical and horizontal stabilizers. The use of A ladders is not an option as they are to be used only in Line maintenance and are not safe to use when working long periods of time. A good tail dock is not only a safety issue but will certainly save time and technicians can work with better productivity and efficiency.

A tail dock can also be built with construction platforms. A tail dock is the only platform that does not have to be moved between the maintenance of different aircraft. The dock can be built as a solid platform secured against the hangar wall. The aircraft can then be towed tail first into the hangar and positioned in the dock. There is a small risk of towing the aircraft´s tail into the dock. This can be prevented with moving floors in the dock. These moving floors can be positioned out when the aircraft is being towed in. Once the aircrafts tail is in position, these floors can be positioned against the aircraft.

The tail dock should also include some essential equipment. A basic toolbox, source of pressurized air for tools and a source of water for cleaning the stabilizers, rudder and

elevators. In winter, de-icing fluid is used on control surfaces and the removal of fluid residue is needed. For this a source of hot water should be installed on the dock. This in mind the tail dock floors should be made of materials that can withstand water and other fluids.

4.4.2 Wing Platforms

The wing platforms can also be built with construction platforms, but it is essential these platforms are equipped with wheels. After the aircraft is in the hangar, wing platforms can be moved beneath the wings. These platforms are needed to gain access beneath the wing. There are many access doors and panels that need to be opened for wing´s internal inspections. The wing has many control surfaces that must be moved freely even when the platform is in position. This must be considered when designing platforms.

Wing platforms should also be designed to endure water and kerosene as the fuel tanks are located inside the wing. Platforms are stored outside the hangar when hangar is being used for Line maintenance or other types of aircraft.

4.4.3 Window Dock

There are many inspections and maintenance tasks on the nose section of the aircraft. These do not require a nose dock as often nose docks are designed to gain access to cockpit windows. Often, structural inspections are made using a personal lift on wheels. A nose dock is very useful in replacing windows.

5 Work Force

5.1 Qualifications of Technicians

EASA rules contain a description of qualifications needed for maintenance. For sign-off performed for Base maintenance a category Part-66 C license with Embraer 190 type rating holder is necessary. To relieve the burden of one engineer, it is a good practice to

have several licensed technicians available. In addition to several B1 technicians, at least one B2 holder is necessary for electrical work and testing of avionics. The C licensed technician should also be the leader or supervisor of maintenance, as the person who gives the final release should be aware of the big picture of the whole maintenance.

5.2 Shifts Policy

Many MRO service providers use either day shifts or day/evening shifts. The shift length is an important factor that affects productivity. Too short a shift lowers productivity and too long shifts have effects on the quality of maintenance and increase the chance of errors as technicians become tired. (HMRG, 2002)

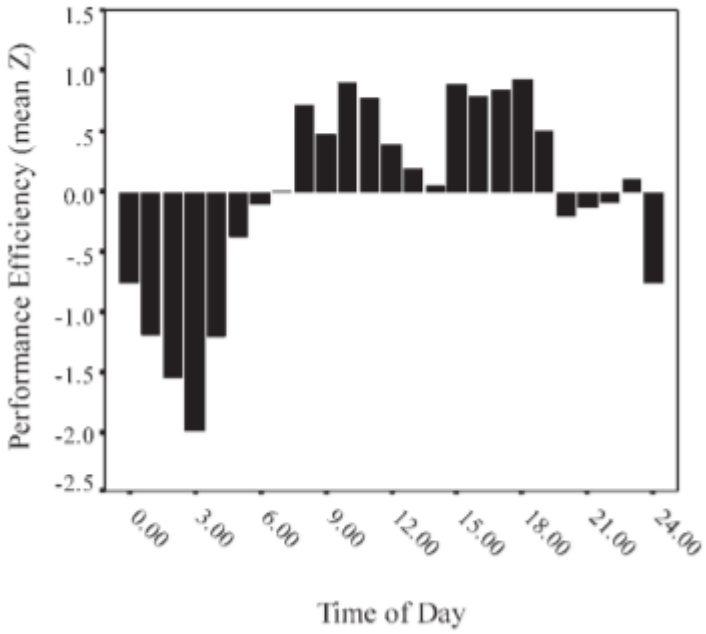

Figure 4 Industrial performance efficiency over the 24h day. Extract from Shift work, safety and productivity (Tucker, 2003)

Some MRO's use only 10-hour day shifts and some use day and evening. Saturdays and Sundays should be normal work days during heavy maintenance. For safety reasons, hydraulic and electrical power is often prohibited during the day time. For this reason, it is important to take into consideration the possibility of performing maintenance tasks in night time as well. Electrical and hydraulic power is needed for performing tests

and it is wise to do this as soon as possible. Doing tests in the end days of the check is dangerous as failed tests are most likely to cause delayed maintenance. (Siren, 2017)

For higher productivity, the shift lengths should be between 10 to 12 hours long. 8-hour shifts are too short and will lower productivity. When performing Base maintenance, the need for workers is high during the maintenance slot, and low when there are no checks. For this reason, the workers should work more hours during the checks and when there is no base maintenance they should have more time off. Instead of permanent employees it should be more cost-effective to use some contractors.

There is little research available on shift work in aviation industry but it is recommended not to use nightshifts unless it is essential. As shown on Figure 4, productivity falls drastically during night hours. Also on figure 5 is shown the impact of relative risk between different shift types. (Tucker, 2003)

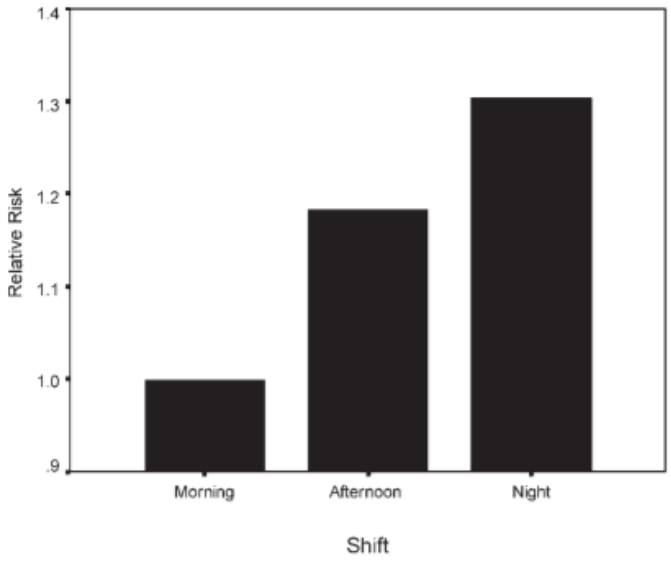

Figure 5 Relative safety risk between shifts. (Tucker, 2003)

5.3 Team Size

The team size is an important factor in accomplishing maintenance. Too large a team has a negative effect on productivity, since areas become crowded. A small-time length will most likely cause a delay and when technicians are in a hurry, errors are more likely.

The size of the team depends on the check being performed. Usually it is between 15-20 employees. Often the need for technicians is bigger in the beginning of the check and smaller in the end. (HMRG, 2002, pp. 11-12)

A team should consist of a check leader, team leaders, technicians and sheet metal workers. A check leader is usually a licensed technician with approval to sign off heavy maintenance (C approval). He or she should also oversee everything during the check. The check leader would report to production manager and oversee accomplishing the check. It is possible for the check leader to be the only one to hold a Part-66 license with the necessary approvals. The check leader would sign off and release the aircraft to service.

Team leaders should be divided into 5 teams, cabin, wing, engines, landing gear and sheet metal. Team leaders do not necessarily need a license, but it is good that they are experienced technicians. They would perform and oversee accomplishing all maintenance in their area. (HMRG, 2002)

Under each group there would be several unlicensed technicians or fitters. It is not necessary for all the maintenance personnel to hold a Part-66 license. There is a lot of work that does not require a license and a fitter's wages are lower. Depending on the phase of the maintenance, fitters could be moved around in different teams depending on where man power is mostly needed. (Siren, 2017)

Using contractors allows for an effective and flexible way of managing man power needs. As the need for man power is very high in the beginning of the maintenance, it would be an advantage if contractors could be used in the beginning of the maintenance.

5.4 Material Management

Base maintenance involves replacing and installing aircraft parts, and it is necessary to have a person who controls all materials traffic. Material availability is one of the key elements required for a successfully accomplished maintenance. (HMRG, 2002)

The need for rotables and consumables should be analyzed before maintenance and it must be ensured that all materials will be available. A good procedure would be to prepare the heavy maintenance schedule plan and the to request material list 45 days in advance. The required materials should be ordered and available 30 days in advance of the heavy maintenance. (HMRG, 2002)

5.5 Engineering Support and Other Personnel

When an aircraft is in heavy maintenance at another station or MRO, there is a technical representative on site who represents Finnair. When maintenance is performed in Helsinki this resource could be used during the check.

Engineering support depends on the check and the tasks being performed. There should be no need for employing new engineers as the engineers in Helsinki are close and available for support if needed. It is recommended to have someone in the first Base maintenance checks, to analyze and develop maintenance processes. (HMRG, 2002)

6 Planning

Good planning for a Base maintenance check does not always have the importance needed. When planning a work package, it is important to consider all the aspects mentioned above: man power, materials, tools and hangar slot. It would be advisable to make a Gantt chart of the whole check to visualize the timeline and identify critical phases of the check. The chart should also be used for controlling and tracking of the check. (HMRG, 2002)

6.1 Phases in Base maintenance

The check begins with receiving inspections of the aircraft. Walk around checks of the aircraft is made and some pre-dock runs or tests are performed. The aircraft should be defueled since the fuel tank access panels are removed during maintenance. Before all platforms are moved into positions it is recommended to wash the aircraft externally. Especially the landing gear bays are dirty and inspections can be performed better when the areas are clean.

The first few days are spent to gain access to different parts of the aircraft for performing inspections. This includes removing access panels, cabin equipment, seats, wall or engines if required. The first phase is quite critical as inspections need to be performed as soon as possible.

The next phase is when most required inspections are executed. This is a critical phase as there might be material needs required if there are unexpected findings. Materials orders need to be placed as soon as possible to minimize delay of the whole check. Modifications and component changes should be started also in the beginning of the check. This phase also requires a lot of man power.

Once inspections are made, it is time to repair any findings. In Base maintenance, many inspections are related to structures, for this it is recommended to have many sheet metal workers.

As several components are not installed during most of the time in the check, tests are not possible. There are usually many tests of various systems that cannot be performed until the required components are installed and electrical and hydraulic power can be applied as needed. (Siren, 2017)

7 Research results

A separate report and more detailed report was made for Finnair and it is not included in this report.

7.1 Plan

Finnair's plan is to start with several smaller basic checks. Four work packages were studied for man hours and requirements for tools. The work packages were extracted from AMOS to excel. This way it was easier to study the man hours and tools from the MPD and MPP. This was very time consuming as all the tasks in the packages were opened to see the required tools for accomplishing the tasks.

The work packages have several check groups and all the tasks inside them had to be extracted using AMOS check control program. Some groups include over 40 individual tasks.

7.2 Man hours

The MPD includes the necessary man hours on each task. As there are over 2000 tasks included on all the work packages mentioned above, a special tool was developed to extract the man hours from the MPD to each task. The result of this is inserted into the separate report made for Finnair.

Jet Blue (American low-cost carrier) has performed several basic 5 checks on their Embraer 190s. According to the experience of their checks, the man hours varied from 6000-7000 MH. 35% of man hours are used for non-routine tasks, 50% on routine tasks and the rest on component removals and engineering orders or service bulletins. Embraer estimates the rates at 5000-6500 man hours as seen in table 9. (Jet Blue, 27)

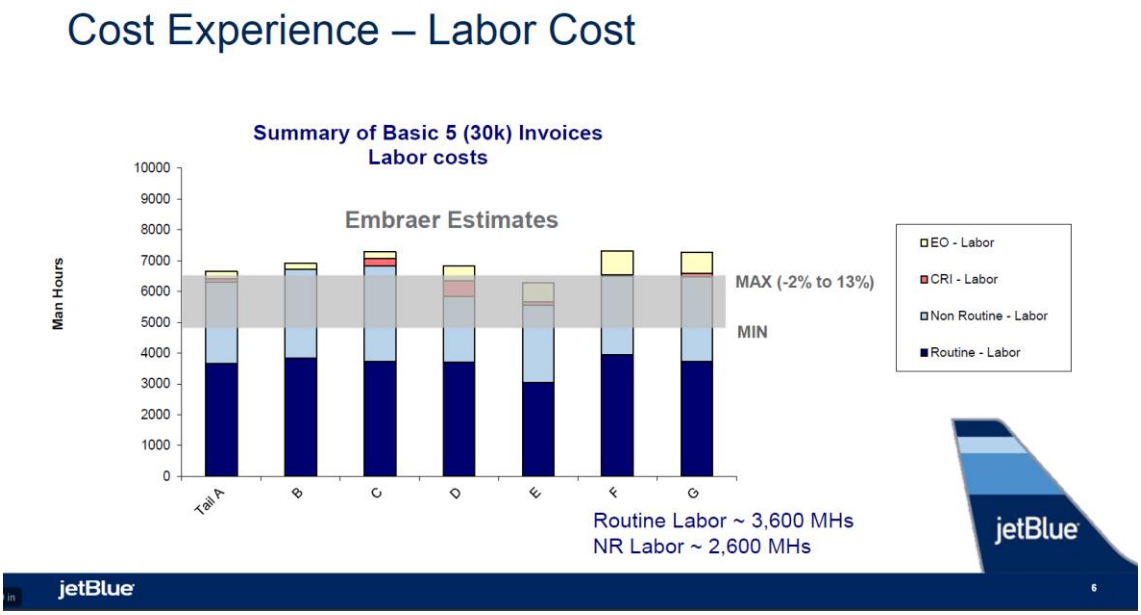

Table 8 Extract from Jet Blue Basic 5 Check Experience (Blue, 27)

7.3 Tool Requirements

The 4 checks were also studied for necessary tools. Under each MPP task there is a description of the required tools and their equivalent GSE number. There is also a list of references or AMM tasks that are applicable for implementing the task. These can include tasks required if findings occur and part replacements, adjustments or repairs are essential. The AMM tasks also have a tool list and these were added to the list of the required tools. In addition to GSE tools, the list includes commercially available tools and not Embraer specific tools. These tools were not listed as Finnair has an extensive collection already.

Once all the necessary tools were identified and extracted into a separate list they were compared to the tools Finnair already has. According to the inventory, the list was reduced from 178 tools to only 37 tools by GSE numbers. The rest of the tools were compared with part numbers. Only 12 special tools need to be ordered according to the inventory and the list of the required tools.

7.4 Materials

Materials used in Base maintenance are similar to which are required during Line maintenance. MPD and CPC define the requirements for the materials needed. All material needs should be checked and ordered before the date of the planned maintenance. There are numerous data on previous checks which include the used materials. Also, it is difficult to determine all needs as most materials are needed for the repair of findings or non-routine cards. Embraer has given some data and an estimate of what materials should be ordered before maintenance. Finnair already has channels for material providers and some materials can be ordered during maintenance.

7.4.1 Fabrication of part

In Base maintenance, the cabin floor panels are removed and inspected. According to findings in the past, these panels that are made of composite materials have been discovered unserviceable. These panels are usually cut from a larger sheet that require a lot of space for moving. (Siren, 2017)

8 Conclusions

This maintenance capability check for Embraer 190 describes the necessary investments to be performed for performing Base maintenance. As Finnair already has several hangars and a large inventory of tools, the only major investment would be maintenance platforms, especially the tail dock. Finnair already has most platforms, and they also can be borrowed from Line maintenance as they are rarely used.

The most time-consuming part of this project was to study the requirements of tools for basic checks. It was discovered that most of the tools required for performing Base maintenance Finnair already has. Only a dozen special tools should be bought or loaned before starting maintenance.

In addition to material needs, Finnair needs to employ more workforce for this project. As Line maintenance needs are very hard to predict, it is recommended to dedicate a group of personnel solely for Base maintenance. There is a risk to delay the release date if Line maintenance staff are used for Base maintenance.

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