THESIS – BACHELOR'S DEGREE PROGRAMME

TECHNOLOGY, COMMUNICATION AND TRANSPORT

IMPLEMENTATION OF REPAIR CAPABILITY FOR AIRBUS A32S EXTERNAL LIGHTS

Finnair Technical Services Ltd

AUTHOR: Soila Korhonen

SAVONIA UNIVERSITY OF APPLIED SCIENCES

THESIS

Abstract

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Abstract

This final thesis was conducted for Finnair Technical Services Ltd as a project to implement a repair capability for aircraft external lights. In the past Finnair had a capability to do these repairs within the company, but later on that operation was outsourced. After several years, due to end of a contract period with the overhauling company, as well as organizational changes at Finnair, it was decided to backsource the capability.

The theoretical part of this thesis introduces the concept of insourcing and outsourcing and compares the benefits and risks of these activities. The second theory section presents a spare part stock calculation method, that can be utilized for inventory optimization in aircraft maintenance operations.

The thesis project itself was very practical and the main objective was to implement a well functioning repair shop for the external lights of certain aircraft. That included research and procurement of the required spare parts, tools and materials, design and manufacturing of test equipment, organization of workshop space, compilation of documentation and training of personnel.

As an outcome of this project, a functional repair shop for the external lights of aircraft was implemented at Finnair premises and the company is no longer dependant on an outside maintenance provider considering these component repairs. The potential need for development will be monitored as the operation continues.

Keywords
Airbus, Aviation, Aircraft maintenance, Capability project, Project management, Backsourcing

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ABBREVIATIONS

FTS – Finnair Technical Services Ltd

A32S – Airbus A319, A320 and A321 aircraft

AMM – Aircraft maintenance manual

CMM – Component maintenance manual

IPC – Illustrated parts catalogue

TOPI – Technical Operations Procedures and Instructions

EASA – European Aviation Safety Agency

AMOS – Aircraft Maintenance Operating Software

1 INTRODUCTION

1.1 Topic description

This thesis was conducted for Finnair Technical Services Ltd, with a purpose to perform a capability study and implementation of a component repair shop for the external lights of Airbus A319, A320 and A321 (A32S) aircraft.

There are several types of external lights installed around aircraft fuselage, that are used for lighting and/or indication purposes. This repair capability project concerns four of them: retractable landing lights, strobe lights on wing tips, anti-collision lights on the bottom and on the top of the aircraft fuselage, and runway turn-off lights installed on the aircraft nose landing gear.

Way in the past, Finnair had a capability to perform external light repairs within the company, but as the business evolved Finnair decided to outsource these component repairs. After several years of outsourcing, the company made a re-evaluation and decided to backsource the external light capability. This was due to end of a contract period with the overhauling company, as well as organizational changes at Finnair impacted by Covid-19 pandemic. Backsourcing was estimated to be more beneficial, considering cost efficiency of the process and workload assurance for Finnair employees.

1.2 Finnair Technical Services Ltd

Finnair Technical Services (FTS) is part of Finnair Corporation and its operating and maintenance base is located at Helsinki-Vantaa Airport, Finland. Main responsibility of FTS is to ensure aircraft maintenance operations and continuing airworthiness management for the Finnair fleet and Finnair group airlines, according to Flight Safety Authority regulations, as well as internal company policies, priorities and rules. Key aspects of FTS operation is to ensure flight safety, occupational safety and cost efficiency aligned with Finnair’s traffic program and fleet management. (TOPI 01.00.02.)

The Finnair fleet consists of more than 80 aircraft, most of them manufactured by Airbus. Fleet includes wide-body aircraft (Airbus A330/A350), narrow-body aircraft (Airbus A319/A320/A321) and smaller aircraft used mostly on domestic or short distance European flights (Embraer 190, ATR-72). (Finnair flight information 2021.)

All European civil airlines are operating under an European Aviation Safety Agency (EASA) regulating laws. A commission regulation of EASA no. 1321/2014 defines the requirements for providing high cohesive level of safety and environmental protection in civil aviation. That includes continuous airworthiness requirements for aircraft and components (Part-M), approvals for maintenance organizations (Part-145), qualification regulations for certifying staff (Part-66) and organizational requirements for training of personnel (Part-147). In commercial flight operations maintenance organization must fill these requirements and it must have a continuous airworthiness management organization (CAMO), which ensures that rules are followed and kept up to date. (Official Journal of the European Union 2014.)

Requirements for component repairs in production and design organisations (Part-21) are presented in EASA commission regulation no. 748/2012 Subpart M. That document shall be utilized in determination of a capability of component repairs for aircraft parts. (Official Journal of the European Union 2012.)

1.3 Aircraft external lights

In this chapter aircraft external lights are introduced generally and in the following subchapters, lights concerning this capability project are presented on more detailed level. Airbus A320 aircraft is used as an example, but the external lighting configuration is very similar in all A32S aircraft.

Considering flight safety, aircraft external lights have a vital role. Some of them are used only on the ground, others only during the flight or certain parts of the flight. In general terms, they can be divided into 3 different categories according to their purpose:

1. To give indication from one aircraft to another about its location and direction, to reduce risk for potential collision.
2. To enhance visibility conditions for pilots during critical phases of the flight, such as take-off and landing.
3. To provide illumination for certain aircraft surfaces for other specific reasons, for example to indicate a potential ice accumulation on the wing leading edges, or to highlight the airline logo for advertisement purposes.
(Skybrary 2016.)

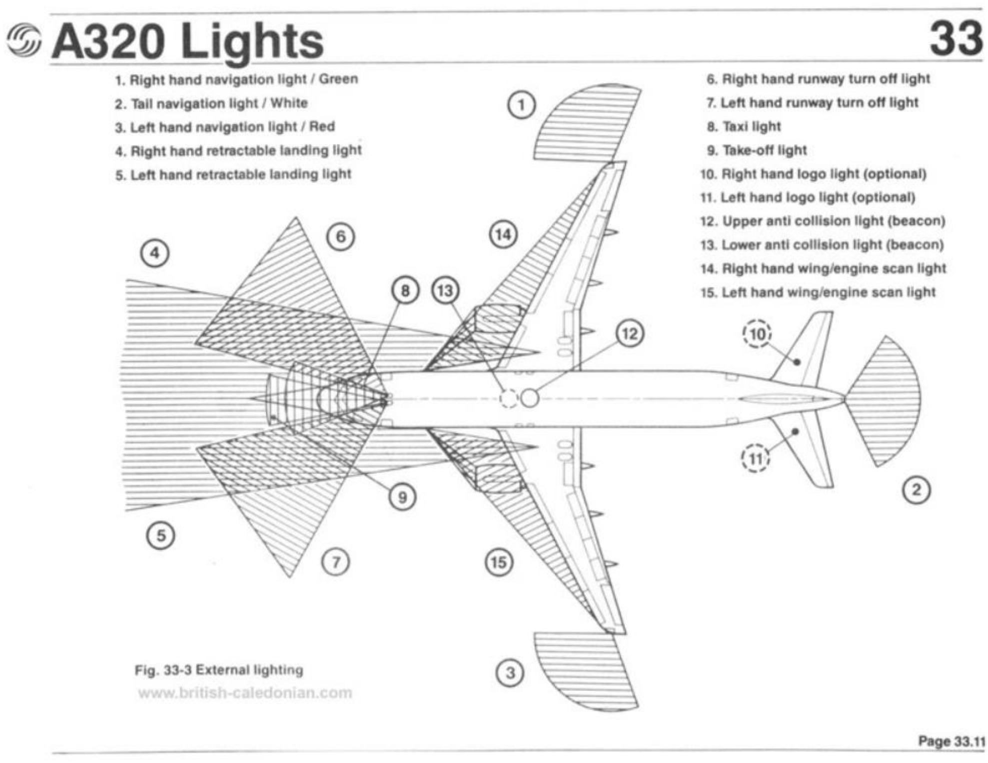

Figure 1. Illustration of Airbus A320 external light locations (BCal A320 Manuals 2020)

The external lights in this capability project belong to the first two categories. Locations of the lights are presented in the picture (Figure 1) where anticollision lights are pointed out as 12 and 13, landing lights as 4 and 5 and runway turn-off lights as 6 and 7. Wing strobe lights are not presented in the picture, but they are part of A320 external light configuration. They are located on wing tips next to left and right hand navigation lights 1 and 3.

1.3.1 Anticollision Light

Anticollision light is part of the aircraft recognition lighting system, that gives visual position indication for other aircraft to prevent collision. It is usually turned on before an engine start and turned off after shut-down of the engines. One anti-collision light is installed on the top and one on the bottom of the aircraft fuselage. It has a high intensity Xenon type flash tube, that gives red flashing light approximately 60 times per minute. It consists of an aerodynamic dome-shaped lens, a flash unit assembly and a power supply unit. (UTC Aerospace systems 2016.)

Figure 2. Anti-collision light and a power supply unit (Collins Aerospace 2013)

1.3.2 Retractable landing light

The primary function of a retractable landing light is to give better visibility for take-off and landing phases of the flight. There are two landing lights installed on the aircraft, one on the bottom of each wing. The light assembly consists of a fixed and a mobile lamp housings; the fixed housing is attached to the wing structure with screws, and the mobile lamp housing is mounted inside of it. Most of the time during a flight light is turned-off and the lamp is retracted, so that it is aerodynamically parallel with the wing. However, during take-off and landing the light is extended, with an extension angle of approximately 90˚. While the lamp extends, the light goes on and it gives better visibility for pilots and also an indication for other aircraft on the ground. (Skybrary 2016.)

Figure 3. Retractable landing light on extended position (Astro Instruments Service Corp. 2021)

1.3.3 Runway turn-off light

Runway turn-off light is used to light up the runway laterally in front of the aircraft. It enables pilots to identificate taxiways and edges of runways, guidance signs and other markings at airport areas.

Runway turn-off light consists of two light units, that are installed on nose landing gear of the aircraft (Skybrary 2016). Like all aircraft lights, runway turn-off light can be operated from a switch located on the cockpit overhead panel, but it also has a relay that turns off the light automatically when the nose landing gear is not in downlocked position, meaning that light is only operative on the ground. As an example, when the aircraft lifts from the ground during take off and the pilot makes a command to lift the landing gear up, a ground signal from the relay disconnects and the light turns off.

Figure 4. Runway turn-off light (UTC Aerospace systems 2016)

1.3.4 Wing strobe light

Wing strobe light is used for the same purpose as anticollision light, except that it indicates width of an aircraft and the flashing light color is white. Two wing strobe lights are installed on the aircraft, one on each wing tip. Light consists of a Xenon flash tube with a reflector, which is electronically controlled by a power supply unit. It emits a double flash, where the second flash follows the first after 200 milliseconds. (UTC Aerospace systems 2016.)

Figure 5. Wing strobe light and a power supply unit (Collins Aerospace 2013)

2 OUTSOURCING VS. INSOURCING

2.1 Concept

According to Schniederjans, Marc J., Schniederjans, Ashlyn M. & Schniederjans, Dara G. (2015, p. 3) outsourcing is defined as a relocation or allocation of the company´s business activities from internal source to external, whether it is concerning a service or manufacturing activities. In a modern organization, it is common that significant part of its operations are outsourced. This can bring economical benefits for a company as well as to ensure the resource for labor, services, materials or other factors that might be limitating business operations.

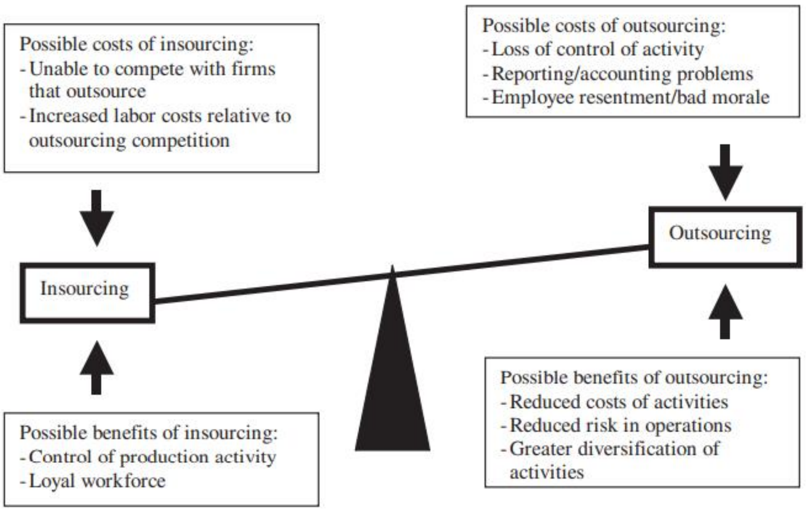

Figure 6. Balance between costs and benefits of outsourcing and insourcing (Schniederjans, Marc J. et al. 2015)

Commonly start-up businesses and smaller organizations insource most of their operations, but as the business grows, companies might face issues with keeping up the demand or find limitations on resources, such as labor, material or services. At that point, outsourcing can be an effective solution. However, to balance with the proportion of outsourcing-insourcing activities is a constant case of observation for a company, and the way to succeed is to be able to determine the most beneficial combination that would increase efficiency and would suit the organizational objectives. Since every company is unique there is no common pattern to achieve that, but every company must make the estimation themselves. Incorrect ratio can lead to failure of the business. (Schniederjans, Marc J. et al. 2015, p. 4.)

2.1.1 Benefits and risks

Ideal insourcing-outsourcing relation for a company can be very difficult or impossible to estimate and there is always a risk involved when the company decides to outsource its business operations. On the other hand, it can bring significant benefits as presented in figure 7.

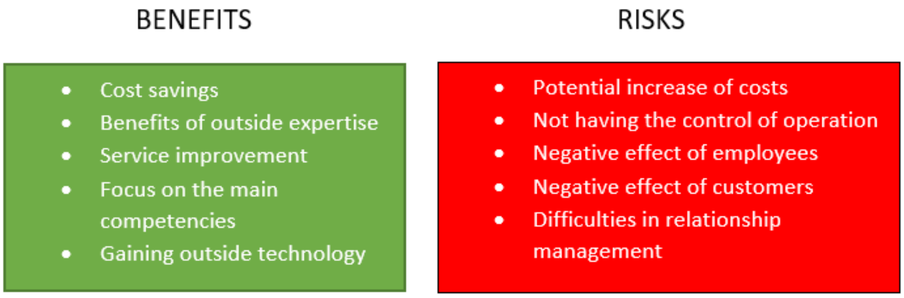

Figure 7. Benefits and risks of outsourcing

Most often the reason why companies decide to outsource is because of cost savings, especially with labor costs. Second highest reason is to gain outside expertise from the outsourcing company. To earn that alliance, the company needs to give support to the outsourcing firm and help them grow their abilities to provide that service or expertise to the client. In addition, there can be several other reasons depending of companys operations and objectives, such as gaining expertise on technology. (Goldsmith, N. M. 2003, p. 24-28.)

None of the outsourcing advantages are for certain; with a potential benefit comes a risk. A loss of control of the outsourced operations is a drawback that can escalate and is usually linked to all other disadvantages. For example, if the outsourcing company takes care of material purchases for the client company and the client company managers do not have access to observe and control the operation, there is a possibility that material costs will increase. Reason for that can be for example, geographical location of the outsourcing company and moreover accessibility of resources. (Schniederjans, Marc J. at al. 2015, p. 28-30.)

However, the material costs are not as big of a risk as human resource management. Outsourcing can have a negative impact on employees. Some employees might lose their jobs during the outsourcing process and that can lead to decreasing productivity, trust and loyalty on their colleagues. Also, for a customer point of view it might have a negative impact, if the outsourcing activity affects to the sustainability image of the company or quality of the service or product. (Schniederjans, Marc J. et al. 2015, p. 30.)

2.1.2 Backsourcing

In case company receives undesirable results from outsourced business operations or there are operative changes in the organization, the company might need to reconsider bringing the oursourcing back in the house, meaning insourcing it again. That action can also be defined as backsourcing. (Schniederjans, Marc J. et al. 2015, p. 8, 14.) Possible reasons for backsourcing can be for example: high outsourcing costs, quality issues, structural barriers, managemental, political or economical issues or desire to have more control. Backsourcing can be a major change for a company, since it has to gain back the expertise, competence and capabilities which are required to manage the organizational change. (Kaplan, Jeff 2005.)

Considering this project, the decision to backsource external light repair capability was made mainly because the contract period with the overhauling company was about to expire and at the same time company was undergoing organizational changes that supported this decision. Main objectives with this change were to be able to simplify the process, increase cost efficiency and to assure workload for Finnair employees.

3 OPTIMIZED SPARE PART INVENTORY

3.1 Stock calculation of spare parts

One of the key features for a well-functioning repair shop operation is to have an optimized spare part inventory. In order to provide that, the company must have an ability to estimate the spare part demand. In aviation industry lead times can be long and variable and there might not be many suppliers to choose from, so predictability is in the key role in spare part management. Also, the fact that flight can be delayed, or even cancelled if required spare parts are not available, is a risk, which would have a negative effect on customer satisfaction and cause major financial losses.

There are several tools and methods available for companies to estimate their spare part demand. One calculation method (SAP documentation, n.d) is presented below, which is based on: the number of aircraft on the fleet, annual flight hours, annual part demand predictions and criticality of parts. Probability models like Poisson distribution are utilized on the calculation. This method includes following steps:

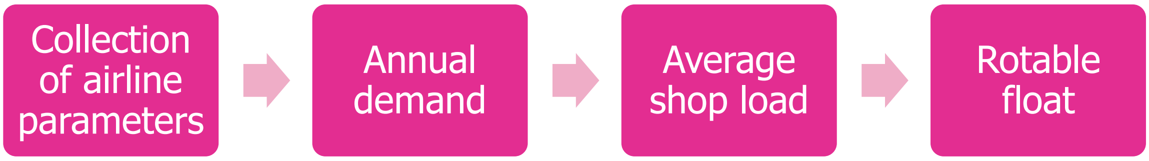

Figure 8: Calculation flowchart

3.1.1 Parameters

For the spare part demand calculation, the first step is to gather information about airline statistics. The following parameters are to be discovered considering materials and the airline itself:

PARAMETER	EXPLANATION
Fleet size	Number of aircraft on the fleet for the model in question
Annual flight hours	Fleet flight hours per year altogether
Number of parts	Quantity of parts in question per aircraft
Meantime between unscheduled removal (MTBUR)	A statistical number of how many hours aircraft can fly with particular part installed before it fails or must be replaced due to service life limitations.

Turn around time (TAT)	A definition of the time difference of unscheduled removal of the part from an aircraft, to the time when it is serviceable again and ready to be re-installed.
Service level (SL)	A probability percentage that a spare part will be in stock as serviceable. Chosen service level is dependant of essentiality of the part.

Figure 9: Comprehensive background research is required to achieve accurate calculation results.

3.1.2 Annual demand

The second step is to calculate the annual demand (AD) for a part, which identifies the number of parts replaced per year. With this formula the average annual shop load for a certain part can be determined. It is calculated as follows:

$$\text{Dann} = \frac{FHRS*FS*QPA}{MTBUR}$$

D_{ann}= Annual demand

FHRS= Flight hours (annual)

FS= Fleet size

QPA= Quantity per aircraft (parts)

MTBUR= Meantime between unscheduled removal

After the annual demand is resolved, risk analysis shall be performed to determine whether the first spare part should be protected against a risk of first stock-out. That can be performed by comparing AD to a minimum annual demand (MAD). MAD is a statistical number that sets a threshold, whether the part needs to be protected against a risk of stock-out. In other words, if AD is equal or more than MAD, it means that the part needs to be protected and further calculations are required. If it is less, the recommended quantity is 0, meaning that risk is so minimal due to low demand that protection is not needed. (SAP documentation, n.d.)

3.1.3 Average shop load

After AD is known and it is equal or greater than MAD, an average shop load (ASL) shall be determined. ASL is the average amount of parts on a hangar-repair-stock-hangar cycle. It explains the average required amount of spare parts in stock, while the initial part is being repaired. In other words, the amount of removals/repairs that occur during the initial provisioning. (SAP documentation, n.d.)

The formula for ASL calculation is:

$$ASL = TAT * DD$$

ASL= Average shop load

TAT= Turn around time (see Figure 9)

DD= Daily demand (D_{ann}/365)

3.1.4 Rotable float

Rotable float (RF) defines the required spare part quantity, which is dependant on the average shop load (ASL) and chosen service level (SL) (SAP documentation, n.d). Service level is based on poisson distribution, which is a statistical distribution function that indicates a probability of an event occurring within a certain time limit. (Hayes, Adam 2021.)

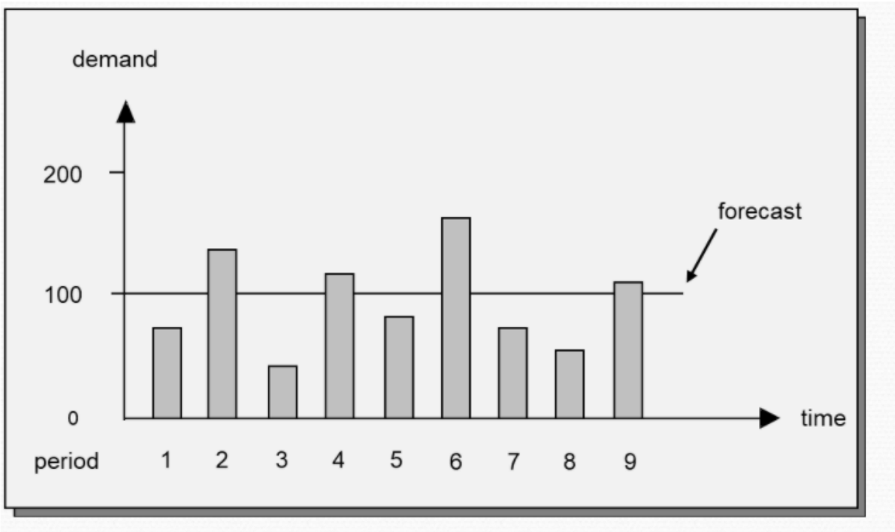

Figure 10: Poisson distribution can be utilized in the estimation of a spare part demand (Prof. Dr. Schönsleben, Paul 2021).

Service level %	Safety factor
50	0
65	0.385
80	0.842
90	1.282
95	1.645
98	2.054
99	2.326
99.9	3.090

Figure 11: Safety factor related to the chosen service level (Eilon, S. 1962)

Service level and the related safety factor is defined according to essentiality of the part. If the part is essential for a flight so that the aircraft cannot depart without it, the service level would be set high, around 98%, meaning that the safety factor for the calculation would be 2.054. With the safety factor and ASL, rotable flow can be calculated as:

$$RF = ASL + K(SL) * \sqrt{ASL}$$

RF=Rotable flow

ASL=Average shop load

K=Safety factor (according to a chosen service level)

With proper research and calculations, the optimized amount of spare parts can be determined and reserved in stock and company can minimize their inventory related risks. In addition to this, the company shall have a supply chain management software or another management tool to follow and control their inventory loads and rotation of spare parts. An example of spare part stock calculation can be found at the end of this document (appendix 1).

4 PROJECT MANAGEMENT

4.1 Project life cycle

Project is defined as a one time activity that has a specific goal. All projects are unique and they always have a beginning and end (Nicholas, John M. & Steyn, Herman 2017 p. 3). A life cycle of a project is traditionally divided into 4 phases: initiation, planning, executing and closing. Level of effort varies along the project, as does the nature of it and people involved. The project life cycle usually grows, until it reaches its peak at the execution phase and then declines to a closure of the project. (Nicholas, John M. & Steyn, Herman 2017 p. 67-68)

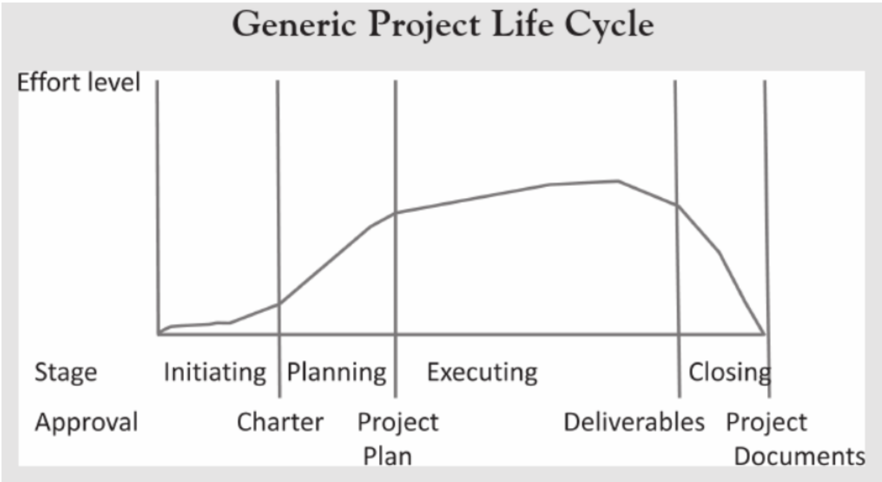

Figure 12: Distribution of workload on different stages of a project (Wells, Kathryn N. & Kloppenborg, Timothy J. 2019)

For this final thesis, the time frame was 3 months. When the author got involved in the project, the initiation phase had already been performed. Initiation of a project is the phase, which answers the question “why” it shall be implemented. That phase includes for example: recognition of demand, feasibility study, the definition of scope of the project and approvals on management behalf. (Projectmanagement-training.net n.d.)

4.2 Planning

In the planning phase the project is broken down into details and a comprehensive plan is implemented including timeline of the project, which is divided into milestones and tasks. Roles are specified within the team and assignments divided, so that responsibilities are clear for each team member. Also, estimation for budget, resources and risks are to be defined. (Lucid Content Team 2021.)

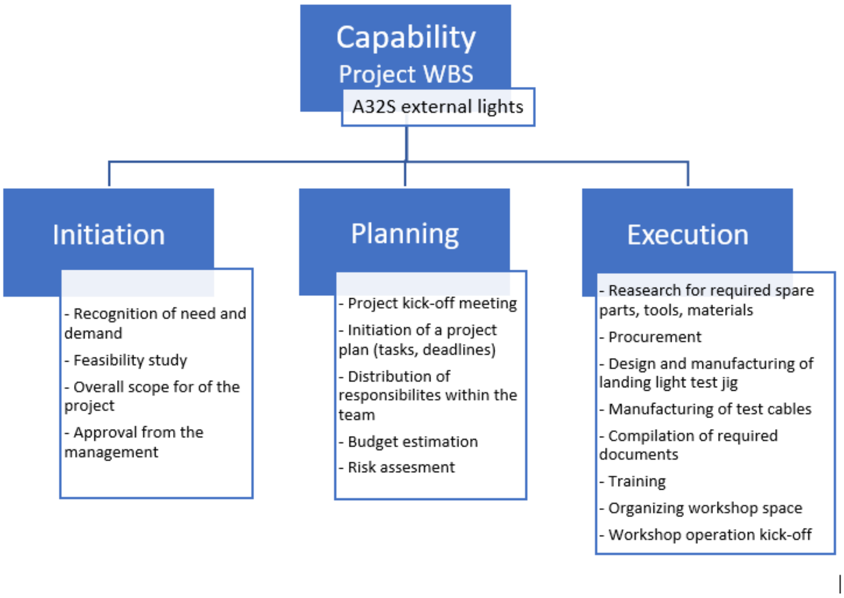

Figure 13: The work breakdown structure of the external light capability project

The planning phase commonly starts with a kick-off meeting, including all project team members. Different illustrative charts and project management tools can be implemented to organize, follow and control the project, such as a work breakdown structure (Figure 11) and Gantt chart (Figure 12).

4.3 Execution

In the execution phase plans are turned into operations. The project team will proceed with their tasks according to plan, while the project manager follows the progress, gives guidance and reacts to possible changes and challenges. Open communication and co-operation at this stage is essential; pre-determined meetings with the project team are important to keep everybody aware of the progress and possible obstacles or delays. (Lucid Content Team 2021.)

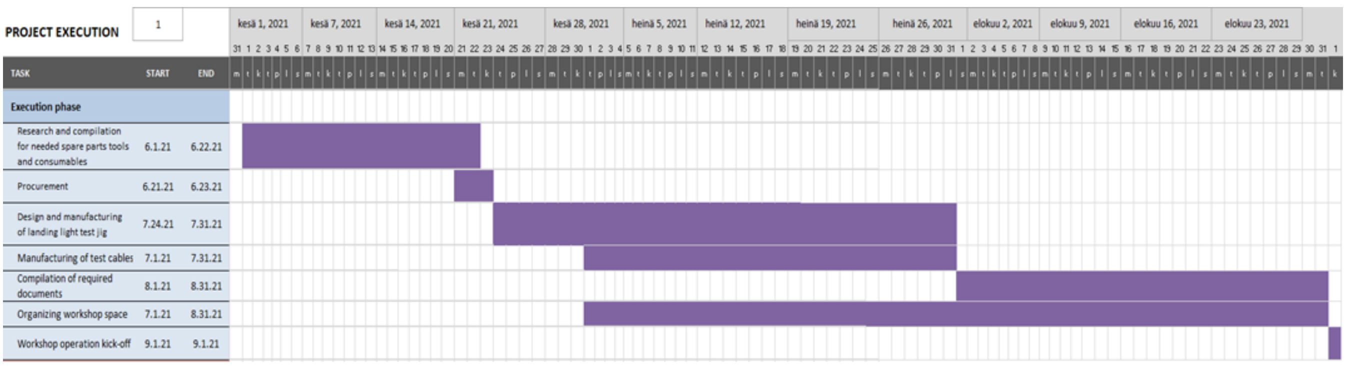

Figure 14: Example of a Gantt chart from a project execution phase

The execution phase of this capability project was divided into following steps. They are explained in the following subchapters:

1. Research and compilation of required spare parts, tools and consumables
2. Procurement
3. Design and manufacturing of testing equipment
4. Compilation of documents
5. Organization of workshop space
6. Training of personnel

4.3.1 Research and compilation of needed spare parts, tools and consumables

One of the main features for a well-functioning repair shop is to have all required material resources available. The first step in this project execution was to search through maintenance history records, component maintenance manuals (CMM) and illustrated parts catalogues (IPC), provided by part manufacturers. By searching through the documents, it was possible to map all spare parts, tools and consumables required to overhaul the applicable external lights.

After the research, the next step was to determine which parts/tools/consumables were already available at FTS and which were to be procured. FTS use an aviation maintenance management software (AMOS) to manage its operations. Along other features, AMOS has a material management module which covers all required information related to supply chain management of the company (Swiss Aviation Management Software, Material Management, n.d). Through AMOS, it was possible to search through the part- and material availability and based on that, create a list of items that were to be procured. In addition to this, physical research was performed at the repair shop facilities concerning tool- and material availability.

The last step before procurement was to determine the number of spare parts needed. A similar kind of spare part calculation method that was presented in the chapter 3, was utilized for that purpose. An example calculation is presented in the appendix 1.

4.3.2 Procurement

Considering the time frame, procurement was one of the most crucial steps in the project. All required spare parts and materials had to be procured as early on as possible due to the fact, that lead times for some parts could be weeks or even months. Research and listing was performed by project engineers and then responsibility was handled to the FTS procurement department that took care of the orders, according to engineers requests.

4.3.3 Design and manufacturing of testing equipment

For operational testing for the lights during overhaul, some testing equipment was required. The first one was a test jig for retractable landing light. According to the component maintenance manual, the extension angle for the retractable landing light must be confirmed to be 88-90°. A commercial test jig is available for that purpose, but because of a high price and a long lead time it was decided to manufacture the test jig in the house. The design and manufacturing process was relatively simple. The outcome is presented in chapter 5.2.

In addition to that, connecting cables had to be manufactured for the test equipment, power supply boxes and lights. Research and procurement for the required components were performed by project engineers and the cables were manufactured by Finnair mechanics at FTS facilities.

Thirdly, a protective box had to be manufactured for operational testing of the strobe lights. This box was required as a safety equipment for mechanics. Light output on the strobe is very bright, which can damage eye vision if a person gets exposed to it. For that reason, a closed protective box had to be manufactured to obscure the light during operational testing.

4.3.4 Compilation of documents

Clear and unambiguous documentation is essential in aviation industry. In a maintenance facility, all needed information related to operative work must be documented with the latest revisions and they need to be available for the mechanics to enable standardized processes. For this capability project all documents were prepared and compiled in folders including: component maintenance procedures, illustrated parts catalogues, specified tool- and material lists and capability documents.

4.3.5 Organization of workshop space

The main requirements for a suitable workshop space were defined as: safe, fit for purpose and close to the aircraft maintenance hangar. It was decided to place the external light repair shop in connection with another component maintenance facility; mainly because there was some extra space, many of the required tools and testing equipment were already available and authorized mechanics were already working there. Because of this, organizing the workshop did not require major physical or financial efforts. Still some items, such as test benches and power supplies had to be organized.

4.3.6 Training of personnel

FTS has already got authorized personnel for external light repairs (according to EASA regulations), so comprehensive training was not required in the context with this project. Some overall system training and refreshment about safety, usage of the documentation and equipment were held to the mechanics before starting the workshop operation.

4.4 Risk management

All projects have risks, even the project itself can be considered as one. However, not all risks are negative, and the key point in risk management is to be aware of potential risks, so that they can be reacted to, when necessary. Without proper risk management additional costs and delays are likely to occur and even the whole project might fail. (Kim Heldman, Project Management Jumpstart, 2018, p. 149)

The risks in a project can be internal or external. Internal risks are related to the project itself, they can be for example lack of experience, resources, a workforce or organizational problems. External risks are usually more complicated to control, because they are not dependent of the project group. Common topics for external risks on a project are often related to political, legal, social or environmental issues. (Heldman, Kim 2018, p. 150-154.)

Figure 15: Risk management planning is an important part of successful project management (Dr. Rahim, Emad 2016).

Risk management planning begins with identification and analyzation of potential risks. Several methods can be used for this purpose, such as brainstorming sessions with the project group and stakeholders, interviews, as well as research of history records from a similar kind of projects. Charts and checklists can be created to list down possible risks and to describe characteristics of them. The probability of occurrence and impact shall be analyzed to prioritize risks and also actions defined to respond to the impacts in case they occur. (Heldman, Kim 2018, p. 154-162.)

Risk management goes along throughout the project alongside with the project plan. Constant monitoring and control is necessary to be able to recognize and react to possible obstacles and challenges during the project. (Dr. Rahim, Emad 2016)

The most probable risks concerning this capability project were identified at the beginning of the planning phase. On top of the list was a concern for spare part inventory: the decision for a variety and amount of spare parts to be ordered and having all spare parts available when needed. Another considerable risk was task management and communication within the project group and between stakeholders, since the project was carried out during the summer vacation season. Also, due to covid-19 pandemic some Finnair employees were on full- or part time lay-offs, which also affected to reachability of people and resources.

5 PROJECT OUTCOME

5.1 Workshop facilities

The outcome of this project was a functional repair shop for aircraft external lights. Because the repair shop was implemented in connection with another component repair facility, organization process of the workshop was relatively simple and cost efficient. However, the following items had to be ensured or organized:

- Test benches
- AC power supply 115V/400Hz (aircraft supply)
- AC power supply 230V/50Hz (standard supply)
- Air pressure supply
- Safety equipment

Figure 16: Test bench for the external lights

Suitable test benches were already available at FTS storage, so they had to be carried to the workshop. An external provider was hired to run electrical wiring to them. Safety features were taken into consideration when manufacturing and compiling testing equipment and all safety gear required by part manufacturers were provided to the shop, such as protective goggles and gloves. Air pressure was already available at the shop. The test benches are provided with a power supply connection to the lights enabling operational testing, as well as testing equipment to measure necessary values such as current, voltage and resistance.

5.2 Testing equipment

Most of the testing equipment, such as multimeters, high voltage testers and scales were already available at FTS, others were manufactured on the site. Only a few testing cables for strobe lights and anticollision lights were procured ready-made. The retractable landing light test jig was designed by a Finnair employee, who had previous experience overhauling these lights and had used similar kind of test jig in the past. It was not seen as necessary to invent a new design since that was considered to be a functional solution and simple to manufacture and use. The landing light test jig (Figure 17) was manufactured at FTS.

Figure 17: Landing light test jig on the left with landing light unit set on top, power supply and measuring equipment on the right

The test jig functions so that the landing light is set on top of the rack as seen in the figure 17 (to applicable slots) so that lense is pointing down. The light is connected to the power supply and when it is operated, mobile lamp housing extends from fixed housing. A spring loaded rod rests against the lense, which moves along the lamp while it extends. At the other end of the rod there is a caliper that indicates angle. When the lamp is fully extended, reading is checked from the scale. To pass the test, extension angle must be 88-90˚. As a safety feature, the frame of the test jig is covered with transparent plastic sheets to prevent anything getting between the lamp while it moves.

The protective box for strobe lights was also manufactured at Finnair premises. The result was a simple metallic box that obscures the light during operational testing. The light component is set on the box so, that lense is pointing inside the box. Then strobe light is connected to the power supply and the test can be performed safely. Additionally, mechanic needs to wear protective goggles with darkened lenses during the operational testing.

5.3 Spare part management

Spare parts that were procured at the beginning of the execution phase, arrived well before the start of the workshop operation. At the time of procurement, parts were created to the material management system which Finnair uses (AMOS) and by doing so, they can be tracked through that software. Spare parts are stored in the hangar warehouse, from where internal logistics department controls the material flow. Spare parts can be ordered to the workshop via AMOS, as needed. Inventory loads can also be followed through that system and reorders made as necessary.

5.4 Documentation

Before starting the repair shop operation, all required documents had to be prepared and available at the workshop. One folder was prepared for each light, 4 folders all together. Each folder included: component maintenance manual (CMM), tool- and consumable lists and capability amendment lists.

CMM is a comprehensive document, which contains all information about the component in question, such as: description and operation, testing and fault isolation, wiring diagrams, maintenance procedures, special tools and consumables and parts catalogue. Even though tools and consumables are listed on the CMM, separate lists were prepared for those, because part identification numbers mentioned in manuals are not necessarily same that Finnair uses. Also, some of the parts Finnair uses are not the same at all, but since they were confirmed to be equivalent to the originals, these parts could be accepted.

A capability amendment list is the final document, which confirms that all capability requirements are met for the operation. It is prepared individually for each part, containing: manufacturer and part information, company capability for the part (repair, overhaul, inspection, testing, modification), appropriate facility for the operation, required tool- and test equipment, references to technical data (CMM), a list of qualified personnel and miscellaneous information. After the capability amendment list was filled and approved by the shop manager with signature, it was possible to begin the repair shop operation.

6 CONCLUSION

This capability project can be considered successful, since implementation of the project held the schedule fairly well and as a result, capability for the external light repair shop was approved and the operation was able to begin. Although the timing of the project happened during a summer vacation season, it did not cause major issues, since vacations of the team members were spread over different months. Proper planning and scheduling at the beginning of the project, as well as previous experience that other project engineers in the team had from similar kind of capability projects, played a big role for the success in this one.

The project was beneficial for the company, since it is no longer dependent on an outside provider considering these component repairs. It will simplify the process and help to ensure workload for Finnair employees, as well as increase cost efficiency and reliability. Functionality of the repair shop will be monitored as it begins to operate and development actions implemented as necessary.

The scope of the project was excellent for a final thesis and this was a good opportunity for author to broaden understanding of the company operations as a whole. Also this was a great learning experience and enhanced her project management skills and professional skills as an engineer.

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APPENDIX 1

STOCK CALCULATION FOR SPARE PARTS EXAMPLE (Airline statistics are fictional)

Aircraft type: Airbus A321

Spare part: Anticollision light

Fleet size (FS)	20 ea
Annual flight hours	3000 h
Quantity of parts per aircraft (QPA)	2 ea
Meantime between unscheduled re-moval (MTBUR)	2500 h
Turn around time (TAT)	7 d
Service level (SL)	98% (K= 2.054)

Annual demand:

$$Dann = \frac{FHRS\ x\ FS\ x\ QPA}{MTBUR} = \frac{3000\ x\ 20\ x\ 2}{2500} = 48\ anticollision\ lights\ per\ year$$

Average shop load:

$$ASL = TAT\ x\ \frac{Dann}{365} = 7\ x\ \frac{48}{365} = \ 0{,}92\ lights$$

Rotable float:

$$RF = ASL + \ \mathrm{K(SL)}\ x\ \sqrt{ASL} = 0{,}92 + 2{,}054\ x\ \sqrt{0{,}92} = 2{,}89\ lights$$

There are 2 anticollision lights installed on each aircraft, so with current fleet size and flight hours presented on the table, the annual demand for anticollision lights is 48 ea.

An average shop load is the regular amount of lights needed during the time while the original part is being repaired. If the repair cycle (TAT) of the initial part is 7 days, the average shop load is 1. But if the service level is set to 98%, meaning that this part is so important, that it needs to have 98% protection for availability, then the needed amount of spare parts in stock is 3.