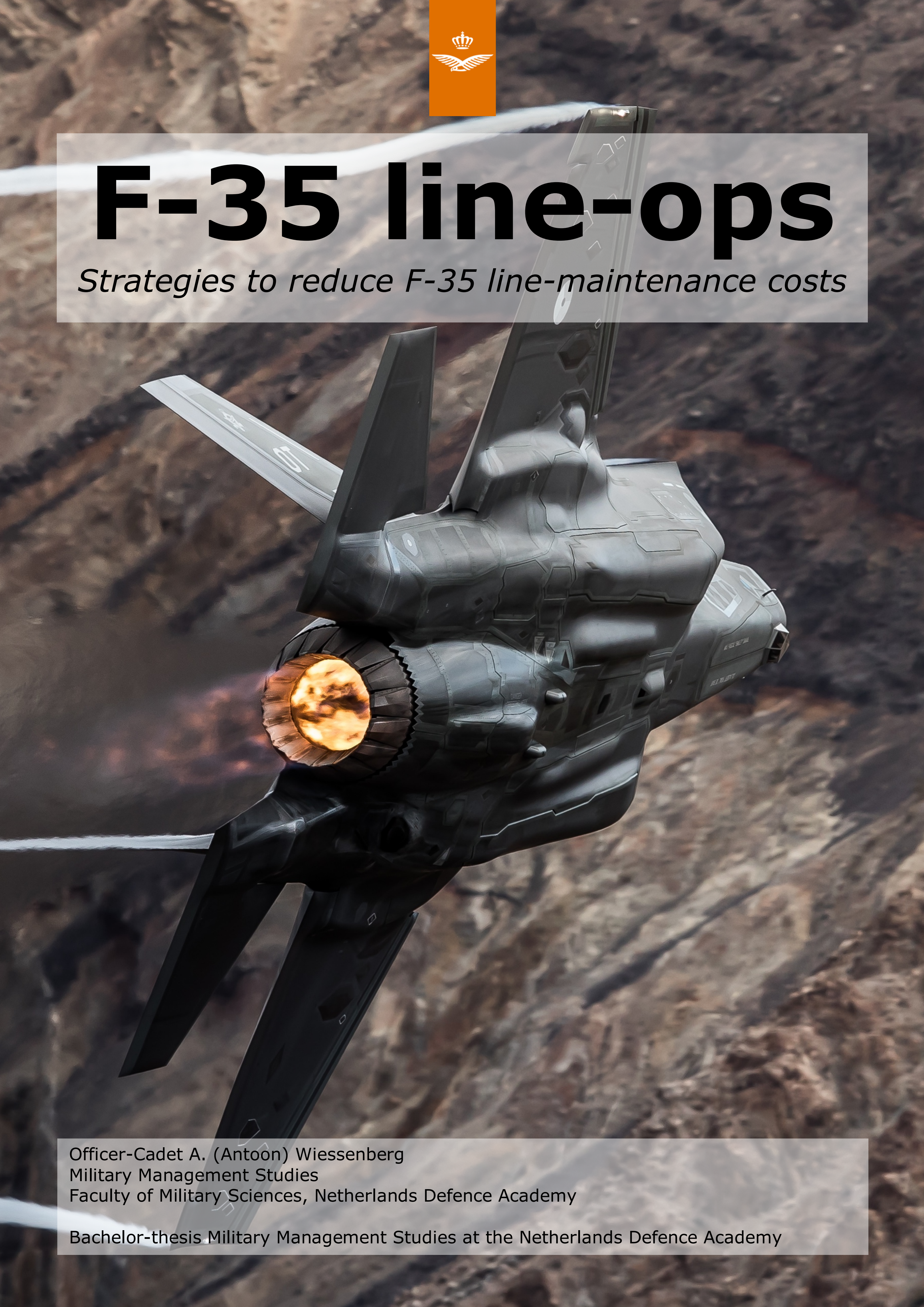
F-35 line-ops

Strategies to reduce F-35 line-maintenance costs



Officer-Cadet A. (Antoon) Wiessenberg
Military Management Studies
Faculty of Military Sciences, Netherlands Defence Academy

Bachelor-thesis Military Management Studies at the Netherlands Defence Academy

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Colophon

Officer-Cadet A. (Antoon) Wiessenberg
Military Management Studies
Faculty of Military Sciences, Netherlands Defence Academy

371 790

a.wiessenberg@mindef.nl

Kraanstraat 4
4811 XC Breda

Postbus 90002
4800 PA Breda
MPC 71C

Supervisor:
Prof. Dr. R. (Robert) Beeres
Faculty of Military Sciences, Netherlands Defence Academy

Peer-assessment:
Prof. Dr. M.T.I.B. (Myriame) Bollen
Faculty of Military Sciences, Netherlands Defence Academy

Preface

Before you lies my thesis *F-35 line-ops, Strategies to reduce F-35 line-maintenance costs*, which I wrote in order to conclude my bachelor Military Management Studies at the Faculty of Military Sciences of the Netherlands Defence Academy. Throughout this preface, I would like to thank some of the key players who helped me develop this thesis.

To start off, Professor Beeres. More than a year ago I visited your office with a kind of bold question; *"Can I write a thesis allowing me to visit the US?".* On which you answered; *"Yes and I would like to supervise that thesis"*. Unfortunately, COVID-19 made that I could not visit the United States, but it didn't make the thesis a less enjoyable experience. I always appreciated your direct and humorous way of explaining management issues, as well as your approach in supervising my thesis. You always let me develop my own thoughts, but were also clear and detailed in providing feedback. This helped me a lot in creating a good thesis, but also allowed me to learn a lot about academic writing as well as military management, for which I would like to thank you.

Then, Major van der Linden. We first met at the staff of The Netherlands Air Force in Breda, just before the COVID-19 outbreak in The Netherlands. I visited you in order to discover what subjects The Netherlands Air Force were interested in to be investigated and I was directly overwhelmed by your enthusiasm. You did not only help me with getting in touch with key players within The Netherlands Air Force, but also used your own experience from writing your master-thesis to get my thesis to a better level. For that I would like to thank you.

Next, Gerard de Bruyn. You were my entrance to Transavia and, even though COVID-19 was not always cooperating, showed me your airline in great detail. When I started my thesis I would not have imagined that I would end up standing on a civilian flight-line and learning a great deal about airline operations, for which I would like to thank you.

Concluding, I would like to thank all others who participated in the construction of my thesis. I did not have the room to mention you all up here, but that does not make me less grateful.

Thanks for all of your help and for now enjoy reading this thesis.

Officer-Cadet A. (Antoon) Wiessenberg

Hollandsche Rading, April 9 2021

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Samenvatting

Recentelijk is de Nederlandse Luchtmacht gebruiker geworden van de nieuwe F-35 *Joint Strike Fighter*, ter vervanging van de oude F-16. Voor het gebruik van de F-35 wil de Nederlandse Luchtmacht de directe gebruikskosten zo laag als mogelijk houden. Deze scriptie beschrijft de resultaten van een onderzoek naar mogelijke kostenbesparende strategieën voor F-35 *line-maintenance* door F-35 *line-maintenance* te vergelijken met die van een civiele gebruiker, Transavia.

In het theoretisch kader komt naar voren dat *line-maintenance* kan worden gedefinieerd als al het werk op de *flight-line* zoals *pre-* en *after flight checks*, maar ook kleine reparaties. De hoofdkostenbesparingscategorieën voor *line-maintenance* zijn arbeidsloon en tijd.

Op basis van de gehouden interviews bij Transavia en de Nederlandse Luchtmacht zijn de volgende kostenbesparende maatregelen voor *line-maintenance* ontdekt:

1. Het opslaan van alle gereedschappen in een onderhoudsbus
2. Overschakelen naar lijnoperatieën
3. Het bouwen van nieuwe infrastructuur
4. Het aanpassen van functiewaarderingen voor monteurs

De scriptie sluit af met het adviseren van de Nederlandse Luchtmacht om *business cases* te ontwikkelen voor de ontdekte kostenbesparende maatregelen, alsmede het herhalen van dit onderzoek zodra nieuwe situaties zich voordoen. Bovendien raadt de scriptie aan om vaker civiel-militaire vergelijkingen te maken bij bedrijfswetenschappelijke casussen.

Abstract

The Netherlands Air Force has recently become the operator of the new F-35 Joint Strike Fighter, replacing the old F-16. When operating the F-35, The Netherlands Air Force wants to keep direct operating cost to a minimal and therefore this thesis investigated possible cost reduction strategies for F-35 line-maintenance by benchmarking F-35 line-maintenance with that of a civilian operator, Transavia.

In the literature review, it was discovered that line-maintenance is defined as all work done on the flight-line like pre- and after flight checks, as well as small repairs. It was determined that the main cost saving categories for line-maintenance are the labour rate and time.

Based on interviews held at Transavia and The Netherlands Air Force, the following cost reduction strategies for F-35 line maintenance were identified:

1. Storing all tools in a maintenance van
2. Transferring to line-ops
3. Constructing new infrastructure
4. Changing job evaluations of technicians

The thesis concluded by recommending The Netherlands Air Force to produce business cases out of the identified cost reduction strategies, as well as repeating this investigation if new circumstances occur. Also, the thesis advised civil-military benchmarks to be used more frequent in management case studies.

1. Introduction

The Netherlands Air Force is changing. The current flying corps is based on the challenges experienced in the Cold War and not on the events experienced nowadays such as cyberattacks and electronic warfare. Also the modus operandi has changed and shifted towards more network oriented operations where information dominance is key (Bekkers, Sweijs, de Rave, de Spiegeleire, & Bolder, 2019). The Netherlands Air Force calls this transition to the new generation of warfare *The Fifth Generation Air Force*. One of the components of this transformation is the implementation of new technology, including a *Fifth Generation* fighter; the F-35 Lighting II (Marchand, 2017).

The F-35 program is a multi-national project in which eight countries ally to produce and operate their *Fifth Generation* fighter. The Netherlands is one of the partner countries within the project and therefore one of the first users of the new aircraft (Vijge, 2018), and as such, the Netherlands Air Force is interested in operating the aeroplane as cost efficient as possible, just as all other partners. A relatively cheap direct operation cost of the asset will ensure that more funds can be allocated into for instance training the use of the capabilities of the new plane, aiming to become better in achieving operational goals (Safaei, Banjevic, & Jardine, 2011). Also, as the armed forces are a publicly financed good, governments are interested to show their population that they are trying their best effort to spend tax money wisely and, thus to perform their duties at minimal costs (AFC CLSK).

In order to operate an asset efficiently, organisations need to try to reduce their operational cost to a minimum. Within the F-35 program this is to be achieved by sharing certain assets between partners (e.g.; logistics and maintenance). The Netherlands, for example, will provide the European warehouse for F-35 spare parts, saving costs by reducing stocks. Also engine maintenance is provided by The Netherlands, eliminating the need for each country to have its own engine maintenance shop at high expenses. This sharing of facilities is likely to decrease the operational costs drastically (One Logistics, sd) (Topsector Logistiek, sd).

Civil aircraft operators are also interested in decreasing the operating cost of their operation. In the commercial world, it is all about increasing revenues and one way to achieve that is by decreasing expenses, like operating costs. Airlines also try to save money by sharing facilities or even by outsourcing their entire maintenance programs. Another way to reduce maintenance cost is by operating only one aircraft type and brand-new aircraft, reducing the cost of spare part management due to the high availability of parts and eliminating the necessity of large stocks. Aviation companies also reduce expenses by leasing assets and using them up to optimal level. Lease costs of aircraft are mostly fixed prices, so the more an airline flies, the lower the operating costs (Doganis, 2019, pp. 105-129).

It stands out that both military and civilian aircraft operators have a need to keep their operational costs to a minimum and sometimes use similar strategies to achieve their goal. It is therefore relevant to compare the two in order to discover if one can learn from the other. At first it may seem an impractical comparison; commercial companies are all about maximizing revenue while public organisations are based on achieving public goals, such as providing security in the case of the armed forces. However, as pointed out before, in both industries, low operational costs are key and the constrains experienced are quite similar. Both organisations work at a high pace and weather influenced environment where work needs to be done efficiently, but also safely. For example airline schedules are planned tightly and therefore delays are catastrophic (Kinnison & Siddiqui, 2013), but military aircraft are also facing constant demands and so delays are to be avoided. Even though their usage differ, the operating environment of both civil and military organisations is quite similar and therefore a comparison can be made. It would actually be quite interesting for the Dutch defence organisation to compare itself to a profit-oriented industry. These companies are more concerned to keep costs within budget then public organisations, as their existents is based on making revenue, and therefore it is interesting to observe if something can be learned from those firms.

In order to compare the two industries, the relevant operational costs of both need to be determined. It may be obvious that a fighter aircraft does not carry passengers and so all flight operation charges (e.g.: personnel, airport charges and fuel) are hardly comparable due to the very different type of machine usage. Also the lease and depreciation of assets is not very comparable, again due to the highly different type of operations. A comparable aspect, however, is maintenance. (Doganis, 2019, pp. 42-61). Both aircrafts need to be worked on from time to time and even though one industry needs to maintain their plane more frequently than the other, due to the work it does, organising maintenance is comparable due to the similarities in the working environment.

The Joint Program Office (JPO), the coordination organisation of the F-35 project, already identified maintenance to be a good cost saver in the military world and therefore hangar maintenance (e.g.: engine overhaul and airframe reconstruction) is centralised in order to reduce direct operation cost (Topsector Logistiek, sd)(AFC CLSK). However, no investigation has been initiated into possible cost reduction strategies for line-maintenance, including; small repairs and daily checks. In the commercial sector, however, line-maintenance is regularly revised, as it is essential in preventing delays. Therefore it would be interesting to investigate cost reduction strategies for line-maintenance in the military environment.

1.1 Research objective and questions

The aim of the thesis is to help The Netherlands Air Force discover cost reduction strategies for their F-35 line maintenance. In order to achieve the aims the following research objective is formulated:

Identifying possible cost reductions strategies for line maintenance of the F-35 Joint Strike Fighter, by benchmarking Netherlands Air Force F-35 with Transavia line-maintenance.

From the research objective it appears that this study will to perform a benchmark between The Netherlands Air Force and Transavia in order to discover possible cost reduction strategies. Transavia is chosen as they are a Dutch low-cost airline and located close to The Netherlands Air Force operating sides. Moreover, being a low-cost airline Transavia can be expected to be very critical about their expenses.

To achieve the research objective, the goal needs to be translated into concrete research questions. To start off the main research question will be formulated and will then be divided into theoretical, empirical and theoretical-empirical partial inquiries.

Key question

Which cost-reduction strategies for F-35 line-maintenance can be identified?

Theoretical questions

1. What is line-maintenance?
2. What are the main cost categories of line-maintenance?
3. What line-maintenance cost reduction strategies can be identified in literature?

Empirical questions

1. How does Transavia line-maintenance look like?
    a. What cost reduction strategies are used?
        - Which cost category do those strategies effect?
        - What are the results of these strategies?
    b. What are the limitations of cost-reduction strategies?
2. How does F-35 line-maintenance look like?
    a. What cost reduction strategies are used?
        - Which cost category do those strategies effect?
        - What are the results of these strategies?
    b. What are the limitations of cost-reduction strategies?

Theoretical-empirical questions

1. How do F-35 and Transavia line-maintenance compare?
2. Which discovered cost-reduction strategies are usable within both organisations?
3. Can these cost-reduction strategies be implemented within F-35 line-maintenance?

1.2 Research model

In order to describe the outline of the investigation, the research model shown in figure 1 is created. The process is started with analysing existing theories and research about line-maintenance, it is cost categories and cost reduction strategies for line-maintenance. Out of those findings assessment criteria will be developed, which will be used to specify the data collection and for analytical purposes. During the data collection, both Transavia and The Netherlands Air Force will be analysed and compared in a benchmark. After the benchmark the discovered cost reduction strategies will be review for their effectiveness within both organisations and an estimate of the cost-reduction will be made. The workable strategies will then be transformed into recommendations to both Transavia and The Netherlands Air Force.

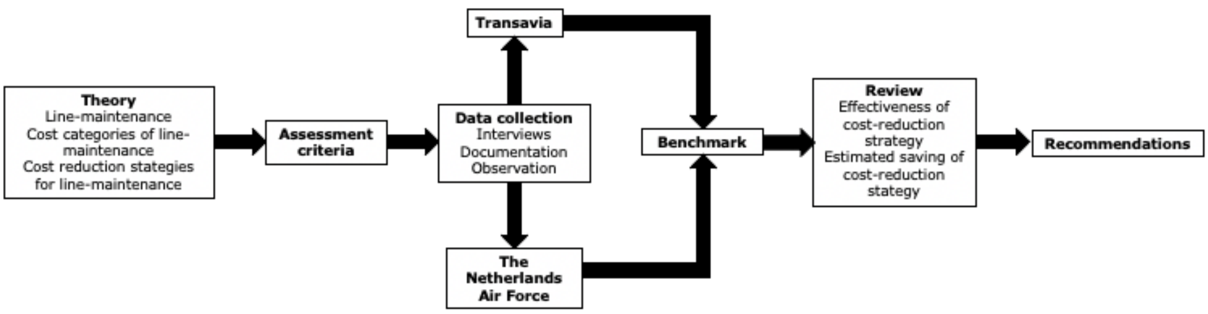


Figure 1: research model

1.3 Outline

The thesis will try to accomplish the research objective by first analysing existing theory and research in the literature review. In this section the definition of line-maintenance, cost categories of line-maintenance and existing cost reduction strategies found in literature are discussed. After that the research method of this investigation will be described. Then the results will be displayed, analysed and linked to existing knowledge. Out of those finding conclusions will be drawn and reviewed for workability within both aviation organisations. The resulting cost reductions strategies will be presented in the recommendations together with an evaluation of this investigation.

2. Line-maintenance in literature

To start off the investigation, this section provides the theoretical framework for the thesis. To this end, a literature study serves to: define line-maintenance, to determine the cost categories of line-maintenance and to identify line-maintenance cost reduction strategies found in literature, in order to answer the theoretical questions.

2.1 Definition of line-maintenance

The exact meaning of line-maintenance varies per aircraft operator, but in general, line-maintenance is any work that can be done on the flight line (outside parking positions for aircraft) of both a company's operating base and an outstation (airfield where the operator does not have own staff), which is performed during the turn-around-time (time between two flights (TAT)) and therefore does not interrupt the flight schedule of the airplane (Kinnison & Siddiqui, 2013) (Safaei, Banjevic, & Jardine, 2011). There are two types of work carried out by line maintenance crew: scheduled maintenance (the plannable work) and unscheduled maintenance (the defaults). Scheduled maintenance normally consists of the following components:

- Pre-flight inspection
- After-flight inspection
- Intermediate-flight inspection (performed between flights during the day)
- Daily oil checks
- Inspections (e.g.; 48 hour check, A check, B check)

Unscheduled maintenance varies widely and is done after the discovery of a malfunction during scheduled maintenance or by report of the flight crew (Kinnison & Siddiqui, 2013); (Safaei, Banjevic, & Jardine, 2011); (Mx Volkel)

Because of the variety of labour done by the line crew, they are generally experienced mechanics. Not only as they need to have a lot of knowledge about how to perform all kinds of repairs on different aircraft, but also because they need a lot of certifications e.g.: being allowed to maintain avionics, engines, airframes and sign off the aircraft for resumption of duty (Kinnison & Siddiqui, 2013). Within the Air Force specifically, this is even more necessary as line-technicians are also used to perform hangar-maintenance, which are more combined in that industry (Safaei, Banjevic, & Jardine, 2011). In both sectors the job must be done in a stressful environment as delays are terrible and work may have to be done in harsh weather conditions. This all requires a well experienced crew with a good work attitude (Kinnison & Siddiqui, 2013); (Safaei, Banjevic, & Jardine, 2011).

Following up, within the civil sector line maintenance is organised into different components who each perform a critical task. Crews are normally quite small and one for each aircraft. A small office or van is used to store: parts, tools and aircraft manuals. Somewhere on the flight line there is normally also a breakroom and a supervisor office. The control of the maintenance is done by the maintenance control centre (MCC), which is normally situated close to the flight line at the operators home base. This centre tracks all company flying assets and plans checks, repairs and maintenance, all done at the last minute. They do not only plan, but are also essential in the communication between the flight and ground crew. Pilots can mention the issues with their aircraft in flight to the MCC and also sensors send detailed information of the aircraft's performance towards the controllers desk. The MCC operator then ensures that the information is send to the line mechanics, which will start to trouble shoot the problem even before the broken part lands. This flow of information is essential for quick problem solving and so preventing delays in operations. If delays occur, MCC is also the authority to solve the issue as efficiently as possible. All actions which MCC takes are documented so, if another issues arises, information can quickly be found. All maintenance which can be scheduled on the long run, like hangar maintenance and check interval, are determined by production, planning and control (PPC), who are in charge of the larger maintenance picture (Kinnison & Siddiqui, 2013).

On the other hand, the armed forces have their line-maintenance organised slightly different. Fighter operations are mostly performed in so called *waves*, groups of aircraft scheduled to depart and be operated at the same time (Safaei, Banjevic, & Jardine, 2011). The line-maintenance is then arranged as shown in figure 2.

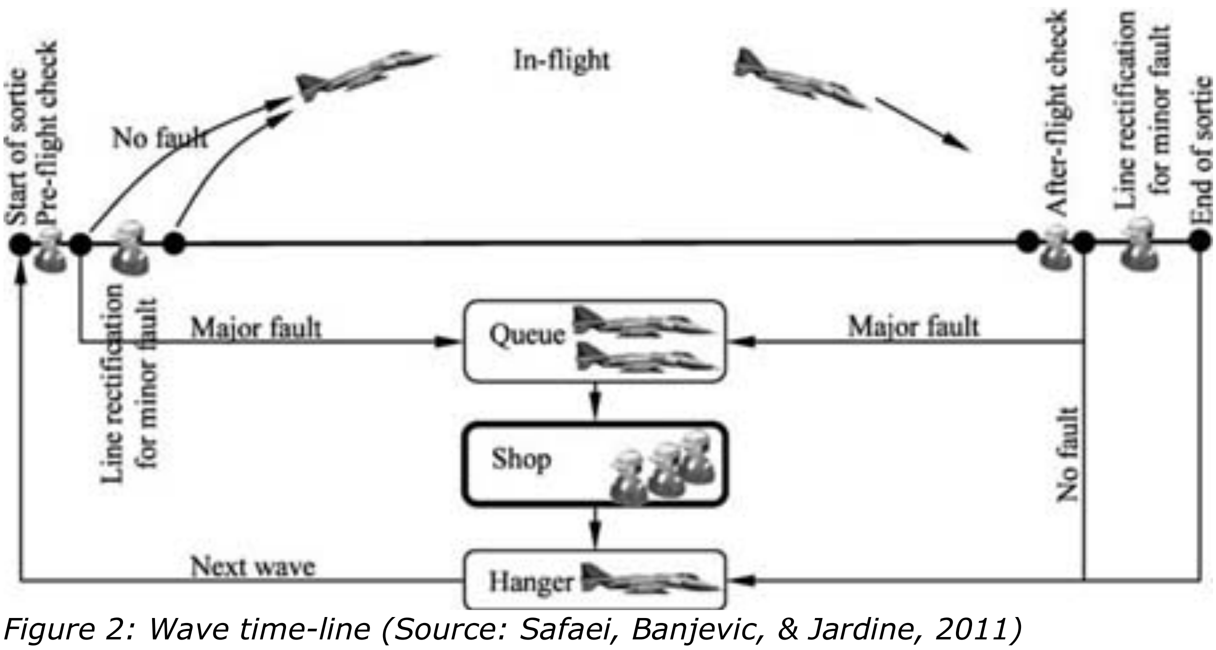


Figure 2: Wave time-line (Source: Safaei, Banjevic, & Jardine, 2011)

To start off, pre-flight inspections of all participating aircraft are performed. Fighters airworthy are flown and malfunctioning planes are either repaired on the flight-line, when a minor fault is discovered, or rolled to hangar-maintenance to fix major defects. Until now there isn't much difference between civil and military line-maintenance, but, when the fighters hit the air military, mechanics have no more line-maintenance work until the next aircraft returns. Civil operators, on the other hand, would move on to the next arrival. To make good use of this time-gap, soldiers perform hangar maintenance in this timeframe. When aircraft return from operations an after-flight inspection is performed. Again damages are assessed and minor problems are solved directly on the flight-line, where bigger problems are dealt with by hangar maintenance (Safaei, Banjevic, & Jardine, 2011).

In both the military and civil work a large emphasis is placed on the pre-, intermediate, after-flight check. During those checks it is not only determined if an aircraft is airworthy, but also critical decisions about the maintenance program are made. Mechanics need to decide if they; they ground an aircraft (big repair in hangar maintenance), repair it on the line or let the aircraft fly with the default and repair it during the next overnight or check-up (Kinnison & Siddiqui, 2013); (Safaei, Banjevic, & Jardine, 2011); (Papakostas, Papachatzakis, Xanthakis, Mourtzis, & Chryssolouris, 2009). When making this decisions, the workers have several criteria to consider like:

- Cost
- RUL (policies about how long aircraft can fly with defaults)
- Operational risk
- Risk of delays

Using those criteria technicians decided what they are doing with an aircraft and therefore also how much work needs to be done, if delays are caused and for how long (Papakostas, Papachatzakis, Xanthakis, Mourtzis, & Chryssolouris, 2009).

Concluding, line-maintenance is defined as any maintenance that is performed on the flight line and which duration is no longer than the turn-around-time of the serviced aircraft, including over-night repairs.

2.2 Cost categories of line-maintenance

Line maintenance consists of the following cost categories (Papakostas, Papachatzakis, Xanthakis, Mourtzis, & Chryssolouris, 2009):

- Equipment rate (equipment and facility cost)
- Component procurement costs (supplies and logistics cost)
- Labour rate (personnel costs)
- Overhead rate

The equipment rate, together with overhead rate, can be considered indirect costs and therefore a reduction in those costs affects each individual line-maintenance work, in terms of cost, via a certain distribution key. Component procurement on the other hand are direct-cost and therefore are dependent on the type of work performed, resulting in a reduction in those expenses not automatically leading to an reduction in cost for every individual line-maintenance work. Labour rate is dependent on the labour contracts used by employers if they are direct or indirect cost. However, a saving on labour rate will positively affect all line-maintenance work in terms of money (Doganis, 2019, pp. 42-61); (Kinnison & Siddiqui, 2013).

In order to calculate how much one line-maintenance task cost, per component, (Papakostas, Papachatzakis, Xanthakis, Mourtzis, & Chryssolouris, 2009) developed the following formula:

$$\begin{aligned} &\mathit{Maintenance\ cost\ per\ task, per\ component} \\ &\quad = \big((\mathit{Equipment\ rate} + \mathit{Labour\ rate} + \mathit{Overhead\ Rate}) \\ &\quad \times \mathit{Operating\ time\ per\ component}\big) + \mathit{Component\ procurement\ costs} \end{aligned}$$

In order to use this formula, one must first calculate the minutely rate of the equipment, labour (personnel) and overhead costs. This can be done by determining the total cost an factor (e.g. labour) per given period and dividing that by the operating time in minutes (the time worked) of that period. Those outcomes can then be inserted into the formula on the, for that factor, corresponding place. Following the total minutely rates (equipment, labour and overhead) are multiplied by the time in minutes that it takes to work on a component, after which the expenses of the parts installed (part cost and logistics) are added (Papakostas, Papachatzakis, Xanthakis, Mourtzis, & Chryssolouris, 2009). That will then give an idea of the cost of maintenance per task, per component and can be used to compare different cost reduction strategies in the thesis.

2.3 Line-maintenance cost reduction strategies found in literature

Now the thesis has established a definition of line-maintenance and determined it is cost categories, it can look into the cost reduction strategies found in literature. Seven different strategies have been identified:

1. Forward planning
2. Tail assignment

3. Mathematical optimisation models
4. Outsourcing
5. Delaying repairs
6. LEAN management
7. Line-ops

This section will address the discovered strategies in the sequence displayed above.

Cost reduction strategy 1: forward planning

Line maintenance is time critical work, in which every minute spared can save money and delays can result in profit margins shrinking drastically. Therefore it is essential that potential issues are solved rapidly (Papakostas, Papachatzakis, Xanthakis, Mourtzis, & Chryssolouris, 2009). An method to ensure faster repairs is forward planning. This planning mechanism has two sides: predicting possible defects and anticipating on malfunctions before the aircraft even lands (Samaranayake, Lewis, Woxvold, & Toncich, 2002); (Beliën, Demeulemeester, & Cardoen, 2010).

To start off, predicting possible defects deals with the statistics that a certain product will fail after amount X of flight hours. Those statistics are normally used in order to perform preventive maintenance done during standard checks (Safaei, Banjevic, & Jardine, 2011). However, they can also be used to determine which parts are possible necessary during unpredictable repair work. A operator can then ensure a certain part is available on site for line mechanics and therefore time waiting for parts is saved, bringing an aircraft quicker back into service

(Samaranayake, Lewis, Woxvold, & Toncich, 2002); (Beliën, Demeulemeester, & Cardoen, 2010).

Another way of forward planning is acting on the problem the moment it occurs. In the airline-industry this normally means that an issue is investigated before the wheels touch the ground. Essential in this process is the communication between the air- and groundcrew. If the pilots inform technicians inflight, they are able to investigate the situation and find a possible solution before arrival, using aircraft manuals and previous experience (Kinnison & Siddiqui, 2013). This will result in engineers being able to install the possible fix right when the aircraft lands, saving valuable time. In order to use this strategy a proper information flow and forward planning capability are essential (Samaranayake, Lewis, Woxvold, & Toncich, 2002); (Beliën, Demeulemeester, & Cardoen, 2010).

To sum up, this strategy will reduce time spend working on the aircraft. If we look at the formula for line-maintenance cost, this means that the factor operating time per component is reduced, leading into a lower total rate and therefore resulting in lower maintenance cost per task, per component.

Cost reduction strategy 2: tail assignment

Another cost-reduction method is planning aircraft usage based on their maintenance requirements. This strategy defines flight planning as a constant changing environment and therefore constant rescheduling is required. The most influential criteria for planning is the work that needs to be done on an aircraft and that work can suddenly occur when an aircraft has an unexpected malfunction. Therefore, tail assignment is not about scheduling an aircraft to a specific route, but plan in order to maximise maintenance efficiency and so assigning aircraft different routes as soon as an new situation occurs (Lagos, Delgado, & Klapp, 2020). To maximise efficiency it is not only important make an optimal flight schedule, but also make an optimal maintenance schedule. Studies show that line maintenance is quicker if work is disturbed over the shift and so one aircraft is handled at an time instead of multiple (Beliën, Demeulemeester, & Cardoen, 2010).

In accordance with the previous strategy, this strategy is a time-saving measure. Therefore operating time per component will be influenced in the cost of line-maintenance formula reducing the total cost of maintenance per task, per component.

Cost reduction strategy 3: mathematical optimisation models

One of the most investigated aircraft maintenance cost-saving strategies is the use of mathematical optimisation models. The definition of those equations is; *"Maintenance optimisation models as those mathematical models whose aim it is to find the optimum balance between the costs and benefits of maintenance, while taking all kinds of constraints into account"* (Dekker, 1996, p. 231). Specifically for aviation, the most used framework is linear programming with as result the most efficient maintenance planning. The constraints which are used are items like: crew-availability, aircraft planning, etc. (Sriram & Haghani, 2003); (Beliën, Demeulemeester, & Cardoen, 2010); (Safaei, Banjevic, & Jardine, 2011).

Even though those models may seem perfect, there is criticism about their use in practical scenario's. Most of the equations and mathematical methods used in those models are difficult to understand for non-mathematicians and therefore outside help is needed in order to use them, resulting in additional expenses for advice or application creation. Also, is the model trying to describe a perfect world, but especially within maintenance nothing is certain and therefore prediction only work until a certain degree. Also it can be dangerous to make decisions just from analysing data and overlooking the possible underlying cause. Especially within technical aviation systems this plays a role and therefore those mathematical optimisation models are sometimes regarded as just mathematical analysis, rather than solutions to real-life problems (Dekker, 1996).

However, those investigation may give helpful advice when reviewing patterns in maintenance and which can be used to optimise schedules. They for instance advice in the redistribution of work, arrival times, flights (Beliën, Demeulemeester, & Cardoen, 2010). Also with modern technology those models can be made usefully, when presented in an customer friendly and understandable interface (Dekker, 1996).

Unlike with the prior strategies, this strategy may influence several factors of the cost of line-maintenance equation. To start off, similar to the earlier strategies, operating time per component can be reduced, which will result into a lower total rate and therefore lower cost of a maintenance task. On the other hand, overhead cost may also be reduced. Even though it may take some time and money to develop mathematical formulas, especially as it probably needs to be outsourced due to the complexity of formulating those models (Dekker, 1996), in the long run it may reduce working time for the maintenance planning department. Mathematical optimisation formulas can simplify planning processes and therefore reduce worktime, which can result in lower overhead cost. A lower overhead cost factor in the line-maintenance formula reduces the total rate and therefore maintenance cost per task, per component.

Cost reduction strategy 4: outsourcing

Another common strategy to reduce expenses is outsourcing. For large maintenance (hangar maintenance) this is quite usual for a lot of operators as combining facilities reduce cost of work-force, facilities, etc. (Doganis, 2019, pp. 105-129) A problem of outsourcing however is that the aircraft needs to be moved from the user towards the hired company. For hangar maintenance the aircraft is already taken out of service and so the extra time spend transporting the airplane is calculated in, but with line maintenance such movement can be inefficient. Therefore, often outsourcing is not efficient for line-maintenance, but it can be if the contractor moves to the aircraft instead of the aircraft moving towards the garage. In this situation a company can for instance service all airplanes landing at an airport, not matter which firm they are from. This structure is seen a lot at airlines outposts, where it is too expensive to fly-in or station own mechanics. Sharing facilities between operators is shown to be efficient and therefore can reduce costs (Lagos, Delgado, & Klapp, 2020) (Sriram & Haghani, 2003).

If work is outsourced, the line-maintenance formula changes a bit. As factors like equipment, labour and overhead cost are not managed internally anymore and therefore a change in them has no effect to the aircraft operator. Also time-saved in maintenance is not beneficial for the operator, but for the contracted company. This results in the following revised formula:

$$Maintenance\ cost\ per\ task, per\ component$$
$$= Agreed\ labour\ rate\ (including\ overhead\ cost\ and\ equipment\ rate)$$
$$+ Component\ procurement\ cost$$

As seen in the formula, the sum of different rates is combined into one single rate. This number will be determined based on the outcomes of the price negotiations between the operator and the providing firm. The component cost will remain the same, as parts are both from the same supplier or can be provided by the airline.

In result, in order to save cost when outsourcing the cost of performing the job by own personnel needs to be higher than when the work is outsourced. Therefore, for outsourcing to be cheaper, the following formula needs to be true:

$$\big((operator's\ equipment\ rate + operator's\ labour\ rate + operator's\ overhead\ rate)$$
$$\times\ Operating\ time\ per\ component\big) + Component\ procurement\ costs$$
$$>\ labour\ rate\ contractor\ (including\ overhead\ cost\ and\ equipment\ rate)$$
$$+ Component\ procurement\ cost$$

Cost reduction strategy 5: delaying repairs

At misconception which is sometimes made is that everything which is broken on an airplane needs to be fixed. An aircraft is capable and tested to operate without some of its equipment. The essential parts in order to safely operate an aircraft are summarised in a minimal equipment list (MEL). Everything which is not on this list does not have to be repaired directly, but can wait until the next overnight of hangar maintenance. Airlines therefore may choose to wait with repairing certain items, as it saved them time during the turn-around, avoiding delays (Papakostas, Papachatzakis, Xanthakis, Mourtzis, & Chryssolouris, 2009).

When it is best for aircraft-operators to repair those issues is dependent on a lot of factors. Items which are taken in consideration are: costs (it may be cheaper to do a repair at hangar maintenance, than during line maintenance), policies maximal repair time, the risk of disrupting operational plans and the risk of delays (Papakostas, Papachatzakis, Xanthakis, Mourtzis, & Chryssolouris, 2009). Often it is chosen to fix those issues overnight of at the next hangar maintenance, depended on the stated criteria (Doganis, 2019, pp. 105-129).

Even though some repairs are not essential to aircraft operation, it is most effective to solve small issues directly during the turn-around. This prevents repairs from piling up, eventually costing a lot of time to perform all at ones (Lagos, Delgado, & Klapp, 2020).

Delaying repairs influences two factors of the cost of line-maintenance formula: operating time per component and component procurement costs. To begin, operating time is saved as repairs are performed during inspections and so the items that need to be removed in order to repair the default are already removed, therefore work does not have to be done twice. Component procurement cost are reduce, as parts are replaced less often resulting in less need to buy new spare-parts.

Cost reduction strategy 6: LEAN management

One of The Netherlands Air Force most favourite cost saving strategies as an organisation is LEAN. However, this method is not only a strategy; it is a way of management. For LEAN to work every part of the company needs to be willing to strive for maximum efficiency by continous learning and eliminating every not value-adding activity for the customer (de Jong & Beelaerts van Blokland, 2015). This is what LEAN is all about; maximizing value for the customer. Both internal, other departments for instance, and external to direct consumer or partner companies (Nanova, Dimitrov, Neshkov, Apostolopoulos, & Savvopoulos, 2012).

In order to achieve its philosophy LEAN identifies waste categories within organisations and tries to eliminate them. These items are:

- Transport
- Inventory
- Motion
- Waiting
- Overproduction
- Over processing
- Defects

Another important waste, according to LEAN, is not using the full potential of the employees. In the management method the worker plays an important part and should be use efficiently (Nanova, Dimitrov, Neshkov, Apostolopoulos, & Savvopoulos, 2012).

If we look specifically at LEAN usage in aviation maintenance, we discover that LEAN implementation results in an more efficient maintenance process. It is observed that aircraft spend a shorter amount of time in maintenance and therefore planes can be used longer operating for the customer and turning a profit for the firm (de Jong & Beelaerts van Blokland, 2015). LEAN can improve repair work by eliminating transport of materials by making sure the parts can be brought to the aircraft. Also overproduction and inventory can be reduced by using the Kanban-system of LEAN. This method revers to a pull demand mechanism, where a mechanics gets parts if he needs them, instead off a push supply in which he is overloaded with unwanted parts, resulting in inventory and processing time (Nanova, Dimitrov, Neshkov, Apostolopoulos, & Savvopoulos, 2012).

Another useful aspect of LEAN management for aircraft maintenance is the use of visual aids. There are two way in which they are used: to organise and to show process flow. The usage of the visual aids to organise is describe in the LEAN 5S method. It stands for an clean and standardised work environment, where every item in the process (e.g.: tools and the aircraft itself) has its own place clearly marked by coloured signs (Parry & Turner, 2006). This results in technicians being able to find the right materials quickly, but also ensures that everything is in the right place to achieve maximum efficiency (Parry & Turner, 2006); (Kramer, 2019). Another effect is that the visualisation eliminates the variation in work, as it is clearly marked how work should be done, and therefore reducing time fixing work mistakes. An military example of this is seen in figure 3 and 4. They show a fighter maintenance hangar before and after the implementation of 5S and visual tools (Kramer, 2019).

Figure 3: before 5S (Source: Kramer, 2019)

Figure 4: after 5S (Source: Kramer, 2019)

When LEAN is used to describe flow, the method revers to the use of visual planning boards. The management philosophy emphasizes the need to show flow and simplify processes. Visualisation is the answer to this, according to LEAN, and planning needs to be shown on the place where it is used, the work floor. Therefore, like seen in figure 4, planning boards are visual all over hangar. Studies show this help workers working more efficient and even motivates them more in their jobs (Parry & Turner, 2006); (Kramer, 2019).

LEAN influences several factors of the cost of line-maintenance equation. The philosophy does not only potentially save time, but may also result in reduced equipment and overhead rates. The method is about elimination everything which does not contribute to the aims of the customer and therefore it will abolish everything which is not contributing to that goal, therefore possibly leading to cost reductions in equipment and overhead costs (Kramer, 2019).

Cost reduction strategy 7: line-ops

The Joint Programme Office of the F-35 (JPO) advised partner-nations to use the F-35 in a line-operations (line-ops) configuration. The Netherlands however decided to not to follow that advise and therefore use the old F-16 shelter operations (shelter-ops). The difference between line- and shelter-ops is that with line-ops aircraft are parked close to the maintenance shop and next to each other, where with shelter-ops aircraft are parked far from the maintenance shop and each other in bomb-proof shelters (Vreeburg, 2018).

It has been investigated that the advised modus operandi of the F-35, line-ops, is far more efficient than shelter-ops. The study looked into three variables for successful F-35 operation and how those variable compare to each other in line- and shelter-ops. Those variable are:

- Reliability, how effective maintenance task can be performed measured in mean time between maintenance actions
- Maintainability, how efficient maintenance task can be performed measured in mean maintenance time
- Supportability, how efficient the maintenance support taks, like towing the aircraft to the workshop, can be performed measured in mean logistic delay time (Vreeburg, 2018).

The thesis concluded that line-ops score much better on all three variables compared to shelter-ops:

- The reliability of maintenance increases in line-ops, as line-ops offers more working space and hangar are conditioned, meaning that the climate can be controlled to have optimal drying conditions for the paint. Because of the stealth capabilities of the F-35, the aircraft needs to be painted almost after each maintenance action and therefore optimal drying times are crucial.
- The maintainability increases as work supervision is easier to perform, due to the aircraft being parked next to each other, and working conditions are better for personnel in line-ops.
- Supportability also increased as aircraft needed to be moved far less often, leading to shorter logistic times.

Based on the conclusions the thesis recommended line-ops to be used for the F-35. It is argued that, because of the higher scores for line-ops on the describe variables, aircraft availability increases and therefore line-ops is more effective for F-35 operations (Vreeburg, 2018).

3. Method

This section of the thesis provides an overview of the research-method. To do so, at first the research strategy is introduced. Second, the data collection will be addressed. Third, the processing of the collected data is reviewed. Fourth, the analysis of the processed data is described. Finally, the quality aspects of the investigation will be discussed.

3.1 Research strategy

The empirical part of the thesis compares two research objects: Transavia and The Netherlands Air Force line maintenance. This comparison of cases is called a comparative design; investigating the differences and similarities between cases (Bryman, 2016, pp. 39-72). The goal of the thesis is to develop theoretical knowledge of cost-reductions strategies for line-maintenance. To this end, various methods and types of sources are used to explore the cases, which stimulates the internal validity. Verschuren and Doorewaard distinguish two types of comparative designs: hierarchical and sequential. With the hierarchical method two scenarios are investigated independently and then compared. The sequential method, on the other hand, starts with one situation and based on the findings of that case it selects the next case to examine (Verschuren & Doorewaard, 2016). This thesis will investigate Transavia and The Netherlands Air Force independently, therefore using the hierarchical method. The logic of comparison will then be used to discover both differences and similarities between the two research objects and so develop an answer to the research question (Bryman, 2016, pp. 39-72).

3.2 Data collection

To start off, the literature review of the thesis has been used as foundation for the data collection. It not only identified existing cost reduction strategies, useable as starting points for investigation, but it also provided a formula useful to categorise data. In order to collect the data several strategies have been implemented. For both Transavia and the Netherlands Air Force the same research methods have been used to ensure identical data outcomes, suitable for comparison (Bryman, 2016, pp. 39-72). To collect the data, both Netherlands Air Force sites, as Transavia facilities, have been visited. At those locations observations have been made of the process of line-maintenance and conversations held in order to develop an understanding of the research topic. Interviews were held in an informal manner, meaning that the interviewer joined most interviewees in their normal working day and asked questions throughout the day. Those question were mostly to define observations and to relate findings of pervious interviews with the situation in the interviewee's situation. Also the following types of question were asked:

- How does line-maintenance look like in your organisation?
  - What cost reduction strategies are used?
    - Which cost category do those strategies effect?
    - What are the results of these strategies?
  - What are the limitations of cost-reduction strategies?

When a proper understanding of line-maintenance and their cost reduction strategies was discovered at both Transavia and the F-35, interim conclusions were constructed aiming at identifying possible cost reduction strategies. Those outcomes have been presented to the interviewees in order to discover if those strategies are workable within their organisation.

Also, interviewees provided documentation to support and explain their claims, which have been used to acquire a deeper understanding of the subject matter. In table below an overview is given of the interviews held for this investigation:

Interview	**Subject**	**Location**	**Number of interviewees**	**Remarks**
1	F-35 line-maintenance	Microsoft Teams (online)	1	- Introduction into F-35 line-maintenance. - Review of cost-reduction strategies found in literature.
2	F-35 accounting	Staff Netherlands Air Force, Breda	2	- Introduction F-35 accounting - Identifying constrains in investigating F-35 cost reduction strategies
3	Transavia line-maintenance	Microsoft Teams (online)	1	- Review of cost-reduction strategies found in literature.

4	Transavia line-maintenance	Flight line Eindhoven Airport, Eindhoven	1	- Observation of Transavia line-maintenance - Identifying difficulties experienced by mechanics - Identifying cost-reduction and their constrains from mechanic perspective.
5	Transavia line-maintenance	Hangar 5, Schiphol	4	- Observation of Transavia line-maintenance - Identifying difficulties experienced by mechanics - Identifying cost-reduction and their constrains from mechanic perspective.

6	F-35 line-maintenance	322 Squadron, Leeuwarden Air Base	8	- Observation of F-35 line-maintenance - Identifying difficulties experienced by mechanics - Identifying cost-reduction and their constrains from mechanic perspective.
7	F-35 infrastructure	Volkel Air Base	4	- F-35 infrastructure
8	Peer-review Transavia	Hangar 5, Schiphol	1	- Peer-review of Transavia interviews
9	Peer-review 322	322 Squadron, Leeuwarden Air Base	4	- Peer-review of 322 interviews
10	Calculations cost reduction strategies	Staff Netherlands Air Force, Breda	1	- Determining actual cost reduction of strategies

		Total number of interviewees:	**27**	

Figure 5: Overview of interviews held

3.3 Data processing

The style for data processing depends on the research method used. An overview of the data processing is presented in the figure 6.

Research method	**Data processing**
Observations	Observations made during field days have been written in a notebook. Those notes were brief and only work as an memory in order to write a detailed memo back at base. In those memo all relevant findings are discussed, both from own observation as interesting points from talks, together with mind thoughts and possible effects of the collected data for the investigation (Bryman, 2016, pp. 423-464).
Interviews	In the same memo as the one in which the observations are documented, the outcomes of the interviews is documented. Just like the observations, those come down to brief notes. Back at base those notes are, together with the observations, transformed into conservation notes. Those notes gives an overview of the discoveries of the day and has been coded in order to categorise aspects. The coding is then transformed into a matrix, which gives an overview of the different

	categories as an comparison to other interviews (Bryman, 2016, pp. 465-499).
Documentation	Documentation that will be used for the investigation will be processed in an similar way to the interviews. Important aspects of the documents are summarised and coded into the conversation notes. Those codes will then be transformed into an matrix for overview and easy comparison (Bryman, 2016, pp. 570-600).

Figure 6: Data processing

3.4 Data analysis

The analysis of the data is done in relation to the theoretical framework, especially the cost categories of the line-maintenance formula. Out of the processed data different possible cost reduction strategies are identified. Then it is discovered which aspect of the line-maintenance formula is effected by the plausible cost reduction strategy. If possible, it was investigated why that cost-saving effects the specific cost category and in what amounts. The identified strategies of Transavia and the Netherlands Air Force will then be implemented within one another. The analysis looks into the usability of the saving-method in that organisation and also the effectiveness. At last, the acceptance of the strategy will be looked into, meaning if the strategy is acceptable as modus operandi for either Transavia or the Netherlands Air Force.

3.5 Quality aspects

In this section the reliability, internal and external validity of the thesis investigation will be discussed.

The reliability of an research is about the reproducibility of an investigation and so if they same results are discovered when an investigation is repeated (Bryman, 2016, pp. 148-169). Even though this investigation cannot be generalised, because of it being an case study, it tried to make the research reproduceable by making the research as transparent as possible. The transparency is ensured by clearly describing the research method used and the results gathered. Also, a member-check is performed to make sure the answers of interviewees were understood correctly. The check ensures that, if the same respondents were interviewed again, the same answers would be given.

Internal validity askes the question if the questions asked within the investigation are proper, therefore the answers to them being a reflection of the truth and not suitable for other interpretations (Cuncic, 2020). First of all, the internal validity of the investigation is ensured by asking questions based on the literature review and contrasting the results with the literature. By critically comparing the process with state of the art research, it is ensured that statements made are correct and can be supported by others. Also, a member-check is performed. Interviewees and experts can point out misunderstandings made by the researcher and further clarify their thoughts, allowing only proper information to be used in the investigation. At last, method and source triangulation is used to ensure internal validity. The triangulation ensures that the subject matter is addressed using different perspectives and so resulting in a deeper understanding of the actual truth (Verschuren & Doorewaard, 2016).

External validity refers to the ability to apply the knowledge developed in this thesis to cases outside the scope of this investigation and so the generalisation.

The thesis being an comparative case study, it is not the goal to be able to generalise the findings. However, it may be that organisations comparable to Transavia and the Netherlands Air Force can profit from the cost reduction strategies developed in the thesis, as the modus operandi of aviation companies are quite similar and experience the same constrains. Therefore, outside factors may be able to adopt the recommendations of the thesis, but it is highly advised to first perform this study at the company in question and check the effectiveness of the cost reduction strategies in that circumstances, before implementing the conclusions of this investigation.

4. Results

This section of the thesis will provide an overview of the results of this investigation, eventually resulting in usable line-maintenance cost reduction strategies for both The Netherlands Air Force and Transavia. To do so first the line-maintenance of both Transavia and The Netherlands Air Force will be described. Then it will be determined how comparable Transavia and The Netherlands Air Force are. After that the discovered cost reduction strategies will be presented and reviewed for effectiveness within both organisations. To conclude the possible cost reduction strategies per organisation will be described.

4.1 Line-maintenance Transavia

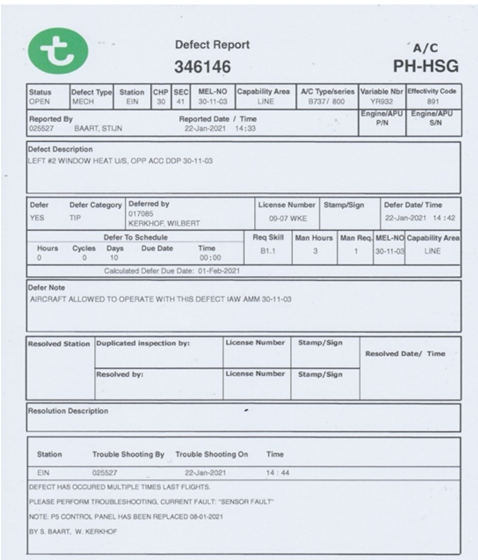
The line-maintenance of Transavia is quite similar to the one describe in the literature review. At Transavia line-maintenance consists of two main task; aircraft servicing (pre, intermediate and after-flight checks) and over-night repairs (source: Transavia Eindhoven).

Figure 7: walk-around of a Transavia Boeing 737 at Eindhoven Airport

Technical crews of the day-shift mostly do the servicing. They are informed by maintenance control about the daily flight schedule and specialties with the specific aircraft. Maintenance control ensures this information is up-to-date and technicians are informed beforehand about defaults experienced by the flight crew. Maintenance crews for servicing are generally quite small and only consist of one or two persons per aircraft. They try to drive themselves to the aircraft parking position even before the aircraft is parked at the gate, to ensure minimal interference with the aircrafts flight schedule. During the walk around (the check) technicians examine the aircraft for defects, look into items mentioned by the pilots and monitor oil levels (see figure 7). A walk around generally takes about 20 minutes, but may take longer if malfunctions are discovered. Technicians at Transavia have a van with them containing tools and spare parts frequently used on the flight line (see figure 8). Frequently used spare-parts are tires, oil and light-bulbs. (Source: Transavia Eindhoven)

Figure 8: maintenance van Transavia at Eindhoven Airport

During over-night shifts issues are dealt with. For that maintenance control produces defect reports (see figure 9). Those sheets describe the discovered defaults and are used to keep track on the resolving process, which can also be used for future reference to see what issues have been discovered on the aircraft and what work has been done. If an aircraft is airworthy with the reported defect and the repair takes place after the next flight(s), the item is placed on the Hold-Item List (HIL) (see figure 10). This list is the operationalisation of *delaying repairs*, as seen in the literature review, and describes the airplanes issues as well as the resolving process. The HIL is kept within the aircraft so both technicians and pilots known the defects to the airplane and their status. Also, to ensure it is known an item is not usable, a sticker is placed near the malfunctioning item (see figure 11). (Source: Transavia Eindhoven)


Defect Report
346146
A/C
PH-HSG

Status	Defect Type	Station	CHP	SEC	MEL-NO	Capability Area	A/C Type/series	Variable Nbr	Effectivity Code
OPEN	MECH	EIN	30	41	30-11-03	LINE	B737/ 800	YR932	891

Reported By: 025527 BAART, STIJN
Reported Date / Time: 22-Jan-2021 14:33
Engine/APU P/N
Engine/APU S/N

Defect Description
LEFT #2 WINDOW HEAT U/S, OPP ACC DDP 30-11-03

Defer	Defer Category	Deferred by	License Number	Stamp/Sign	Defer Date/ Time
YES	TIP	017085 KERKHOF, WILBERT	09-07 WKE		22-Jan-2021 14 :42

Defer To Schedule

Hours	Cycles	Days	Due Date	Time	Req Skill	Man Hours	Man Req.	MEL-NO	Capability Area
0	0	10		00:00	B1.1	3	1	30-11-03	LINE

Calculated Defer Due Date: 01-Feb-2021

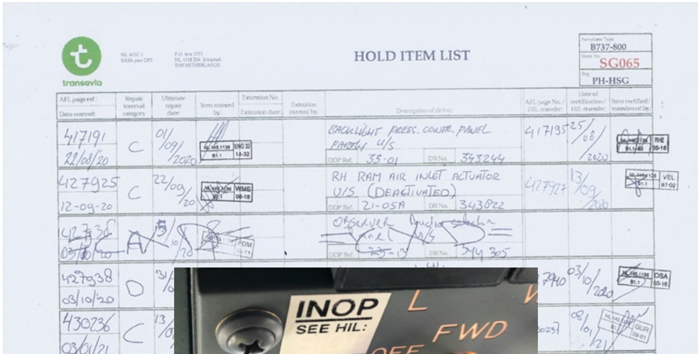
Defer Note
AIRCRAFT ALLOWED TO OPERATE WITH THIS DEFECT IAW AMM 30-11-03

Resolved Station	Duplicated inspection by:	License Number	Stamp/Sign	Resolved Date/ Time
	Resolved by:	License Number	Stamp/Sign	

Resolution Description

Station	Trouble Shooting By	Trouble Shooting On	Time
EIN	025527	22-Jan-2021	14 : 44

DEFECT HAS OCCURED MULTIPLE TIMES LAST FLIGHTS.
PLEASE PERFORM TROUBLESHOOTING, CURRENT FAULT: "SENSOR FAULT"
NOTE: P5 CONTROL PANEL HAS BEEN REPLACED 08-01-2021
BY S. BAART, W. KERKHOF



Left: figure 9: Defect Report
Top right: figure 10: Hold Item List (HIL)
Bottom left: figure 11: Notification sticker

In order to resolve the issue first trouble-shooting takes place. In this process technicians consult the aircraft manual in order to find step-by-step solutions for the discovered problem. If a suitable solution has been discovered, the checklist as describe in the aircraft manual is used in order to resolve the malfunction. If unsuccessful, technicians continue troubleshooting until they have solved the problem. Once the defects is restored, it is noted in the defect report, taken of the HIL (if applicable) and signed off in the aircraft log (see figure 12). The trouble-shooting process is clearly described in the defect report, so during future work it can easily be determined what defects occur and also earlier actions taken can be assessed. The time to perform this administrative work after an maintenance task

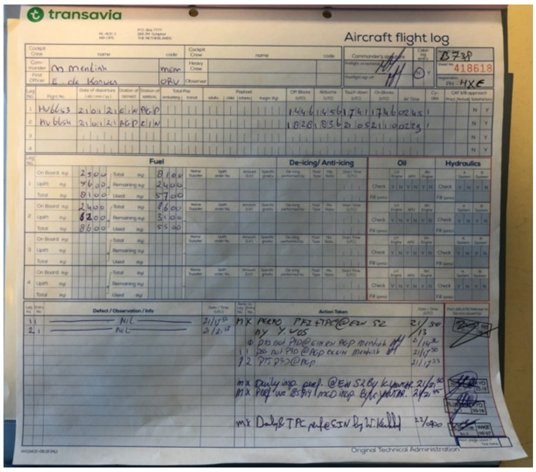


Figure 12: Aircraft flight log

is about 30 minutes for every hour of actually work. (Source: Transavia Eindhoven and Transavia Schiphol)

4.2 Line-maintenance of The Netherlands Air Force

Line-maintenance within The Netherlands Air Force is quite similar to Transavia. The Air Force also distinguishes between servicing and repair work, but within the Air Force the two are more connected and there is a thinner line between line-maintenance and hangar-maintenance (source: 322 Leeuwarden)

Like discovered in the literature review, Air Forces fly in so called waves, which in The Netherlands is mostly a morning, afternoon and, sometimes, night wave. Before the morning wave is due to begin the aircraft already has had its pre-flight, which is normally performed the night before together with the post-flight of the last wave and takes about two hours. Aircraft that are though the be airworthy are then brought to the flight line, where airplanes with issues are kept in the hangar. With this the Netherlands Air Force does not distinguish between issues; the aircraft should work fully in order to be flyable and it therefore even grounded with minor issues. On the flight-line a servicing team, mostly consisting of two to three sergeant's/sergeant-major's, performs the final checks to the aircraft. This is done together with the pilot and the technicians only generally inspect the aircraft (e.g. look for oil leaks, unconnected wires, etc.). The recovery of the F-35 is quite similar and, if applicable, the servicing team supervises the refuelling of the aircraft (source: 322 Leeuwarden)

In the meantime, the crew in the hangar is busy with the issues found during the pre-flight or throughout the day. Those issues need to be resolved in a hangar, as a conditioned environment is needed for F-35 maintenance. During the maintenance the technicians frequently consults the Autonomic Logistic Information System (ALIS); a computer containing: the aircraft handbook, work-orders with interactive checklists, a spare-part order page, etc. (see figure 13). Nothing with the F-35 is still done by hand, but can be found in the computer. Technicians say the computer helps them to perform their work more efficient. It is easy to troubleshoot, as links within the documentation help with easily navigating the huge documents and less time is spend on administration as the computer memorizes the actions performed on the aircraft (source: 332 Leeuwarden)


Figure 13: F-35 technician consulting ALIS

4.3 Comparability Transavia and The Netherlands Air Force

In order to determine the comparability between Transavia and The Netherlands Air Force three key similarities are discovered, relevant when investigating line-maintenance cost reduction strategies: line-maintenance tasks, personnel certification and view on cost-reduction strategies. Those identified three key items will be discussed below and used in order to argue that Transavia and The Netherlands Air Force are comparable when investigating cost reduction strategies for line-maintenance.

Line-maintenance tasks

It was discovered that the line-maintenance tasks for the Boeing 737 of Transavia and the Dutch Air Force F-35 are quite similar. Both operators need to service their aircraft before, between and after flights, using a quite similar procedure to perform the servicing. Also both organisations tend to let line-maintenance crews perform small repairs, possible to be done in a couple of hours, and schedule those tasks in the night time (source: Transavia Schiphol, Transavia Eindhoven and 322 Leeuwarden). Therefore the two organisations seem comparable.

A key difference however is that Transavia uses the *delaying repairs* method, as found in the literature review, in order to save time for line maintenance crew, where within the Netherlands Air Force delaying repairs is unthinkable. A civilian aircraft in that sense has lower operating standard than a military aircraft, which falls down to the fact that the military always wants every element of their aircraft to work, instead of civilian operators which look at minimal equipment lists (MEL's) (source: Transavia Schiphol, Transavia Eindhoven and 322 Leeuwarden) . The reasoning behind this is that military pilots, based on the harsh conditions they work in, need to rely on the fact all systems are in working order and therefore its Air Force policy to fix all defects (source: 322 Leeuwarden). However, this fact does not influence the comparability between Transavia and The Netherlands Air

Force for this investigation, as the effect of this difference is that military personnel spends more time performing maintenance tasks over-night, where civilian operators delay them to the next hangar maintenance. The tasks on the other hand stay the same and therefore the two organisations are comparable to investigate cost reduction strategies.

Personnel certification

Both organisations use the same certification method for their technical personnel, coming down to the ranking shown in figure 14 (source: Transavia Schiphol, Transavia Eindhoven and 322 Leeuwarden).

Type of license	**Limitations**	**Training**	**Remarks**
Intern (no-license)	Not allowed to sign off anything, but allowed to do work under supervision.	In training at post-secondary vocational education centre	Accompanied by a mentor for on the job training and check of work.
Cat. A	Allowed to perform line-maintenance tasks, but no complains or complicated equipment	Finished post-secondary vocational education. Received all part 66 certificates and is offered a type-rating course by employer.	Limited usable mechanic

Cat. B1	Allowed to handle line-maintenance as well as complains. Also allowed to work on the auto-pilot and navigation equipment	Has to complete a list of maintenance tasks as Cat. A in order to obtain job experience (maximum time = 3 years). Also must pass type-rating exam.	Fully usable technician
Cat. B2	-	Same as Cat. B1	Fully usable technician
Cat. C	Allowed to sign off maintenance packages		Mostly performs planning work

Figure 14: types of maintenance licenses within the Dutch Air Force and Transavia

As both organisations uses the same certification system it is easy to compare personnel of both institutions and also to implement certain cost reduction strategies between both organisations. Therefore, the identical personnel certification makes The Netherlands Air Force and Transavia comparable.

View on cost reduction strategies

Transavia and The Netherlands Air Force have very different organisational goals. Transavia is aimed at creating revenue, where The Netherlands Air Force tries to generate Air Power, the Air Force name its output as an organisation. Therefore surprisingly, both Transavia and The Netherlands Air Force have the same vision towards cost reduction strategies, which are influenced by similar constrains. Within the Netherlands Air Force the biggest constrain working with the F-35 is that the Joint Programme Office (JPO) is leading and therefore The Netherlands does not have influence on all the variables of the cost of line-maintenance, shown in the line-maintenance equation in the literature review. The items which can be influenced are: labour-rate, equipment-rate, overhead-rate and time spend on a task. However, both the equipment rate and the overhead rate can be influenced to a limited extend and those savings are hard to measure. This has to do with the fact that those items are also partially decided by JPO and it is debatable to which extent cost reduction strategies in those cost categories eventually effect the actual cost of line maintenance. Therefore, within The Netherlands Air Force the labour rate and time spend on a task are the main cost categories usable for calculating cost reductions. In order to calculated the cost reductions of labour-rate and time-savings The Netherlands Air Force uses their average wages sum for technical personnel, which are show in figure 15 (source: AFC CLSK).

	Non-license **Cpl**	**Cat. A** **Sgt**	**Cat. B1/B2** **Sgt1, SM, WO**
Transavia (source: Transavia Schiphol)	€50,00	€50,00	€50,00
The Netherlands Air Force (Hoofddirectie Financiën en Control, 2020)	€35,86	€39,79	€53,58

Figure 15: Average wages sum for technical personnel per hour

Transavia experiences an similar problem. Although they bought the Boeing 737 off the shelve, instead of being a development partner, they are still restricted in their work by constrains imposed on them by the aircraft manufacturer. Because of those limitations, Transavia is only able to reduce line-maintenance cost by saving on labour rate, as well as the time spend on an maintenance task. Just as they the Netherlands Air Force, they use average wages sums for technical personnel to determine the cost-savings, which are shown in figure 15 (source: Transavia Schiphol). All of this makes that the views on cost-reduction strategies within line-maintenance between Transavia and the Dutch Air Force are similar and therefore they are comparable. As both organisation use average wage sums in order to calculate cost-saving, this investigation will use that method to determine the effect of the discovered cost reduction strategies.

To sum up, it is seen that the Netherlands Air Force and Transavia are comparable for investigating cost-reduction strategies. Both have similar line-maintenance task, personnel licenses and views on cost-reductions strategies. Therefore interorganisational strategies can be used within one another.

4.4 Usability cost-reduction strategies found in literature

In the literature review, earlier in this investigation, some cost-reduction strategies for line-maintenance were distinguished (see figure 16). During interviews with both Transavia and The Netherlands Air Force it was discovered that those strategies are either very common within the aviation industry or already proven to be unsuccessful. An overview of the implementation of those strategies within The Netherland Air Force and Transavia is given in figure 16 (source: Transavia Schiphol and Mx Volkel).

Cost-reduction strategy	**The Netherlands Air Force**	**Transavia**
Forward planning	USED *ALIAS predicts defects and repairs are directly done*	USED *Maintenance control evaluates statistics and plans maintenance based on that.*
Tail assignment	USED *Each aircraft has a log of current defaults and radar cross-sections, which is used to assign aircraft on missions.*	USED *Operational control is constantly busy with rescheduling of routes*
Mathematical optimization models	USED *All implemented within ALIAS*	USED *Used for operational planning by operation control*
Outsourcing	UNUSABLE *Military line-maintenance can only be performed by own military personnel*	LIMITED USED *At outstations line-maintenance is outsourced, because of the lack of scale. At bases however Transavia has scale advantage and so insourcing is cheaper*
Delaying repairs	UNUSABLE	USED

	Military aircraft need to function 100% all the time due to the critical situations they are used in	*Items are written down in Hold Items List (HIL) and fixed during over-night shifts or the next hangar maintenance*
LEAN management	USED *The Netherlands Air Force aims to use LEAN management in all their work, but it has not been fully implemented in all situations*	INTRODUCED *The concept is reviewed for functionality within Transavia, but is currently only known at management level*
Line-ops	LIMITED USED Line-ops was used by 322 Squadron when they had limited number of aircraft, but once the number of aircraft exceeded parking spaces shelter-ops was used.	LIMITED USED Not determined by Transavia, but by airport operator

Figure 16: overview of usage of cost-reduction strategies found in literature

As the strategies found in literature are already investigated in great extent by the aviation-industry, this thesis will not further describe those strategies. However, the thesis may discover strategies that are a supplement of the strategies found in literature and then that strategy will be used in order to develop a further understanding of the proposed cost reduction strategy.

An exception to this is line-ops. Within the literature review Netherlands Air Force investigations were discovered describing the experienced time-saving between shelter- and line-ops. The thesis continues on the idea of line-ops and discovers further benefits of line-ops. Therefore, line-ops is not only describe as a strategy found in literature, but also a newly discovered item as the investigation develops new insights in an exciting theory.

4.5 Discover cost-reduction strategies not found in literature

Out of interviews conducted at Transavia and The Netherlands Air Force, as well as observations made, several cost reduction strategies are discovered not found in literature. In general it can be said that the found strategies are practical strategies and can be seen as a supplement of an existing strategies. Therefore, in figure 17 an overview of the noticed cost-reduction strategies is given together with the relating strategy found in literature. Also the effected cost category from the cost of line-maintenance formula, as seen in the literature review, is shown (source: Transavia Schiphol, Transavia Eindhoven, 322 Leeuwarden, INFRA Volkel).

Cost-reduction strategy	**Implementation**	**Cost category**	**Relation to literature**
Storing all tools in a	Maintenance vans are driven to the flight-line and contain all	Operating time per component	LEAN

maintenance van	tools and spare parts routinely used when servicing aircraft.	and equipment rate	
Transferring to line-ops	Aircraft are parked near each other on a flight-line.	Operating time and labour rate	LEAN
Constructing new infrastructure	New infrastructure is constructed for a new aircraft.	Overhead rate	Not applicable, is dependent on business case
Changing job evaluations of technicians	No-license and Cat. A personnel is given more responsibility, giving Cat. B personnel time to do work at which they are required.	Labour rate	LEAN
Developing a maintenance application	Tablets give mechanics direct excess to relevant information and allow them to direct do administrative tasks.	Operating time per component	LEAN

Figure 17: overview of cost-reduction strategies not found in literature

4.6 Universal use of cost-reduction strategies

In order to determine the universal use of cost-reduction strategies, we must compare Transavia and the Netherlands Air Force modus operandi. For that, this study has looked into the limitations of operators to certain cost-reduction strategies. If these limitations don't affect the aim of the strategy significantly, the strategy is tough to be universal.

Cost reduction strategy	**Limitations within the Netherlands Air Force**	**Limitations within Transavia**
Storing all tools in a maintenance van	- Tools need to be counted after each maintenance action (source: 322 Leeuwarden) - Spare parts are not allowed to be put in maintenance vans, as, until they are installed in an aircraft, they belong to the F-35 program (source: 322 Leeuwarden)	- Some spare-parts are too expensive to keep in stock in all vans (source: Transavia Schiphol)
Transferring to line-ops	- When armed, aircraft can't be parked next to each other (source: INFRA Volkel) - Only enough space to park operational aircraft on the flight line	- Transavia can request specific gates for parking, but is not in charge of airport operations and therefore request can't be granted (source: Transavia Schiphol).

	(source: 322 Leeuwarden)	
Constructing new infrastructure	- The use of civil contractors is limited to construction, as most infrastructure specifications are classified (source: INFRA Volkel)	- Boeing 737's are serviceable in almost all conditions (source: Transavia Schiphol).
Changing job evaluations of technicians	- Mechanics need to be trained properly, so they will report issues when in doubt (source: 322 Leeuwarden). - The Air Force want to have as little number as Corporals and Cat.A's as possible (source: 322 Leeuwarden).	- Mechanics need to be trained properly, so they will report issues when in doubt (source: Transavia Schiphol and Eindhoven). - Transavia wants every mechanic to eventually become a B1 or B2 (source: Transavia Schiphol).
Developing a maintenance application	- Classification of documents (source: 322 Leeuwarden)	- Civil aviation legislation, which makes certification of new systems (time) expensive and hard

		(source: Transavia Schiphol) - The current Boeing 737 can produce diagnostics by herself (source: Transavia Schiphol)

Figure 18: Universal use of cost reduction strategies

4.7 Possible cost-reduction strategies

Now we have established the constrains of the cost reduction strategies, we can develop possible cost reduction strategies per organisation. Also, using the line-maintenance formula given in the literature review, we can calculate the prognosed cost-savings per strategy.

4.7.1 Transavia

For Transavia this investigation identifies the following cost-reductions strategies for line-maintenance:

- Transferring to line-ops
- Developing a maintenance application

Cost reduction strategy 1: Transferring to line-ops

To start off, it is seen that line-ops results, with about 25 minutes per task, in a significant decreases in maintenance time (source: Transavia Eindhoven and 322 Leeuwarden). Also the needed number of staff decreases by about 1-2 each shift, eliminating a supervisor and driver (Source: INFRA Volkel and Transavia Schiphol).

For Transavia however the parking position used is not in their span of control, which makes it difficult for them to make a policy out of this cost reduction strategy (source: Transavia Schiphol). Even though this constrain, this investigation decided to add this strategy to Transavia's option's, as it may be helpful to show Transavia's stake in discussion with airport authorities about parking positions.

Earlier it was seen that line-ops effects the labour rate and operating time in the line-maintenance formula. If a hypothetical scenario is created, using the discovered savings, in which the number of staff members decreases with 1 per line-maintenance task, at an average wage of €50 per hour, and the operating time decreases with 25 minutes, the line-maintenance formula looks like the following:

$$Labour\ rate \times Operating\ time\ per\ component = Maintenance\ cost\ per\ task, per\ component$$

$$Without\ line - ops: (3 \times €50) \times 0{,}75 = €112{,}50$$

$$With\ line - ops: (2 \times €50) \times 0{,}33 = €33{,}00$$

In this hypothetical scenario, line-ops then result in a possible cost reduction of €79,50 per servicing task for Transavia, which comes down to a possible reduction of 71%.

Cost reduction strategy 2: Developing an maintenance application

When comparing The Netherlands Air Force and Transavia an clear difference between the two was discovered; the Air Force uses digital applications where Transavia mostly uses physical paperwork (source: Transavia Eindhoven and 322 Leeuwarden). Even though no exact measurements have been taken in order to compare the two modus operandi's; Air Force technicians experience shorter maintenance times the using applications on their computers. Air Force technicians state that the applications used create a smoother working rhythm, which they mostly dedicate to the integration of multiple maintenance systems in one application. Using hyperlinks throughout the application technicians can quickly navigate within multiple systems and digitalised documents, removing the time spend searching the required document and their relevant chapters. They also emphasise that the interaction between systems is very helpful. For instance, after flight the aircraft is diagnosed by the computer application. The application then automatically produces work orders and send those to all necessary places within the organisation, as well as suppliers of spare parts. All of this reduces administration times, leading to a decrease in maintenance time (source: 322 Leeuwarden).

When looking at Transavia digitalisation can also help them reducing time spend on maintenance and therefore reducing costs. Especially as within such an application not only maintenance data can be integrated, but operational data like gate changes, flight planning, etc. can efficiently be distributed to the technicians. Transavia sees the potential of a maintenance application and is currently in the process of developing such a system (source: Transavia Schiphol). However, The Air Force emphasises that developing a proper application is essential, but the maintenance of that tool is also important. The Air Force therefore has an entire department maintaining the ICT infrastructure of the F-35 squadron (source: 322 Leeuwarden). It is therefore up to Transavia to determine if the time reduction received from creating such a maintenance application weights up against the cost of maintaining an ICT apartment in order to keep the application up-to-date.

4.7.2 The Netherlands Air Force

For the Netherlands Air Force this study identifies the following cost-reduction strategies:

- Storing all tools in a maintenance van
- Transferring to line-ops
- Constructing new infrastructure
- Changing job evaluations of technicians

Cost reduction strategy 1: Storing all tools in a maintenance van

During the investigation it was discovered that F-35 technicians estimated that they spend about 30% of their time locating equipment. This situation resulted from the fact that tooling is kept at different locations and so technicians need to drive to all those locations in order to locate their equipment (source: 322 Leeuwarden). A solution for this problem may be offered by Transavia and is a maintenance van. Technicians can put all their tooling in such a van and it also kept within the van, resulting in them always have the right tooling with them.

However, not taken into account is the investment needed to implement this strategy. This investment also cannot be determined by this investigation, as it depends on specification demands of the operator which type of van is purposed (source: AFC CLSK). 322 Squadron for instance already stated that tools need to be counted by logistic personnel after each maintenance action and so the question rises if it is not cheaper to purpose a trailer instead of a van, as technicians can use another, counted, trailer when their old trailer is being counted (source: 322 Leeuwarden).

In a hypothetical scenario, in which the estimated 30% time lost on searching tools is placed within the line-maintenance formula, the predicted cost reduction in a task which used to take an hour is the following:

$$Labour\ rate \times Operating\ time\ per\ component = Maintenance\ cost\ per\ task, per\ component$$

$$Without\ maintenance\ van\ or\ trailer: €40{,}08 \times 1 = €40{,}08$$

$$With\ maintenance\ van\ or\ trailer: €40{,}08 \times 0{,}7 = €28{,}06$$

Based on this hypothetical scenario, an maintenance van or trailer results in a possible cost reduction of €12,02, which is a cost reduction of about 30%.

Cost reduction strategy 2: transferring to line-ops

The Netherlands Air Force, like seen in the literature review, already performed a lot of studies towards line-ops. It was discovered that towing the F-35 from the shelters towards the squadron averagely takes about 20 minutes (Vreeburg, 2018) and, together with a by technicians estimated 10 minutes to open and close the shelter (source: 322 Leeuwarden), it sums up to 30 minutes extra work. Also, based on calculations made by several Air Force F-35 program managers, it is discovered that line-ops cuts the amount of personnel needed. About 7 crewmembers less are needed in line-ops, saving 4 maintenance supervisors and 3 drivers (source: INFRA Volkel). Therefore, just as seen at Transavia at Eindhoven, line-ops decreases maintenance times and requires less personnel.

On the other hand, within the military it is the question if those functions can actually be saved. During peace-time Air Forces always have a surplus in personnel, as those crewmembers are needed during deployments (source: 322

Leeuwarden and INFRA Volkel). Nevertheless, a reduction of crewmembers in line-maintenance gives the Air Force more flexibility, as those workers can be used in other situations, and therefore the ability to fly more frequent.

If we configure those findings in a hypothetical scenario, in which we assume a task to take about one hour and ten crewmembers in the old scenario, the following happens to the line-maintenance formula:

$$Labour\ rate \times Operating\ time\ per\ component = Maintenance\ cost\ per\ task, per\ component$$

$$Shelter - ops\text{: } (€40{,}08 \times 10) \times 1 = €400{,}80$$

$$Line - ops\text{: } (€40{,}08 \times 3) \times 0{,}5 = €60{,}12$$

Based on this hypothetical scenario, line-ops results in a possible cost reduction of €340,68, which is a cost reduction of 85%.

Cost reduction strategy 3: constructing new infrastructure

The third cost reduction strategy is a bit controversial and harder to calculate. When The Netherlands started the F-35 program it was decided that old F-16 infrastructure would be used to house the F-35 However, the F-16 and F-35 are not identical aircraft and therefore F-16 facilities needed to be upgraded in order to house F-35's (source: INFRA Volkel and 322 Leeuwarden).. At the first Dutch F-35 Squadron, 322 Squadron at Leeuwarden Air Base, this cost are currently estimated between the €5.000.000 and €7.000.000,00 (Source: INFRA Volkel).

The development of new infrastructure is estimated between the €30.000.000 and €40.000.000, which looks way more expensive than upgrading old F-16 infrastructure (source: INFRA Volkel). However, technicians argue that current facilities, even though the upgrades, are not suited for F-35 operations. For instance, the F-35 needs frequent paintwork in order to maintain it is stealth capabilities. Those paintjobs need to happen in a climate controlled environment, which the technicians state is not possible in the current wet and cold F-16 shelters, resulting in frequent towing off aircraft from the shelters towards maintenance shops (Source: 322 Leeuwarden). If the ideas of the technicians are contrasted with Vreeburg's thesis, the claims of the technicians seem valid. The thesis argues that the F-35 transition team needs to determine if it is not better for aircraft flexibility to build new infrastructure and then especially line-ops buildings, like seen in figure 19 (Vreeburg, 2018).

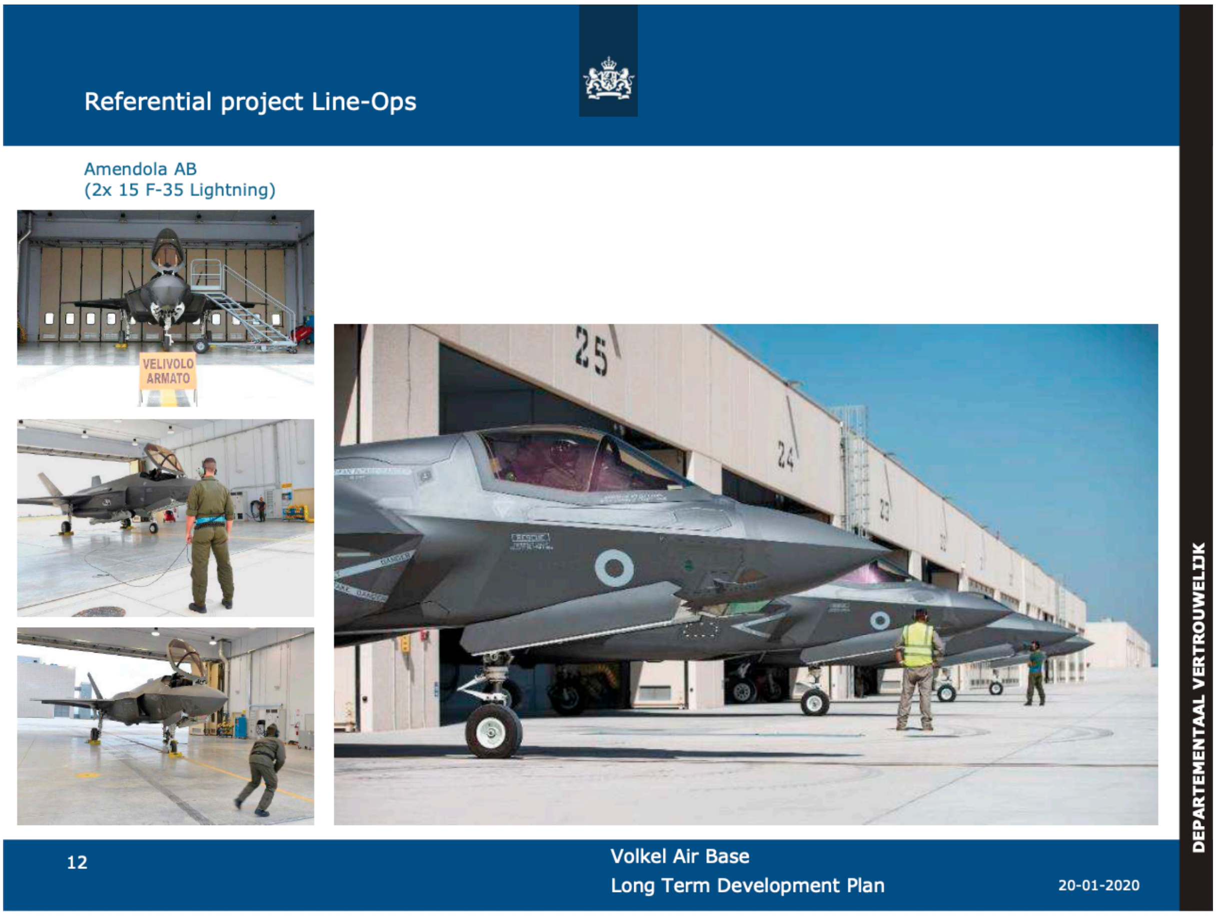


Figure 19: F-35 line-ops at Amendola Air Base, Italy (slide unclassified)

Like said, it is hard to calculate the difference in cost between old and new infrastructure, especially considering that there are also debates about when a building is suitable for F-35 operations. Technicians at that sense look at technical specifications of an building and so are likely to take the option with the best technical specification. Controllers, however, have to deal with the fact that The Netherlands Air Force has limited resources and have to allocated those between different projects. Therefore, they look at the situation from an economical perspective and try to create the maximum output for all the projects combined, possibly leading to a specific project to be performed below its full potential. All of this results in a constant debate on how resources should be allocated, making this option a political decision (source: INFRA Volkel and AFC CLSK).

On the other hand, all actors agree, like advised by JPO, that line-ops is the best modus operandi for the F-35 (source: INFRA Volkel). With the current F-16 infrastructure line-ops is not possible, due to the lack of space and facilities (source: INFRA Volkel and 322 Leeuwarden). Therefore this study argues that building new infrastructure should be preferred above using old infrastructure. Especially as it is likely that, because according the technicians old infrastructure is not suitable for F-35 operations, more upgrades will follow or the new facilities will eventually be build, leading to higher costs in the long run.

Cost reduction strategy 4: changing job evaluations of technicians

When looking at line-maintenance at Transavia and The Netherlands Air Force a key difference can be spotted; the Air Force uses higher qualified personnel to perform it is servicing tasks. Transavia often uses a buddy system, in which mechanics (non-licensed or Cat. A) perform the servicing tasks together with an experienced technician (Cat. B1 or B2). Eventually, after the mechanic is able to perform the servicing by himself, the technician is going to supervise new mechanics and the non-license/cat. A can be used on the flight-line by himself. This strategy has two positive effects: the mechanic is able to gain valuable job experience, necessary to obtain further licenses, and it saves cost as cat. A wages are lower than cat. B1 or B2 wages (source: Transavia Schiphol and Transavia Eindhoven).

Translated to the Netherlands Air Force, this means that Corporals/Sergeants can be used for servicing tasks instead of Sergeant 1/Sergeant-Major's/Warrant-Officers. For this, according to both civil and military aviation regulations, no certifications are required, except of proper on the job training of the mechanic. Therefore, this strategy allows young technicians to gain valuable job experience within their legal limitations, instead of them doing performing support work (source: 322 Leeuwarden).

However, both Transavia and the Netherland Air Force argue that for this system to function an proactive, eager to learn and responsible person is needed. The mechanic will eventually be responsible for signing off aircraft for duty by himself and will, already during training, be checking essential aircraft systems by himself. For an experienced mechanic to be able to trust a young technician to do that, he needs to be able to rely on the fact that the mechanic is not stubborn and will report issues if he is not sure about something. This does not only ask for a specific attitude from the mechanic, but also from the experienced technician as the apprentice needs to feel comfortable to address issues and not be scarred for causing delays, especially when it turns out he is wrong. When this level of trust is present between mechanic and technician, it is seen to be a very nice working harmony (source: 322 Leeuwarden, Transavia Eindhoven and Transavia Schiphol).

Another limitation of this strategy is that currently technical functions are not always as related to rank as described. Within The Netherlands Air Force, there can be a lot of different Cat. A en Cat. B’s, with full or partial certification. However, when in a hypothetical scenario looking at the theoretical concept of changing job evaluations, this leads to the following cost reduction per manhour:

$$Labour\ rate \times Operating\ time\ per\ component = Maintenance\ cost\ per\ task, per\ component$$

$$Sgt1, SM\ and\ WO: €52{,}58 \times 1 = €52{,}58$$

$$Cpl\ and\ Sgt: €37{,}83 \times 1 = €37{,}83$$

Based on the hypothetical scenario above, this strategy provides a possible cost reduction of €14,75 per manhour. A cost reduction of 28%.

5. Conclusion

To sum up the research, this section of the thesis will present the conclusions of the investigation. For that, first of all the main research question will be answered. Then a discussion about the validity of the results will be held, after which some recommendations will be made.

5.1 Answer to research question

The main goal of this investigation was to identify possible cost reduction strategies for F-35 line-maintenance. To do so, this thesis has compared Transavia and F-35 line-maintenance, determined the effectiveness of discovered strategies within both organisations, to eventually identify the following cost reduction strategies for F-35 line-maintenance:

1. Storing all tools in a maintenance van

   Technicians drive to the aircraft to be maintained in vans, in which they keep all their frequently used tooling. Having all tooling in one place eliminates time spend obtaining tools, resulting in a cost reduction.

2. Transferring to line-ops

   Serviced aircraft are parked next to each other on the flight-line, instead of apart in remote shelters. The aircraft being close together decreases the amount of tows necessary, saving both time and drivers towing the aircraft. Also, less maintenance supervisors are needed to oversee the work, resulting in a cost reduction.

3. Constructing new infrastructure

   Instead of upgrading old F-16 infrastructure to comply with F-35 operational specifications, new infrastructure is constructed in order to meet all requirements at once. Even though a large investment is needed to begin, in the long run the strategy is likely to be cheaper than upgrading F-16 facilities.

4. Changing job evaluations of technicians

   Maintenance tasks are to be performed by the lowest certified technician available, resulting in more experienced technicians to be able to perform task at which they are needed for and saving costs by letting the lowest costing certified employee perform the task.

5.2 Discussion

Cost reduction strategies may sometimes be a bit controversial subjects. After all, changes in certain processes have to be made and some individuals even need to give in a little. Therefore, there is always a lot of discussing about the effectiveness of cost reduction strategies. This study tried to discover those shortcomings on the forehand and described them as uncertainties of the strategy in het results chapter. The thesis has in this way tried to make the strategies as valid as possible.

Even though, the thesis tried its best to cope with uncertainties, some variables are hard to control. An important control variable, which could not be controlled within this investigation, is the timeframe. The research was carried out during COVID-19 and within a transition period for both The Netherlands Air Force, as well as Transavia. COVID-19 reduced air traffic significantly, leading to less flights for Transavia (source: Transavia Eindhoven and Transavia Schiphol). The Netherlands Air Force on the other hand also was not operating at the fullest of its capacity, as the F-35 squadron at Leeuwarden has not received all its aircraft yet. Therefore, it could be said that cost reduction strategies cannot be determined yet, because the organisations first need to discover how the work looks like operating a full capacity. Also, Transavia is in the process of replacing its Boeing 737 with the newer models, which may also lead to a different modus operandi.

To possibly resolve the uncertainties, this investigation will in the next paragraph describe recommendations for further research, making this thesis a starting point for further research into cost reduction strategies for line maintenance.

5.3 Recommendations

Based on the identified cost reduction strategies and the point raised in the discussion, this investigation has come up with the following recommendations for both Transavia, as the Netherlands Air Force:

1. Develop business cases for identified cost reduction strategies

   This thesis has identified possible cost reduction strategies for line-maintenance. However, strategies have not been worked out into detail and so cannot be directly implemented within the organisation. Therefore, the thesis recommends business cases to be developed for the described cost reduction strategies, which can then be used to re-evaluate the cost reduction strategies for effectiveness and to implement the strategies within the organisation.
2. Repeat this investigation when circumstances change

   The discussion mentioned that this investigation was carried out during the special circumstances of COVID-19 and organisational changes, which may affect the outcomes of the research. Therefore, the thesis recommends this investigation to be repeated when circumstances change, in order to ensure conclusions are still valid in the new situation.
3. Perform more civil-military benchmarks

Comparing military to civil cases is not something which is done often. Its argued that the military and civil world cannot be related, leading to invalid comparisons. However, this investigation showed that civil and military worlds may sometimes be very comparable and so both worlds can learn from each other. Thus, the thesis recommends civil-military benchmark to be looked into more frequent as a research method for management case studies.

6. Reflection

In the last section of the thesis the author will reflect on the results of the thesis, as well on the performance of the investigator himself.

6.1 Product reflection

At the start of the thesis process the author gave himself the goal to identify cost reduction strategies for F-35 line maintenance. This goal was formulated out of a request of the Finance and Control department of The Netherlands Air Force, who were interested in decreasing direct operating cost of the F-35. Looking back at that assignment, it can be said that the thesis accomplished the assignment and helped The Netherlands Air Force discover strategies for decreasing F-35 direct operating cost. It can be said that the thesis did not provide concrete solutions, that could be implemented directly. However, the study gave clear areas of interest when looking at F-35 cost reductions.

Another goal of this research, it being an bachelor-thesis, was to produce a proper piece of academic work. It was sometimes hard for the author to find a balance between practice and theory, leading to him sometimes struggling to connect discovered strategies to an academical framework. Nonetheless, the produced literature review helped the author to connect the practical and academical world, allowing him to connect discovered strategies with existing theories. This helped the author frame the thesis and so construct a both practical as academic investigation.

As a side-effect, this thesis also contributed to theory development. Although in limited extent, the thesis contributed to Netherlands Air Force line-ops research by, next to time reductions, showing that line-ops could potential save costs by reducing the amount of crewmembers needed. Another theoretical contribution is that the thesis used an uncommon research method, by comparing military with civil operations. The thesis has proven that those two industries can be comparable and therefore lessons-learned can be shared between one another.

To sum up, the thesis has accomplished its practical and academical goals. It has helped the Netherlands Air Force identify cost reduction strategies for the F-35, but also contributed to its research. As well, a theoretical contribution is made to management studies, showing the possibility of civil-military benchmarks. Therefore, the end result of the thesis may said to have met its goals.

6.2 Individual process evaluation

This thesis is the first time the writer has actually done an academic investigation by himself. Therefore, this investigation came with a couple of challenges for the author and him sometimes needing to seek discomfort in order to come further with the thesis. The author being a kind of rookie within the academical world, that leads to some limitations in the authors investigation, which will be described in this section. At first the limitations of the author will be looked, after which the advantages of the investigator will be determined.

To start off, being a beginner in performing investigations, the author sometimes had trouble separating interviewees opinions from actual facts. An good example of that are the numbers given within this investigation. When performing the interviews the investigator knew that exact figures would help the reader develop an understanding of the magnitude of the discussed topics and he was therefore striving to determining the numbers. However, he needed to be careful to make sure to peer-review those amounts. A lot of times the author was excited when interviewees gave exact amounts and processed those amounts within his investigation, to later discover that those figures were off when showing them to peer-reviewers. The author has after that tried it is best to peer-review those amounts or to nuance statements, but being a rookie investigator this may sometimes be proven quite hard. Also, it can be asked if the peer-reviewers of the investigator adjusted the results correctly. Each reviewer looked at the subject matter out of his own professional perspective. This may sometimes lead to tunnel-vision and therefore changing results to fit their viewpoint. However, this viewpoint may be different from the truth, especially when also considering other perspectives. The job of the investigator in those situations is to balance those perspectives and so to come up with his own truth. The problem however is that the investigator is young and therefore does not always have the experience to make a proper comparison. It may also be asked if the researcher even can make an appropriate judgement as, being employed by the Netherlands Air Force, the question may rise if his professional perspective is not coloured by the organisational beliefs of his employer.

On the other hand, it can be said that the investigator tried to look at the subject matter from various perspectives. After all, the author made a quite unorthodox comparison by relating a military organisation with a commercial party. It can be said that this automatically leads to very different viewpoints and therefore a more objective truth. Also, the investigator performed his investigation at multiple hierarchical levels. He did not only interview managers, but also tried to include the opinion of the work floor in his conclusions. By doing that the researcher automatically developed a more objective truth, because he determined support of this results at all levels and therefore concluded with for the entire organisation workable strategies.

To sum up the individual reflection, the author had sometimes trouble separating opinions from facts, especially because of his own inexperienced and coloured perspective. However, it is tried hard to listen to all different perspectives and to include them into the results of this investigation. That is therefore one of the most essential aspects the author learned from writing this thesis; to listen to various ideas and based on that develop his own truth of the situation.

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Overview of interviews held

Interview	Subject	Location	Number of interviewees	Remarks
1 (Mx Volkel)	F-35 line-maintenance	Microsoft Teams (online)	1	- Introduction into F-35 line-maintenance. - Review of cost-reduction strategies found in literature.
2 (AFC CLSK)	F-35 accounting	Staff Netherlands Air Force, Breda	2	- Introduction F-35 accounting - Identifying constrains in investigating F-35 cost reduction strategies
3 (Transavia Schiphol)	Transavia line-maintenance	Microsoft Teams (online)	1	- Review of cost-reduction strategies found in literature.

4 (Transavia Eindhoven)	Transavia line-maintenance	Flight line Eindhoven Airport, Eindhoven	1	- Observation of Transavia line-maintenance - Identifying difficulties experienced by mechanics - Identifying cost-reduction and their constrains from mechanic perspective.
5 (Transavia Schiphol)	Transavia line-maintenance	Hangar 5, Schiphol	4	- Observation of Transavia line-maintenance - Identifying difficulties experienced by mechanics - Identifying cost-reduction and their constrains from

				mechanic perspective.
6 (322 Leeuwarden)	F-35 line-maintenance	322 Squadron, Leeuwarden Air Base	8	- Observation of F-35 line-maintenance - Identifying difficulties experienced by mechanics - Identifying cost-reduction and their constrains from mechanic perspective.
7 (INFRA Volkel)	F-35 infrastructure	Volkel Air Base	4	- F-35 infrastructure
8 (Transavia Schiphol)	Peer-review Transavia	Hangar 5, Schiphol	1	- Peer-review of Transavia interviews
9 (322 Leeuwarden)	Peer-review 322	322 Squadron, Leeuwarden Air Base	4	- Peer-review of 322 interviews
10 (AFC CLSK)	Calculations cost	Staff Netherlands	1	- Determining actual cost

	reduction strategies	Air Force, Breda		reduction of strategies
		Total number of interviewees:	**27**	

Figure 20: Overview of interviews held

Transcripts of the interviews and member-checks are available on request. If interested, contact the author at: a.wiessenberg@mindef.nl