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Obsolescence management scan

A gap analysis on the implementation of a proactive obsolescence management strategy

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Industrial Engineering and Management (BSc)

Obsolescence management scan: A gap analysis on the implementation of a proactive obsolescence management strategy

Bachelor thesis report

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Preface

Before you lies the bachelor thesis that I conducted at Thales and the RNLN, the Royal Netherlands Navy conducted in the period: 1-11-2019 till 31-01-2020.
I look back on a period where I learned a lot. Working at a company provides a setting where other skills are needed in comparison to working at the university, such as taking initiative, planning over a longer period of time and working on a project individually.

My research is on the subject of obsolescence and in particular the logistical obsolescence. I would like to thank both Thales and the RNLN for giving me the chance to conduct the research and I would like to thank the employees of both companies for helping me with providing answers to my questions and for the validation of my research. I would especially want to thank Berend Jongebloed, my supervisor, for helping me with both providing me with answers as well as helping me with the structure of my thesis. From the university I want to thank Matthieu van der Heijden, for providing me with feedback to enhance the quality of this thesis and Engin Topan for being my second supervisor. From RNLN I want to thank Bart Pollmann for the introduction into the company and providing me with feedback. Last I want to thank the members of the Marconi project with their insights and answers.

Vincent Janssen
May 2020

Management summary

Motivation

This research is commissioned by the collaboration of Thales Hengelo and the RNLN, Royal Netherlands Navy, where Thales produces radar systems for the Royal Netherlands Navy. The products Thales produces can become obsolete, which means can be described either as when material or technology is not available from existing stock and from an original manufacturer, which is referred to as logistical obsolescence. Functional obsolescence is another form of obsolescence and can be described as the situation when the product does not meet the required capability standard from the customer anymore.

There are multiple solutions for solving obsolescence, where the costs of some of these solutions can become relative high. Therefore, Thales and the RNLN decided to implement a proactive OM, obsolescence management, strategy to ensure that the costs of solving obsolescence will be minimized. By recognizing obsolescence concerns and issues in an earlier stadium, an appropriate solution can be identified and will be implemented to avoid costly solutions. Thales and the RNLN already implemented parts of a proactive obsolescence management strategy, although it was at the start of the Marconi project not clear how a complete proactive obsolescence management strategy should be implemented to achieve maximum efficiency in handling obsolescence. Improvement of the Obsolescence policy is an on-going process at Thales and at DMI. This research is one of the projects that contributes to the improvement in the collaboration between Thales and DMI in general. Results of a recent and dedicated project of Thales and DMI for a set of sensors are not fully included in this research. That specific project will contribute to further improvement of an pro-active obsolescence policy within the scope of the Marconi Network.

Methodology

This thesis analyses what the challenges are on implementing a complete proactive obsolescence management strategy within the logistical obsolescence subject. To identify the challenges, the subjects risk assessment, obsolescence monitoring and solutions need to be studied as they constitute the logistical obsolescence subject. A gap analysis is used to identify the gaps between the desired and actual situation. The first step is a literature review to assess what the most efficient proactive obsolescence management strategy includes. The second step is to map the current situation, and the third step is to identify the gaps between the actual and the desired situation.

Results

Risk assessment

The risk assessment which is currently performed at Thales results in 95% of the time in a medium risk level. As this is not accurate enough, the risk assessment can be improved by integrating more attributes in the calculation of the risk. Seuren (2018) constructed a model to calculate the risk level concerning more accurately, but used too many attributes which Thales not all could integrate in the risk assessment. Krol (2020) modified the model for RH Marine and reduced the amount of attributes. A similar modification with a reduced amount of attributes is needed at Thales to have the model of Seuren (2018) implemented.

For a risk assessment the information of some of the suppliers of Thales is needed for completion of the calculation. An example of such information is the plan of the coming period. If a supplier decided to stop producing a required component and is the only manufacturer of the component, Thales needs to buy a component similar to the original or a design change needs be implemented. By identifying the situations as early as possible, sufficient time is left to investigate which solution suits the situation best.

Obsolescence monitoring
The process of obsolescence monitoring is executed similar to the literature, but gaps are identified in the communication of the results from Thales to the RNLN. The first gap is due to miscommunication between Thales and DMI. The list of obsolescence concerns and issues which Thales encounters is long. Thales decided not to mention every detailed issue and concern to DMI, to make sure that DMI would only have an overview on the important concerns and issues that directly effect DMI. As DMI only received these messages, the misinterpretation that Thales has a reactive obsolescence strategy was formed. Thales does have an obsolescence strategy in which issues in their own supply chain will be taken care of mainly on a Form Fit Function basis, so DMI will not receive information on all matters. This causes a communication problem.

The second gap is identified in the update Thales gives DMI. The issues and concerns are reported to DMI but the mutual follow up plan on how to deal with the obsolescence is missing. As this information is missing, DMI is unable to properly budget for the solutions of obsolescence. As DMI needs to budget for an entire year for obsolescence, the information on the follow up plans is necessary.

Solutions
Multiple gaps are identified within the subject of the solutions to obsolescence. The first gap is identified in the costs of the reactive and proactive solutions. The costs of the reactive solutions are estimated by investigating the costs of these solutions in previous situations. When these solutions can exactly be calculated and communicated to DMI, DMI is able to more accurately budget for obsolescence. The budget needs to be accessible as solutions are not unlimited accessible, e.g. a last batch can be bought when a supplier announces to stop producing a component, but this offer is not indefinitely useable.

As the costs of these proactive solutions can't be determined on forehand, a plan on when to implement a proactive solution on which components is missing. This is the second identified gap. The third gap consists of a lack of information on which characteristics of a component are identified as possible obsolescence concerns. This information is needed to continue the on-going implementation of proactive solutions.

Furthermore, the RNLN needs to compose an obsolescence policy to adequately act on monitoring and on solving obsolescence issues. The actions of the installation managers of DMI, who handle obsolescence for the RNLN, are based on a general roadmap. By composing an obsolescence policy, fixed actions can be identified and followed by the installation managers to decrease the decision time and ensure the suggested solution to remain useable.

Obsolescence landscape
Subsequently to the analysis on the logistical obsolescence, the other subjects of the obsolescence landscape are identified. Research on all topics should ensure the most efficient proactive obsolescence management strategy.

Furthermore, there are gaps where Thales and the RNLN are already searching for a solution, so a follow up project is not needed. These gaps are identified, explained and added to this thesis to ensure a complete overview of the gaps.

Glossary of terms

Abbreviation	Description
BOM(s)	Bill Of Material(s)
COTS	Commercial Off-The-Shelf
CZSK	‘Commando Zee StrijdKrachten’
DMI	‘Directie Materiele Instandhouding’
DMO	‘Defensie materieel organisatie’
EOL	End Of Life (Component level)
IEC	International Electrotechnical Commission
KPI	Key Performance Indicator
LRU	Line Replaceable Unit
LTB	Last Time Buy
Marconi	Maritime Remote Control Tower for Service Logistics Innovation
MTBF	Mean Time Between Failures
OEM	Original Equipment Manufacturer
OM	Obsolescence Management
OMIS	Obsolescence Management Information System
OMP	Obsolescence Management Plan
ORB	Obsolescence Review Board
PCN	Product Change Notice
PDN	Product Discontinuance Notice
RMB	Risk Mitigation Buy
RNLN	Royal Netherlands Navy
TRP	Technological Refreshment Plan
YTEOL	Years To End Of Life (Component level)

Table of content

1. Problem identification and problem approach

This chapter provides an introduction into obsolescence, an introduction of both Thales and the RNLN and the project of Marconi of which they are part of (1.1). After these introductions, the problem identification (1.2) and the approach to solve the problem (1.3) will be discussed.

1.1. Introduction

1.1.1. Obsolescence

Within this chapter I will give a short explanation what obsolescence is. This topic will be the main topic in my bachelor thesis.

Obsolescence means that a product does not meet the required capability standard, where the gap between actual and desired capability typically grows over the life cycle of the product. This capability gap consists of 2 parts. The first part is referred to as logistical obsolescence, as can be seen in figure 1 below the dashed line. This type of obsolescence is described as when material or technology, which is needed to manufacture or support a product or system, is not available from existing stock or the original manufacturer of the material or technology (Bartels et al., 2012). This could occur when a supplier goes bankrupt or when there is a lack of spare parts and/or maintenance personnel. Logistical obsolescence could also occur when spare parts are infeasible to repair. A common situation on when a product becomes obsolete is when a manufacturer does not find it economically viable anymore to produce a product anymore.

In the case of functional obsolescence the product or the subsystem is still operating as intended and can still be produced and supported, but the requirements by the customers have been increased (Bartels et al., 2012) as can be seen in figure 1 above the dashed line. Besides materials also skills and software can become obsolete. Functional and software obsolescence will be mentioned on later in this thesis as both subjects are part of the transition to a complete OM, obsolescence management, strategy. However, the scope of this research is on the domain of logistical obsolescence.

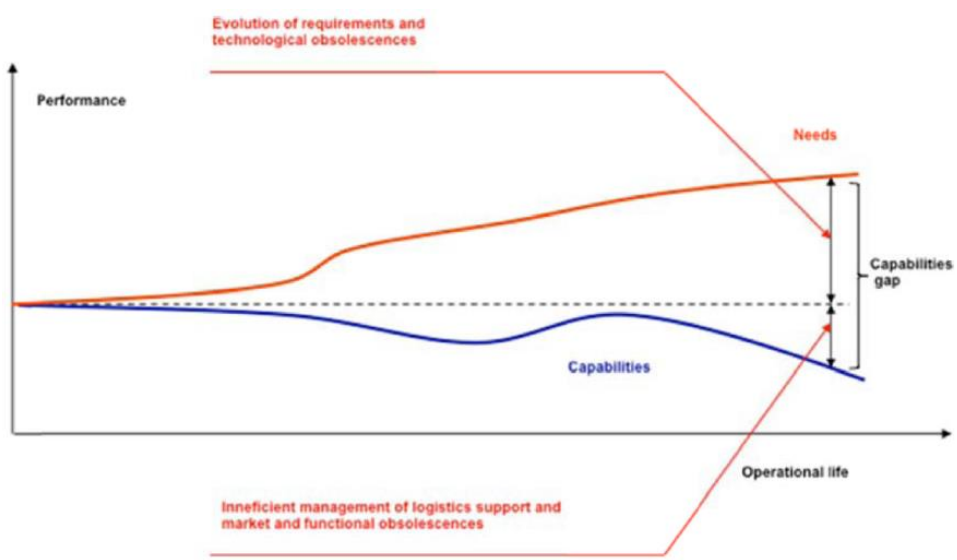

Figure 1, Decomposition of the capability gap (Sols et al., 2012)

1.1.2. Thales

This chapter is meant to give a short introduction of the company where I will conduct most of my research, Thales group Hengelo. Thales Netherlands is part of the worldwide Thales group, which is a company that designs and produces electrical systems which are used in the fields of transportation, defense, aerospace and security markets, where it also provides services for. The headquarter of this multinational is established in Paris, France where the company was founded. Thales group has 64.000 employees who work in 56 countries. Thales Netherlands, consists of 4 sites where the site in Hengelo is the biggest. Thales Hengelo is specialized in Radar and Combat Management technology for naval ships. Innovation of this Radar Technology is done in close collaboration with the Dutch Defense organization.

1.1.3. DMI

DMI, ‘Directie Materiele Instandhouding’, represents the maintenance department of the navy. DMI is responsible for the maintenance of all the systems on board, in the areas of platform, sensors, communication and weapons. The support of DMI starts at the design and manufacturing of a vessel, where on board experience is shared. The whole life cycle of a system or component is supported by DMI. The 2000 employees of DMI work mostly in the Netherlands but if necessary also the mission areas are supported by this department. There are 2 divisions at DMI, maintenance and logistics. Maintenance (Maritieme instandhouding) receives the parts and services from logistics, where DMI logistics (Maritieme Logistiek) receives these parts and services from their own worksite, Thales or other suppliers.

1.1.4. MARCONI project

My bachelor thesis will be a part of the MARCONI project. The next chapter will be an elaboration on the project, the relationship between the companies and the area which will be relevant to my thesis.

The MARCONI project, Maritime Remote Control Tower for Service Logistics Innovation, is a project which is set up to integrate a control tower within the Service Logistics supply chain of the navy and it’s suppliers. Companies which are included within the MARCONI project can be found in figure 2, and are the suppliers of services, knowledge and products. The supply chain acts as support for the CZSK, the ‘Commando Zee Strijdkrachten’, which is the end user of the products. Within the MARCONI project, there are 3 work packages to make sure the control tower can be integrated within the supply chain. The first work package, service logistics decision support models, is the work package which will be the area where my thesis will be of value too. This work package will deliver models to support the primary processes and the supporting, service logistics processes. These processes contains supply, resource and maintenance planning and an operating schedule which focus on supporting the use of assets or products by CZSK. The other work packages are the control tower operating model (WP2) and the information management (WP3). To conclude, the objective within the 3 year duration of the Marconi project is to create a 5 to 10 year roadmap for proactive OM, obsolescence management.

Figure 2, Included companies of the MARCONI project

The relevant area of this bachelor thesis is within the relationship between Thales and DMI, where a more elaborate description of the relationship between the relevant companies can be found in figure 3. DMO, 'Defensie materieel organisatie', is involved in the purchase, conservation and the selling of materials and defines the capability requirements for an Asset. Thales receives there parts from its own suppliers.

CZSK, DMI and DMO are departments of RNLN, the Royal Netherlands Navy. The triadic relationship between DMI Maintenance, DMO and CZSK is called asset management (or Weapon System Management), which refers to the fact that these departments represent the part of the supply chain where the requirements are set.

De Vries (2019) made an overview on how the network looks like in terms of relation to each other (Figure 3). Within my research I will not focus on the relationships between Thales or DMI with their own suppliers, as the scope would be too big to finish for me in time.

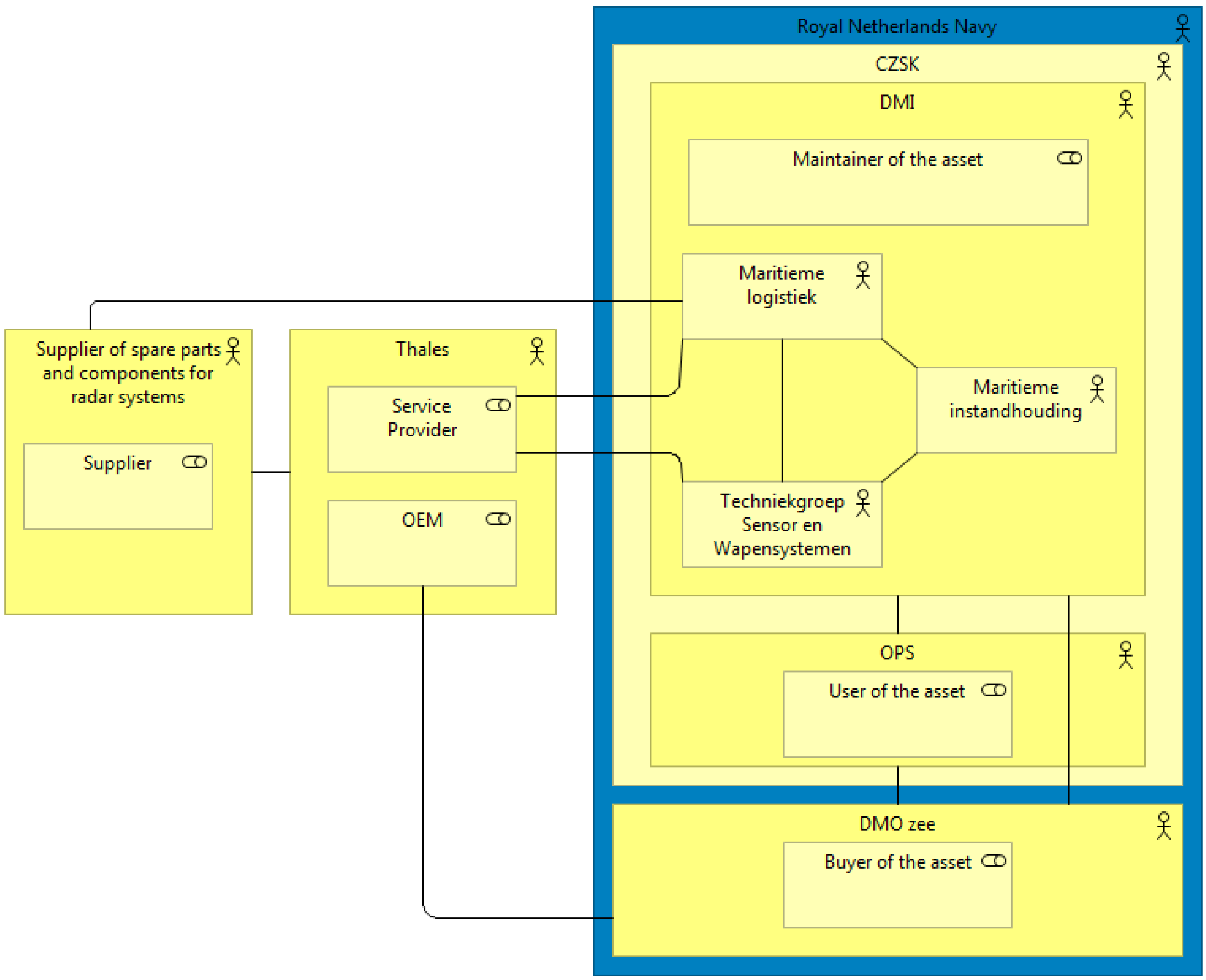

Figure 3 , Visualization of the network between Thales, DMI, DMO, CZSK and the supplier of Thales and DMI (De Vries, 2019)

1.2. Problem identification

This section discusses the problem cause (1.2.1.), followed by the problem cluster (1.2.2.), the identification of the core problem (1.2.3) and finally the overview of the current and the desired situation (1.2.4).

1.2.1. Problem cause

The network (which includes Thales and the RNLN) wants to reduce the costs of obsolescence by optimizing the OM, obsolescence management, strategy to mitigate the risks of obsolescence and to realize a 100% operationality for RNLN. An OM strategy is also meant to gain an understanding of the risk of obsolescence, and a framework to support obsolescence risk assessment and decision making. Currently an OM strategy already exists and is implemented but there are gaps between the current situation and the desired situation. As a first step within the scope of the Marconi project, Thales and DMI desire an explorative study to find out what the total obsolescence landscape is. Within the predecessor of the Marconi project, two research projects took place and were a first exploration, however they did not yet cover the total extend of OM.

After these research projects were finished, the question of which subjects could be identified within obsolescence management arose. These subjects combined form the obsolescence landscape, which is the overarching problem of this thesis. Following this obsolescence landscape, the direction for follow up projects is desired, which should contribute to a complete overview and understanding of OM. Within this research, the subject of logistical obsolescence will be researched in depth, the other subjects won't, as the scope would be too big elsewise. However, as this research is a starting point of the Marconi project, the subjects will be identified, where some will be elaborated more on than others.

1.2.2. Problem cluster

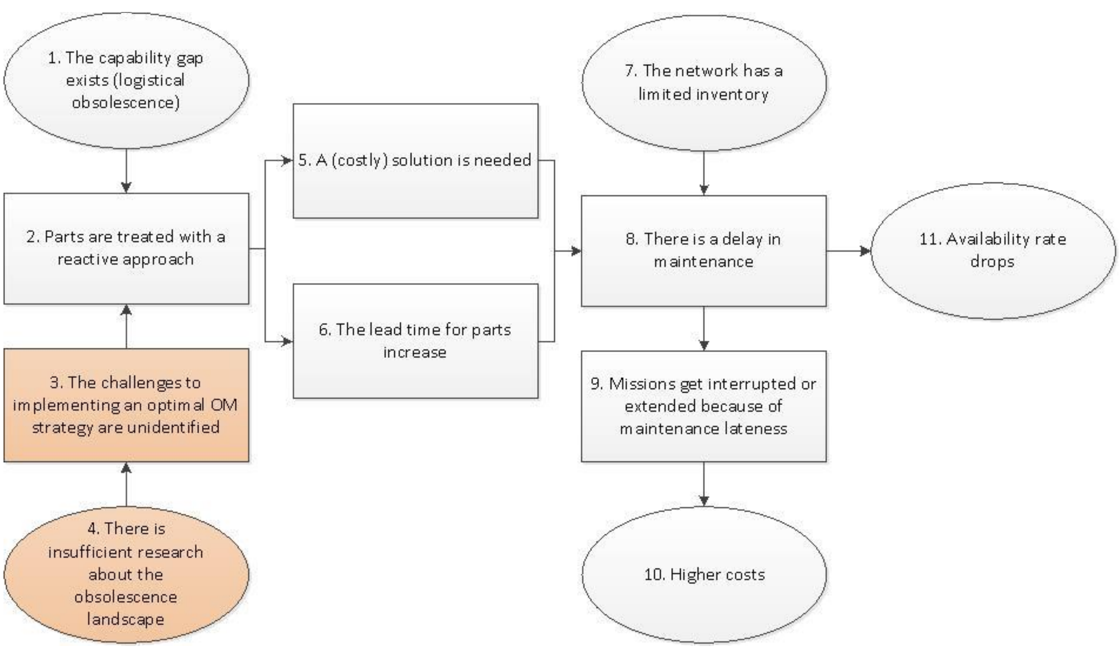

Figure 4, Problem cluster

Figure 4 represents the problem cluster in which the core problem occurs and what the consequences are. The problem cluster begins at the top left corner with the capability gap (1), which is described in paragraph 1.1.1. This gap is present when somewhere in the supply chain logistical obsolescence occurs.

The proactive OM strategy is not optimal at the moment, as there are parts which should have a proactive solution but either the relevant parts for a proactive solution are not identified, or the correct proactive solution cannot be determined at this moment. This causes the situation that a reactive OM strategy complies to these parts (2). By addressing the relevant parts with a reactive approach, the supply chain is vulnerable when obsolescence occurs. Obsolescence is not always identified a long time in advance or there could have been an error in the communication. This leaves with a short time to respond to the obsolescence, what could result in a (costly) solution (5) and an increased lead time for the parts(6).

The proactive OM strategy which is implemented is incomplete. A part of the obsolescence issues which should be treated proactively are now treated with reactive solutions. The Marconi network knows that the strategy which is implemented is incomplete, however there is too little information present which leads to the challenges of completing the OM strategy not being identified (3). These challenges are not identified as the Marconi network does not know which subjects need research to complement the OM strategy. These subjects are referred to as the obsolescence landscape (4).

The problem of the network having a limited inventory(7) is also a problem which needs to be solved but this is beyond the scope of my research. Due to the problems stated at 5,6 and 7, a delay in maintenance will occur (8) which leads to a decreased availability rate (11) and missions which get interrupted or extended (9). The interrupted or extended missions will result in higher costs.

1.2.3. Core problem

To solve the problems described in paragraph 1.2.2, the core problem should be solved, which is depicted as step 4 in the problem cluster. To conclude, my thesis should give an insight in the following core problem:

> There is insufficient research about the obsolescence landscape and the challenges there are to implementing an optimal OM strategy.

After the core problem was identified, I discussed with both my supervisor from Thales and my supervisor from the university that I would identify one subject which would be researched in depth. This identified subject is logistical obsolescence, as literature can be found on this subject and information about this subject is present at both companies. This is important as the time which can be spend on this thesis will be too short when a subject needs to be researched but information is limited or not available.

1.2.4. Current and desired situation

Thales already has an OM Strategy, consisting of an obsolescence policy and an obsolescence handbook. The handbook is produced to describe a more detailed overview of which steps need to be conducted to minimize the risk of obsolescence, which solutions there are to mitigate risk and which solutions there are to solve the situation when obsolescence occurs. At DMI a roadmap is present which can be consulted when Thales communicates when an obsolescence issue or concern is identified. This roadmap is made out of immediate need of it, so it is inefficient.

1.3. Problem approach

This chapter presents the approach on how the research goal stated in chapter 1.2 will be achieved. To achieve the research goal, knowledge questions will be formulated. These knowledge questions will provide a roadmap of coming to a solution for the research goal. The MPSM, Managerial Problem Solving Method, which is invented by Heerkens (2012), is used as a guideline to come to the solution of the core problem and thus achieving the research goal. The MPSM consists of the problem identification, formulating the problem approach, the problem analysis, formulating the alternative solutions, the decision, the implementation and the evaluation. This thesis is a fundamental research, which is a research with the aim to gain an advancement of knowledge (Horváth, 2007), where this knowledge can be used as input for an action research (Pradeep, 2018). As this is a fundamental research, the last three steps are not directly applicable, but are replaced for this research by proposing solutions and follow up projects, and validating them with experts.

Before the current situation of the network concerning obsolescence can be visualized, the methods to identify which information is needed, and how this information should be visualized, need to be researched. To identify which information is needed, the research question from the network will be analysed. The network would like to obtain a clear overview on how to implement a complete proactive obsolescence management strategy. To obtain this overview, the first step is to research what is needed for an organization to implement a complete proactive OM strategy and which adaptions are needed to do so. To obtain this information, the following knowledge question needs to be answered:

- *What is needed to implement a complete OM strategy?*

The second is step is to identify a method which would provide a roadmap on how the information should be visualized. After a brief research on methods which provide a roadmap to visualize the current and the desired situation, a gap analysis would be best applicable to this research, as it is an academic research method, provides a roadmap on how to conduct a gap analysis and has multiple successful examples on why the method proves to be the best choice. To use the gap analysis within this research, an answer must be found on the knowledge question:

- *What is a gap analysis and how can this be used?*

The information which will be depicted in the first part of the gap analysis, the current and desired situation, consists of a comparison between the literature found on the subjects within the logistical obsolescence domain and the current status within the network. The logistical obsolescence domain should be split up into separate subjects which will be researched separately. The following knowledge questions should be answered to provide this overview of the current status:

- *What is the optimal state of the subjects within the logistical obsolescence domain following the literature?*
- *What is the current state of the subjects within the logistical obsolescence domain?*

After the current situation is visualized, the desired situation needs to be identified. The bottlenecks in completing the OM strategy need to be identified, which will lead to the situation where the gaps could be identified. The step which is needed to identify the bottlenecks, is to compare the current situation with the optimal situation found in the literature. Besides this comparisons should the employees be asked which bottlenecks they identify to make to next step in implementing the complete proactive OM strategy. To solve these bottlenecks, the challenges in solving need to be identified and if possible follow up projects should be identified. This information will be the first part of the deliverables of this research, and is obtained by answering the following knowledge questions:

- *Which bottlenecks are there in completing the OM strategy?*
- *What are the possible challenges/follow up projects?*

These challenges and follow up projects should also be identified for the other subjects of the obsolescence landscape, as the relevant stakeholders, who need to make a decision on which follow up projects should take place, are able to construct a list in which they can give their priority preference in follow up projects. This priority should be identified after a validation on the research is conducted. This information will be the second part of the deliverables, and is obtained by answering the next knowledge questions:

- *Which subjects are unidentified but are part of the obsolescence landscape?*
- *How do I prioritize the follow up projects?*

1.4. Used methods

To conduct this fundamental research, two methods will be used to identify what will be researched and how to visualize the findings. The first method on what will be researched is a literature study on which steps are relevant when implementing a proactive OM strategy (Chapter 1.3.1.). The second method, on how to visualize the findings, will be a gap analysis (Chapter 1.3.2.).

1.4.1. What is needed to implement a complete proactive OM strategy?

A proactive approach aims to reduce the risk of occurrence of obsolescence and/or decrease the impact when obsolescence occurs. To accomplish this reduction, the development and implementation of an OMP, Obsolescence Management Plan, in advance is necessary. Within a successful proactive OM strategy, the obsolescence risk is determined well in advance and action plans are made for maximizing the service life of installed systems while ensuring reliability. This should be proportionate to the level of risk. Factors such as item criticality and the likely timeframes or cost of potential resolutions will influence the decision to employ proactive solutions. These factors will be explained later in this thesis. The proactive OM strategy can be described as a strategy where the company, that will manage the obsolescence, takes measures before the obsolescence occurs. Reactive solutions could be a part of a proactive strategy when the consequences of obsolescence are determined as low. This will be explained in chapter 2.1.

The levels on which a business can be present regarding obsolescence management can be found in figure 1 (Romero Rojo, 2010). A proactive obsolescence strategy begins at level three where the essentials are present such as obsolescence managers and the use of obsolescence monitoring tools. Thales is at this point in time in the transition from level 3 to level 4, as obsolescence is assigned in the stadium before the production has started. The missing activities of having a complete proactive OM strategy imbedded in the company will be explained at the end of this thesis and how to come to a solution. Proactive solutions used in a proactive OM strategy to mitigate the risk of obsolescence are design considerations, technology transparency, partnering agreements with suppliers, a lifetime buy, obsolescence monitoring and a design refreshment planning. These proactive solutions are elaborated on in chapter 2.3.

DMI is performing somewhere between level 1 and 2, which could be classified as a reactive obsolescence management strategy. A reactive obsolescence management strategy is a strategy where there will only be reacted to a case of obsolescence when the item is needed and has been declared obsolete. When this obsolescence issue has been communicated, the relevant company (or companies) will react to the issue with a resolution strategy to limit the consequences of the obsolete item. Examples of such a reactive solution are reclamation (cannibalization), emulation, a design change or a life time buy. These examples and the other reactive solutions are elaborated on in chapter 2.3.

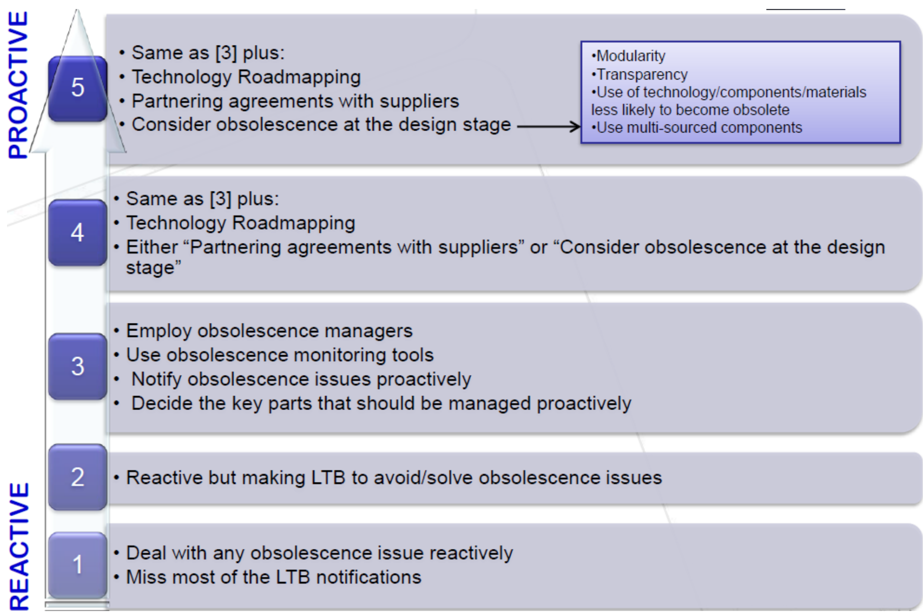

Figure 5, Obsolescence Management Levels, Romero Rojo (2010)

To determine which parts are of more importance in relation to other parts or components, a ranking should be made. A proactive mitigation method should be used for the parts with the highest ranking to reduce the consequences of the obsolescence.

The criteria which should be used to make a ranking are:

- The part should be at some risk of becoming obsolete.
- The part should have a demand from the organisation.
- If the part goes obsolete, there has to be a risk of running out of the part.
- The part must be critical for the functioning of the product and pose some level of difficulty to manage if it goes obsolete.

1.4.2. Gap analysis

A gap analysis is conducted when the desired state of performance is not met in the current state of performance. Therefore it is important to first identify what the desired state should be. By comparing the performance in the current state with the identified desired state, the performance gap can be identified (Franklin, 2006). The desired state could be identified by means of a questionnaire or by interviews (L. M. G. Amaral and J. P. Faria, 2010). Within this research the questionnaires are only used within the validation of the findings, as my knowledge about the subject of obsolescence and the relationship between the companies was limited when the research started.

As the knowledge was limited, the questions which needed to be asked had several follow up questions, or needed an extended explanation from the interviewee. Following from a research which was conducted prior to this research, in the form of an essay, four criteria points were identified which determined what sort of data gathering technique is best suitable for the situation. The criteria points are an in depth survey versus a broad survey, the choice of interaction, the consideration of low costs, high quality or a high response rate and the fourth criteria is the choice for open and closed questions. By comparing the situation at the start of the research and the knowledge about data gathering, the choice for interviews was substantiated.

Another mean of gaining the knowledge about the desired state is through a literature study. By identifying the subjects which are not specified by the employees, the desired state can be extended by results which are not researched yet in the business. The employee performance of the desired state consists of the knowledge or skills which are not present yet to achieve the desired operational results. Whether this is an issue will be identified in the interviews.

The current situation is identified in the same manner. Within the current situation it is important to gain information from both businesses as there could also be a difference in the statement of employees from both companies. By combining these two elements the current performance of the network can be defined.

When the current state and the desired state are measured, the gap can be identified. A downfall of the analysis could be when there is already a solution in mind before executing the analysis. By having the solution in mind the outcomes will be biased and will more likely tend to a support of the solution instead of the intended gap analysis. (Rose, Anastasia & Kiyoshi-Teo, Hiroko, (2017)) The improvement points which will follow from the gap will be the starting points of the follow-up projects.

2. Theoretical framework

This chapter discusses what would be the best practice of implementing a proactive obsolescence management strategy within an organization, following the found literature. This chapter elaborates on the subjects which are identified as the processes of which the strategy is composed of. These subjects are the risk assessment (Chapter 2.1), the obsolescence monitoring (Chapter 2.2) and the solutions to obsolescence (Chapter 2.3).

The relation between the three subjects can be found in figure 6. The decision to implement a proactive obsolescence management approach is originated from the question which solution should be assigned to each component. Before this solution is chosen, a risk assessment is made. Following form this assessment either a solution is chosen or a periodic monitoring plan is set up. An explanation on when which step will be performed is given in paragraph 2.1.5.

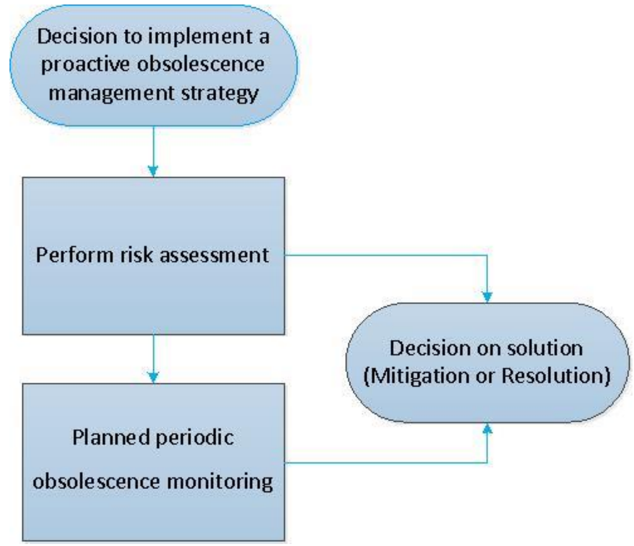

Figure 6, Process to come to a decision of a solution to obsolescence.

2.1. Risk assessment

As mentioned before, not all parts should be approached with a proactive strategy as this will lead to higher costs. To determine which parts need a proactive strategy, a risk assessment should be performed. To perform an obsolescence risk assessment, the following criteria should be researched following from the IEC62402 standard: The costs of reactive obsolescence solutions, impact of the obsolescence and the probability of becoming obsolete. After studying the literature on risk assessment with the focus on maritime solutions, the following method provided steps in which the costs, impact and probability are integrated (Romero Rojo et al., 2012). This method consists of seven steps which will be elaborated on below.

2.1.1. Step 1: System support plan assessment

The first step in the risk assessment is focused on the timespan of how long a system or product needs to be sustained and future upgrades. The obsolescence manager who is performing the risk assessment should determine the YTEOL, Years till end of life. For identifying this time span, it is necessary to research when upgrades are planned and which subsystems have a high probability of being modified or replaced.

2.1.2. Step 2: Planning of resources

After the timespan has been defined, the following step should be to investigate which resources are needed for conducting the risk analysis. There is a limited amount of resources available, so an overview is needed to identify what the capabilities are regarding obsolescence management. The resources which should be reviewed are the people who could be allocated to the project, the obsolescence monitoring tools which could be used in the project and the budget which is assigned to obsolescence management.

2.1.3. Step 3: Extract and filter the Bill of Materials

The actual risk assessment can start after the first two steps are completed. The BOM (Bill of Materials) should be present for the obsolescence manager who will perform the risk assessment. The BOM will contain systems or equipment which should first be divided in the components of which the system has been made of. By breaking the system or equipment down to a component level the obsolescence engineer will have a detailed view on the BOM which is needed for the next step.

The next step is identify the low risk components which need no further investigation to determine that these are low risk components. By filtering these components out the obsolescence manager should prevent the making of a complete risk assessment for components that obviously do not need some form of monitoring or solution to obsolescence, and thus saving time and extra costs. Rojo et al. (2012) uses the following criteria to filter out the low risk components:

- Mechanical components, for instance screws and bolts.
- Components with a standard design. A standard design represents a design where standard connectors are integrated, an architecture with public known specifications and which is modular.
- The YTEOL, Years Till End Of Life, is eight or higher.
- Passive components. These components do not require energy to operate.

It is of importance to investigate whether these components have only one manufacturer or whether the system will not work without these components. If a component is subject to one of these criteria the component should be further investigated in the risk assessment.

2.1.4. Step 4: Risk analysis

At this step within the process of risk assessment, the risk analysis itself is performed. This risk analysis consists of two parts, the probability of the component of becoming obsolete and the impact of the obsolescence on the system. The probability of becoming obsolete considers multiple factors. These factors are the consumption rate, the available stock level, the YTEOL and the number of manufacturers.

The first part of determining the probability of becoming obsolete will be a comparison between the consumption rate and the available stock. If there is a high level of stock and a low consumption rate the comparison should be assessed as low. When the consumption rate and level of stock are on the same level, for instance both low or both high, there is a medium level assessed to the comparison. When the consumption rate is high and the stock level is low the obsolescence risk is assessed as high.

The second part could either be the YTEOL or the number of manufacturers who are present for the selected component. This depends on the information which is present. A YTEOL of less than two years yields a high risk obsolescence level, between two to five years a medium level and more than five years has a low risk level of becoming obsolete. One manufacturer present for the selected component represents a high level of obsolescence, two manufacturers a medium level and more than two manufacturers represent a low risk level regarding obsolescence.

The impact of the obsolescence on the system consists of the potential loss of capability or availability of the system. Rojo et al. (2012) constructed the following criteria to resemble the different levels of risk: a high level of obsolescence risk is specified as safety critical, mission critical resembles the medium level and all other criteria could be referred to as a low risk regarding obsolescence.
To determine the level of obsolescence risk, both parts of the risk analysis should be combined. First a matrix should be conducted to determine the probability of a component becoming obsolete.

This matrix is made by combining the comparison between the consumption rate and the level of stock, and the YTEOL or the available number of manufacturers. The highest level of risk of the YTEOL or the impact should be on the axis if both numbers are present. This matrix is visualized in figure 7. After the probability risk matrix is made the obsolescence risk matrix can be made by combining the probability risk with the impact of the obsolescence. Figure 8 represents this matrix.

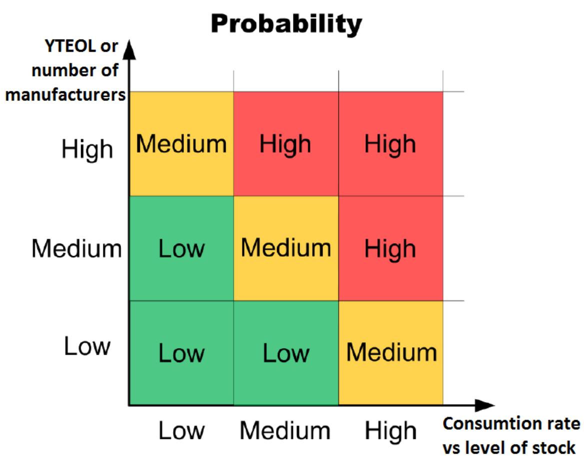

Figure 7, Probability risk matrix

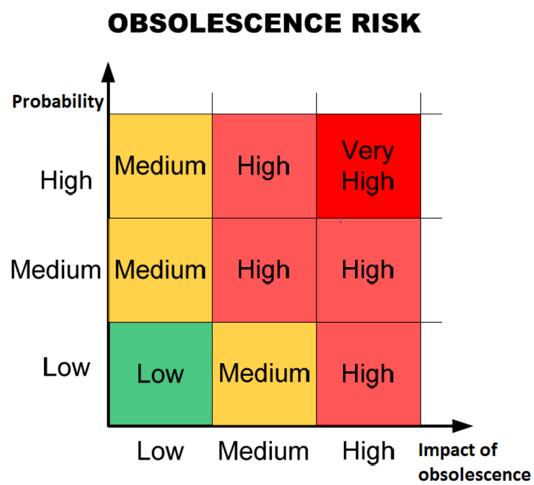

Figure 8, Obsolescence risk matrix

2.1.5. Step 5: The solution decision

When an obsolescence risk matrix has been made for all components from the extracted BOM, the decision for a mitigating or resolution solution must be made. Components with a very high obsolescence risk, as can be seen in the upper right corner in the matrix from figure 2, should have the highest priority in deploying a mitigation strategy. The mitigation strategies which could be deployed can be found in chapter …. Components with a high level of obsolescence risk should have the next priority in addressing the obsolescence concern. The medium level of obsolescence risk components should be monitored in order to identify in an early stadium when these components will have a high risk of becoming obsolete. A reactive obsolescence solution is applicable to components which have a low risk of becoming obsolete.

2.1.6. Step 6: Update the risk register

In order for another person than the person who performed the previous steps to investigate what the outcomes are of the risk analysis and mitigation or resolution decision, the data need to be stored. This stored data of all the components will be the risk register. Rojo et al. (2012) composed the following list of information which should be present for each Line Replacement Unit, LRU, in a risk register:

- Information whether the component is currently obsolete or not.
- The risk level following from the obsolescence risk matrix.
- Period for which the component is required.
- Used data in the risk analysis, which contains the number of manufacturers, the YTEOL, consumption rate, the level of stock and the impact of obsolescence.
- The decision which mitigation or resolution strategy is used (Chapter 2.3).

2.1.7. Step 7: Review

By reviewing the risk analysis the data will be updated. This is necessary as making decisions based on outdated data would possibly lead to making the wrong decision. The recommended time period to have the next risk analysis is a half year or one year. This depends on whether the manufacturing phase has been completed. If this phase has been completed, the period of a year should be sufficient (Romero Rojo et al., 2012).

2.2. Obsolescence monitoring

Obsolescence monitoring involves tracking the through life availability of the processes, materials and components used in the system. A periodic report of obsolescence findings is then developed to highlight obsolescence issues and propose resolutions.

Before obsolescence monitoring can be conducted it is necessary to determine the scope of the monitoring. This scoping is done by defining the following points of interest:

- Who will perform the monitoring.
- The level on which the monitoring will be conducted. So component, LRU (Line Replacement Unit), system level etc.
- How the monitoring will be conducted, which tools are being used, which processes will be used etc.
- The communication of the monitoring, how will the results be presented, how many times per year etc.

This chapter describes more in depth how the obsolescence monitoring is conducted, what the purpose of the monitoring is and what will be done with the monitoring (2.2.1.). Besides the current executed obsolescence monitoring, a method which calculates how well an organization is monitoring their parts is explained (2.2.2.).

2.2.1. Planned periodic obsolescence monitoring

To have a complete overview of the status of a product and to contribute to standard product management, periodically a standard analysis is made for the active products portfolio. This analysis is generally made by matching the BOM with huge databases, which provide information on the state of the components. This information could be either that the part is obsolete or not (Romero Rojo, 2010). Another purpose of such an analysis could be the upcoming production of a new batch of the product or spares. The goal-oriented interpretation of product-specific obsolescence data combined with stock on obsolete items regularly gives a status update.

To ensure the notice of obsolescence to be on time to take proper measures, the obsolescence monitoring should be conducted at a frequency which is appropriate for a company and corresponds to the outcomes of the risk assessment.

These findings are described as triggers, which reach the organization. Product discontinuance notices (PDN), End-of-life notices (EOL), Product change notices (PCN) and Lifetime Buy (LTB) notifications are triggers which need to be followed up in time in order to analyze resolution alternatives. These triggers should be evaluated and if necessary the change process should start. This process is explained in chapter 2.3.

Another form of monitoring is direct contact monitoring (IEC62402, 2019). Instead of triggers that reach a company, the company has direct contact with the manufacturers. This contact could be contractually agreed if applicable to ensure the update to be complete and in time. The data which should be in the update are updated item support information, upcoming releases and related items, assessment of manufacturer stability and planned item upgrades.

2.2.2. Health monitoring

Health monitoring measures the fraction of parts which are "under control", thus are either monitored properly or do not need monitoring (Bartels et al., (2012)). The health monitoring represents the degree to which the organization has implemented a proactive approach towards obsolescence monitoring. The health monitoring can be calculated as follows:

$$PI = 100 * \frac{(G + Y1)}{(G + Y1 + R + Y2 + B)}$$

PI is the fraction of parts which are under control.
G represents the situation where there are two suppliers or more.
Y1 means that there is one supplier and a funded solution is present.
Y2 represent the situation in which there is one supplier but no funded solution present.
R represent the obsolete components with no solution.
B means that the status is unknown.

Besides the result of the PI, the other attributes which need to be filled in within the equation are binary numbers, ranking either zero or one. Ranking one means that the described situation is reached, zero means that the current situation does not coincide with the described situation.

To indicate how well an organization scores on the health monitoring, the following scores of PI have been determined by Bartels et al. (2012):

100 – 90	means that the organization performs optimal.
89 – 80	indicates that the organization is performing solid but there is room for improvement.
79 – 70	represents the situation that there is probably no solution on how to research the unknown status parts yet.
69 – 55	indicates that the process of proactive obsolescence monitoring has just started and measures should be taken to have a solid monitoring process present at the organization.
55	or less means that potentially catastrophically problems could occur.

2.3. Solutions

To react to an obsolescence issue, a resolution is used to mitigate the consequences of the issue. For an obsolescence concern a proactive mitigation method can be used. There are two approaches to the issue of obsolescence, a reactive and a proactive approach. The solution is chosen by analysing multiple factors, where the proactive approach analyses both reactive and proactive solutions. The reactive approach only considers reactive solutions. The factors which have influence on the decision are the probability of obsolescence, the impact on the product/system and the costs, which have been described in chapter 2.1 about risk assessment. Within this chapter the resolution strategies (2.3.1) and mitigation methods which are present (2.3.2.), are elaborated on.

2.3.1. Reactive resolution strategies

The reactive approach is the approach where a solution will only be provided after an obsolescence issue has emerged. The solution following a reactive approach will be a strategy where the consequences of the obsolescence issue are only mitigated. In paragraph 2.1.5 is explained that a reactive obsolescence resolution strategy is used when the risk of obsolescence is low, as the resolution strategies which can be used in this situation are less expensive in comparison to implementing a proactive mitigation method.

Explanation

To understand what the common resolutions and their particular considerations (IEC62402, 2019) are, a short explanation is given below. The explanation on the resolution strategies is derived from the IEC62402 (2019) standard, which should be the standard in the terminology.

Existing stock: The conduct of an item search to find an alternate source for the same item from stock that has been purchased from the manufacturer.

LTB (Last Time Buy): Following the description of the IEC, the current term of an LTB, or Last Time Buy, is LNB, the Life of Need Buy. An LNB is the procurement of sub items sufficient to support the item throughout its life cycle, or until the next planned upgrade.

Reclamation (Cannibalisation): This is the process of re-using items or components from other systems or products which are unserviceable (Romero Rojo, 2010); each reclaimed item should be checked to see if requalification is necessary (IEC62402, 2019).

Equivalent: These are items which are functionally, parametrically and technically interchangeable with the obsolete item. This includes minor software security updates, which are backwards compatible. Minor testing may be required to validate the use of an equivalent item.

Alternative: These are items that provide a limited parametric match, but which, after consultation with the person or organization responsible for the design are an acceptable application specific alternative for the obsolete item. This includes major software updates or changes (upgrades) that may result in use of software provided by a different manufacturer, running on a different platform or operating environment, and providing similar, but not identical functionality. Major testing may be required to validate the use of an alternative item.

Authorised aftermarket: Items are produced through emulation, reverse-engineering, or design change, that match the manufacturer's specifications and satisfy customer/end user needs without violating the manufacturer's intellectual property rights, conducted by an organization. These items can also be obtained from traders.

Emulation: This solution is a process that produces an equivalent item using either the original specification or from characteristics gained from an in-depth examination of a working example of the item to be replaced. In theory this solution could be applied by Thales.

Design change: A new design is done to resolve obsolescence by means of updating or upgrading the item, as well as enabling the use of newer items. A design change should be considered when it is not possible, practical, or cost effective to procure or emulate a substitute item. There are two levels of design change:

- **Minor design change**, for example: A subcomponent
- **Major design change,** for example: An LRU.

Costs and probability of reactive solutions

The base non-recurring costs of the resolution strategies used in a reactive obsolescence management strategy can be found in figure 9, which are the result of research including broad expert opinions (Romero Rojo, 2010). From this figure can be concluded that the costs for the major redesign are substantial higher in comparison to the other types of reactive solutions. These costs are high as the new item needs to be engineered, tested and implemented (Romero Rojo et al., 2011).

Base Non-Recurring Resolution cost	
Solution	**Costs**
Existing Stock	£300
Last Time Buy	£2,000
Reclamation	£1,700
Equivalent	£3,500
Alternative	£3,500
Authorized Aftermarket	£4,500
Emulation	£26,700
Minor Redesign	£21,300
Major Redesign	£100,000

Figure 9, Base Non-recurring cost reactive resolution strategies

	OM1	OM2	OM3	OM4	OM5
Existing stock	16.1%	28.8%	25.3%	24.6%	22.6%
LTB	12.7%	21.3%	27.0%	23.0%	23.9%
Reclamation	25.5%	2.2%	0.5%	2.1%	2.0%
Equivalent	6.9%	9.1%	8.2%	11.0%	12.0%
Alternative	9.9%	11.8%	13.2%	14.0%	15.0%
Authorised aftermarket	6.0%	8.0%	10.0%	12.0%	14.0%
Emulation	1.0%	1.5%	2.0%	1.8%	1.5%
Minor redesign	9.3%	8.0%	7.0%	6.0%	5.0%
Major redesign	12.6%	9.3%	6.8%	5.5%	4.0%
Average costs	£16,442	£13,046	£10,648	£9,243	£7,620

Figure 10, Distribution of using reactive resolution strategies.

Figure 10 represents the distribution of using each obsolescence reactive solution per obsolescence management level. These levels are explained in paragraph 1.3. Both figures 9 and 10 are a representation of obsolescence resolutions in general in the defence sector (Romero Rojo et al., 2011). £14,580.90 of the total average of £16,442 costs when operating on level 1 are generated by implementing a minor or major redesign. Operating on level 5 generates an average of £5,065 of the total average of £7,620

To conclude, on average per obsolescence reactive resolution type, the costs for emulation and a minor or major redesign are relatively high. By investing in a proactive OM strategy, where the desired situation is to reach level 5, a decrease in average costs can be achieved as the probability to use a minor or major redesign decreases per OM level.

2.3.2. Proactive mitigation methods

The following methods are the methods which could be used when using a proactive obsolescence management strategy, following the IEC62402 (2019) standard.

Technology transparency: This method is a methodology which is based on the specification of interfaces (IEC62402, 2019). This term is also referred to as hardware independent (North Atlantic Treaty Organization (NATO), 2001), which means that the technology can still be used where it is possible that every component can still be substituted (Seuren, 2018). A condition for this method is that the form, fit and function is maintained (IEC62402, 2019), which represents the criteria on the design that is required when the part is used as a replacement part (Bartels et al., 2012).

Design considerations: If obsolescence has been addressed at the design stage of the parts the costs in the rest of the lifecycle concerning obsolescence will drop. For instance, regulations should be taken into account. If future restrictions causes the part to become obsolete, the design of the part should be altered to comply to the regulations (Schallmo, 2012). Another example could be the indication of a technology which is highly likeable of becoming obsolete in the near future.

Partnering agreements with suppliers: If suppliers are contractually bound to keep producing the parts, the risk of obsolescence has been mitigated. Only in case of a bankruptcy is obsolescence inevitable if there are no other suppliers (Romero Rojo et al., 2009).

Design refreshment planning: By determining optimal points within the life cycle of a product for an update of parts and/or replacement of obsolete items, the costs could be mitigated. These optimal points are referred to as "just in time" moments, which are the moments immediately before the next production (Zheng et al., 2015). By planning a design refreshment, long term mitigation methods can be implemented as the planning ensures a time period without the loss of potential operating hours.

Risk Mitigation Buy (RMB): The procurement of items sufficient to support the product throughout its life cycle, or until the next planned technology upgrade (JSP886) . Penalty and disposal costs, inventory and procurement are the factors related to this proactive solution approach. (Venkatesan, 2014). This is also referred to as a Life of Need Buy, or an LNB.

3. Actual situation

3.1. Risk Assessment

3.1.1. Thales

Thales is currently working to implement the same risk assessment as is described in chapter 2.1 and is currently in the progress of having the process completely aligned with the proactive OM strategy. However, the risk assessment until now was mostly based on an expert opinion of the obsolescence engineers instead of plain numbers only. This is due to the fact that the result of the risk assessment is mostly a medium risk level, which is elaborated more on in chapter 5.2.2.

The obsolescence risk following the literature review is determined by the probability and the impact of the obsolescence. The costs aspect, as is mentioned as one of the three criteria to assess when conducting a risk assessment, is not integrated in this risk analysis. Thales integrated the costs aspect as a part of the risk assessment.. When the component is already obsolete, a medium or a high supply risk level is assessed. The matrix which resembles the probability of obsolescence, as is described in step 4 of the risk assessment (chapter 2.1.4), could be extended in the assessment of Thales. The consumption rate versus the level of stock is used in the impact of obsolescence. In this case, Thales, focuses on years till end of stock.

3.1.2. DMI

Concerning the systems which Thales delivers at DMI, a risk assessment is not made by DMI. This is not necessary, as Thales is the design authority who reports obsolescence concerns. Reporting by Thales is done according to contracts, which leads to different ways of communication within multiple contracts

3.1.3. Bottlenecks

The risk assessment currently conducted by Thales results in a medium risk level in approximately 95% of the time. The risk assessment is based on an expert opinion where only 6 attributes are used in the determination of the level of risk. These attributes are the costs of solving obsolescence, YTEOL, number of manufacturers, level of available stock, the criticality of the component for the functioning of the product and the date, used to determine the impact. By integrating more attributes in the calculation of the level of risk, the accuracy of the risk assessment could increase. Low and high levels of obsolescence risk will be determined more frequently and reactive or proactive solutions can be implemented at an earlier stage. As an example, figure 11 (Appendix 1) represents the attributes which Seuren (2018) used to conduct a model on how to assess the risk of obsolescence.

3.2. Obsolescence monitoring

3.2.1. Thales

Thales is currently working with the described form of obsolescence monitoring. Approximately eighty percent of the data which is needed for the monitoring is gathered from an external database and the database from Thales in France, information provided by the own engineers and the present database at Thales Hengelo. Between the external database and the database from Thales in France a big overlap could occur. The remaining twenty percent of the data is requested from the suppliers of Thales.

Furthermore, customer-specific obsolescence reports are created and delivered according to agreed contracts. The customer obsolescence report elaborates on detected obsolescence, its severity and the impact, and already taken and planned corrective obsolescence actions. This means, e.g. that if a component is no longer available, or its non-availability is imminent, and a Form, Fit and Function replacement of the component is not available, it will be reported as obsolete.

On average fifteen triggers are reported at Thales per week, which affect around twenty products. Triggers are notices that a component will be obsolete in a short period of time. On this part of proactive obsolescence management, Thales is on the level of a solid performance. The results of this process are stored in the OMIS (Obsolescence Monitoring Information System) and configuration management systems. Decisions on the resolution are communicated with the customer in case of costs for DMI, changes in the availability of spares or if there is an impact on maintenance.

The reviewing of the obsolescence monitoring was performed once a year in the beginning of the implementation, but soon was discovered that this period was too long. In the actual situation Thales reviews the obsolescence monitoring every 3 to 6 months. In the first initiation of this contract it was decided that Thales would deliver a yearly report to DMI. After both companies experienced this time span to be too long, the subject of obsolescence was added to the agenda of the telecom meeting, which takes place once a month, where the obsolescence triggers are presented. After the resolution decision was made, both companies agreed that DMI would specify the need of components and LRU’s, Line Replacement Units, and Thales would investigate the available quantity and propose a resolution to the issue. A big rapport is sent to DMI 1 times a year. In this report, the obsolescence issues and concerns are stated, as well as the solutions.

3.2.2. DMI

DMI experiences the communication as rather late, which results in DMI to experience the time frame in which to decide as too short. With the current amount of updates DMI is satisfied, however the organization is not content with the information which is given. DMI recognizes that the triggers are mentioned, but there were several times when the follow-up projects of actions are not elaborated on enough, which leaves DMI uncertain about what is to happen next. To gain more insight in what is going to happen, the decision moments within the life cycle of a component should be identified beforehand and DMI should know when these moments are, in order for the organization to make sure there is enough budget to make a decision. It is difficult for DMI to make a decision ad hoc when a trigger reaches them, because the budget is predetermined at the beginning of the year. The money which is not spent immediately will be withdrawn from the budget.

3.2.3. Bottlenecks

The bottlenecks which are identified are not within the execution of the monitoring itself, but within the communication of the outcomes from Thales to DMI. Thales currently does not mention every obsolescence issue which they encounter to DMI, as it would be a long list and could potentially cause a disturbance on the side of DMI. Several issues will be take care of in Thales own supply chain and can be handled with a Form Fit Function component replacement strategy. With this method of communicating DMI thinks that Thales only has a reactive obsolescence strategy to all issues, although Thales explained otherwise several times in more detail. Thales does have an incomplete proactive obsolescence strategy and as problems follow which do not need a decision from DMI, DMI will not receive any information on this matter. This causes a communication problem.

Another communication problem between Thales and DMI is identified in the update which Thales gives to DMI. The mutual follow up plan has not mentioned or not elaborated on enough a couple of times, a roadmap is missing, which leads to DMI being uncertain about what will happen next. Because this is uncertain, DMI cannot budget for a possible decision which needs to be taken and when the decision point is reached, DMI is unable to take a decision due to budget restrictions.

3.3. Solutions

3.3.1. Thales

As can be seen in figure 11, the current assessment of the resolution strategy at Thales is visualized when a trigger concerning the end of life for a component arrives at Thales. This visualization is the simplified representation of the actual resolution strategy. As a first step in solving an obsolescence issue, Thales will investigate whether or not an equivalent or alternative item can be found. This type of resolution is relatively cheap as can be seen in figure 11, and makes sure the system stays operational as no extra steps are needed. This type of resolution is only relatively cheap if no requalification is needed. Requalification is needed when an alternate component is not exactly the same as the original component and needs to be requalified. This requalification assures that the design with the new component works as good as the design with the original component. Requalification is mostly executed because of regulations made by the government, to assure the safety of the machine or system (Bartels et al., 2012). The costs of a requalification depends on the level of integration. A small or medium level increases the costs by a factor of 1.36, a large level of integration increases the costs by a factor 2.46 and a very large level increases the costs by a factor 3.58. A small level of integration relates to components that standalone and a very large level are components that are fully integrated within the product (Romero Rojo, 2010).

After the option of choosing an alternative or equivalent item, the option of a life time buy is used, if possible. This is determined after an impact analysis is made. This impact analysis consists of an estimation of the expected new products and of the estimation of spare parts and repairs for the installed base and the expected new products. After this analysis is conducted a decision has to be made whether or not it is beneficial for Thales or the end user. If it is approved, an order will be made at the supplier. If it is not approved, Thales will move on in the same decision tree as where a trigger is identified from the obsolescence monitoring.

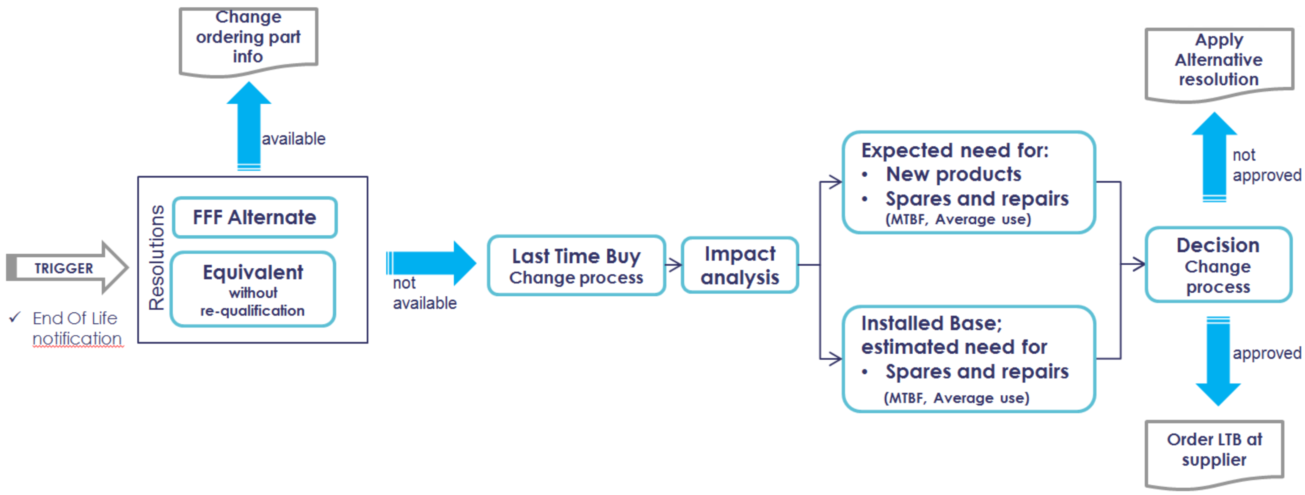

Figure 11, Flowchart of the decision for the resolution strategy LTB based on a trigger of EOL

Following from the monitoring, as is explained in chapter 3.2, a trigger could be identified at Thales which needs a solution, as can be seen in figure 12. The current level of stock is directly checked after the trigger is identified. Same as with an EOL trigger, first the resolution strategies of an alternate or equivalent part are considered. If no alternative or equivalent is available, Thales will investigate whether an authorised aftermarket buy or an additional buy is available. In the case of an EOL trigger which cannot be solved by the solutions presented in figure 11, this point in the flowchart is the starting point for finding the alternative solution as depicted on the right side of figure 12.

If neither one of the previous mentioned resolution strategies is available, first the option of a minor redesign will be considered. When there is no other choice, a major redesign is necessary to solve the obsolescence issue. The solution will be discussed with DMI, who makes the final decision. The option of an emulation is at this point considered by Thales after the option of a minor redesign, although is it not present in the flowchart. This option is rarely used, following from an expert opinion less than in 1 percent of the solutions. This is because Thales would be responsible to produce the part, which brings along extra costs such as start-up costs, training of the employees etc. The reclamation resolution is not considered at Thales, as this is a resolution strategy which should be executed by the end user. Only when the major redesign would be the other solution, a reclamation is considered, as it would become a second-hand part after a reclamation. When the major redesign would be too expensive, the reclamation solution will be chosen. This solution, same as the emulation solution, is only used less than 1 percent.

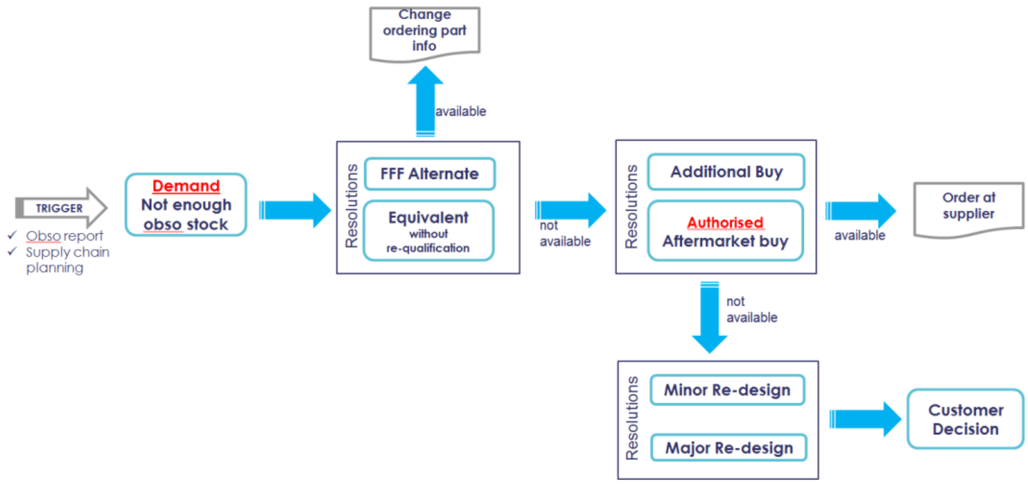

Figure 12, Flowchart of the decision for a resolution strategy based on a trigger from the obsolescence monitoring

Thales is currently researching whether the mitigation strategies, as described in paragraph 2.3.2, would be beneficial. Implementing one or several mitigation methods requires an investment. However, in the current contract between Thales and DMI the distinction which company is responsible for these costs is not specified. More information on the changing relationship between the companies can be found in paragraph 4.2.4. The agreement with suppliers, on whether the supplier will remain to produce the required component is something in which Thales is currently investing. By making new contracts with subcontractors where this subject is integrated, as well as more clarity what the supplier wants to achieve is the first mitigation option where Thales is focussing on. The need for more insight in the supply chain is further elaborated on in paragraph 4.2.4.

3.3.2. DMI

In the current situation DMI only reacts to an obsolescence occurrence, which is communicated by Thales. In the current situation the installation managers at DMI cannot follow an obsolescence policy because there is none. Instead, these installation managers make individual agreements with the supplier, where in consultation with the supplier a resolution strategy is chosen. This is done by following a general roadmap. However, the installation managers need to make decisions depending on the situation and the expert experience. By acting in this way, DMI is not capable of implementing a proactive obsolescence management strategy in any way, as a more detailed guideline on how to handle obsolescence is missing, especially before the obsolescence is identified.

3.3.3. Bottlenecks

The costs for the different resolution strategies have not always been exactly calculated because they differ case by case, which could be a substantiated argument for the decision of a resolution strategy. Paragraph 2.2.1. offers an overview on the average costs in the defence sector but such calculations of the resolution strategies is missing at Thales right now. These costs are now estimated by investigating what the costs were in the previously obsolescence issues and it is estimated by relying on an expert opinion. As the costs cannot always be calculated precisely upfront, exact costs for different situations cannot always be given.

Thales currently has developed an OMP, an Obsolescence Management Plan. Within this plan the proactive solutions, which are explained in chapter 2.3, are integrated. However, in contrast to the resolution strategies, a flow chart on the decision on which solution to use, and when, is missing right now. This flowchart is missing because an overview on the costs of the mitigation methods is missing. Literature exists about mitigation methods but at Thales there has not been research on which methods are proven to mitigate the risk of obsolescence and are cost efficient. If these costs are identified, Thales and DMI should investigate what costs each company is responsible for. This fact is unknown at the moment.

A detailed obsolescence policy is missing at DMI. There is no flowchart for what action to take if an obsolescence issue or concern is presented at DMI. The actions of the installation managers are now based on a general roadmap, the situation and the expert experience. As the obsolescence issues and concerns are identified by the obsolescence monitoring, the time between the message with a proposal for the solution and the decision time is short. DMI needs to budget for obsolescence and is unable to agree with the proposal if there is insufficient budget for the proposal.

At the moment of the design of a component, obsolescence is an even more important factor which should be thought of. At this moment in time, many characteristics of a component are taken into account for identification of possible obsolescence concerns. When more characteristics are known, possibly a more accurate future forecast and solution for specific situations can be identified on LRU, Line Replacement Unit, level.

4. Desired situation

Within this chapter the bottlenecks, which are identified in the previous chapter, will be reviewed and the possible solutions will be discussed. First the bottlenecks within the logistical obsolescence domain will be discussed and which follow up projects should resolve the bottlenecks (4.1). Besides the logistical obsolescence the knowledge gap will be elaborated on (4.2). In this paragraph the other subjects of the obsolescence landscape are briefly explained and follow up projects are identified.

4.1. Logistical obsolescence

4.1.1. Thales

The bottlenecks which are identified for Thales, are within the calculations of various aspects and a flowchart of the proactive solutions.

Calculations

The attributes which are used to determine the level of risk (Chapter 3.1) could be weighted more or less. However, in the current risk calculation no weights are given to the various criteria. Additional to the new implementation of the risk assessment, a research can to be conducted on acquiring the information needed for the calculation of the risk. The calculation of the risk can be made by using the method described in this chapter, but Seuren (2018) made a model in which another method is described to calculate the risk of obsolescence. Within this method, Seuren (2018) describes that the subjects, which altogether form the criteria, have weights assigned to them in order to distinguish the importance towards obsolescence in relation to the other subjects.

Thales already considered to use this model but concluded that there are too many attributes which need to be considered. Commissioned by RH Marine, Krol (2020) analysed the model and altered it to make it applicable for RH Marine, where multiple attributes where taken out of the model. The model of Krol evaluates 26 attributes, where the outcomes of the tool represents the reality in most cases, according to experts. A similar study needs to be conducted at Thales to integrate the model. This leads to a follow up project where a research will be conducted how the model of Seuren can be implemented within the risk assessment of Thales and which attributes should be used.

The costs for the solutions for obsolescence (Chapter 2.3) are not always calculated at this moment at Thales, so an overview of the costs is missing for both the reactive resolution strategies and the proactive mitigation methods. Sometimes the prices of the solutions are delivered to DMI by price brackets. These price brackets were presented to DMI as several solutions had to be implemented but the exact costs for all separate solutions was not clear. The exact calculation would have been costly for DMI so price brackets were presented to give an indication of the costs but to prevent making extra costs. As only rough costs for all solutions can be identified, price cannot always be avoided.

The follow up project on a strategy for decisions on selecting the right resolution is already conducted at Thales. Level 5 of the obsolescence management proactiveness strategy (paragraph 1.4.1.) describes that obsolescence should be addressed at the design phase. The bottleneck on which characteristics are possible obsolescence concerns (paragraph 3.3.3.) should be researched in a follow up project.

Flowchart proactive solutions

Because the costs of the proactive mitigation methods are not exactly known, an overview on which proactive solution to implement is missing, due to two reasons. First the prices of the proactive solutions need to be calculated, as is explained in the previous paragraph. Second, a method on how to assign the appropriate proactive solution is not constructed. As no research has been conducted on implementing proactive solutions within the network, a plan is missing, which ensures that a more cost efficient strategy has been considered. After the costs of the proactive solutions are calculated, this plan should be composed. A research needs to be conducted to compose this plan.

4.1.2. DMI

The bottleneck for DMI consists of not having an extensive obsolescence policy. At the moment, a roadmap is present for the installation managers at DMI, as is mentioned in chapter 3.3. A subject of an obsolescence policy, as identified by DMI, would be to add time brackets for making a decision. The time brackets DMI wants to assign between the notification from Thales and the decision deadline depend on the situation, where the urgency of obtaining a certain component is the key factor of determining these time brackets.

By restricting the decision time, DMI would prevent that the solution, as will be proposed by Thales, will become more expensive or the solution will become infeasible to execute. These time brackets should be determined by a part of a research, which should be in collaboration with Thales. Within this research, the subjects which should be covered in an obsolescence policy by DMI, must be determined and a flowchart or detailed roadmap must be made.

4.1.3. Communication

The following bottlenecks are identified within the communication between the companies of the network. As the relationship between the client and the company that manages obsolescence is changing, the way of communicating is another subject which should be adapted to the changing situation.

At this moment, DMI is missing an overview on which obsolescence issues are solved. Thales proposed to provide an overview in the meetings with DMI where the top five or top 10 obsolescence concerns or issues are discussed. These concerns or issues could be suppliers who go suddenly bankrupt, skills obsolescence, hardware obsolescence etc. These subjects are important to discuss with DMI during the meetings to provide a complete overview. More on the relationship between a customer and the organization that manages obsolescence can be found in paragraph 4.2.4.

4.2. Knowledge gap – Obsolescence landscape

As is described in chapter 1, about the obsolescence landscape, the other subjects besides the logistical obsolescence should be identified. Within this chapter the subjects will be shortly introduced, as well as a proposal on which further research is needed for the separate subjects.

4.2.1. Functional obsolescence

Functional obsolescence means that that the subsystem or product is still operating as it was designed to do and can still be supported and produced as intended. However, either the customer has increased the requirements, or the subsystem or part cannot meet the functional demand in terms of performance anymore. The customer could choose to increase the requirements because the technology, on which the subsystem or part runs, has been upgraded or updated.

Upgraded means that there is improved hardware or software with new functionality available.
Updated represents the situation where the existing software has been improved so errors or bugs are eliminated.

As this world is rapidly changing, which has resulted in new warfare domains as the cyber and space threats the RNLN (user) is facing, Thales and DMO should keep pace with the developments in technology in these domains. However, not only the technology development in the new warfare domains is rapidly changing, technology in all domains is improving and enhancing at a pace which cannot be supported by the current obsolescence approach of the network. This is regarded as functional obsolescence by the network, on which only a small amount of literature can be found. The found literature exclusively describes the mitigation method of an technology refreshment plan, which is explained in Appendix 2.

Further research direction

One of the solutions that Thales considers to keep pace with the changing customer requirements and decrease in system capabilities over the life cycle, is to increase the number of system upgrades, and to plan upgrades in smaller steps. More information on upgrades and updates can be found in Appendix 2. However, questions arise on how frequent these upgrades should be implemented. The questions which belong to this subject, and thus require further research, are:

- What is the impact on maintenance and service logistics (e.g. spare part supply) for DMI and Thales?
- What are the consequences of more frequent upgrades for the RNLN in terms of less downtime and better capabilities, etc.?
- What are the pros and cons of more frequent and planned upgrades related to Obsolescence Management?
- Which costs are implied when increasing the number of system upgrades?

To start the research on answering these questions, the case of the Spanish navy frigate F-100 and Navantia, as is described by Sols, Romero & Cloutier (2011), should be investigated, as a similar solution could be implemented at the RNLN and its suppliers. Another starting point of this research could be the research of resilience. A definition of resilience has been described by Sols (2014): “Resilience is the ability of systems to mitigate the severity and likelihood of failures or losses, as well as to be able to adapt to changing needs and conditions, by responding appropriately.” (p. 26). More information can be found in appendix 2.

4.2.2. Software obsolescence

A distinction in obsolescence could be made between hardware and software obsolescence. Software obsolescence means that software is no longer supported. Making this distinction is a complex process, as both hardware and software obsolescence could influence the other form of obsolescence. The different types of software obsolescence are explained and a link to hardware/software, logistical and technological obsolescence is made. After this link is made, the domains in which these types of software obsolescence occur are discussed. To conclude, mitigation methods for software obsolescence are proposed in appendix 2.

Types of software obsolescence

Software obsolescence can be divided in four areas in which the obsolescence could occur.
The first area is media software. This type of software obsolescence represents the storage of software information. The formats and data storage materials which a company uses could also become obsolete, which could as a consequence have that the software information which is stored within the formats or storage materials could not be accessed anymore.

The second area of software obsolescence is the skills obsolescence. In all areas of obsolescence, a skill could become obsolete as knowledge is lost, which could also befall within a software obsolescence issue. New programmers are likely to learn only the new coding language, as they will not be working with the old one. However, as the older programmers retire, knowledge about the old coding language could be lost. If an organization did not upgrade the software of all of their systems to the new coding language, software obsolescence in the area of skills will most likely occur.

The third area consists of the problems at the development platform and tooling. The software which has been developed within the organization itself could also become obsolete, where no solutions outside of the organization can be found as it is made for the organization specific. Integration problems between different departments could also be the cause of software obsolescence within this area.

The fourth and most common area of software obsolescence is the COTS software obsolescence, the Customer Of The Shelf software obsolescence. This type of software obsolescence represents the inclusion of software packages of (COTS) suppliers into the in-house developed software and the associated licenses of this COTS software. The occurrence of this type of software obsolescence is due to the decision of the supplier of the software to stop supporting the release of the software and/or continue with new software products. The date of the decision is hard to predict for an organization which leads to a difficulty in preventing the loss due to this type of software obsolescence. (Romero Rojo F. , et al., 2010)

Areas of software obsolescence and root causes

The areas of software obsolescence as has been described can be divided amongst logistical, hardware/software and technological software obsolescence. By investigating which root causes apply to the situation of software obsolescence, a forecast about the lifetime of each relevant part of a software type could be made. Various methods of calculating the forecast are present but will not be discussed within this thesis as it is outside the scope.

The first area, media software, is directly related to logistical obsolescence. As this type is specified as parts which are unavailable or inaccessible, the last part of this explanation is coherent to the explanation of logistical software obsolescence as has been described by Bartels et al. (2012): “The ability to access the software is limited or terminates”.

The second area, which is skills obsolescence, could be linked with hardware/software obsolescence. This type of software obsolescence contains the issues which arise between software and hardware, as when one type experience obsolescence the other type is directly affected. This is due to the fact that hardware needs software to run and software should support the hardware for which it is coded. Following from this issue the system could have a limited performance or could not perform at all (Bartels et al., 2012).

The third and fourth area of software obsolescence, the in-house software and COTS software obsolescence, relate to technological software obsolescence, which consists of 2 parts. The first subject includes the issues concerning purchasing such as being unable to purchase a legal copy of the required software or when a supplier does not offer an extension of a software license. The second part represents the situation when there is no option of technical support anymore or when updates for the software are being discontinued. This second part can be linked with the explanation of both areas.

Domain

The types of software obsolescence, as were described in the previous chapter, describe the nature of the software obsolescence and what the consequences of the obsolescence issue could be. The types of obsolescence all occur somewhere in the range visualized in figure 17. The numbers one to four represent the areas in which the types of software obsolescence could occur. *For example, the Hardware/Software obsolescence mechanism of the COTS software obsolescence* is located at number 4, which represents the relationship between software and hardware obsolescence. A complete research on how the types of software obsolescence and the layers of a system, as depicted in figure 17, are connected is missing at the moment.

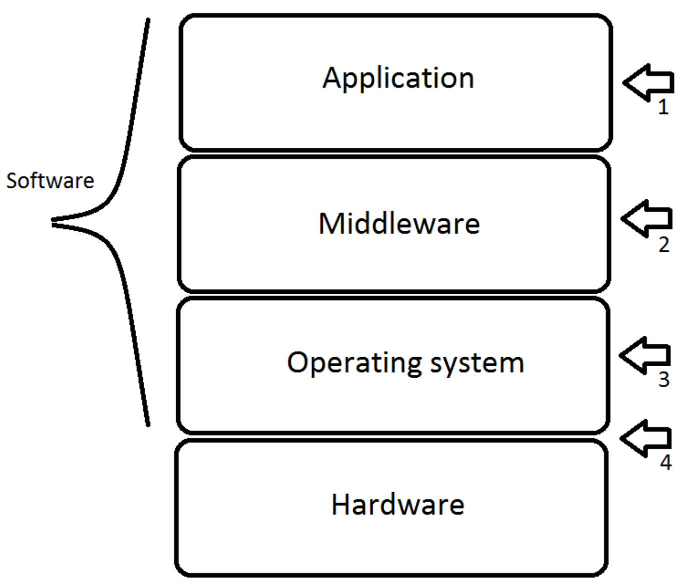

Figure 13, The software and hardware layers within a system

Further research direction

As is stated by Rojo (2010), there is only a small amount of information on software obsolescence. To gain an understanding of this subject within the network, the following three recommendations should be the starting point for further research on this subject. The first recommendation is that a research should be conducted on how the layers in figure 15 are connected. After this research has been conducted, the current status of the software obsolescence at the four numbers, which make up the software domain, as depicted in figure 13, should be researched.

The second recommendation on further research is to investigate what the costs of solving software obsolescence are and what the costs of the mitigation methods are. Similar to logistical obsolescence, these costs are not yet known within the network, whereas DMI would like a complete overview of the possible costs for obsolescence. This is a part of the life cycle costs, which will be elaborated more on in paragraph 4.2.3.

The third recommendation is to construct a flowchart for the mitigation methods for software obsolescence. After the costs have been calculated, following the previous recommendation, the mitigation methods could be ranked from least costly to most expensive which should be visualized in a flowchart. Besides this flowchart, other possible mitigation methods should be searched for within the literature on the subject of software obsolescence.

4.2.3. Approach to calculate the capabilities of OEM's

The RNLN buys systems which should operate for 30 years and as part of the purchasing process, the RNLN wants to receive an impression of what the life cycle costs will be. Especially the costs for a obsolescence resolution can become very high, because sometimes a costly redesign is needed. The RNLN wants to prevent this, and that is why they want to have an insight on what they can expect from their OEMs in terms of obsolescence management. A first step within this approach is to determine on which level all the OEMs are in terms of obsolescence readiness levels, as is depicted in paragraph 1.4.1, figure 5. By gaining insight on which level all the OEMs are, the relevant OEM can identify which steps and actions should be executed to improve to the next readiness level.

The second step will be for the OEMs to provide the RNLN with the lifetime buy costs of the relevant products. The life cycle costs can be calculated according to the attributes proposed by Sandborn (2013), as is depicted in figure 14. This cost estimation could also be made by using a commercial tool, such as *TruePlanning* offered by Price or *Seer* by Galorath. However, it is difficult for the OEMs to calculate these costs. For example, as is mentioned before in this thesis, the costs about the resolution strategies and mitigation methods, for various types of obsolescence, are sometimes not exactly calculated but only roughly estimated at Thales.

Even when these costs are calculated, it is hard to estimate the lifetime buy costs, as various factors could have an influence on the life cycle costs. For example, the costs of a redesign of a component need to be calculated, but also of the requalification of the component and the quantity of the components. Suppliers who decide to stop producing a certain part of system, suppliers whom go bankrupt or a client who changes its wishes concerning the requirements of a part or system, cannot be accounted for when calculating the lifetime buy costs.

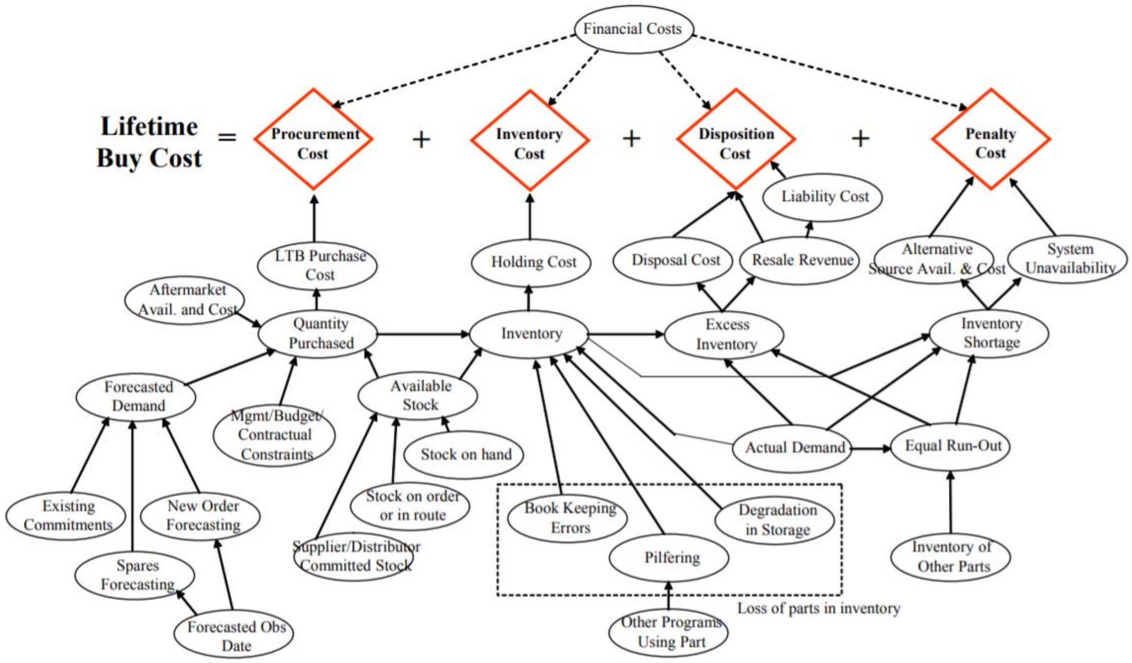

Figure 14, Lifetime Buy Cost, Sandborn 2013

4.2.4. Relationship between Asset Management, Product Management and Obsolescence Management

As is explained by Rojo (2010), the relationship between an OEM and the customer is changing more and more, concerning obsolescence management. Before, the OEM just handled the obsolescence and the customer paid for it. As these costs can become real high, more information about the current situation of obsolescence management is required by the customer, as is explained in the previous chapter. As a result of this requirement, the relationship between the asset management, product management and obsolescence management needs to be redefined, as it is outdated.

The first step is to identify how the current state of obsolescence management is within both Thales (product design authority applying Product Management) and DMI (Asset Owner and Asset maintainer applying Asset Management). An important part of the current state is the information stream between the companies but also within the companies themselves. Additionally to this part is the responsibility which every person has in the obsolescence landscape. When these 2 parts are identified a conclusion can be made whether this needs further research or whether this part is sufficient to support an environment to implement the proactive OM strategy.

This information stream between the companies refers to the current state of the products and parts, whether or not they are obsolete or if they have a potential of becoming obsolete. Next to the enhanced insight, DMI would like to have more influence in the complete supply chain, and would like to be able to make changes. The prices which will belong to the decision will depend on the deadline DMI sets for the proposed change. When the change should be completed and/or implemented in a short period of time, a higher price will be paid in contrast to when Thales, or a supplier of Thales, would have a larger time span to complete or implement the required change proposed by DMI. Following from the theoretical framework, the health monitoring could be an added value to provide an overview for DMI. A research whether the result of the health monitoring outweighs the time which needs to be invested in the health monitoring should conclude if the health monitoring is of added value.

At this moment there exists a gap between Thales and several suppliers on the subjects of forecasting and planning. An example of this gap is when certain products can only be used for around five years, but the contractor has not investigated which possible problems could occur and which possible solutions there are to solve these problems. These contractors do not have a plan on what the organization of these contractors wants to achieve in the coming ten years and how the organization will look like in ten years. This is a problem when DMI wants to have an overview of the complete supply chain. Thales is currently trying have these contractors to make roadmaps for the coming years by making new contracts in which this topic is integrated.

5. Validation

Now that the bottlenecks and follow up projects are identified, it is important that this information is validated with the expert opinions. The validation is needed for both the subjects within the obsolescence landscape as for the bottlenecks and follow up projects of the logistical obsolescence subject. The subjects of the obsolescence landscape are first validated by the experts of the Marconi project and secondly validated by an expert panel consisting of employees of Thales. These employees of Thales will also validate the findings within the logistical obsolescence domain.

Within the complete validation, the subjects will be ranked in order of importance on whether a follow up project is needed. After these validations, 2 ranking methods are shortly introduced, where an excel sheet is conducted in which these ranking methods can be filled in for the subjects within the obsolescence landscape.

5.1. Marconi project meeting

On the 21st of January, the meeting of the Marconi project took place, where Boskalis, RH Marine, DMI, Thales, Damen and IHC were represented. Next to the employees of the companies, some professors and students from the Universities of Maastricht, Eindhoven and Twente were present. The goal of this meeting was for the students to present their findings and to discuss on the topics raised by the students. After a short presentation about the findings of this thesis, the following two questions were discussed:

- Which subjects of the obsolescence landscape are the most important for you?
- Which subjects of the obsolescence landscape should have the highest priority to be investigated further?

The first conclusion which can be drawn from this discussion is that the OEM's of DMI first need to investigate what the current status of OM is at the companies. This corresponds with chapter 4.2.3, where the 5 levels of OM readiness are discussed. Besides the current status of the OM, the changing situation of OM between the OEM and the client is brought up as a subject, where a more elaborate description of this relationship is needed. This statement is directly related to chapter 4.2.4, where this bottleneck is further explained. According to the present members of the Marconi project, these 2 subjects are important to make the other subjects of the obsolescence landscape relevant.

Besides the representative of Boskalis, who states that logistical obsolescence is the most important subject for Boskalis, the other companies identify the logistical, functional and software obsolescence as equally important. Besides, the software obsolescence cannot be separated from the hardware obsolescence, as is explained in chapter 4.2.2. Following from a short discussion at the meeting the conclusion can be drawn that the software obsolescence is in fact essential as the other forms of obsolescence are influenced by software obsolescence. A suggestion given in the meeting is to combine the research of functional and software obsolescence, as they cannot be seen apart from one another and little information is known about both subjects.

5.2. Expert panel meeting Thales

On the 29th of January a meeting took place where four experts were present for a panel meeting about this research. Six experts were asked to attend and accepted the invitation, however due to circumstances two experts were absent. The goal of this meeting was to discuss the findings within the logistical obsolescence and to discuss the subjects of the obsolescence landscape. However, due to time limitations, only the findings within the logistical obsolescence were discussed.

An important aspect which followed from a discussion during the meeting was the follow up from this research and the previous researches in the subject of obsolescence. There is a plan to integrate the found knowledge, to gain an insight of what is supported by the researches and to present the added value of having the knowledge. However, at the moment this knowledge is unknown within the organisation.

5.2.1. Obsolescence landscape

As mentioned before, this subject was not discussed during the meeting itself, but is reviewed by the answers given by the experts on the questionnaire. This questionnaire is filled in by the four experts who were present at the meeting, and one expert who could not attend the meeting. From these questionnaires, a summarization is made, which is explained below.

The idea of reaching level five of the obsolescence readiness levels is not shared by the experts. The opinion that is not the most cost efficient to be on level five is shared by three experts. One expert expressed his concern that Thales first has to aim to have an organization where the reactive obsolescence solutions are investigated thoroughly, that the costs for these solutions are clear and how the different components relate to the obsolescence which occurs later in the life cycle. When this process is streamlined, the other subjects should be investigated in his opinion. He did however agree that the logistic obsolescence, especially the monitoring and solutions, and the relationship between asset management, product management and obsolescence management subject which belong in the obsolescence landscape.

The two present obsolescence engineers did not agree with the findings of this research. Their opinion is that the requirements from DMI, the theory on obsolescence and the way of working at Thales are not aligned and a plan on addressing all 3 opinions is missing. By comparing this statement to this research, the conclusion of the current situation is the same, but the questionnaire missed clarity for the obsolescence engineers. The other 2 experts agree with the proposed obsolescence landscape, and defined the relationship between asset management, product management and obsolescence management the most important subject, with the approach to calculate the capabilities of OEM's as the second most important subject.

5.2.2. Logistical obsolescence

The experts who were present at the meeting discussed whether the risk assessment is of added value to the obsolescence management. The results of a risk assessment are almost always that there is a medium risk of obsolescence. This would result in a monitoring plan for every component, which is true in the current situation. With the introduction of a model, which is adapted for Thales, this will not be a problem.

Another suggestion, which was suggested by an obsolescence engineer, was to create an impact matrix, similar to the probability matrix and obsolescence matrix (Chapter 2.1). The axes of this matrix would be the criticality of the component and the date. The criticality is based on the experience of the obsolescence engineer and the date resembles the date on when the (obsolete) stock will be running out. The amount of days until the impact will determine the high, medium and low level of obsolescence risk. What the exact amount of days should be for the different levels of risk should be discussed in an expert meeting.

The proactive mitigation method of an RMB could lead to multiple possible problems in the future according to the experts. With an RMB the organization buys enough stock to support the component for the complete life cycle of the component, or until the next upgrade, but there is no guarantee that the component will still work after laying for years in a warehouse. Another problem that could occur is the changings needs of the customer. When the customer decides that the product needs something else, where the new plans do not contain the component. When the technology of the component is shared, following the technology transparency method, this problem can be avoided. This solution is considered at Thales, and the knowledge on how to make the calculation for the RMB is present. However, a validation on the calculation can be improved, which could be a potential follow up project.

Thales / DMI interaction

There was a discussion on the report going to DMI. One expert never received any complaints about the report where another expert stated that the problems, as described in paragraph 4.1.3, were issued by DMI. After a validation with employees of DMI, the roadmap on how the obsolescence issues will be solved is the problem. The main problem which is encountered by the experts is the case when a trigger is presented to DMI, but DMI does not always respond to this trigger. An example given is when Thales proposes an LTB, which can cost ten thousands of euros. This proposal is often not acknowledged by DMI, which can lead to a redesign of tens of millions euros for a system.

The information which DMI would like to receive from Thales is the subject where the experts encounter multiple questions. As the life cycle costs are required by DMI, and the solutions to the obsolescence concerns or issues can also be offered to DMI, the overview of the triggers will not be necessary anymore according to the experts. When DMI would like more influence on in the supply chain, the life cycle costs will become higher, but this factor cannot be considered in the calculation as it is unpredictable. The questions whether DMI would like to receive the triggers and the calculation of the life cycle costs are raised by the experts.

The upgrading of systems often requires extra costs for new trainings to train the employees to work with the upgraded system, new handbooks are needed etc. By determining the optimal points of upgrading the system, the costs can be reduced to the minimum following the design refreshment planning ideology (paragraph 2.3.2). However, as these optimal points are not calculated at the moment, the total costs of upgrading cannot be estimated accurately and therefore are often most likely to be higher than the most efficient strategy on implementing upgrades.

To conclude, the experts at Thales would like to gain an insight where DMI identifies problems. Thales identifies problems, as are explained in this research, but the problems that are identified by DMI are not clear for the employees of Thales. Within this thesis, the problems of budgeting for DMI, the communication problems etc. are identified but there are most probably more, smaller problems which need to be identified. This question should be one of the first steps in the follow up project following the experts. Besides the problems, the experts would like an overview on how much of the components and systems DMI think they need in the upcoming years. This calculation should also be follow up project.

5.3 Priority list

As there is a disagreement about the priority in which order the follow up projects should be conducted, two priority rules are programmed in excel. By filling in these priority rules, experts are able to state their preference about the order of the follow up projects. The two priority rules which are programmed in excel, are the hundred dollar test and the ranking method. These priority rules are not used at this moment, as the meetings where the validation of the research were at the end stage of this research, which resulted in a time constraint for every relevant stakeholder to fill in the excel file and to evaluate these findings.

The 100-Dollar Test

Within the 100-dollar test an *n* amount of units needs to be divided over the subjects which need to be ranked. Normally the *n* amount of units will be 100 units, as it is the easiest and fastest amount to divide, where a ratio scale is used to present the results of the test. When there are too many subjects which need to be ranked, for example 30 subjects, 1000 units can be used to be divided over the 30 subjects.

There are two situations where the 100-dollar test can be manipulated and the outcomes will not represent the actual ranking. The first situation occurs when the test will be filled in a second run. When the subject which a stakeholders identifies as a top priority scored low in the first run, the stakeholder will be try to make the subject the top priority in the overall ranking by assigning too much units to the subject. In this situation, the subject will be prioritized too much by the stakeholder too even it out in the overall ranking. This will only happen when multiple stakeholders rank the subjects.

The second situation will also occur when a second run will be performed, as a stakeholder can assign more units to a subject to rank it higher in the overall list, even when another subject is valued higher by the stakeholder. The individual ranking of the stakeholder will not represent the actual ranking of the stakeholder, but the overall ranking will be similar to the actual ranking of the stakeholder. As the 100-dollar test is meant to provide an overview of the combined prioritization, the two situations should be avoided. Therefore, the test should be run only once.

Ranking

The ranking principle is the most simple to represent the prioritization of stakeholders. By assigning a 1 to the most important subject and a *n* to the least important subject, a priority list can be composed. An advantage in comparison to the 100-dollar test is that two or more subjects cannot be ranked equally important. However, this can also be regarded as a disadvantage. Another disadvantage is caused by the difference in importance, which cannot be visualized by the ranking principle. The ranking principle can be manipulated comparable to the 100-dollar test. Therefore, the ranking principle should be run once too (Aurum & Wohlin, 2005).

Priority method	Suitable/Unsuitable	Reason
Hundred-dollar test	Suitable	Convenient when it is hard to prioritize or when a relative distinction needs to be made in importance
Ranking	Suitable	Every prioritylist can be prioritized using this method
Analytical Hierarchy Process (AHP)	Unsuitable	Too many subjects that need to be compared (45 comparisons), software oriented
Numerical Assignment	Unsuitable	Method assigns priority to groups, no clear groups can be formulated
Top-ten	Unsuitable	Too few important stakeholders, too few requirements to make a top ten per stakeholder

Priority method	Pro's	Con's
Hunderd-dollar test	Relative difference in importance	The stakeholder cannot come to a distribution
	X aantal units kan zelf worden bepaald	Outcome can be manipulated by stakeholder
	Detailed priority list	Outcomes can be given an equally important rating
Ranking	Straightforward	General priority list
	Actual difference between importance	Stakeholder has to choose even when equally important
	Suitable for few stakeholders	There is no relative difference in importance

Figure 15, Explanation on chosen methods.

Follow up project	Hundred dollar test (100 units)	Ranking (1 to 6, 1 is the most important)
Organisational research	43	1
Obsolescence policy DMI	18	6
Integration model Seuren	9	5
Calculations on solutions	11	3
Design for obsolescence	6	4
FO&SO	13	2
Total	100	21
Difference (Needs to be 0)	0	0

Example Hundred dollar test (Pure random)

Follow up project	Hundred dollar test (100 units)
Organisational research	43
Obsolescence policy DMI	18
Integration model Seuren	9
Calculations on solutions	11
Design for obsolescence	6
FO&SO	13
Total	100
Difference (Needs to be 0)	0

Example Ranking test (Pure random)

Follow up project	Ranking (1 to 6, 1 is the most important)
Organisational research	1
Obsolescence policy DMI	6
Integration model Seuren	5
Calculations on solutions	3
Design for obsolescence	4
FO&SO	2
Total	21
Difference (Needs to be 0)	0

Figure 16, Example of the filled in priority methods.

6. Conclusion

This chapter will provide a conclusion of the research, where the found bottlenecks and follow up projects are summarized. The recommendations of this research are elaborated on, followed by a discussion.

6.1. Conclusion

This research is conducted to find a solution to the core problem and to identify follow-on research about the obsolescence landscape and the challenges which there are to implementing an optimal OM strategy. Thales and DMI are currently implementing a proactive OM strategy but the challenge is on how to make this as efficient as possible.

Thales and DMI want to implement the most efficient proactive OM strategy to minimize the life cycle costs. Besides high costs of solving obsolescence, the obsolescence could also lead to an interruption in missions due to maintenance lateness, which is caused by a delay in solving an obsolescence issue. Since the primary objective of DMI is to realise a 100% operationality the obsolescence must be solved before maintenance lateness could occur. In the current situation Thales implemented the obsolescence monitoring and the implementation of a proactive OM strategy is still under development. Within the research the subject of logistical obsolescence is analysed where the following question is answered: What are the challenges on implementing an efficient as possible obsolescence management strategy?

Through a gap analysis between the current and the desired situation, the points of improvement are identified within the subjects of the risk assessment, the obsolescence monitoring and the solutions to obsolescence. The analysis on the risk assessment results in an enhancement by implementing a model, designed by Seuren (2018), where a modification is required to adjust the model to the situation at Thales. Despite the obsolescence monitoring process operating according to the literature, the communication on the outcomes is sometimes incomplete and the detailing of follow up plans are part of the ongoing improvements in communication and decision making together with DMI.

Within the subject of the solutions to obsolescence, multiple gaps are identified. As calculations about the exact costs of both the reactive and proactive solutions are missing, in some cases the estimated costs of a solution are within a wide range. A more exact calculation or minimal margins aids in the decision on a solution proposal, since DMI has to budget far in advance for obsolescence. The costs of the proactive solutions are estimates. The existing plan on how to design for obsolescence can be integrated in a the method to assign the most efficient proactive solution.

Currently DMI does not have an obsolescence policy for the situation where an obsolescence concern or issues is reported by Thales. The installation managers of DMI handle these situation separately and coming to a conclusion requires some time with the lack of an obsolescence policy. As the decision time on a proposal for a solution from Thales requires more time, the proposed solution has a higher chance of becoming unavailable and a more expensive solution is required to solve the obsolescence.

Besides analysing the logistical obsolescence, the subjects that need to be researched are identified and a preliminary research is conducted. The subjects are the functional obsolescence, software obsolescence, an approach to calculate the capabilities of OEM's and the relationship between asset management, product management and obsolescence management.

6.2. Recommendations

This paragraph summarizes the bottlenecks which are identified in chapter 3 and solutions for these bottlenecks, discussed in chapter 4. The recommendations together form a construction to solve the main problem. The order in which the recommendations should be researched should be determined by making use of the excel tool.

Recommendation 1:

Start a research on the subjects of the approach on how to identify the capabilities of OEM's and the relationship between asset management, product management and obsolescence management. The subjects complement one another on the subject of what the consequences are for the involved companies when implementing a complete proactive OM strategy. The research on the capabilities of OEM's should start with the 5 levels of obsolescence readiness and a method on how to test on which level the companies operate. A precondition for the research on these subjects is that the companies within the network that contribute to the realisation of the end product, are present and informed about this process.

Questions as who will be responsible for which costs, who will determine what solutions will be implemented and what is the deadline on when the proactive solutions must be implemented, do not have a clear answer at this moment. This research which aims on the organisational subject between DMI and the suppliers such as Thales and sub suppliers should be researched as well.

The literature written by Romero Rojo et al. (2012) should be investigated to start this research.

Recommendation 2:

An obsolescence policy needs be developed at DMI to adequately react to the proposes on solutions from Thales. At the moment the installation managers of DMI handle the obsolescence concerns and issues coming in from Thales separately. By developing an obsolescence policy, the installation managers should be able to react on a shorter term notice as the steps in the policy need to be checked in comparison to the current situation where the situation needs to be investigated and researched. The exact sections which should be included in the policy needs be investigated, but an elaborate roadmap on how to respond to Thales when an obsolescence issue or concern comes in should be a part of it. Another section within the obsolescence policy could be when the idea of having more influence in the supply chain is continued.

Recommendation 3:

Integrate the model of Seuren (2018) in the risk assessment and modify it so it complies to the system Thales is working with, similar to the modification which Krol (2020) made for RH Marine. By enhancing the risk assessment more components can be identified as low or high obsolescence risk and adequate measures can be executed conform the risk level. The combination of the improved risk assessment and the developed obsolescence policy will allow DMI to make faster decisions and prevent a solution from becoming unavailable before the decision moment.

Recommendation 4:

A research on more exact calculations on reactive and proactive solutions can be conducted to minimize the margins in the estimated costs. DMI needs to budget a vast time in advance on obsolescence, so a calculation on the life cycle costs of a component is required. The calculations on the solutions are part of these life cycle costs. A start on this research is to investigate how Romero Rojo (2010) calculated the costs.

Recommendation 5:

The Marconi network has done no research on how obsolescence can be mitigated from the beginning of a life cycle. Therefore, a research should be conducted which characteristics of products are vulnerable to obsolescence and which products and components should be designed differently to mitigate obsolescence.

Recommendation 6:

A plan on how to implement a method to assign the appropriate proactive solution has not been composed, as the calculations on the prices are missing and the research of recommendation 5 has not been conducted. When these 2 researches have been completed, a research on a plan how assign the appropriate proactive solution should start.

Recommendation 7:

A research on software obsolescence should be conducted similar to this thesis. As only a limited amount of research has been conducted on the subjects, the preliminary researches as described in appendix 3 should be the starting point to this new research. As opposed by the idea of the members of the Marconi team, this research should be separated from the research on functional obsolescence. Software obsolescence can be linked to other types of obsolescence, as is explained in paragraph 4.2.2., thus also to functional obsolescence. This link is a part of the complete area of software obsolescence and should be a part of the research, however the other parts of software obsolescence, such as the link with logistical obsolescence, should also be a part of the research. To start the research, the following three recommendations should be researched:

1. A research on how the layers in figure 13 are related and what the current status of software obsolescence is at the four areas depicted in figure 13.

2. A research on the costs of reactive and proactive solutions.

3. Construct a flowchart on the solutions for software obsolescence after the calculations on the costs are finished.

Recommendation 8:

A research on functional obsolescence should be conducted. As only a limited amount of research has been conducted on the subjects first of all the origin of the problem and the stakeholders related to the subject should be clear. A start of this research should be to investigate the literature of Sols et al. (2011) and Sols (2014) to answer the following four questions:

1. What is the impact on maintenance and service logistics (e.g. spare part supply) for DMI and Thales?

2. What are the consequences of more frequent upgrades for the RNLN in terms of less downtime and better capabilities, etc.?

3. What are the pros and cons of more frequent and planned upgrades related to Obsolescence Management?

4. What costs are implied when increasing the number of system upgrades?

6.3. Discussion

The recommendations are based on a gap analysis between the desired and actual situation. As the desired situation is the literature review, the findings of the gap analysis cannot be tested in the actual situation as the outcomes of the researches take time to be finished and the validation of these findings will be too late to implement within this thesis.

The second discussion point is the opinion of the involved experts at Thales. These opinions do not completely align with the proposed challenges as well as with the opinions of all the other experts on obsolescence at Thales. In the expert panel meeting with the experts of Thales the transition to level 5 of proactiveness is not a shared thought with all the experts yet. The supportability engineer stated that it is important to first have the reactive OM strategy work as efficient as possible and only then the proactive OM strategy can be implemented further. The product manager services, who has been discussing the topic with RNLN multiple times, thinks that the transition to a proactive OM strategy is the first step which needs to be taken and the literature supports this mindset.

To align the different points of views, a clear set of definitions is needed which is accepted by everyone within the Marconi project. A start is made with a glossary with all relevant terms related to obsolescence, which needs to be accepted by everyone and expended where possible. The next step is to convince all stakeholders that the 5 levels of obsolescence management is a decent method to determine a roadmap in obsolescence management between the different companies. To create the consistency between the companies, an obsolescence policy following the guidelines of the IEC62402(2019) should be composed .

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Appendix 1

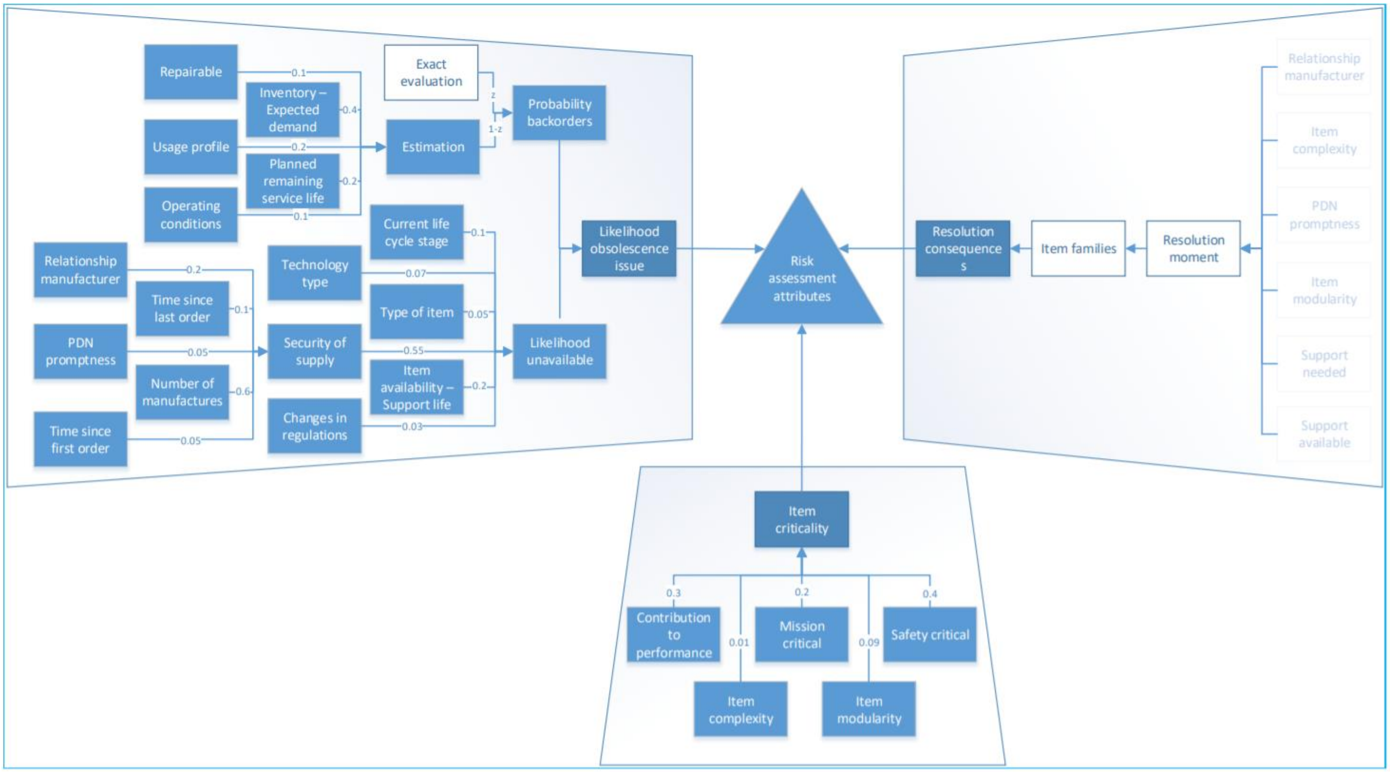

Figure 17, Overview of the considered attributes and their relationship towards their parent category, Seuren (2018)

Appendix 2

Functional obsolescence

The gap between the top line at a certain moment in time and the begin stage of that line in figure 1, which has been described in chapter 1.1.1, is referred to as functional obsolescence and mainly consists of two parts. These first part is obsolescence due to a new technology which causes the old technology to become obsolete and the second part is new technology on an existing platform. These two parts could also be described as respectively upgrades and updates. Next to updates and upgrades Thales also uses the term upkeep.

Update: Maintaining the function inside the radar by means of using new technology, not implementing new technology unless it is free to implement and perform maintenance to ensure the function and technology keep running.

Upgrade: Maintaining the function by means of new technology, not implementing new technology unless it is free to implement and performing maintenance to keep the function and technology running.

Upkeep: Maintaining the function inside the radar by means of using the original technology, performing maintenance and to ensure that the function and technology keeps running.

End product update

Functional obsolescence due to updates is generally also referred to as technological obsolescence. As new products enter the market, the predecessors of these new products are likely to eventually become obsolete. An example of an update is the introduction of the USB stick. Instead of having a big, heavy external hard disk, a small product was created. These USB stick can even store more data while weighing less and taking up less space in the end solution. Updates can be introduced into the market when the older version already is present, as is the case in the example of the smartphone, but could also occur in the manufacturing phase. After the design and development of the software has been finished, a considerable amount of time could be passed in which the customer identified enhanced needs of which the software should comply to (Sols et al., 2011).

End product upgrade

Functional obsolescence (new user requirements or new user features) create the opportunity for upgrading an end product or solution. These improvements, which can be realized by applying new technology as well, consists often of an enhanced functionality and performance. An example of an update can be found in smartphones. After it has been sold, all kind of functionality can be added by adding new apps. These additional apps generate revenue for the OEM of the smartphone (Apple business model).

Mitigation strategy: Technology Refreshment Program

There is little to none literature about functional obsolescence which also means that there is a limited amount of literature present for a strategy to mitigate the risks of this type of obsolescence. There is one mitigation strategy which can be assessed within the organization where a methodology has been conducted on how to implement the strategy of TRP's, Technology Refreshment Programs. TRP's aim for shorter cycles in which the software will be updated or upgraded. This type of mitigation strategy is also referred to as planned updates or planned upgrades. Sols (2014) has conducted a methodology on how to implement such a TRP. In an earlier research, Sols (2011) mentions various conditions to ensure the implementation of TRP's to be a success.

Software obsolescence

In contrast to hardware resolution strategies, there are no standard reactive resolution strategies. This is due to the fact that for solving the problem, the cooperation of the original supplier would be required. Another possible solution involves the accessibility to a large amount of resources, which is sometimes even inaccessible. Since an organization is depending on external factors which have a high probability of being inaccessible, a standard reactive resolution strategy is missing.

Proactive solutions

In contrast to solving the problem of software obsolescence, mitigating methods could ensure a decrease in costs of software obsolescence. A method for the calculation of the costs of software obsolescence is not present at the moment, so the exact decrease in costs cannot be calculated. Various general mitigation methods have been developed for software obsolescence, where some of these methods are explained in the next paragraph. More strategies are developed but a research on which could be used best in which situation is missing.

Open source software: by making use of the software offered in the open source environment, the probability of software obsolescence will be mitigated as the support cannot stop in a short period of time. However, as Thales and RNLN use software which is classified this option could be infeasible.

Technology roadmaps: When designing the software, the evolution of technology and the requirements of the customer should be considered. Functional obsolescence, which is the term for this sort of obsolescence, has been explained in paragraph 4.2.1.

Third party escrow: Within this mitigation method the source code will be handed over to a third party. When the original software developer decides to stop the support, the third party can operate as the new software support party. By making use of the model as proposed by Rode (2014), a suitable escrow provider can be identified. This type of obsolescence mitigation could also be used for hardware.

Outsourcing development and/or maintenance of software: By outsourcing the development and/or the maintenance of the software, the costs could be mitigated as skills are not necessary anymore within an organization. A disadvantage of this mitigation method could be that an organization has no control over the supplier anymore, which leads to an uncertainty about a possible software obsolescence issue.

Planned upgrades: By planning the upgrades of the software, the entire organization should have stored the relevant data in a way, that it could be used within the upgraded software.

Standardization: By using a minimum of programming languages, software components and compilers, the software obsolescence regarding skills is mitigated.

Contract for entire lifetime support: In order for an organization to prevent a supplier to discontinue the support, the support for the entire lifetime of the software should be part of the contract with the supplier (Romero et al. (2012)).