Prioritization of process descriptions within the supply chain of Thales Hengelo

Bachelor Thesis

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Preface

This thesis is conducted for Thales Hengelo. Firstly I would like to thank Henk Gerritsen and Dirk Verloop for their help and guidance within Thales. Thales is a huge company and without their experience I would be totally lost. Additionally I want to thank Thales Hengelo for the opportunity to conduct my thesis with them. I have learned a lot and hope to be part of Thales for some time after finishing this assignment. It has been a pleasure doing this assignment within the industrial supply chain. Lastly I want to thank Ipek Seyran Topan for her positive guidance. Overall I am happy I got the chance to do this study and learn from it and I hope it has a positive influence on Thales' current documentation situation.

Management Summary

Motivation

With technology and market circumstances changing rapidly, Thales should change accordingly. From diversifying production to changing department roles, all is possible and maybe necessary for Thales to compete in their markets. This means that over the years Thales' supply chain can look very different than how it currently looks. Individual processes may change, interaction between processes may change or even whole supply chain department roles may change. Recently, The industrial Supply chain manager joined Thales as industrial supply chain manager. He realized that after all these years of continuous change, the documentation behind all processes and procedures had not aged well. Many process descriptions are not up to date, some date back to before the year 2000 and overall the findability of these documents within Thales information programs is very poor. To keep the Supply chain competitive and before improvements can be implemented, first, the current situation regarding documentation needs to be improved. It is for this reason that this Thesis project is started and I hope personally that I can help Thales and The industrial Supply chain manager by giving more insight in the situation and possible improvements.

Methodology

To give more insight the whole situation, first all the relevant documents are identified and saved in a list. During this study 4 different information environments are taken into account: Chorus 2.0, TOL, Project discs and Personal discs. The file names, edit date, type and other information is gathered and put in the main document excel list. Eventually around 400 files were found and added to the framework. Another part of this study to help Thales with prioritization of these files. Since there are so many, department managers want an efficient path to review all files. This is done through a prioritization model based on a multi-criteria analysis method called ELECTRE.

In short: All files are quantified through 6 criteria: Out-datedness, Findability, Level of document, Impact on Cash, Impact on Cost and Impact on Customer Satisfaction. Based on this method and the scoring of these 6 criteria, the individual documents get a grade assignment between 1 to 10.

Conclusion

When looking at the overall document list the following becomes clear. A lot of documents are outdated / unused. Documents are saved on many different locations which only makes things more invisible. The list provided in the excel file gives a list of all relevant documents. Through prioritization it is now possible to tackle the biggest risk factors and slowly go to a better situation. The industrial Supply chain manager and other decision makers can choose the direction they want to go by changing weights of the criteria according to their strategies.

Overall the biggest improvement leaps can be obtained by tackling the TOL environment. A lot of documents are on there but less than 10% is recently updated and most likely only these files get used.

Another big leap can be gained through centralization of the documents that are now saved on project discs and personal discs. More usage of Chorus 2.0 is required to achieve this centralization. This eventually will improve findability / out-datedness scores.

Recommendations

Central location
One of the big issues in the current situation is that 2 out of 4 departments hugely rely on project discs. This negatively influences the transparency and limits the overall standardizations that can be implemented for the whole supply chain. Centralization of documents is important. This makes sure every Thales employee can look at what other people do. This in turn can create bigger consciousness of the impact of someone's work. It also improve collaboration between colleagues. For example work can more easily be handed over when everyone has access to everything. And lastly it improves the visibility for managers to look at how employees work if everything is structurally and centrally saved.

Note that is important to think of when a document should be saved on this central place. To keep the information environment of high quality, reviews should be taken before a document can be saved on it. It can be inefficient if every small document that has ever been made by a employee has to be reviewed and saved on something like Chorus 2.0. A recommendation would be to safe only documents that score a grade higher than 6 on the "level of document" criteria. Also be wary of people who have to use different documents daily. When everything is saved centrally and structured in some manner. It can be an annoying job finding all the files you need every day. These people will probably download and copy the files and save them in one convenient folder for themselves to work from. Agreements have to made for these situations. I recommend to give employees the freedom to choose if they want to work like this. In hindsight this way of working can be more practical and less time consuming. I would however make the agreement with everyone, that whatever is saved on the central spot, is leading.

Collaboration documents
When interviewing employees a lot of people noted that they miss collaboration documents. Instead of documents telling you how to do something, there is a demand for documents that say how to work together with employees. A single process mostly gets done through multiple departments. Instead of all departments have their own version of the process activities, it could be useful to combine everything and add how the activities impact each other. This not only emphasizes ones job, it also promotes thinking a like. Solving problems is easier when more people have context from different areas.

Management influence
A big reason for why the current situation regarding documentation occurs, is because the current way people work with documents is tolerated by management. To ensure the same situation does not occur twice, management should be strict on this and the new strategy should be implement top down.

Update / maintain procedure document
In addition to management being more present in this issue. Why not have an official document that states how to handle updating/deleting/making files? This document can illustrate who is responsible for reviewing, what and when to review, what documents can be saved on project discs and which ones need to be addressed for Chorus 2.0. Ultimately this document can serve the purpose of raising awareness of the current situation. It also keeps everyone in check and makes sure the methodologies developed to get to the new situation do not get forgotten when people leave for new jobs. Additionally new employees can use this document to immediately know how to handle professional documentation.

In addition to this document, the excel file from this Thesis should be used to stay on the path towards a better situation. By maintaining the excel file, you know where you are and what still has to be done. This way you can efficiently go to the new desired situation.

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1. Introduction

To give more context surrounding Thales and Thales' problems, a short introduction is given. This chapter starts with a short introduction about Thales and its location in Hengelo in section 1.1. Section 1.2 contains some context regarding the industrial supply chain. In Section 1.3 the current situation is illustrated to provide more information surrounding the problem solving approach. In Section 1.4 the problems are mentioned and afterwards in section 1.5 the core problem is stated and explained. Lastly in section 1.6 the norm is defined and indicators are given to measure if the norm is reached.

1.1. Thales Hengelo

Thales, originally a France business, is a worldwide electronics company. In 2000 they changed their name to Thales, before it was called Thomson-CSF. Thales specializes in aviation, weapon manufacturing, information technology. In the Netherlands; Thales is known for very advanced radar/IR systems and for example the NS gates inside train stations. The location Thales Hengelo was bought by Thales in 1990. Before the location was held by Philips, known as Hollandse Signaal BV. Thales Group has over 64.000 employees, located in 56 countries and has a sales volume of almost 15 billion euro's in 2016.

1.2 Industrial Supply Chain

The Industrial supply chain is a part of the total supply chain. This part of the Supply Chain focusses on the main process called: "Procure, Make and Deliver". This process can be summarized as the process that procures the materials for production, is responsible for the logistics, inventory management and plans all these activities in such a way that deadlines are reached. All head processes are numbered; Procure, Make and Deliver has the number 7.2. The departments that are part of the industrial supply chain are manufacturing buying, Master planning, Warehouse & Logistics and Costing & Obsolescence. These departments work closely together as collaborative and efficiently as possible.

1.3. Current situation

The way process documentation is saved can be grouped by 4 different information environments and their characteristics. Chorus 2.0, TOL, Project Discs and Personal Discs.

- Chorus 2.0
  Chorus is used for the whole Thales group internationally and is in accordance with Thales' business strategy, it is the main information system used for documentation. High-level procedures can be found here. These documents are ordered, reviewed, maintained and are of high quality. Currently Chorus 2.0 is used for high level documents only. Only a handful of employees actually look at Chorus, mostly management. Around 70 documents can be found here.

- TOL
  In the contrary of Chorus, TOL gets used more often by employees. This is probably due to it being easier and faster to access. Additionally TOL has less restrictions saving documents, and as a result there are over 2000 documents saved in the 'Procure, make and Deliver' folders. (These are the specific folders used by H. Gerritsen' departments). Clutter of irrelevant documents is a main issue of this environment, also the coherence between documents is poor. Finding a specific document can be quite challenging if you do not know where to look. Lastly since there are so many files, most files are very outdated (some are over 10 years old) and these files are barely used or sometimes do not get used at all.

- Project discs

  This environment is even less transparent than TOL. Project Discs can only be accessed by a single department. This means that only people in the department Manufacturing Buyers are the only people who have access to their own files. All the project discs aggregated probably contain more documents than there exist on TOL and Chorus combined. It is unknown how many there are saved here exactly. This is mostly due to the fact that there exist no restrictions for saving and editing files. Once you have access as a department member you can do whatever you want. It is obvious that when over 20 people save/edit/delete files in different folders on the same disc for 10+ years, the environment gets chaotic very fast.

- Personal discs

  The final environment are the personal discs. These are information environments that only individual people can access. There is no insight in how many files are saved in these 1500+ discs. One can imagine that saving files on these discs is very problematic for collaboration between employees, since access rights make sure it is not possible. Overall Thales does a good job of avoiding important documents get saved somewhere on a personal disc.

1.4. Problems

Currently the most generic problems would be that a lot of process descriptions are not up to date and the saved on different places. However more problems arise in this situation. Because documentation is saved on different places, the majority is formulated without the usage of templates and they barely link to other processes well. For example: Description A describes how to handle an order if a supplier delivers late and is loosely described by Piet and saved in the Manufacturing buyers department's project disc. Although it might be useful information for manufacturing buyers, master planners might also want to use this information. Unfortunately due to the nature of project discs, master planners do not have access rights. Additionally, in this example the file is written by Piet, that is just one person's point of view. Does everyone agree?

When files are handled like the previous example a lot of questions are unanswered: Does management agree with Piet's view? How does this one piece fit in the bigger picture of the supply chain? What is the impact of this process on other departments? How do people know it is still up to date and relevant? When enough of these documents are continuously made/used/edited the transparency of what people do gets worse and worse. This makes in turn the supply chain very non-transparent and that creates a lot of difficulties regarding optimization, workflow and management.

Another pin point in this dilemma is why are there so many outdated documents. How could it have grown in such numbers. When a completely new process is started, its description usually gets formulated properly, reviewed and placed on Chorus 2.0. But when an older process is altered, renewed, improved or changed, most of the time it does not get re-formulated in Chorus 2.0. Hence, through new innovations, current descriptions get less relevant day by day.

The problems mentioned earlier result in even more problems experienced by Thales. These problems are listed below:

- Many process descriptions are not up to date
- The supply chain is not transparent
- The findability of documents is poor
- The coherence of documents is bad
- Documentation is saved in multiple places
- The department managers do not know where to start with updating process descriptions
- Process descriptions do not get updated
- It is hard to make improvements to the supply chain
- There is a big amount of outdated documentation
- There is no framework for updating process descriptions
- There is not much insight in the current documentation situation.
- There exist little support from management to maintain documentation

So the sheer number of outdated process descriptions (and is still growing) is a problem on its own together with where all these files are saved. When The industrial Supply chain manager realized, that the current situation regarding process descriptions is suboptimal, he asked his department managers to take a look at their own documents. However, at the moment there are hundreds of process descriptions. These documents are saved in many places, they are hardly linked, and most of them haven't been reviewed in years. Hence, the department managers have no idea where to start. Some documents are more important than others however, how does one know this? On what criteria?

1.5. Core problem

When looking at figure 1, two core problems can be obtained. It can be seen that the absence of a framework for updating process descriptions is one of the core problems. The other one is that so far there was little support from management. To implement any new strategy support from management is required. However the first core problem mentioned is the only one that can be influenced by this study. Hence this problem is the focus of this study.
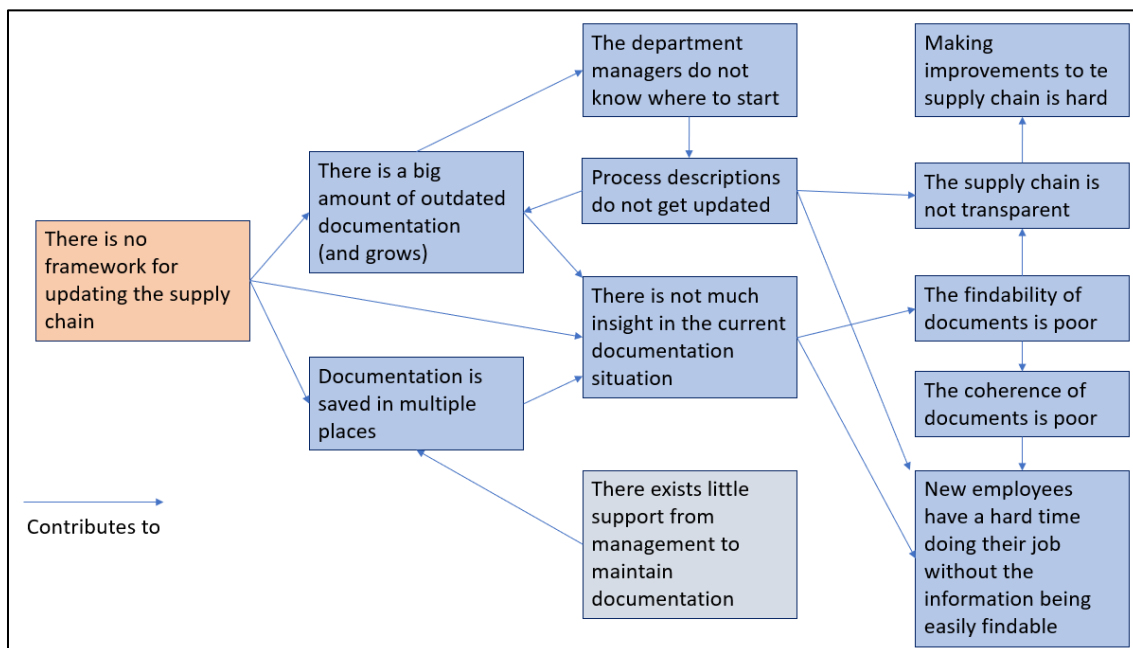

Figure 1 – Problem Cluster

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The selected core problem (there is no framework) is very general. To link the core problem better to difference between norm and reality and to give it more depth, the problem is phrased with the following sentence:

There exists no framework that says what process descriptions should get updated.

Motivation:

As seen in the problem cluster, having out dated process descriptions results in many other problems. At first, I thought the existence of outdated documents was the main problem. However, let's say we could fix this problem, by updating all process descriptions, the problem would eventually return. This is because descriptions do not get updated when processes get altered.

Updating all process descriptions is very hard right now. The amount of documents is too high, and not all are relevant to update. The department managers do not want to waste time fixing irrelevant documents, and there is no overview right now what documents are relevant. Thales is at the point right now where the problems influence each other in a negative way, which in turn negatively influences the "starting" problems again. There exists a downwards spiral: the department managers do not want to update because there are too many documents out dated. This results in a growing number of outdated documents which again makes sure that the department managers task will get more and more difficult. This circle of causes and effects is an indicator that these problems cannot be core problems. This is because following the theory of the MPSM (managerial problem solving method), the core problem cannot have a cause, hence another problem must be the core problem.

The first question I asked myself, why does the documentation not get updated when supply chain processed get changed. And what could be another reason for why the department managers do not know where to start with updating. Ultimately both these problems exist because there is no tool/procedure for updating the process descriptions. This means that if there would be a framework that could tell Thales employees what and when to update, both problems can be resolved. However this would mean that there is support from management, otherwise they will also fall back again. This study however is initiated by management, so you might say there is management support. This is another reason that we will not focus on the management support problem but on the problem that there is no framework.

To conclude, when there exists a framework that helps prioritize work for department managers, so it gives them a good indication where to start, process descriptions can be prioritized and updated efficiently. Where "updating" means making the documents relevant, saving them centrally or deleting them if they are irrelevant to reduce clutter.

1.6. Reality to norm

In the current reality there exists no framework. Obviously creating a framework for Thales would already be an improvement. But before we can say the framework is useful, we have to define a norm. So first I phrase the core problem into a variable:

There should exist a framework which provides a list of all process descriptions with relevant importance scores regarding the supply chain, currently Thales lacks such a thing.

Norm

There exists a framework which provides a list of all descriptions with a structured/relevant importance score in the supply chain.

For example, through this framework scores are calculated and a list is created with all descriptions linked to a score between 1-10. Another option could be that all process descriptions are ranked, this would also be done through calculations. More information about the exact calculations can be found later in this paper. Ultimately this framework would make sure that the documents can be ordered by importance. These kind of lists will give the department managers a good starting spot and the means to update efficiently.

Indicators

So how do we know this norm reached? "a structured importance grade" is very vague. When is something structured? When is it accurate enough? Therefore I check my progress by using indicators. These indicators are key performance indicators (KPI's) and are stated in such a way that the difference between norm and reality can be calculated. Following the MPSM having only a few indicators is preferable. Not to many but also not one, around 3 or 4 is great. In this section the indicators will be listed and motivated.

1. **Amount of difference between importance scores.**

   For the prioritization list to be useful, clear "winners" have to come out of this list. Having some process descriptions tagged as critical to update, gives the department managers a good place to start. For example, a ranking of all processes would be perfect, in this case it is all individual process descriptions have different grades. In the case of a rating system, scores should have a meaningful difference. Having 100 process descriptions with the score 9.8 would still not give a starting point for the department managers.

2. **The document scores are relevant.**

   The scores provided by the framework should tell Thales something meaningful. Also, it is preferable that the scoring system is applicable to all documents. This can mean that the scoring is very general and the same for all descriptions, or this can mean that it differs per segment or department. Ultimately it should contain criteria logically selected and supported with research and weights. Additionally, it should be stated why the criteria are relevant.

3. **All process descriptions are supported by the framework.**

   Thales has hundreds of process descriptions. So, you don't want a portion of these documents not being supported by the framework. To avoid an incomplete list, together with decision makers the scope will be discussed to make sure no important documents are left out.

4. **Additional to the prioritization list, the framework shows where in the supply chain the process is located.**

   To get a good idea about how important some processes are. Just a grade is not enough. Grades can be the same. When the supply chain is mapped and the department managers can see what processes are described in the supply chain, a better prioritization choice can be made. For example, 2 processes both with grade of 7.1 need to be updated. Both have a high grade however one is connected to more processes within the supply chain, hence that one is more important. Delivering a view of the supply chain alongside the prioritization list can be very helpful in some of such edge cases, especially since the supply chain is very non-transparent for Thales currently.

2. Problem approach and analysis

In this section the third phase of the MPSM is discussed. In section 2.1 the research scope is discussed. In section 2.2 the used methodology in this study is explained and in section 2.3 the steps done in this study are shown. Section 2.4 is used to state the Research Goal and section 2.5 the research questions are listed and motivated. Afterwards in section 2.6 the planned deliverables are given.

2.1. Research scope

This thesis is focused on the process descriptions in the industrial supply chain of Thales Hengelo regarding the departments managed by The industrial Supply chain manager. There are more departments inside Thales struggling with the same problem. However, this study has a time scope of 10 weeks. Hence, the choice is made to only update The industrial Supply chain manager his departments to today's standard. This means only documents that are part of the 7.2 "Procure, Make and Deliver" process will be considered.

When considering the 4 environments on which the documents are saved: Chorus 2.0, TOL, Project Disc, Personal disc. It was discussed with the decision makers that personal discs are out of scope. Personal files are often irrelevant and just for personal archiving. When a file is truly relevant to the supply chain it would not be saved on a personal disc. Additionally, the project discs contain hundreds of folders. Together with the department managers it is discussed which folders are relevant, only these folders and the files were taken into account. Lastly, both on TOL and project discs there still exist irrelevant files. Together with the Thales employees exclusion criteria was setup:

- Files from another Thales location in the Netherlands
- "Personal files" (for example holiday planning)
- Non-Procedures/non-work instruction files.
- Incomplete documents or documents that are still worked on

Together with directions from decision makers and exclusion criteria the overall scope is defined. It can occur that I am uncertain if a file should be excluded or included. This can be because of my lack of knowledge, jargon or something else. If this is the case, decisions makers will choose to exclude or not.

2.2. Research Methodology

The managerial problem solving method (Hans Heerkens & Arnold van Winden, 2012), in dutch: "Algemene bedrijfskundige aanpak (ABP). This is a systematically approach to solve the problem felt by Thales. The data gathering will contain primary and secondary data. In the first few week interviews will be held with people close to the state of the art of Thales. However in the end criteria, weights, grading structures will be setup with research, theories and other literature.

2.3.   Research Steps

In the following bullet points it is described what steps are done to complete this study. Note that they are ordered in a somewhat chronological order. This means that the first point is preferably finished first. Although the points are ordered strictly, it is meant as a guideline.

1. **Create questions/Question lists for interviews and information gathering.**
   There is a lot of information inside the people working at Thales. This information is very useful for me as an outsider. I will need information from them so I will have to think of what to ask them

2. **Talk to department managers/Thales employee and do research. (information gathering)**
   The valuable information of Thales employees needs to be subtracted. They probably know more about Thales' state of the art than I do. Also, information can be found on the internet regarding mapping a supply chain. The interview questions can be found in Appendix C.

3. **Map the supply chain.**
   Mapping the supply chain is not only useful for the department managers. It can only be used for me track if I have found all documents and helps me understanding the supply chain myself, which in turn can be useful while setting up importance criteria.

4. **Aggregate all process descriptions.**
   At the moment the localization of all process descriptions is a bit messy. Some are in the cloud, while others are in folders on places in their databases. This is the reason why Thales does not know how many process descriptions they have and how many are outdated. I am unable to analyze or work with these documents when they are organized chaotically. Therefore, one of the first steps would be to create order. This would mean I would have to assess all document and gather them all in one place.

5. **Define importance criteria and research how to grade properly.**
   In order to get a meaningful importance grade, I need to know when something is important and how to measure documents. This is why importance criteria need to be setup. Obviously, these criteria are based on information gathered during this study.

6. **Grade all processes.**
   When all information is gathered one of the final steps must be done. This means creating the importance list. This can be done following different theories, for example multi criteria analysis.

7. **Study the performance of the importance grades.**
   In order to check whether the grades are meaningful not biased and fair, a sensitivity analysis needs to be conducted.

8. **Give recommendations and extra information how to use the tool.**
   When the list is created and the managers know what to update. It is useful for them what to keep in mind when they are updating.

2.4. Research Goal

Ultimately the main goal of this thesis is to help Thales. This is possible in multiple ways, however the emphasize is on the prioritization list of the process descriptions. The difficulties lie into the specifications of this list. The criteria are specific for Thales' processes and should be in accordance with their supply chain/culture/business strategy. These criteria/weights for prioritization grades should ultimately get Thales to their favorable current state. So, to conclude the research goal is how to get to the norm mentioned in section 2.4.

2.5. Knowledge Problems and Research Questions

In this section the research questions that will be answered during this study will be listed and motivated. Regarding the framework multiple Knowledge problems are present. I will divide the research questions into their corresponding knowledge problems.

When do you need to update a process description?

Before I can grade process descriptions I need to know if they are outdated or not. It would be inefficient to grade all processes, so I only want to target the outdated documents. This knowledge problem needs to be answered first before I can grade the process descriptions.

- **How do you measure the "outdated-ness" of a process description?**
  When two processes are outdated, it can be useful to prioritize the one that is more outdated than the other one. This question is answered in chapter 4.1.

How do you differentiate in importance of processes within a supply chain?

When mapping the supply chain it is necessary to setup a way to measure the importance of a process. This plays a role in the grading of the processes.

- **How do you measure the importance of a process in the supply chain?**
  It is important for the framework to know which processes are more important. It has to be researched when a process is "important" and how do you measure this based on literature and information gathered from Thales employees. Calculating importance is done in chapter 4.2.

How do you grade all processes descriptions

- **What criteria should be used to grade process descriptions?**
  Obviously, you want more important processes to get updated first. However, there are more things to consider. Thales strategy is also important. For example, how do they see the future state. Updating documents from processes that might be changed/deleted in the near future might not be a priority. Also, the Criteria might be different for the different departments. The criteria thought of during this study are noted in chapter 4

- **What weights should be linked to the criteria?**
  Once criteria are setup it is important that weights are linked to these criteria. This should be done with Thales decision makers. It should be researched how these weights interact and how much I and Thales affect them. The influence of the weights is discussed in chapter 4.3

2.6. Deliverables

As mentioned, many times, the goal is to deliver a framework to Thales that helps them with deciding what process descriptions they prioritize. This can be done through a simple list of all process descriptions and linked to an importance grade. This is also what is mentioned by The industrial Supply chain manager and probably the easiest and most efficient way to portray the importance of the process descriptions. Additionally, these processes descriptions can be linked to the supply chain. The list can be conducted from an excel sheet. Computations of criteria and weights can also be done in excel, either with excel spreadsheet formulas or with the use of Visual Basic programmed Macro's. So, in short:

- A List of the process descriptions ordered by their grade.
- Excel (VBA) file containing all computations and weighted criteria. Where Thales can tweak the criteria's weights, can see the impact of these criteria on the prioritization and buffer inputs.
- A list of recommendations additionally to the list to help Thales with decisions.
- A dashboard showing the performance per department

3. Theoretical Framework

In this chapter the theoretical perspective of the study is discussed. Since a good prioritization is mandatory to deliver a useful document list, a lot of emphasize is put on this part of the framework. In section 3.1. the prioritization tool is discussed. In section 3.2 all the candidate multi criteria techniques are compared and discussed, afterwards in section 3.3 the chosen technique is explained and why it is chosen.

3.1 Multi criteria analysis

There are a lot of ways to prioritize processes. Process A might be prioritized over process B if for example more people come in contact with that process, or it might be prioritized because it fits the core of the business strategy better. So there are many different ways of tackling this prioritization problem, however one thing becomes clear. All these directions have one thing in common. They all look at single or multiple attributes of the processes. When looking at Thales' situation it becomes clear that prioritization by only using one attribute does not translate well in an intricate business such as Thales. This is why the prioritization in this study is based on multi-criteria analysis.

Multi criteria decision making (MCDM) techniques are a good fit for this problem due to their nature to calculate prioritization using more than one attribute. MCDM is a heuristic that helps decision makers choosing the best alternatives. For example when a company needs to choose new suppliers. This company would go over all of these suppliers and go over the positive and negative attributes each supplier has. A good MCDM technique goes over all the supplier attributes and sets up criteria. In this case, it looks for example at cost, reliability and responsiveness of suppliers. The suppliers get scored per criteria and eventually a ranking/rating of the suppliers comes out by using the criteria and the importance of the criteria, (importance of criteria is also called Criteria Weights). Eventually the MCDM technique shows which supplier fits best.

 There exist many different Multi criteria decision making techniques(*Velasquez & Hester, 2013*). These range from highly complex techniques that can take uncertainty into account to simpler techniques that simply compares scores. In its core a multi criteria analysis regarding Thales' situation would do the following*(Dodgson, Spackman, Pearman & Philliips, Lawrence, 2009):*

Step 1: Identify the process documents (inventory).
Step 2: Identify the main objectives and criteria.
Step 3: Score the 'options' (documents).
Step 4: Assign weights to the criteria.
Step 5: Combine the weights and the criteria based scored to get the final value.
Step 6: Rank the process descriptions.
Step 7: Examine the result / sensitivity analysis.

3.2. Multi criteria decision making techniques

Since there exist a lot of multi criteria decision making techniques, first a structured literature review was conducted to find candidates to consider using. This review can be found in appendix A. The following list followed from the review. All these techniques have all in common that they are viable in ranking problems. To select a good fit for Thales' prioritization problem, all of the following techniques will be evaluated and eventually one will be chosen.

- *Data envelopment analysis (DAE)*
- *Aggregated Indices Randomization method (AIRM)*
- *Weighted Product Model (WPM)*
- *Elimination Et Choice Translating Reality (ELECTRE)*
- *Simple Multi-Attribute Rating Technique (SMART)*
- *Multi-Attribute Utility theory (MAUT)*
- *Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)*
- *ViseKriterijumska Optimizacija Kompromisno Resenje (VIKOR)*
- *Preference asking Organization METHods for Enrichment Evaluation (PROMETHEE)*

TOPSIS

Topsis is a method which requires numerical values as input *(Serafim Opricovic, Gwo-Hshiung Tzeng, 2004).* It then uses weights and standardized scores of the criteria to determine the value of a certain document. After all values are calculated, the best and worst are used to determine the grade. So a process description with the highest grade, has the most priority and is first place. The second place is the document which is closest to the best alternative and the farthest from the worst alternative.

Although Topsis looks like a good method for this study, it nicely uses numbers to get a ranking. However the idea that document rankings are partly based on the similarity to the highest scoring document only is weird. Place one and two might both score pretty high in importance, however they could be totally different in content and place in the supply chain. Because there is almost no correlation between documents, ranking on similarities in regards to the best "alternative" is therefore sub-optimal for Thales' problem.

VIKOR

This method is similar to TOPSIS. It determines a compromise ranking list, and a compromise solution first. This method does this by focusing on selecting from the set of alternatives in the presence of their criteria scores and weights. Eventually, similar like Topsis, the ranking list is determined with the measure of "Closeness" to the "ideal" solution*(Serafim Opricovic, Gwo-Hshiung Tzeng, 2004)*. However, the notion that grades are based on similarities between documents is not applicable to Thales. The highest scoring documents, the "ideal' solution, can (and probably is) very different from other documents. Thus VIKOR is just like TOPSIS sub optimal to use in this situation.

SMART

Smart is quite straightforward. It is a more basic Multi-criteria analysis technique. If we follow this technique we setup criteria first. Then we assign values to these criteria and add weights. Smart states that the most important criteria gets weight 100 assigned (*David L. Olson, 2012*). The second best criteria weight is a number reflecting the ratio of relative importance to the most important criteria, for example 50. This method is attractive to use, because of its simplicity and reliability. On the other hand what it gains in simplicity, it loses in possibilities. Thales is looking for a system where priorities change, importance of criteria change and weights change. So although Smart is suitable for this prioritization problem, unreliability's may arise when simplifying assumptions.

AIRM

In contrast to earlier discussed methods, AIRM does things very different. It aggregates single criteria into complex characteristics. Where one complex characteristic is equal to a certain "Point of view" of an alternative *(Aruldoss, Miranda Lakshmi,Prasanna Venkatesan, 2013*). The pro's to this approach is that NNN-information, in other words subjective and sometimes non-numerical information, can be handled. Using this method the process descriptions will be scored on how well they describe the complex characteristics. This method is definitely possible to use however, the luxuries gained by using this method are not really needed as the input from Thales problem is pure numerical and only complicates the grading system with irrelevant extra calculations. This is why a "simpler" method is preferable.

MAUT

In short MAUT is a method that uses utility functions of attributes where the function with the highest expected payoff is preferred. In this method probabilities are linked to the scored criteria. In Thales' case, the scores are given and using a technique based on probability is not necessary since all inputs and outputs are absolute.

WPM

Weighted product model is a well-known multi criteria technique. The core of the technique is as follows: Once criteria and weights are setup. The total score of an individual document will be calculated by adding the scores per criteria to the power of the weight of that criteria (*Zavadskas, Turskis, Antucheviciene., 2012*). However, problems arise when equal weights are given. In this case no solution is given. Ultimately Thales wants flexibility in weight choices. This means that other methods, that do not have this property, might be more suitable.

DAE

Data envelopment analysis can be described as an technique that uses linear programming to find efficiencies and slacks (inefficiencies) in combinations of criteria scores (*Kaoru Tone , 1999).* It has the ability to find links between attributes that may otherwise be hidden. Eventually the alternatives with the most efficient criteria get the highest scores, and so on. To use DAE some assumptions have to be made. The data is static and absolute. Statistical tests are not applicable because the method is quite mathematically demanding. This method is suitable for Thales' problem and is taken into account in the next paragraph.

ELECTRE

This is a method developed in 1996 (*Buchanan, Sheppard, van der pooten 1999*). ELECTRE has many different versions of the method; ELECTRE I,II,III,IV,IS and TRI. All methods appear to be similar in describing the concepts but differ in type of decision problem. For example ELECTRE I is good for selection problems while ELECTRE TRI is best suited for assignment problems. The other ELECTRE methods are good for Ranking problems. ELECTRE is based on an outranking principle. It gives scores to alternatives based on how many times it outranks other alternatives per criteria. In the next section it is discussed why ELECTRE III is chosen out of all other methods (even DAE).

PROMETHEE

Promethee is very similar to Electree. Promethee also makes use of the outranking principle. There is however one big difference. Promethee does not look at how big the outranking is *(Mary & Suganya, 2016*). Differences in criteria values is not taken into account totally. It does not matter how much the preference threshold is exceeded. Which means that when A outranks B, it does not matter how much it outranks B, rather it only notes that A outranks B. This function of promethee is the main reason why it is not chosen. The older a document is, the more risk it has (see section 4.2). The latter means that when A outranks B on criteria outdated-ness, let's say A is 2 weeks older, this is noted as "outranked" in the algorithm. But when A outranks B, with over 2 years, the same outcome is noted by Promethee. While in reality the priority on A should be a lot higher since the difference is 52 times bigger.

3.3. Why ELECTRE (III)

After considering multiple different multi-criteria techniques, ELECTRE is chosen. ELECTRE has some nice properties that are useful. Firstly, the outranking principle is very useful and fits well. This principle simply means that if Document A outranks Document B on criteria 1, A is better than B on criteria 1. This outranking principle is a very consistent way of assigning values to a relation while it has human opinions as input. Note that in section 4.3 the exact details and formulas used are given and discussed.

The second benefit of using ELECTRE is that it uses buffer zones. This principle is the main reason why ELECTRE is chosen rather than DAE or PROMOTHEE. Let's say you buy 2 coffee and you want to evaluate which one is "better". You look at different attributes; looks, smell, sugar etc. Is a coffee with 10 mg sugar better than a coffee with 11 mg sugar? Probably not, that small amount is not noticeable. While having a coffee with 200 mg of sugar is probably noticed and evaluated as a bad coffee. A small deviation in the amount of sugar is not enough for coffee A to be better than coffee B. It is this principle that is very useful for process descriptions. A document that is only 2 weeks older than another one, you should probably not differentiate between, rather focus on bigger differences.

Note that there are different versions of ELECTRE. All are based on the same principles but have small differences. In this study ELECTRE III is used due to its nature for ranking problems and it is ultimately chosen because it is the only ELECTRE version that uses fuzzy relations like the credibility matrix *(Denis Bouyssou, 2001)*. This is necessary because the input for the prioritization calculations are based on human opinions, hence they are subjective. A credibility check (through the credibility matrix) makes sure the outcomes are more consistent.

Also Note that I am not implying that ELECTRE III is the best multi criteria analysis method for this problem. It simply has some nice attributes which I like to use (The simple outranking principle, buffer zones and fuzzy relations). The question: "What multi criteria analysis tool is the best for this situation?" has no answer. This is a paradox. Criteria analysis methods are used to find the best solution/ranking. So to know what method is best, you need to know the best solution beforehand. Thus, it is impossible to know what method should be used.

Outranking models like ELECTRE are used worldwide. It is not possible to give all applications since there are so many. However a few significant applications in several fields are mentioned below. *(Denis Bouyssou, 2001)*

Finance
- Investment planning (France)
- Allocation of grants (Belgium)

Health
- Hospital management (Canada)
- Airports (Canada, The Netherlands)

Environment
- Solid waste management (Finland, Greece)
- Water resource management (Hungary, USA)

Planning
- Regional planning (The Netherlands)
- Inventory management (France)

4. Methodology

In this chapter the implementation and the workings of the chosen MCDM and its criteria is explained. In section 4.1 the criteria that will be used in the MCDM are explained. Afterwards the exact scoring methodology of the criteria is shown in section 4.2. In section 4.3 the workings of ELECTRE III is explained. Afterwards in section 4.4 the implementation of this method is elaborated.

4.1. Defining Criteria

Before the decision making tool is chosen, first the criteria need to be defined. For a MCDM to work well, criteria must be chosen in such a way that complements the main objective. In this case, the prioritization of process descriptions. What and when a certain document has priority of another should be discussed with the decision makers. Additionally criteria must be formulated in a way that makes sure that they are measurable. Together with the decision makers, the criteria below are chosen. The following criteria are used in the MCDM, they are quantified and used as labels for the individual documents. In the next segments the operationalization of the criteria is explained and why the criteria fit well in the model for Thales.

- **Out-datedness**

This criteria measures how old a document is. Documents that are quite old are often very risk full. There are a couple of reasons for why a document may be old and thus scores high on this criteria. First, the person in charge of maintaining the document left the job. This can be quite problematic if a lot of people rely on this document. If nobody maintains or knows when something is outdated people may be using it in their daily work. This has the consequence that employees may work in a sub optimal "old way".

The second reason could be that it is simply not being used anymore. In this case this document also scores high on this criteria, which is appropriate. An old unused document can simply be deleted quickly. By getting these documents on the radar quickly due to their high scores, one problem can quickly be found and simply be resolved by deleting the document. This improves clutter and thus the overview of the total documentation. However, sometimes a document may be old but may be still fine and used for today's standards. If this is the case, this document does score high, which is suboptimal since the document does not need priority. However most of the time a document is old because of the first two reasons. Documents that function well and are used regularly are often maintained and score low on this criteria.

- **Level of Document**

This criteria measures the importance of a certain document. High level documents are often crucial to the performance of the business. For example documents that state the overall business strategy must be maintained all the time, while low-level or local work instructions have less impact. A document containing the Best-Practice for doing a VLOOKUP in Excel does not have big impact, hence it will score low on this criteria. The higher the level of a document the higher it scores on this criteria, and thus the bigger the priority on these documents. How the scores are operationalized can be found in table 2 (chapter 4.2.).

- **Findability**

This criteria measures how easy it is to find a certain document. Remember the 4 different environments where documents are saved? Something being saved in a chaotic department disc is harder to find than in the structured Chorus 2.0 system. Since Thales aims for more transparency, documents that are harder to find score higher on this criteria and thus get prioritized. You could say; the easier it is to find a specific document, the lower the score on this criteria.

▪ **Impact on Cash, Cost and Customer Satisfaction**

These 3 criteria measures what it states, the impact on Cash, Cost and customer satisfaction. Unfortunately there are no numbers within Thales that for example show how much processes cost the supply chain. That is why a more subjective approach is used. To measure individual documents, the question is asked, "what if this procedure not followed correctly?". The department managers rate all documents on these three dimensions. The bigger the impact the higher the score. This means that high impact documents get a higher priority.

So now 6 Criteria are defined. Note that for simplicity all criteria are formulated in such a way that higher criteria score leads to higher priority score contribution. The exact details of scoring criteria is discussed in the next chapter.

4.2. Scoring Criteria

In chapter 4.1 the criteria are in detail discussed. However how the documents were individually graded and quantified is something that will be discussed here. Out of the 6 criteria that needed to be graded, only out-datedness was objectively graded. The other 5 criteria have some subjective human-like element within them. This is mostly due to the fact that the opinions of the decisionmakers is taken into account during grading.

▪ **Findability of Document**
The findability scoring is done through the following table, this table (just like the other tables) are defined with the decision makers. To keep things easy, only numbers between 1 to 10 were asked, hence the following table got created.

Table 1 – Findability of document scoring criteria

Score	Description
10	Document is findable on a personal disc only.
8	Document is findable "somewhere" on department project disc
7	Document is findable on department project disc in a structured work instructions folder
5	Document is findable on TOL environment, within its process map
4	Document is findable on TOL environment, within its process map with less than 20 documents inside this map. (When folders hold more than 20 documents, decision makers found clutter to be a problem, hence a document is less findable)
2	Document is findable on Chorus 2.0
1	Document is findable on Chorus 2.0, structured under its main process

So again, the harder it is to find a document, the higher the score! This is because you want to prioritize documents that are hard to find first.

- **Level of Document**
  The level of Document scoring is done through the following table
  Table 2 – Level of document scoring criteria

Score	Description
10	A Thales Group document (global strategy document)
9	High level procedure (Thales NL strategy document
8	Procedure used by multiple departments
7	Strategy document focused on operational activities (one way of workings)
6	Documents regarding: Export control / Law compliance / Inventory counting
5	Documents regarding: Data analysis / Analysis of Man-lists / ERP analysis / Data integrity documents
4	Local work instructions (for example how to print a label)
3	Checklists
2	Best Practices (for example Best practice for VLOOKUP in Excel)
1	Templates

- **Out-datedness**
  Out-datedness is simply computed by using the difference in current date and the last edited date of the file. Afterwards the number is shown in weeks. So 2 years old, gives the number 104.

- **Impact on Cash, Cost and Customer Satisfaction**

  These criteria are not based on a table, rather they are scored individually. The basis for scoring is done through the following questions:

  "How big is the impact on "Cash/Cost/Customer Satisfaction" if the process description is <u>not</u> followed?"

  Every document falls under a specific department and under a main process if it is a local work instruction. The department managers that also fall under these main processes were asked this question for all the documents they are responsible for in the list. To help answering and keep the numbers reliable and more consistent they were given the following table

  Table 3 – Impact on Cash/Cost/Customer Satisfaction scoring criteria

Score	"How big is the impact per criteria if the document is <u>not</u> followed?"
0	It has no impact
1	It has noticeable impact.
3	It has noticeable impact and it will have to be addressed afterwards
9	It has dramatic impact and document must be followed at all cost.

  Note that this way of grading the criteria has impact on the threshold values used in ELECTRE III. The 0,1,3,9 system is used in many different industries and popular in Lean six sigma systems (*H.C. Theisens, 2017*). It is a nice tool to make sure that people score quite consistent. This system however is not necessary for the first 3 criteria since they can easily be scored following one table, which results in consistent scoring. This is why the 0,1,3,9, system is only used for the Cash/Cost/Customer satisfaction criteria.

4.3. How ELECTRE III works

The ELECTRE approach emphasizes 2 concepts, the buffer thresholds and the outranking principle. Both principles together with the workings of this method will be discussed now.

There exist a set of alternatives A (in Thales' case a list of documents) (*Iman Majdi, 2013*). Where the relation of two alternatives (a, b) ∈ A can be described in only 3 ways:

a**P**b   (a is preferred to b) | $g(a) > g(b)$
a**I**b   (a is indifferent from b) | $g(a) = g(b)$
a**J**b   (a cannot be compared to b).

Where g(j) is a specific criteria, j=1,2…∈ A
Here is where ELECTRE has an advantage over more traditional approaches. Consider the indifference threshold, q. So now we redefine the earlier mentioned relations.

a**P**b   (a is preferred to b) | $g(a) > g(b) + q$
a**I**b   (a is indifferent to b) | $|g(a) - g(b)| \leq q$
a**J**b   (a cannot be compared to b)

With the introduction of this buffer zone, the decisions made by the algorithm are more realistic regarding the actual decisions the decisionmaker would make. However one problem remains. ELECTRE introduces another buffer zone, the preference threshold is introduced, p. This threshold creates a more clear difference between indifference and strict preference. Additionally it lets the decisionmaker choose when something is weakly preferred or strongly preferred. Hence we now have a double threshold system with a new relation Q, which considers weak preference.

a**P**b   (a is strongly preferred to b) | $g(a)-g(b) > p$
a**Q**b   (a is weakly preferred to b) | $q < g(a)-g(b) \leq p$
a**I**b   (a is indifferent to b) | $|g(a)-g(b)| \leq q$
a**J**b   (a cannot be compared to b)

Note that together with the decision maker the values for the buffer zones are discussed. Considering the above 4 relations, ELECTRE uses it second main principle to start with outranking. There exists an outrank relation **S**.

a**S**$_j$b   (a is at least as good as b with respect to the jth criterion)

To further explain the outranking relationship two definitions are used. These are <u>Concordance</u> and <u>Discordance</u>. (*Mary, G. Suganya , 2016*)

The jth criterion is in <u>concordance</u> with the assertion a**S**b if and only if a**S**$_j$b.
So if $g_j(a) \geq g_j(b) -q_j$. This ultimately means that even when $g_j a$ is less than $g_j b$ by an amount up to q, it does not contradict the assertion a**S**$_j$b, hence it is still in concordance.

The jth is in <u>discordance</u> with the assertion a**S**b if and only if b**P**$_j$a.
So if $g_j(b) \geq g_j(a) + p_j$. This means that if b is strictly preferred over a, then it is not in compliance with the assertion a**S**$_j$b, hence it is in discordance.

These two concepts concordance and discordance are also thought of as "harmony" and "disharmony". Now for each pair of alternatives (a, b) and for each criterion, ELECTRE looks if the pair is in harmony or disharmony with the assertion a**S**b, which means, 'a is at least as good as b'.

With these concepts it is now possible to obtain the measure of the strength of the assertion a**S**b. This is done through the concordance index: C(a, b), where (a,b) ∈ A. Let w_j be the weight for criterion j, then the following outranking principle follows:

$$C(a,b) = \frac{1}{W} \sum_{j=1}^{n} w_j c_j(a,b)$$

Where,

$$W = \sum_{j=1}^{n} w_j$$

And

$$c_j(a,b) \begin{cases} 1, & if \ g_j(a) + q_j > g_j(b) \\ \dfrac{p_j + g_j(a) - g_j(b)}{p_j - q_j}, & otherwise \\ 0, & if \ g_j(a) + p_j \le g_j(b) \end{cases}$$

Which means that concordance is equal C(a,b) = 1 and Discordance means C(a,b) = 0.

Since the concordance matrix is calculated, calculating the discordance matrix is left. For this a new threshold is introduced, the veto threshold, v. The veto threshold v_j allows for the possibility to refuse the assertion a**S**b totally if, for any one criterion j, $g_j(b) > g_j(a) + v_j$. The discordance index for each criterion j, $d_j(a,b)$ is computed by the following formula

$$d_j(a,b) \begin{cases} 1, & if \ g_j(b) - g_j(a) \ge v_j \\ \dfrac{g_j(b) - g_j(a) - p_j}{v_j - p_j}, & otherwise \\ 0, & if \ g_j(b) - g_j(a) \le p_j \end{cases}$$

Eventually the concordance matrix and discordance matrix are combined in the so called Credibility matrix. The credibility matrix indicates the reliability of outranking hypothesis a**S**b. If the concordance index is higher or equal than the discordance index, than the credibility matrix is equal to the concordance index. If this is not the case then the degree of the credibility is equal to the concordance index lowered in direct relation to the discordance.

$$S_j(a,b) \begin{cases} C(a,b), & if \ d_j(a,b) \le C(a,b) \forall j \\ C(a,b) * \pi_{i \in j(a,b)} \dfrac{1 - d_i(a,b)}{1 - C(a,b)}, & if \ d_j(a,b) > C(a,b) \forall j \end{cases}$$

Where $\pi(a,b)$ is the set of criteria for which d_j (a,b) > C_j(a,b)

The credibility matrix tells us the strength of the assertion a**S**b. Now it is known for every pair of alternatives if outranking happens. However currently there is no overall ranking yet. This is done in the last step, the distillation procedure.

The algorithm for ranking all alternatives is done using two pre-orders and combining them afterwards.
-   Descending distillation
-   Ascending distillation

Descending distilation
Step 1: The maximum value of the credibility index is determined using λ_{max} = max S(a, b)
Step 2: $\lambda = \lambda_{max} - (0.3 - 0.15 * \lambda_{max})$, where 0.3 and 0.15 are preset values for distillation.
Step 3: Determine the λ – strength (# alternatives with S(a, b) > λ. (*Iman Majdi, 2013*)
Step 4: Determine the λ-weakness (# alternatives with (1 – (0.3 – 0.15 λ) * S(a, b) > S(b, a))
Step 5: setup the T-matrix where:

$$T(a,b) \begin{cases} 1, if\ S(a,b) > \ \lambda \ and\ S(a,b) > S(b,a) \\ 0, Otherwise \end{cases}$$

Step 6: Define the qualification score of each alternative Q(a) as the number of alternatives that are outranked by alternative a, minus the number of alternatives that outrank alternative a Hence, Q(a) can simply be calculated by subtracting the row sum to the column sum of the matrix T.
Step 7: The largest qualification score is the first Distillate of D1. If all values above the initial cutoff level λ are "used". Then step 1 – 7 are repeated for all remaining alternatives.
With Ascending distillation the same process is used but instead of starting at the maximum, the algorithm starts at the minimum.

Afterwards the Descending and Ascending distillation pre-orders are combined to form the final ranking.

4.4.   Implementation of ELECTRE III

The in section 4.3 explained version of ELECTRE is used and implemented. In this chapter the way ELECTRE III is implemented is explained. As soon as the ELECTRE code was implemented values needed to be obtained. Together with the decision makers the following values for the threshold values are chosen.

Table 4 – threshold values (also part of Appendix E)

Criteria	Indifference value q	Preference value p	Veto value v
Findability of Document	1	2	6
Level of Document	1	2	6
Out-datedness	52	100	300
Impact on Cash	1	5	8
Impact on Cost	1	5	8
Impact on Customer -satisfaction	1	5	8

For example for the criteria Out-datedness, 52 was chosen for the indifference threshold. This was done because the Thales decisionmakers decided that documents that are only one year older are not significantly more important. In Section 5.1 even more elaboration is given why these values are chosen.

Note that for the criteria impact on Cash/Cost/Customer Satisfaction the values are based on how the criteria are scored. By making the decisionmakers choose between 0,1,3,9, preference is obtained. For example, scoring in such a way makes sure the indifference threshold is not necessary. This is why these threshold values are specifically chosen for these criteria, they take the way of scoring into account.

Table 5 – Threshold Values of impact on Cash/Cost/Customer Satisfaction

Threshold values for Impact criteria	Score
Indifference q	1
Preference p	5
Veto v	8

Ultimately by choosing these numbers, there is always strict preference between 3 and 9. And veto always applies between 1 and 9. All this makes sure that grading these criteria is practical, easier and eventually leads to logical outcomes.

Representation of importance scores

Additionally to the chosen threshold values, some modification to the scoring method were implemented. In the final list around 400 documents are listed (see table 6, next chapter). Giving all documents their individual spot is not useful information for Thales. The representation of importance in this way, is very vague. When one process description is on rank 200 and another on 350, people know that process A is more important than process B. But how much? 150 spots much? Things even get more vague when filtering per department. When one filters the list to only show documents from for example the manufacturing buying department, their highest ranking document has rank 150. Does that mean they are doing a good job? This is why some simplifications to the ranking are done to give Thales more meaningful information regarding the importance of a document.

Together with The industrial Supply chain manager the eventual grading system was thought of. In short it transforms the ranking that is produced by the MCDM to a rating list. Based on the former ranking, the individual documents get a importance score assigned (a number 1 to 10.)

The document with the highest qualification score gets assigned grade 10. The document with the lowest qualification score gets assigned grade 1. Now 10 differentiation levels are calculated for the number 1 to 10.

10 is given to all documents with a qualification score above ((Max score – Min score) * 0.9)
9 is given to all documents with a qualification score above ((Max score – Min score) * 0.8) and below or equal to ((Max score – Min score) * 0.9).
The same is done for all documents and as a result all documents are graded with a number between 1 to 10.

In the figure below a snapshot is taken from the excel file. This table can be found in the Dashboard sheet and it represents the top 40 documents (the documents with the highest prioritization score). It shows the name, last updated date, the actual grade, save location, the row number of the file in the full list and lastly the department that is responsible for the file. The Grade is calculated by using the algorithm explained in chapter 4.3. The programming code that is used to do this can be found in Appendix F.

Note that color scales are used for the final grades, where 10 is dark red and 1 is green.

Picture not visible due to Thales sensitive information.
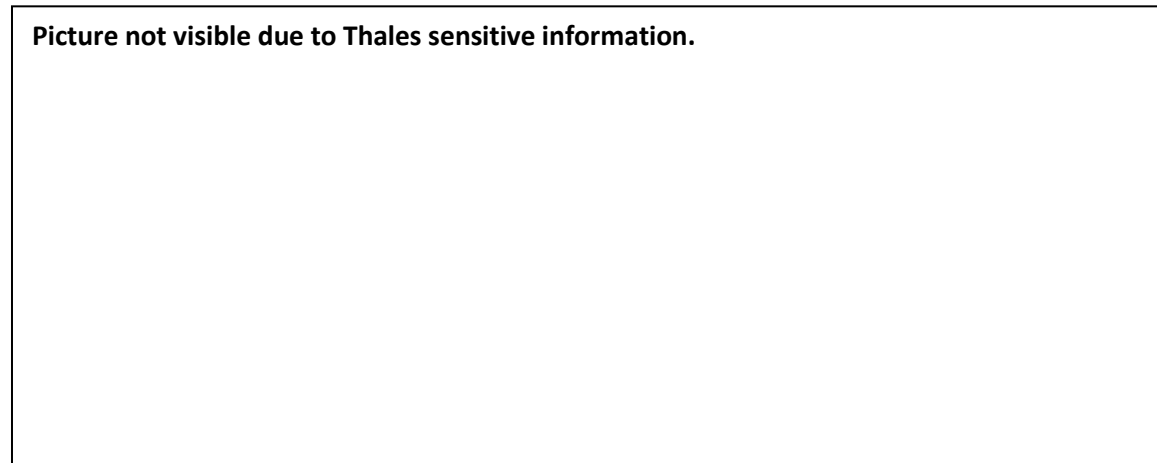
Figure 2 – Representation of document prioritization.

5. Data analysis and results

In section 5.1 a sensitivity analysis is conducted to validate the multi criteria analysis method. And key observations will be made in section 5.2. Following a sensitivity analysis in 5.3 and lastly the data analysis conclusion is given in section 5.4.

5.1. Data analysis

There are in total 393 files taken into account.

Table 6 – Overview of the amount of relevant documents

Manufacturing buying	93 Documents
Master Planning	49 Documents
Warehouse & Logistics	211 Documents
Costing & Obsolescence	7 Documents

From the total list a dashboard is created to analyze the list. Snapshots of this dashboard and a manual of the excel file can be found in Appendix B.

When looking at the date some observations can be made; First of all, it is quite obvious that more than half of all the documentation is older than 2 years. When one looks more closely at this, it becomes clear that the department Warehouse&Logistics mostly contributes to this statistic. (see Appendix D for total comparison of criteria charts)
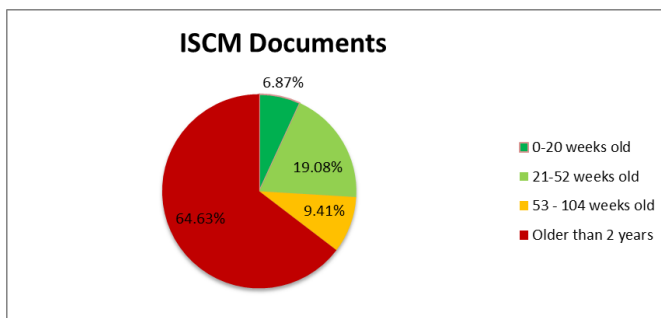
Figure 3 – Outdated-ness of Industrial supply chain
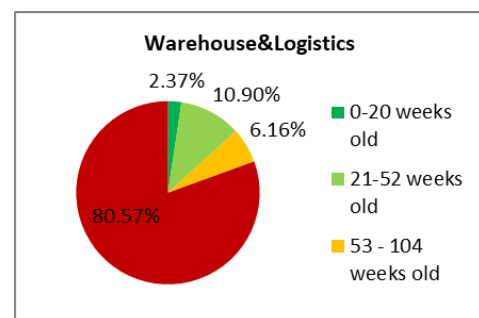
Figure 4 – Outdated-ness of W&L

So a question comes up. Why do the other departments perform considerably better on this criteria? There are a few main differences between the documentation of the departments. First of all, warehouse & Logistics has saved almost all its documents on the TOL environment. While Masterplanning/ Manufacturing buying and even Costing&Obso uses project Discs and sometimes even personal Discs. A good example of this difference is the department masterplanning.
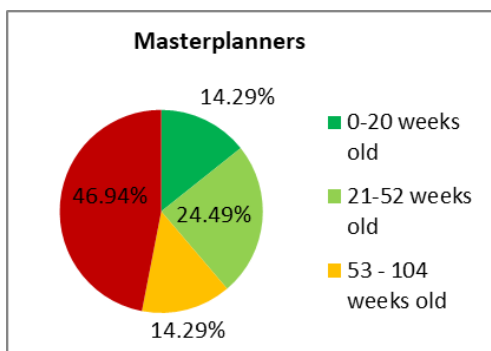
Figure 5 – Outdated-ness of Masterplanning

Masterplanning has almost 50% of its documents older than 2 years. However when we look at the out-dated files of the masterplanning department, almost all of them are saved on the TOL environment. The other, more updated files, are saved on their project disc.

Secondly Warehouse & Logistics has a lot of low level work instructions, documents that explain how to do very specific tasks. These tasks do not change regularly so there is less need to update these documents. This could be another reason for why Warehouse & Logistics has such a high percentage of old documents.

Ultimately both reasons contribute to the high out-datedness score of the warehouse & Logistics department, however there is one thing we can definitely take away from this and that is that it looks like documents in the TOL environment tend to be more outdated. This something Thales could address in the future.

Comparing Departments

While it looks like Warehouse & Logistics is the worst student in the classroom, actually when we look at the average priority grades another department steals the show.
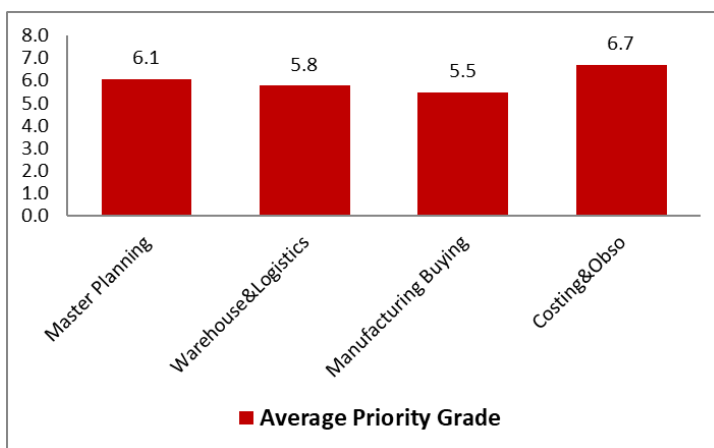
Figure 6 – Average priority grade per department

Costing & Obsolescence performs on average the worst. First of all, after interviewing Obso employees, it became clear that for a lot of daily activities there are no process descriptions yet. Additionally a lot of documents are not finished and they even score the worst on the criteria findability, since a portion of their documentation is saved on a personal disc.

While Costing & Obsolescence can benefit a lot from improvements, the other departments could also be helped a lot of improvements. Master planning for example, their big portion of documents that is outdated significantly influences their performance on the criteria. In the next section, key observations will be given regarding these shortcomings of each department.

When looking at the overall distribution of the importance grades and the total documents each department possesses. It becomes clear that Warehouse & Logistics has by far the most Grade 9 and 10 documents. Costing & Obsolescence has a weird distribution, this is due to their small amount of documents.

Document scores distribution% of Total
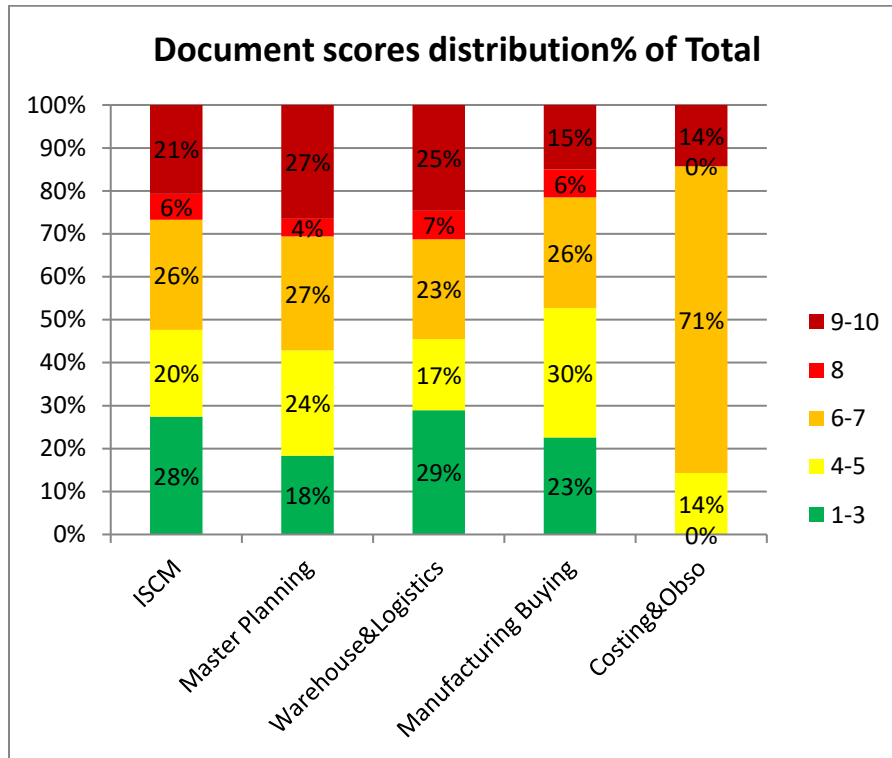
Figure 7 – Over scoring distribution per department (ISCM = all departments combined)

5.2. Key observations

As discussed before there are many observations that can be made from the dataset. However not only the dataset gives information. Thales employees are also a source for information. During the study interviews are held and a couple of observations are made. To give a good overview of all important observations, this paragraph is written.

5.2.1. Master Planning

Master planning uses only a few documents compared to manufacturing buyers and warehouse & Logistics. Overall the documents that are on the Project disc are well maintained and used frequently. The documents that are on TOL are almost always old and it is questionable if they are even used.
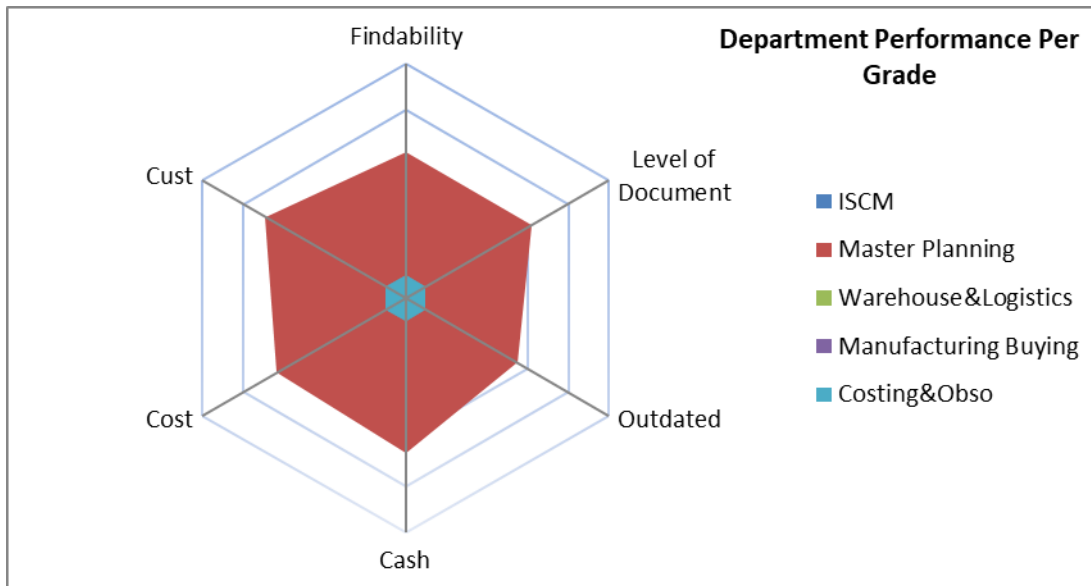
Figure 8 – Overall performance of the master planning department

In Figure 8 it can be seen that Master planning is quite balanced. It scores average on all criteria. One interesting thing to note is that master planning scores the highest on impact on Customer Satisfaction. This is logical, if planning processes go wrong, it has a huge impact on delays and eventually the lead times and delayed orders are very annoying for customers.

5.2.2. Warehouse & Logistics

As discussed in 5.1 this department has a lot of old documents. The TOL environment can be a reason for this and the fact that a lot of documents are low level can also be reason. On the other side however, the findability of the files is pretty good. They are all saved centrally on the TOL environment, which is good. As can be seen in figure 9, this departments main problem is the out-datedness.
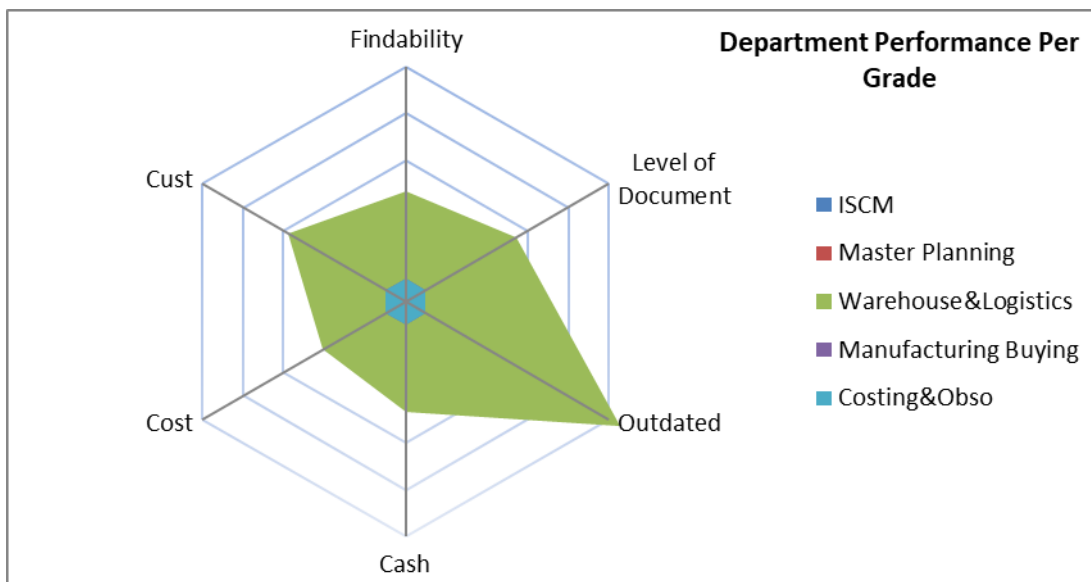
Figure 9 – Overall performance of the Warehouse & Logistics department

When interviewing Thales employees, I also came to the conclusion that most employees do not know where to find these files or don't use these files. Which could also be a reason for the fact that the documents are quite old.

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5.2.3 Manufacturing Buyers

This department also mainly uses its project disc. 91 % of all documents are found on their project disc. This can be seen back in figure 10, where this department scores the highest on the findability criteria. While this is sub optimal for the transparency of the supply chain, they do however maintain their documents very well. Only 35% of all documents are older than 2 years and these documents are often low level documents. Just like warehouse & Logistics, manufacturing buyers have a lot of low level work instructions. However most of them are up to date and in use in contrast to the other department. The main thing is that they rely heavily on the use of their project disc.
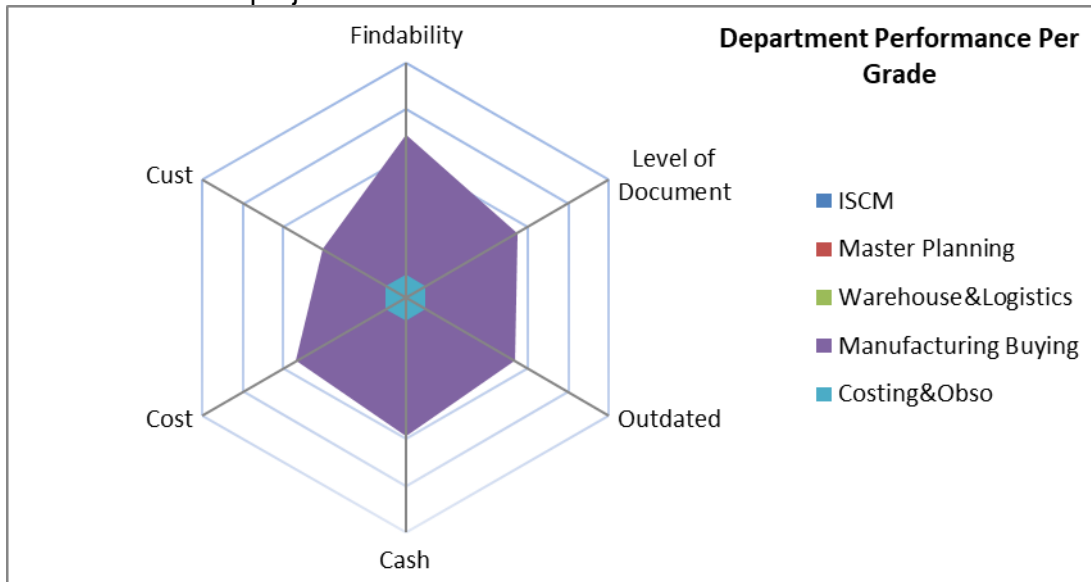
Figure 10 – Overall performance of the Manufacturing Buyers department

5.2.4 Costing & Obsolescence

The main problem for Costing and Obsolescence is that for activities there exist no documents yet. Especially for Costing, where they follow a few high level procedures. When looking at a lower level/ operational level, there is barely any documentation about that. On the other hand, the documents that exist are maintained well, although some are saved on a personal environment. When looking at figure 11, it shows that this department has a big impact on customer satisfaction and overall cost(what the department name suggest). This is why it is important these documents are made since Thales can not afford to make too many mistakes while doing costing&Obsolescence processes.
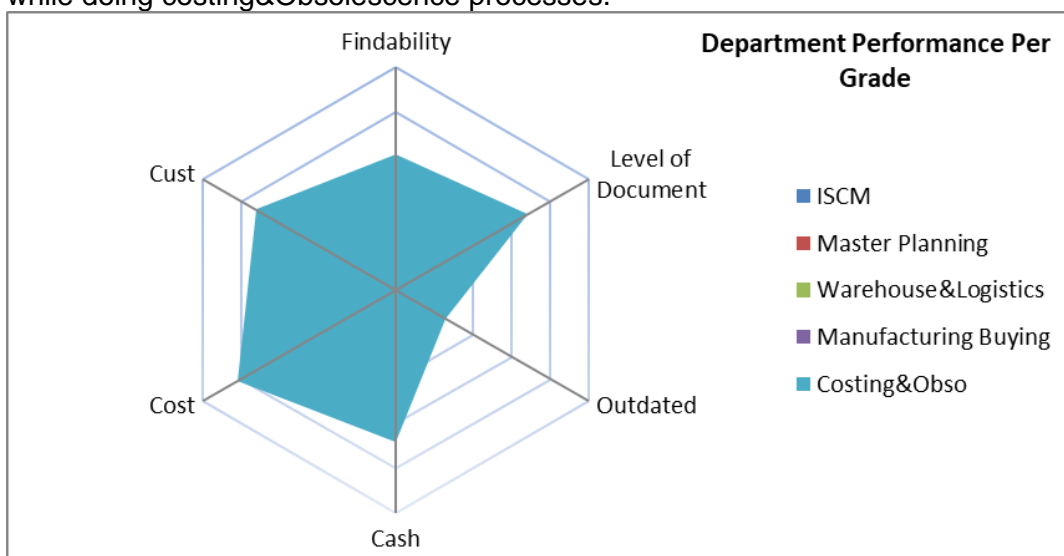
Figure 11 – Overall performance of the Costing & Obsolescence department

5.3 Sensitivity Analysis

Too measure the impact of the weights, the consistency and robustness of the multi criteria analysis a sensitivity analysis is conducted.

As discussed in chapter 4.1. there are 6 criteria. Each criteria has a weight linked to it. The numbers of the weights are changeable by Thales. However weights are restricted to the number 0,1,3,9 only. This is similar to the Impact of cash, cost and customer satisfaction scoring. Using these numbers makes sure the system is more consistent by making the subjectivity of the decision makers less variable. A weight of 0 means the criteria is not taken into account. The other numbers are used to multiply a certain criteria score in the Credibility matrix. See section 4.3 for the exact math details.

To measure the influence of the weights 14 runs are done with different weight settings. Every run consists of 5 weights having 1 as input, while the 6th has a higher number. See figure below

| Run	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Findability of Document	1	3	1	1	1	1	1	9	1	1	1	1	1	9
Level of Document	1	1	3	1	1	1	1	1	9	1	1	1	1	9
Out-datedness	1	1	1	3	1	1	1	1	1	9	1	1	1	9
Impact on Cash	1	1	1	1	3	1	1	1	1	1	9	1	1	9
Impact on Cost	1	1	1	1	1	3	1	1	1	1	1	9	1	9
Impact customer satisfaction	1	1	1	1	1	1	3	1	1	1	1	1	9	9

Figure 12 – Weights settings per run

For this experiment all documents were taken into account. When looking at the grades of these documents over the 14 runs some observations can be made. Taking run 1 into account, the other runs are compared to this "initialization run". The average deviation of all the Grades around 15%. Run 8 and 10 deviate the most, on average 25% and 24% respectively. A deviation of 20% is equal to a difference of 2 in the grade compared to run 1. This means the weights have meaningful impact however the change of a grade would on average not be more than 2.

There are however edge cases. The biggest deviation found is 5. The lowest deviation found is 0. In the graph below the distribution of the deviation is given.
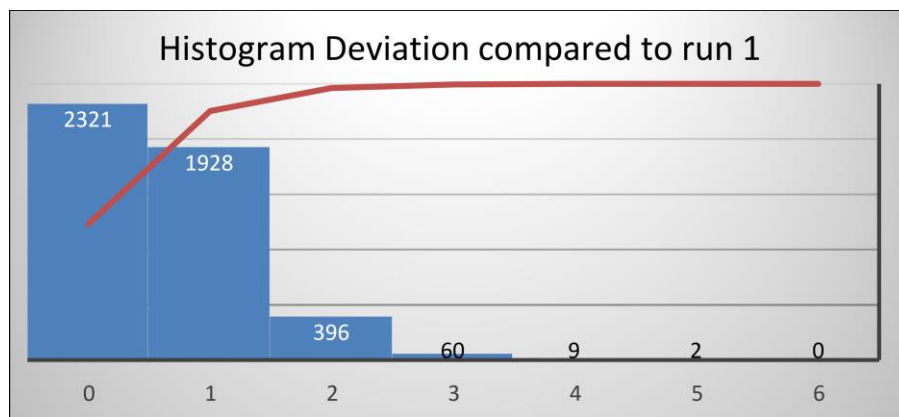
Figure 13 – Histogram deviation compared to run 1

Note that in this histogram the intervals are the x-axis + 1. So 0 refers to the interval:

$[0 \geq x < 1]$.

So while inserting the weights in an extreme manner, (one criteria be 9 times more important than all the others), the outcome of the algorithm is still believable. Which means the order of documents does not change completely. Obviously one wants to have influence in this order,

which is possible through the weights. However the ranking of documents is still mostly influence by its performance compared to others. So while the weights have meaningful influence it is resistant to over manipulation of the inputs.

5.4 Conclusion Data Analysis

The data shows that the TOL environment is very old. Less than 10% of the documents in the TOL environment have an out-datedness of less than 2 years. This means that Thales should take a look at TOL and check which documents are worth keeping and which ones are outdated, unused and irrelevant now. Mostly Masterplanning and Warehouse & Logistics departments have a lot of documents saved on the TOL environment.

Additionally the reliance on Project environment is very noticeable. Especially Master Planning and Manufacturing buyers rely on this environment. In the future this should be addressed and the documents saved on this environment should be saved somewhere more central. Still the main issue of the Industrial supply chain documentation would be that the documents overall are very outdated. Over 60% of all the process descriptions is older than 2 years, to keep the supply chain competitive this is not acceptable.

6. Conclusion and Recommendations

In this final chapter the conclusion and recommendations are given. These can also be found in the management summary at the start of this paper. In Section 6.1 the conclusion is given and discussed. Afterwards in section 6.2 recommendations are given which are useful for Thales to keep in mind. Eventually in section 6.3 research questions for future work are given and in section 6.4 the contribution to practice and theory is discussed.

6.1 Conclusion

To conclude a lot of improvements can be made to the whole situation. A lot of documents are outdated / unused. Documents are saved on many different locations which only makes things more invisible. The list provided in the excel file gives a list of all relevant documents. The save location of these files, the edit date, title and much more information is now known. Through prioritization it is now possible to tackle the biggest risk factors and slowly go to a better situation. The industrial Supply chain manager and other decision makers can choose this direction by changing weights of criteria or changing scoring inputs according to their strategies.
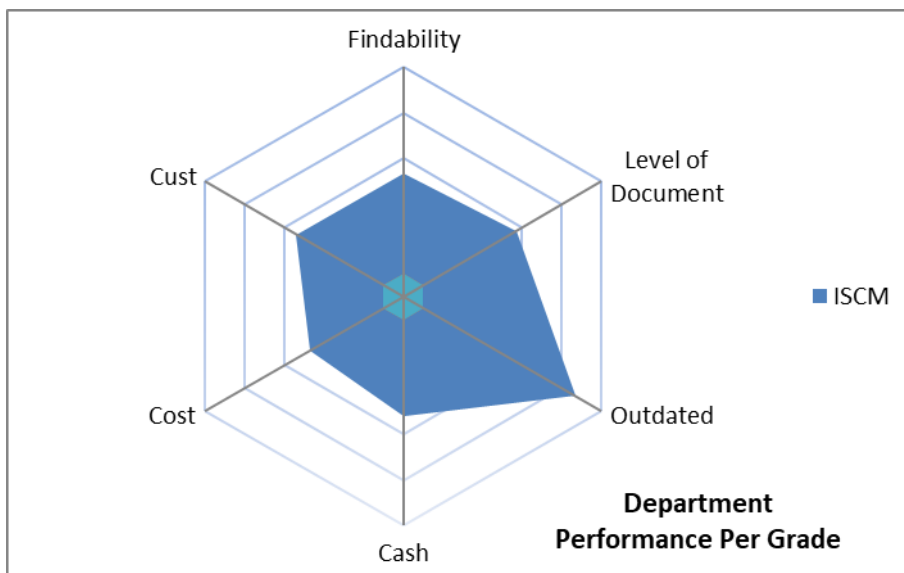
Figure 14 – Overall performance of Supply chain per criteria

Overall the biggest improvement leaps can be obtained by tackling the TOL environment. A lot of documents are on there but less than 10% is recently updated and probably gets used. It can be seen in the graph above that overall the supply chain as a whole, performs the worst at the "outdated-ness" criteria.

Another big leap can be gained through centralization of the documents that are now saved on project discs and personal discs. More usage of Chorus 2.0 is required to achieve this centralization. In the future Thales can use the excel list to stay up to date on the documentation situation. In practice the excel file is a very practical tool that shows the current situation and can be used to identify important documents. The excel tool is programmed in such a way that it keeps track of out-datedness, so in 2 years new documents become outdated and these files are easily identified through the excel file. In Appendix B a manual on how to use the excel file is given.

To conclude, this study shows how to build a practical prioritization model using ELECTRE III. In Appendix B the representation of the data, that is gathered through this prioritization model, is shown and can be reused for future work. Additionally the 0,1,3,9, model is used in practice and works very well. This also can hopefully help future studies when struggling with subjective/changing human opinions while consistent scores want to be obtained.

6.2 Recommendations

Central location
One of the big issues in the current situation is that 2 out of 4 departments hugely rely on project discs. This negatively influences the transparency and limits the overall standardizations that can be implemented for the whole supply chain. Centralization of documents is important. This makes sure every Thales employee can look at what other people do. This in turn can create bigger consciousness of the impact of someone's work. It also improve collaboration between colleagues. For example work can more easily be handed over when everyone has access to everything. And lastly it improves the visibility for managers to look at how employees work if everything is structurally and centrally saved.

Note that is important to think of when a document should be saved on this central place. To keep the information environment of high quality, reviews should be taken before a document can be saved on it. It can be inefficient if every small document that has ever been made by a employee has to be reviewed and saved on something like Chorus 2.0. A recommendation would be to safe only documents that score a grade higher than 6 on the "level of document" criteria. Also be wary of people who have to use different documents daily. When everything is saved centrally and structured in some manner. It can be an annoying job finding all the files you need every day. These people will probably download and copy the files and save them in one convenient folder for themselves to work from. Agreements have to be made for these situations. I recommend to give employees the freedom to choose if they want to work like this. In hindsight this way of working can be more practical and less time consuming. I would however make the agreement with everyone, that whatever is saved on the central spot, is leading.

Collaboration documents
When interviewing employees a lot of people noted that they miss collaboration documents. Instead of documents telling you how to do something, there is a demand for documents that say how to work together with employees. A single process mostly gets done through multiple departments. Instead of all departments have their own version of the process activities, it could be useful to combine everything and add how the activities impact each other. This not only emphasizes ones job, it also promotes thinking a like. Solving problems is easier when more people have context from different areas.

Management influence
A big reason for why the current situation regarding documentation occurs, is because the current way people work with documents is tolerated by management. To ensure the same situation does not occur twice, management should be strict on this and the new strategy should be implement top down.

Update / maintain procedure document
In addition to management being more present in this issue. Why not have an official document that states how to handle updating/deleting/making files? This document can illustrate who is responsible for reviewing, what and when to review, what documents can be saved on project discs and which ones need to be addressed for Chorus 2.0. Ultimately this document can serve the purpose of raising awareness of the current situation. It also keeps everyone in check and makes sure the methodologies developed to get to the new situation do not get forgotten when people leave for new jobs. Additionally new employees can use this document to immediately know how to handle professional documentation.

In addition to this document, the excel file from this Thesis should be used to stay on the road to a better situation. By maintaining the excel file, you know where you are and what still has to be done. This way you can efficiently go to the new desired situation.

6.3 Possible Future research Questions

The following research questions can be used for additional research into Thales documentation / documentation in general. Note that there are a lot of different directions future studies can take. The focus on documentation is strong in this study however in future work the role of employees using documentation can play a more central role.

- What techniques can be used to improve transparency in a supply chain?
- How do you link high level strategy documentation to low level operational documentation?
- What criteria can be added to add focus on the future?
- How does the prioritization change while using other MCDM?
- What other methodologies can be used to give department managers insight in where to start?
- How can subjective human scoring criteria be replaced?
- How can one make the prioritization system more reliable?
- How do you measure how complete the documentation list is?
- How could Thales implement a new documentation system that makes sure they do not fall back into the current situation?
- What documentational hierarchies are there that operational and strategic document can benefit from together?
- How can management influence employees to use and write good documentation?
- What practices can be implemented to make documentation overall more transparent?
- What are good templates that Thales can use for their future documentation?
- How do employees interact with documentation and what are the effects of this?
- How does work culture affect the use of documentation?

6.4 Contribution to Theory and Practice

6.4.1 Contribution to Theory

In this study it is shown how ELECTRE III can be used as a multi criteria analysis method for prioritizing documents. In this study it also shows how this prioritization can be used as a risk factor instead of a pure outranking list. ELECTRE III and ELECTRE in general are mainly used as pure rating/ranking methods. In this study it is shown how ELECTRE can also be used for pure risk association. It is shown that ELECTRE is very robust and consistent while having meaningful influence from decisionmakers to focus on general strategic directions of a company.

Additionally this study compares a lot of different MCDM's to this specific situation and it can be concluded that ELECTRE is a very good fit for problems similar to this one. It's ease of implementation, flexibility and good translation to practice can be taken from this study. Note that ELECTRE is one of the few MCDM's that use buffer zones to get a more nuanced translation of reality. This is something what other MCDM's lack and it is shown in this paper how decision makers, at Thales, benefit from these buffer zones. This is mostly due to the fact that human subjectivity is less apparent since Decision makers can make judgements that are more nuanced than good or bad, it can also be something in between.

6.4.2 Contribution to practice

Thales is probably not the only company that struggles with this documentation problem. Many companies probably experience the same. In this study it is shown that a framework can easily be built from 2 main pillars to tackle such problems.

From this study it can be concluded that an inventory of all documentation is necessary. After the list is created, it is shown that by adding prioritization a clear path is obtained. Now Thales decisionmakers know where to start with updating process descriptions. This methodology can be used in other companies as well. When the sheer number of documents is too big to know where to start, prioritization of documents creates focus and insight of a starting position. Additionally focus not only shows the current situation it also shows the road to an improved situation. Note that in Thales' case a Multi-criteria analysis method is used for prioritization. This is useful due to the nature of this situation, however other situations/companies do not have to restrict themselves to ELECTRE or any other MCDM. They can use whatever other prioritization method there is, this study only shows that ELECTRE is useful for a latter purpose in practice.

Additionally in this paper the usefulness of the 0,1,3,9 principle is shown. It not only makes it easier and more practical for decision makers to score criteria. It also improves consistency, hence reducing human subjectivity and overall improving the reliability of the criteria grades.

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Appendix A - Structured Literature Review Decision making

Theoretical Perspective

The goal of this study is to give Thales a tool that gives them a prioritization on what process documents they would need to update. At the start of this study a lot of questions are present. However most questions are partly answered through on hand experience within the company. So most of these questions are not viable to answer through a structured literature review. The grading system design however, that is the design on how the prioritization grades are calculated, can be designed in advance. I want to know how does one prioritize based on multiple objectives. In order to choose the best heuristic or strategy to compute these grades given Thales' KPI's, I want to know more about different heuristics/strategies/analysis and when to use them. This is the theoretical perspective.

Research Question

What decision making techniques are best used when grading over multiple objectives?

Key Constructs

Regarding the research question, multiple key concepts can be subtracted. I want to do a broad exploratory search because the situation of Thales is not fully known. I want to know the best technique for multiple situations. So when the situation is known, I can choose the decision making technique that fits best.

The constructs taken from the research question are:

- **Decision making techniques**
- **Objectives**
- **Grading**

The constructs are both mutually exclusive and collectively exhaustive (MECE). For example there exist many different decision making techniques, however such an exact strategy can only be described by 1 technique and not null techniques.

Table 7 – Search Matrix

Construct	Related terms	Broader terms	Narrower terms
Decision making techniques	Choose, primed intuitive, rational tactics.	Choose procedure, decision analysis, Decision making Heuristic, Decision making theories,	Rational choice, logical choice, problem solving.
objectives	Criteria, policy, Goals, KPI	multiple objectives	Business strategy, SMART criteria, Action plan, Strategy
Grading	Rating, review,	Score, add value to things	Ranking

Table 8 – Documentation Matrix

Date	Database	Search Terms	Amount of hits
29-05	Google Scholar	Decision making theory objectives	4.5 Million hits (Too vague and too many)
29-05	Google Scholar	"Decision making theories" "criteria"	5 Thousand (Not relevant enough)
29-05	Google Scholar	"Decision making techniques""Ranking"	8 thousand (Found a 7 good articles)
29-05	Google Scholar	"heuristic" "ranking" "Criteria"	139 thousand entries (not relevant)
29-05	Google Scholar	"Decision making technique""score""multiple objective"	328 hits (found 19 relevant items)
29-05	Google Scholar	"Decision making technique""ranking""multiple objective"	503 hits (found 12)
Total Endnote			**38**
Removed by Exclusion criteria			-20
Removed Paid papers			-6
Removed duplicates			-4
Removed after complete reading			-5
Total			**3**

Table 9 – Criteria Matrix

Number	Criteria	Reason for exclusion
1	A specific situation	An approach based on a specific situation is irrelevant to Thales' specific situation.
2	Watermanagement	Not relevant for the company
3	Medicine	Not relevant for the company
4	No pro's or cons of the technique are given	I want to compare pro's and cons of techniques from different literature, this is only possible if it is given within the articles
Number	Criteria	Reason for Inclusion
1	Multiple techniques are discussed and compared	This is the core of the review and these articles let me do extra reviewing of the comparing step of separate

	techniques which is really useful.

Table 10 – Concept Matrix

Article	Review
1	*An Analysis of Multi-Criteria Decision Making Methods*
Decision making techniques	1.Multi-Attribute Utility theory (MAUT) 2.Analytic Hierarchy Process (AHP) 3.Fuzzy set Theory (FST) 4.Case-based Reasoning (CBR) 5.Data Envelopment Analysis (DEA) 6.Simple Multi-Attribute Rating Technique (SMART) 7.Goal Programming 8.ELECTRE 9.PROMETHEE 10.Simple additive Weighting (SAW) 11.Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)
Summary of techniques	1. MAUT gives a utility to every possible consequence given the attributes. 2. AHP is a method that does pairwise comparisons of attributes and relies on experts for advice to give priority scales. 3. Extension of the classical set theory. It allows solving a lot of problems related to dealing the imprecise and uncertain data. 4. It proposes an solution to a decision making problem based on the most similar case. 5. Uses a linear programming technique to measure the relative efficiencies of alternatives. 6. SMART is a simple form of MAUT, it only requires two assumptions: utility independence and preferential independence. It converts weights into actual numbers. 7. Pragmatic programming method that chooses from an infinite number of alternatives. 8. It is an outranking method and based on concordance analysis. 9. Similar to ELECTRE, also uses an outranking method. 10. A value function is established based on a simple addition of scores that represent the goal achievement for each criterion. Eventually multiplied by all the weights. 11. An approach to go for the alternative which is closest to the ideal situation and farthest from the most negative situation in a multi-dimensional computing space.
Pro's and Cons	1.one of the few MCDM that takes uncertainty into account. Good precision. 2.easy to compare alternatives. Scalable 3. Allows imprecise input. Few rules required for complex problems 4. Requires little additional data. It improves over time when more cases are added to its database 5. Able to handle multiple inputs and outputs, efficiency can be analyzed. It can uncover relationships that	1.Data intensive, Need high precision data 2. problems with interdependence between criteria and alternatives. Inconsistencies due to judgment and ranking criteria. 3. Difficult to develop, can require numerous simulations to be practical. 4. very sensitive to inconsistent data. 5. It cannot handle imprecise data and assumes all data is exactly known.

	would otherwise be hidden in the data. 6. Simple to use, allows for any type of weight assignment technique. 7. Can handle large-scale problems, build infinite amount of alternatives. 8. takes into account uncertainty and vagueness 9. easy to use, 10. Has the ability to compensate among criteria. Intuitive to decision makers 11. Simple process, easy to use and programmable.	6. Complicated framework and same problems as MAUT 7. Is unable to weight coefficients. 8. Process and outcomes can be hard to explain, the outranking method causes the alternatives impact hard to be measured, 9. No clear method by which weights can be assigned. 10. All values must be maximized, very specific syntax is required. Estimates do not always reflect the real world. 11. It does not consider the correlation of attributes. Difficult to weight attributes and keep consistent judgement.
2	*Multi-Criteria Decision Making: An overview of different selection problems and methods*	
Decision making Techniques	1. Analytical Hierarchy process (AHP) 2. Technique of Order Preference by Similarity of Ideal Solution (TOPSIS) 3. ViseKriterijumska Optimizacija Kompromisno Resenje (VIKOR) 4. Elimination Et Choice Translating Reality (ELECTRE) 5. Preference asking Organization METHods for Enrichment Evaluation (PROMETHEE)	
Summary of Techniques	1. AHP decomposes a decisionmaking problem into systems of hierarchies of attributes/criteria. Uses pair wise comparisons 2. TOPSIS is based on the fact that the best solution has the shortest Euclidean distance from the ideal solution and the most negative the farthest. 3. This method has its focus on ranking and selecting alternatives in the presence of conflicting criteria. It looks for "Closeness" to the ideal solution 4. It chooses the best action given a set of actions. Main problems are: Choosing, Ranking and sorting. 5. This method is based on comparisons of alternatives with respect to the selected criteria.	
Pro's and Cons	1. Flexibly and intuitive, it is able to check for inconsistencies. 2. Easy to use and fairly intuitive since consideration is based on distance from ideal solutions 3. It calculates the ratio of positive and negative ideal solutions. So it already proposes a compromise solution. 4. Allows using fuzzy analysis. Accepts Qualitative and quantitative criteria.	1. A lot of computations need to be made. Can be difficult to get marginal differences in the result. 2. Can easily give unreliable results. It is deterministic and does not consider uncertainty. 3. It uses Crisp values. These values often do not fully represent the real-life situation. Also it cannot read ambiguous data. 4. Hard to understand since it is using complex matrices. Outcomes are subjective. 5. Suffers from rank reversal problem when a new alternative

	5. Can deal with qualitative and quantitative inputs and does not need a lot of inputs.	is introduced. Can be hard to obtain a useful solution
3	*A survey on Multi Criteria Decision Making Methods and Its Applications*	
Decision making Techniques	1. Analytic Hierarchy process (AHP) 2. Analytic Network Process (ANP) 3. Data envelopment analysis (DAE) 4. Aggregated Indices Randomization method (AIRM) 5. Weighted Product model (WPM) 6. Weighted Sum Model (WSM) 7. Goal Programming 8. ELECTRE 9. Grey Analysis	
Summary of Techniques	1. AHP builds a decision from different goals and criteria and through pairwise comparison of the criteria it obtains the solution 2. Similar to AHP, however now networks are used as hierarchies. 3. DAE tries to find the answer by finding efficiency in the combination of inputs and outputs 4. This method solves complex problems where uncertainty plays a role . 5. In this method alternatives are being compared by the weights and ratios of on for each criterion. 6. It is used to compare alternatives, where the criteria are expressed in the same unit so they can be summed. 7. Goal programming is a division, it has more than one objective and finds the solution minimizing the irrelevant information resulted by arranging the conflicts of these goals. 8. It is used to find the best choice with maximum advantage and least disadvantage. 9. This methods deals with incomplete data and overcomes the deficiencies of other methods.	
Pro's and Cons	1. Flexible, intuitive, no bias 2. Independence among elements is not required and has accurate prediction 3. Easy to handle different inputs and outputs. Comparisons are directly against peer solutions 4. Ambiguous data can be used, deals with inconsistencies. 5. Removes any unit of measure, relative values are used. 6. Strong in single dimensional problems. 7. Handle large numbers, simple to use 8. Outranking is used 9. Perfect information gives a unique solution	1. Irregularities in ranking 2. Time consuming, Uncertainty is not supported. 3. Prone to inconsistencies, Statistical tests are not applicable and the method can be demanding. 4. It only aims at complex objects multi criteria estimation under uncertainty. 5. No solution is given if there are equal weights 6. Hard to use when trying multi-dimensional problems 7. Weights must be appropriate. 8. Time consuming 9. Does not provide an optimal solution.

Main Conclusion	In the papers listed above, a lot of different methods are described. It's advantages and disadvantages are discussed. For example it is described in all papers that AHP is a quite flexible and easy method to use, however it has difficulties ranking solutions due to for example interdependencies. This crosses AHP off the list of possible methods that should be used in ranking problems. When comparing all methods with each other and compare the methods in different papers, I got to the following list of methods that could be used in ranking problems. - Data envelopment analysis (DAE) - Aggregated Indices Randomization method (AIRM) - Weighted Product Model (WPM) - Elimination Et Choice Translating Reality (ELECTRE) - Simple Multi-Attribute Rating Technique (SMART) - Multi-Attribute Utility theory (MAUT) - Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) - ViseKriterijumska Optimizacija Kompromisno Resenje (VIKOR) - Preference asking Organization METHods for Enrichment Evaluation (PROMETHEE) These methods are all applicable in a ranking problem. Since I do not have all the information of my ranking situation it is hard to say which method is most useful for me. However by using this list and this literature review, the best method can easily be obtained when I know the full scale of the problem of this thesis study.

Reference Articles 1-3 are used for this structured literature review.

Appendix B – Excel Manual

The excel file consists of 3 sheets: Dashboard, All, Cluster Scoring.

<div style="border:1px solid black;">

Picture not visible due to Thales sensitive information.

</div>

Figure 15 – Snapshot of the Dashboard

How the dashboard is build:

- On the right the list of the top 40 (highest grade) documents are listed. This list can be filtered per department or for the whole ISCM combined.
- The pie charts illustrate the performance per criteria. All charts can be filtered by criteria and shows the performance per department and for the whole ISCM.
- Next to the pie charts on the left is the total grade contribution per department and ISCM
- Under the grade contribution the average grades of all departments are illustrated in a bar chart.
- In the left lower corner the performance per department can be seen on every criteria. This chart is filtered just the way the top 40 list is.

Figure 16 – Snapshot of the All sheet

How the All sheet works:

The all sheet is where all the individual files are noted. There are around 400 files in this list. From left to right the columns say the following:

- o Doc: which is the document number
- o Department: the responsible department of the file
- o Locatie 1: The main location the file is saved at
- o Locatie 2: a secondary save location, if applicable
- o Werkinstructie naam: The name of the file
- o Laatst geupdate: Last edit date of the file
- o Opmerking: optional notes are filled in this column
- o Process: Which process the file is part of
- o Document label: this is a label that is used to score the files on the level of document criteria (moreover in next sheet)
- o Criteria score: This is the main importance grade.
- o Findability score: this is the score of the findability criteria
- o Level of document score: this is the score of the level of document criteria
- o Out-datedness (in weeks): This is the score of the out-datedness criteria
- o Impact on Cash: this is the score of the impact on cash criteria
- o Impact on Cost: this is the score of the impact on cost criteria
- o Impact on Customer Satisfaction: this is the score of the impact on customer satisfaction criteria
- - Note that some columns contain formulas to calculate scores.
- - If the user wants to change the list with adding/deleting a file, this person can simply delete the whole row of this file, or add a file in a row that is empty or underneath the list.
- - Note that when adding rows under the list, the formulas existing in columns M, N, O and P must be dragged down as well.
- - After adding a document, the user should give the scores in the designated criteria scoring columns. The user can do this by following the scoring tables given in Chapter 4. Or by dragging the formula or by adding a document label in column i. See the next segment for more information about how document labels work.

Department				Impact		kiezen uit	0
							1
							3
							9
				Cash	Cost	Customer Satisfaction	
Warehous	1	Spares		9	9	9	
Warehous	2	Acceptance Test/afkeur/dispostion		3	3	9	
Warehous	3	Cycle Count/magazijn quantities/invetory		9	9	3	
Warehous	4	Export Control/doane/wetgeving		9	9	0	
Warehous	5	Quality Inspection/inspectie rapporrten		3	3	9	
Warehous	6	Logistiek/handle incoming materials/verplaatsen van goederen		1	1	0	
Warehous	7	ERP systeem/data integriteit		3	3	1	
Warehous	8	Reparatie/cleaning		1	1	9	
Warehous	9	Divers werkinstructies/montage/kanbankaarten		3	3	3	
Warehous	10	HSV		9	9	9	
Warehous	11	HSV/Verpakkingen		3	3	9	
Warehous	12	Safety/brandpreventie/etc.		3	3	3	
Warehous	13	Deliver		3	9	9	
Manufactu	1	FRACAS (alle documenten die hiermee te maken hebben, het l	Fracas	3	3	9	
Manufactu	2	Best practice (hiermee bedoel ik documenten die als best prac	Best Pract	1	1	1	
Manufactu	3	BPA (alle documenten die invloed hebben op de BPA's)	BPA	9	9	3	
Manufactu	4	Collaboration (dit zijn documenten die uitlegt hoe manufacturi	Collaborat	1	3	1	
Manufactu	5	Oracle algemeen (algemene oracle dingen, lijkt op Best practi	Oracle alg	1	3	1	
Manufactu	6	Oracle PO (documenten die beschrijven hoe production orders	Oracle PO	9	9	3	
Manufactu	7	Oracle Requisition (Hetzelfde idee als Oracle PO maar dan me	Oracle Re	1	1	1	
Manufactu	8	Export Control (Gezien dat wetgeving erg belangrijk en grote ir	Export Co	3	9	9	
Manufactu	9	Strategisch Document (Dit zijn high level documenten die moei	Strategic	9	9	9	
Master Pla	1	Order Acceptatie	Order Acc	9	9	9	
Master Pla	2	Doorlooptijd verkorten	Doorloopt	3	9	3	
Master Pla	3	Escalatie	Escalatie	3	3	9	
Master Pla	4	Strategic Document	Strategic	9	9	9	
Master Pla	5	ERP analyse	ERP analy	3	3	3	
Master Pla	6	Diverse Werkinstructie	Diverse W	1	3	1	

Figure 17 – Snapshot of sheet Cluster Scoring

This sheet is used to score the Impact on Cash/Cost/Customer satisfaction criteria. When documents are linked to a department and a document label (which should be filled in column i, All sheet) a VLOOKUP is used to score the individual files automatically. It can be done by hand but that is just more work.

Note that only Costing & Obsolescence do not use this VLOOKUP function, all of the files of this department are scored by hand.

Values in the table in this sheet can be altered if the decisionmakers wish too. Adding labels is also possible by inserting a row and adding the department name, number (count upwards), description of the label and by filling in the actual scores per criteria.

Appendix C – Interview Questions

1. *What function do u have and what are your responsibilities?*
2. *What is your opinion about the current situation regarding process descriptions.*
3. *When do you make use of the document database? (how often?) (weekly?)*
4. *What files or folders do u use the most? (Only you?)*
5. *How many times do files you use get changed/deleted/renewed and by who?*
6. *Which department are you most dependent on?*
7. *What written procedures are very critical for the operationality of your department.*
8. *What KPI's would you use to quantify how important a process is?*
9. *What happens when new process descriptions are made? Are they saved on chorus?*
10. *What actions are taken when the law changes? How does it affect certain regulatory files?*
11. *How would you like to see the current situation change?*
12. *Why do you think not everything gets updated?*
13. *When is a file seen as "outdated"?*
14. *How important is it that all documents are up to date?*

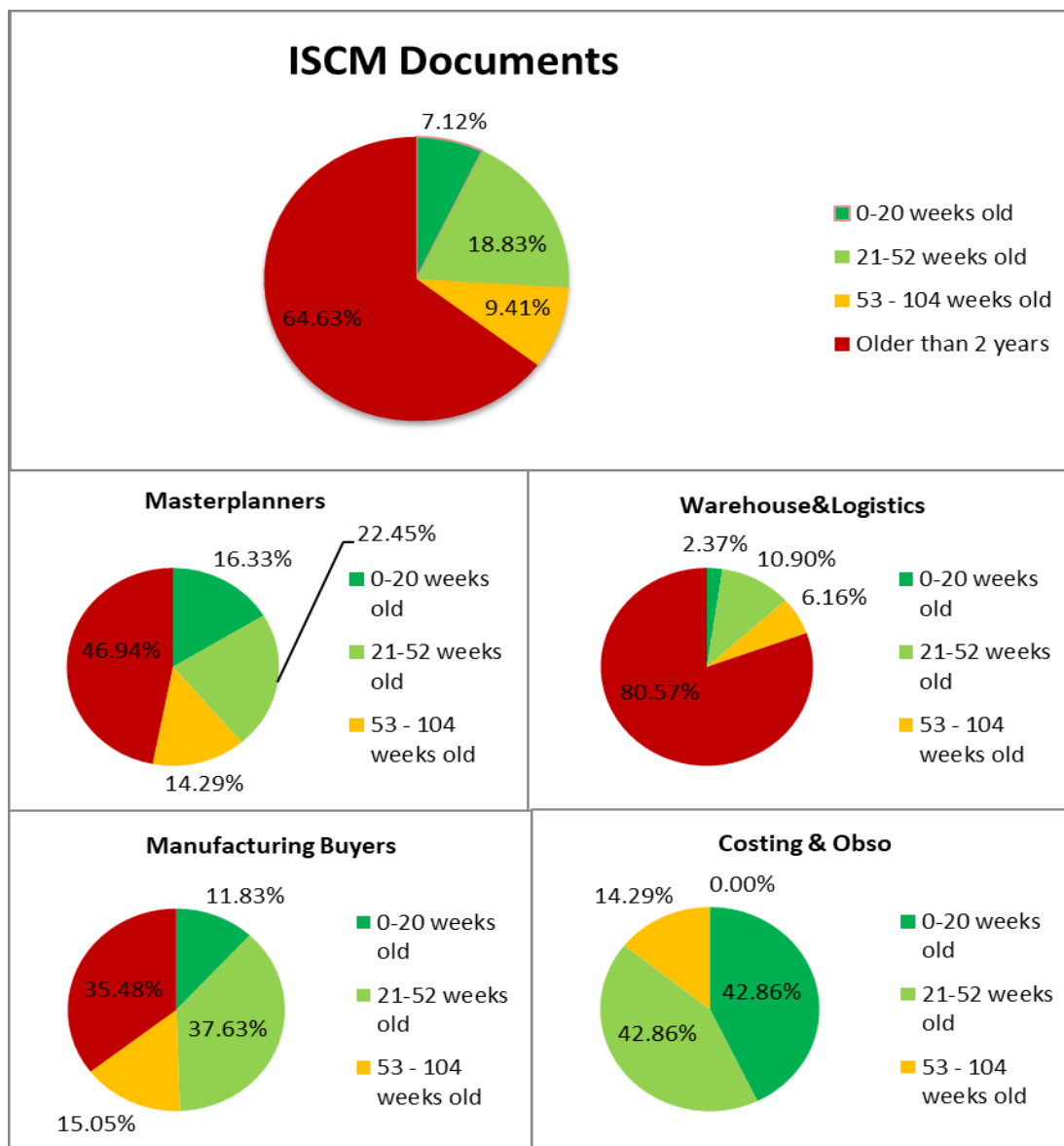# Appendix D – Criteria scoring Graphs per department

Out-datedness

Figure 18 – out-datedness performance of the supply chain

Findability

Figure 19 – Findability performance of the supply chain
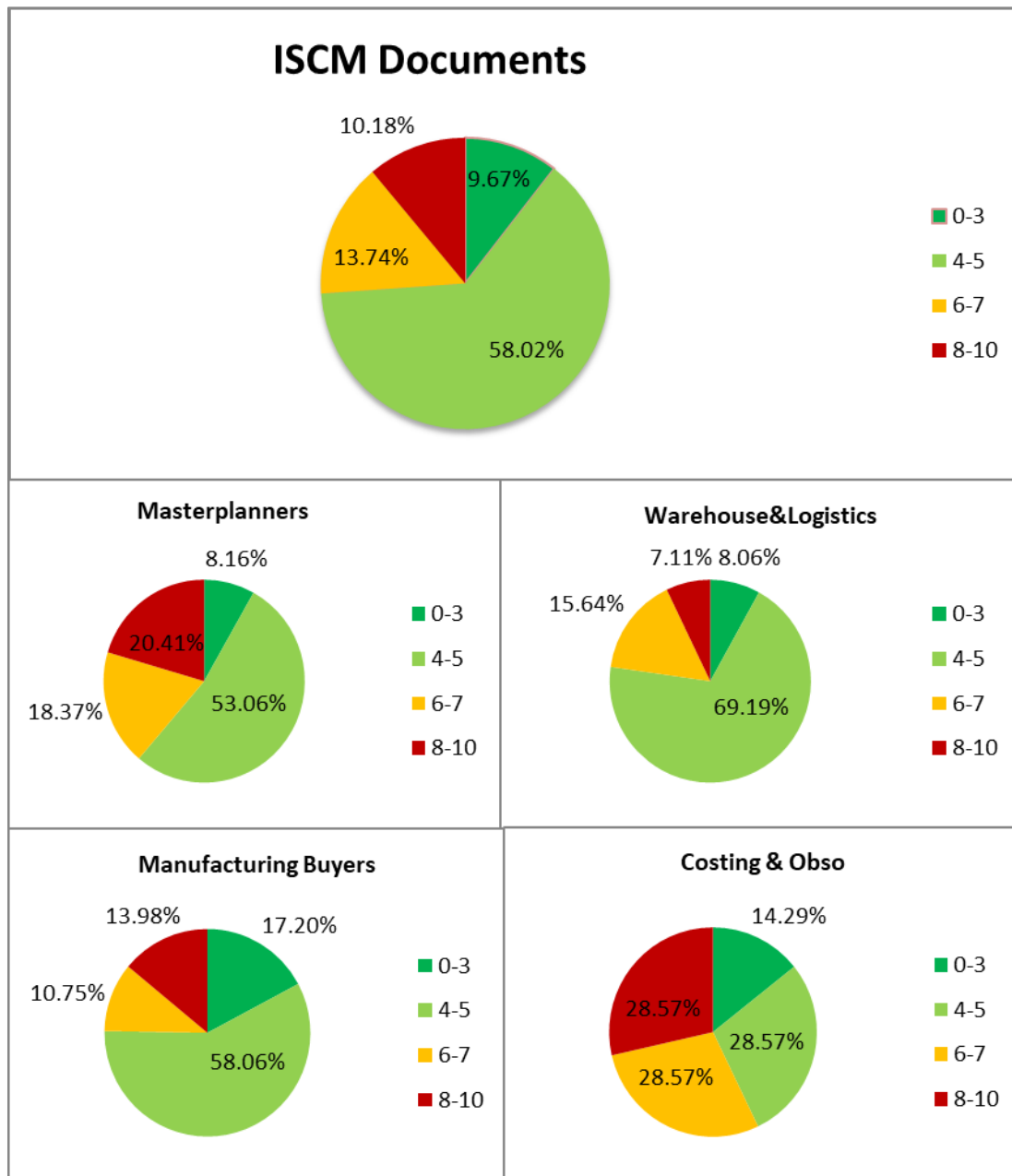
Level of Document Score

Figure 20 – Level of Document performance of the supply chain

Impact on Cash

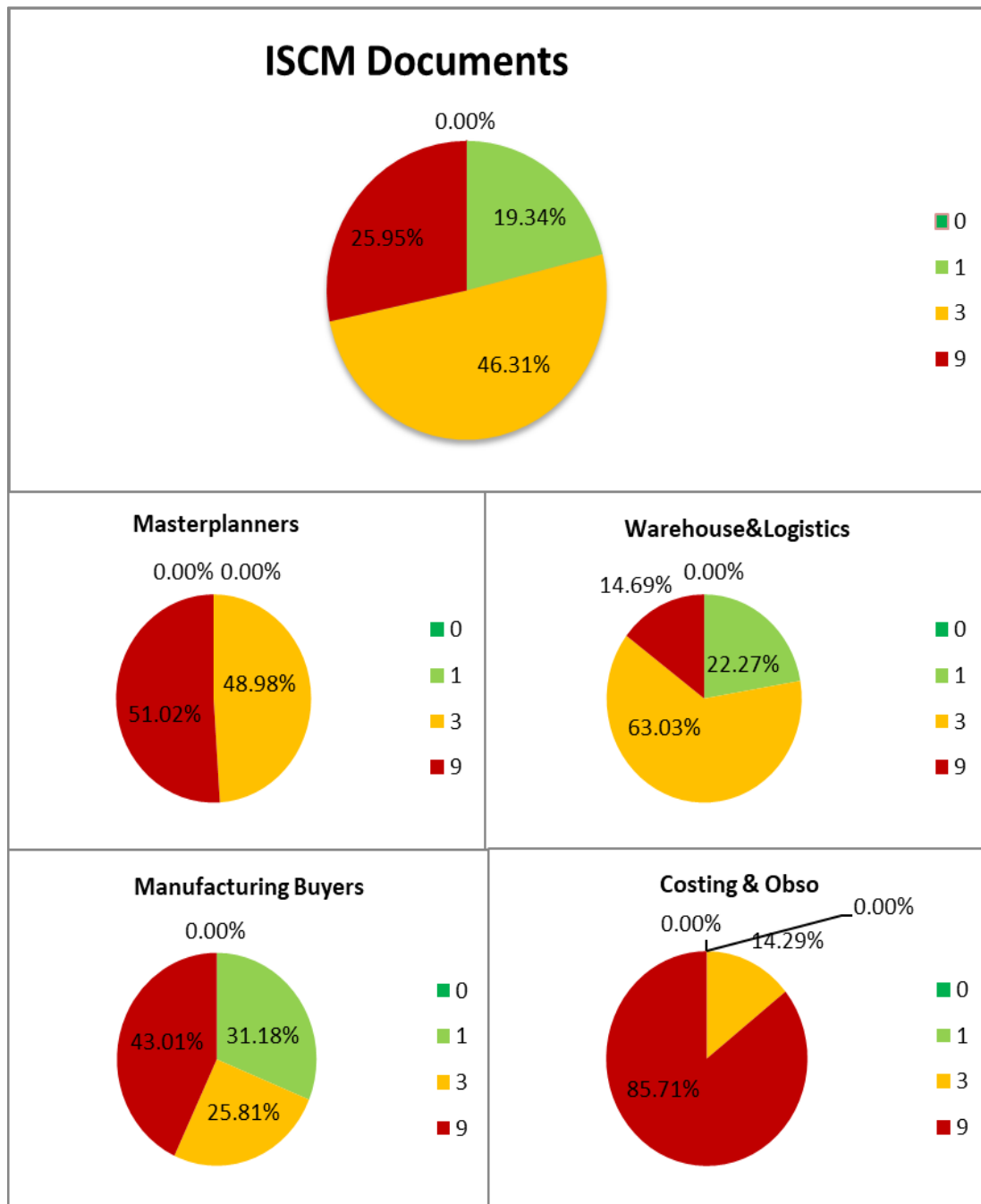Figure 21 – Impact on Cash performance of the supply chain

Impact on Cost

Figure 22 – Impact on Cost performance of the supply chain
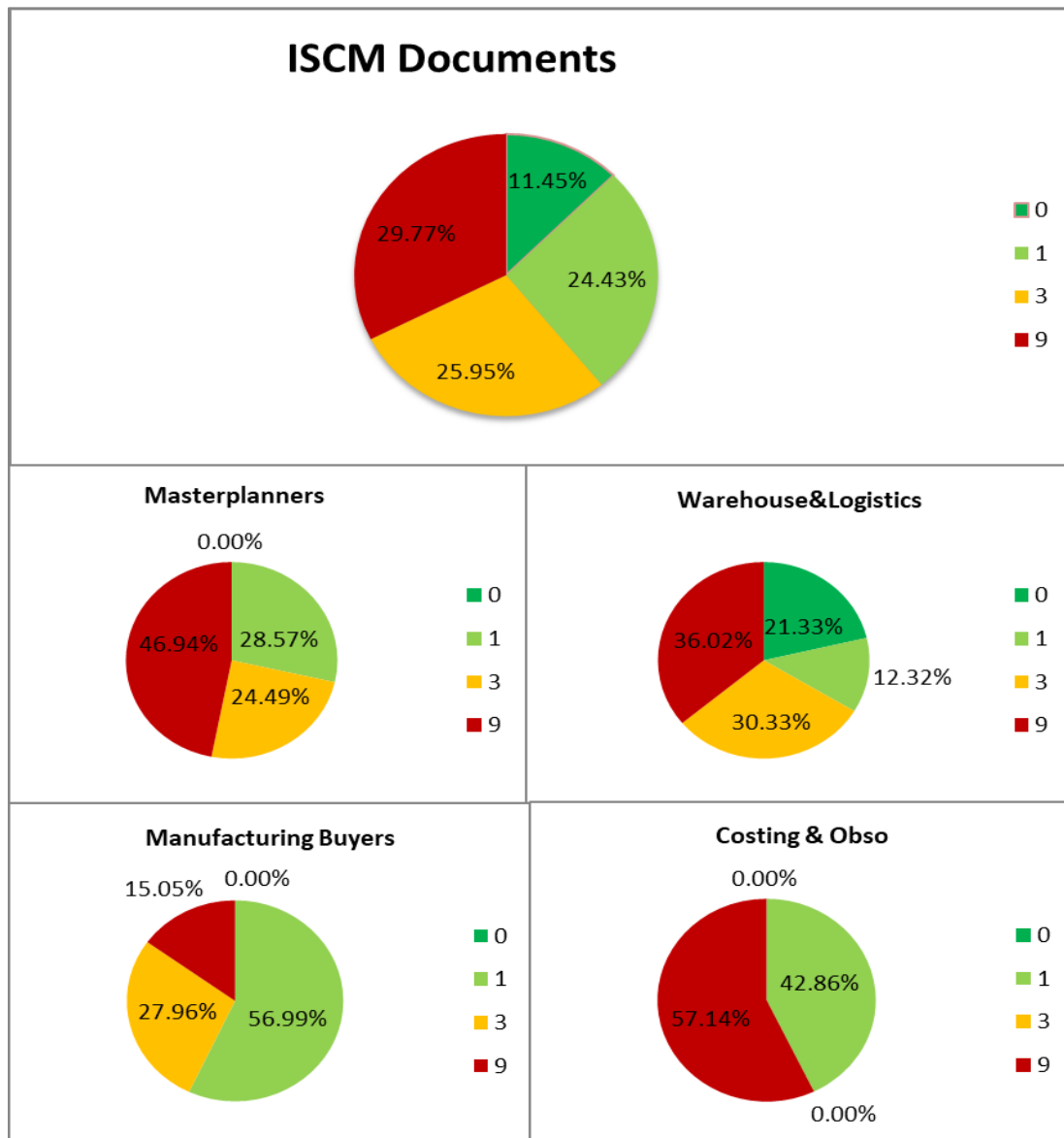
Impact on Customer Satisfaction

Figure 23 – Impact on Customer Satisfaction performance of the supply chain

Appendix E – Threshold values determined with decision makers

Table 10 – Threshold values

Criteria	Indifference value q	Preference value p	Veto value v
Findability of Document	1	2	6
Level of Document	1	2	6
Out-datedness	52	100	300
Impact on Cash	1	5	8
Impact on Cost	1	5	8
Impact on Customer - satisfaction	1	5	8

Appendix F – ELECTRE III Code used for calculating grades

```vba
Option Explicit
Sub I()
Application.EnableEvents = True
End Sub

Sub Calculation()
Application.ScreenUpdating = False
Application.Calculation = xlCalculationManual
Application.EnableEvents = False

Dim dash As Worksheet, All As Worksheet

    Set dash = ThisWorkbook.Sheets("Dashboard")
    Set All = ThisWorkbook.Sheets("All")

'Paar definities
'a P b (a is preferred over b)  g(a) > g(b)
'a I b (a is indifferent)      g(a) = g(b)
'a J b (a cannot be compared)

'Tolerantie q
'a P b -> g(a) > g(b) + q
'a I b -> abs(g(a) - g(b)) <= q
'a J b -> -

'Strong Preference pr
'a P b (a is strongly preffered to b)-> g(a) - g(b) > pr
'a Q b (a is weakly preferred to b)-> q < g(a) - g(b) <= pr
'a I b (a is indifferent to b) -> abs(g(a) - g(b))<= q

'a S b ( a is at least as good as b)
'a Sj b (a is at least as good as b on criteria j)

'concordance:
'a S b if and only if a Sj b -> gj(a) >= gj(b) - qj

'discordance
'NOT a S b if and only if b Pj a -> gj(b) >= gj(a) + pj

'Concordance index C(a,b) for all criteria j. wj = weight for criteria j

'            1, if gj(a) + qj >= gj(b)
'Cj(a,b) =      0, if gj(a) + pj <= gj(b)
'            (pj + gj(a) - gj(b))/pj-qj

' C(a,b) = (1/w)^r * kjcj(a,b), where k = kj (j = 1 to r)


Dim weight(1 To 6) As Integer ' Weights for criteria 1-6
'1 = Findability
'2 = Level of document
'3 = Outdated-ness
```

```
'4 = Impact on Cash
'5 = Impact on Cost
'6 = Impact on Customer satisfaction

Dim Criteria As Integer
Dim lastrow As Integer
Dim Doc As Integer 'documentscore per criteria
Dim Doc2 As Integer 'second document for pairwise comparison
Dim good As Boolean
Dim Min As Integer 'min is used to change sign of comparison for Findability criteria (the
lower the score the more important, this is contradictionary to other criteria)
Dim Q(1 To 6) As Integer ' Tolerance
Dim P(1 To 6) As Integer 'Strong preference tolerance
Dim v(1 To 6) As Integer ' Veto tolerance
Dim Diff As Double
Dim SUM As Double
Dim SUM2 As Double
Dim cutoff As Double
Dim threshold As Double
Dim laagste As Integer
Dim labda As Double
Dim hoogste As Double
Dim sumweights As Double

Dim Concordancematrix() As Double
Dim Discordancematrix() As Double
Dim Credibilitymatrix() As Double
Dim qualificationscore() As Double
Dim outrankscore() As Integer

'setup the dimensions of the matrices
lastrow = All.ListObjects("Table1").Range.Rows.Count - 1
ReDim Concordance(1 To lastrow, 1 To lastrow, 1 To 6) As Double
ReDim discordance(1 To lastrow, 1 To lastrow, 1 To 6) As Double

ReDim Concordancematrix(1 To lastrow, 1 To lastrow) As Double
ReDim Discordancematrix(1 To lastrow, 1 To lastrow) As Double
ReDim Credibilitymatrix(1 To lastrow, 1 To lastrow) As Double
ReDim qualificationscore(1 To lastrow, 1 To lastrow) As Double
ReDim outrankscore(1 To lastrow) As Integer


'assign Q,P,V values
For Criteria = 1 To 6
    Q(Criteria) = dash.Cells(80 + Criteria, 11)
    P(Criteria) = dash.Cells(80 + Criteria, 12)
    v(Criteria) = dash.Cells(80 + Criteria, 13)
    weight(Criteria) = dash.Cells(5 + Criteria, 11)
    sumweights = sumweights + weight(Criteria)
Next Criteria



'Calculate Concordancematrix
For Doc = 1 To lastrow
```

```
For Doc2 = 1 To lastrow
For Criteria = 1 To 6
   Diff = All.Cells(Doc + 1, Criteria + 10) - All.Cells(Doc2 + 1, Criteria + 10)
      'CALCULATING THE CONCORDANCE MATRIX
      If Diff >= -Q(Criteria) Then
      Concordance(Doc, Doc2, Criteria) = 1
      End If

      If Diff <= -P(Criteria) Then
      Concordance(Doc, Doc2, Criteria) = 0
      End If

      If Diff < -Q(Criteria) And Diff > -P(Criteria) Then
      Concordance(Doc, Doc2, Criteria) = (Diff + P(Criteria)) / (P(Criteria) - Q(Criteria))
      End If

      'CALCULATING THE DISCORCORDANE MATRIX
      discordance(Doc, Doc2, Criteria) = (All.Cells(Doc2 + 1, Criteria + 10) - All.Cells(Doc + 1,
Criteria + 10) - P(Criteria)) / (v(Criteria) - P(Criteria))

      If All.Cells(Doc + 1, Criteria + 10) + P(Criteria) <= All.Cells(Doc2 + 1, Criteria + 10) Then
      discordance(Doc, Doc2, Criteria) = 0
      End If

      If All.Cells(Doc + 1, Criteria + 10) + v(Criteria) <= All.Cells(Doc2 + 1, Criteria + 10) Then
      discordance(Doc, Doc2, Criteria) = 1
      End If

Next Criteria
Next Doc2
Next Doc

'CALCULATE TOTAL MATRICES
For Doc = 1 To lastrow
For Doc2 = 1 To lastrow
For Criteria = 1 To 6

SUM = SUM + (Concordance(Doc, Doc2, Criteria) * weight(Criteria))

Next Criteria
Concordancematrix(Doc, Doc2) = SUM / sumweights
SUM = 0
Next Doc2
Next Doc

'CALCULATE THE CREDIBILITY MATRIX
For Doc = 1 To lastrow
For Doc2 = 1 To lastrow

For Criteria = 1 To 6
    If Concordancematrix(Doc, Doc2) < discordance(Doc, Doc2, Criteria) Then
       good = False
       Criteria = 6
    Else
       good = True
```

```
        End If
Next Criteria

If good Then
    Credibilitymatrix(Doc, Doc2) = Concordancematrix(Doc, Doc2)
End If

If good = False Then
    SUM2 = 1
    For Criteria = 1 To 6
        If discordance(Doc, Doc2, Criteria) > (1 - Concordancematrix(Doc, Doc2)) Then
            SUM2 = SUM2 * ((1 - discordance(Doc, Doc2, Criteria)) / (1 -
Concordancematrix(Doc, Doc2)))
        End If
    Next Criteria

Credibilitymatrix(Doc, Doc2) = Concordancematrix(Doc, Doc2) * SUM2
End If

Next Doc2
Next Doc

'CALCULATING THE QUALIFICATION SCORE
'Do While labda0 > 0

For Doc = 1 To lastrow
For Doc2 = 1 To lastrow
If Credibilitymatrix(Doc, Doc2) - Credibilitymatrix(Doc2, Doc) > 0.15 And
Credibilitymatrix(Doc, Doc2) > Credibilitymatrix(Doc2, Doc) Then
qualificationscore(Doc, Doc2) = 1

Else
qualificationscore(Doc, Doc2) = 0
End If

Next Doc2
Next Doc

For Doc = 1 To lastrow
For Doc2 = 1 To lastrow
outrankscore(Doc) = outrankscore(Doc) + qualificationscore(Doc, Doc2) -
qualificationscore(Doc2, Doc)
Next Doc2
Next Doc

For Doc = 1 To lastrow
If outrankscore(Doc) > hoogste Then
hoogste = outrankscore(Doc)
End If
If outrankscore(Doc) < laagste Then
laagste = outrankscore(Doc)
End If
Next Doc

'CALCULATE GRADE
```

```
cutoff = (hoogste - (laagste)) / 10

For Criteria = 1 To 10
For Doc = 1 To lastrow
If outrankscore(Doc) > (hoogste - (cutoff * Criteria)) And outrankscore(Doc) <= (hoogste -
(cutoff * (Criteria - 1))) Then
All.Cells(Doc + 1, 10) = 11 - Criteria
End If
Next Doc
Next Criteria


    Application.ScreenUpdating = True
    Application.Calculation = xlCalculationAutomatic
    Application.EnableEvents = True

End Sub
```

Appendix G – Explanation of VBA Code and adding/removing Criteria from the framework

What the code exactly does:

The code in Appendix F is mostly derived from the mathematical analysis of ELECTRE III. In the Sheet All (see appendix B excel manual) the list of documents is placed. Columns K, L,M,N,O,P are used to note the score of each individual criteria. The code reads these numbers and links them to a row number. The row number indicates the actual row number the document is saved in. Following the formulas described in section 4.3, the criteria scores are saved into arrays which represent the Credibility/Concordance/Discordance matrices.

In every loop 2 documents are taken, where Doc1 and Doc2 are compared per criteria and the results are saved in the credibility matrix. Eventually all documents have a number of outranks associated with them. The Document with the most outranks is number 1 and the document with the least outranks is last place. As discussed in section 4.4 (Implementation of ELECTRE III). The top 10% documents get assigned the risk number 10, then the next 10% gets the number 9 and so forth. Since the Document grades are still linked to a row number, the Importance grade is saved in column J with the right row number.

How to add/remove Criteria

Note that Columns K, L, M, N, O, P are used for criteria scores. All columns to the right of column P are unused as of yet, this is because only 6 criteria exist as of right now. If Thales would want to add criteria they can simply do this by filling a column with criteria scores to the right of column P. They would have to make sure that the scores in row 20, are the scores that are associated with the document that is saved in column E and in row 20. This is because the list is build in such a way that all the information of one document can be found horizontally in one row.

When this is done the loop number which is called Criteria should be increased by 1. In this manner Criteria 7 takes the criteria scores saved in Column Q. Additionally Buffer values for the indifference/strong preference and Veto zones have to be filled in. This can be done in sheet Dashboard. In Cell J80 a table can be found. One can simply add the name of the criteria beneath the current 6 criteria and fill in the table with the input values. When all of this is done a new criteria is added. Afterwards Layout can be changed accordingly to 6+ Criteria.

To remove a criteria one can simply delete the values in the column of the criteria in sheet "All". The 0 values will be taken into account however due to the nature of ELECTRE III they do not influence the outcomes of the outranking, hence the Criteria does not participate. Another way in which a criteria can be deleted is by setting its weight to 0. This way the Criteria also does not participate due to the algorithm however you keep the data stored in the sheet "All".