Master Thesis – Public Version

A suitable alternative? How Product-Service System can support Schiphol in the transition towards a Circular Economy

29/09/2016

T.W. Duffhues

S1007181

Master: Industrial Engineering and Management
Track: Financial Engineering and Management

Schiphol Group	Supervisor	Ir. H.J. Hofstede RC
	Supervisor	Ir. H. Kroon
UNIVERSITY OF TWENTE.	First Supervisor	Dr. B. Roorda
UNIVERSITY OF TWENTE.	Second Supervisor	Dr. R.A.M.G. Joosten

Colophon

Master Thesis	A suitable solution? How Product-Service Systems can support Schiphol in the transition towards a Circular Economy
Version	Public Version 1.0
Date	29/09/2016

Author	**T.W. Duffhues** S1007181 Master Industrial Engineering and Management Master Track Financial Engineering and Management Faculty of Behavioural Management and Social Sciences Dept. Industrial Engineering and Business Information Systems. University of Twente.
Supervisor Schiphol	**Ir. H.J. Hofstede RC** Senior Manager Control & Pricing Business Area Aviation Schiphol Group
External Supervisor	**Ir. H. Kroon**
First Supervisor University of Twente	**Dr. B. Roorda** Associate Professor of Financial Engineering Faculty of Behavioural Management and Social Sciences, Dept. Industrial Engineering and Business Information Systems. University of Twente.
Second Supervisor University of Twente	**Dr. R.A.M.G. Joosten** Assistant Professor Faculty of Behavioural Management and Social Sciences, Dept. Industrial Engineering and Business Information Systems. University of Twente.

Table of Content

1. Preface

Dear reader,

The last 9 months I have been working one my Master Thesis in order to graduate from the University of Twente. I performed my internship at Schiphol Group and I have enjoyed my time on the airport.

I want to thank a few people who have made this research possible, but also gave me the room, time and opportunity to find my way with graduating, which was not easy at times due to unforeseen events. The first person I want to thank is Huub Hofstede. Huub, you offered me the opportunity to perform my internship at Schiphol, not only allowing me to graduate at a firm which has inspired me for a long time, but also to get a taste of the complexity of operation an airport has to deal with on a daily basis during their 100th year existence. You granted me the space to make the research mine and take Circular Economy to the next level for me personally. But most of all I really appreciate the openness, time and space you have given me to make sure that the most important parts of life were given enough attention.

The second person I want to thank is Henk Kroon. You have set me on a great start with sharp insight and asking the right questions, but also the space and time you provided when I needed it. I have enjoyed our corporation and enthusiasm you seem to spark with people. I also want to thank you for the great advice on my final presentation at Schiphol, which really enabled me to give a good presentation and spark a good discussion without losing the goal of the presentation.

The last persons I want to thank are Berend Roorda and Reinoud Joosten. You made it possible for me to graduate on short notice and with great support. I enjoyed the courses I have had over the last years from the both of you.

The most important persons whom I want to thank are my parents and my brother. You have shown what perseverance and unconditional love really are. I could not be more proud on what we have achieved the last year, despite all the troubles and challenges. I feel blessed.

Lastly, I would like to thank my family and friends for their support, friendship, (un)wanted advice and distraction which is always important.

I hope you all are proud of what I have done the last year, I certainly am.

Tom Duffhues

Amsterdam, 21/09/2016

2. Management Summary

Circular economy is a term which can be heard more and more in business and in the academic world. At Schiphol they are also working on incorporating Circular Economy into their business model. One of the ways Schiphol could introduce more, is via Product-Service Systems. But is it a suitable solution for the transition towards circular economy and how can success be guaranteed?

Product-Service Systems can contribute to more Circular Economy at Schiphol when the result-oriented approach is followed. This approach consists of that performance is the main aspect which Schiphol needs and the ownership remains at the supplier. Because Schiphol acquires a service instead of a product, it engages in a longer relationship with the supplier and it is important to capture the new relationship in proper KPIs. In order to make sure Schiphol has a clear decision process which enables PSS to be a suitable alternative, a decision framework is developed which captures the elements needed for decision making and is tailored towards Schiphol's decision making process, as well as the lessons learned from the Light-as-a-Service pilot project.

The first step is to check if an asset is suitable to be transformed to a Product-Service Systems. Four criteria need to be met, otherwise it is not advised to consider Product-Service Systems as an alternative. These criteria are; i) material/labour and/or energy intensive ii) not part of the primary process iii) consequence of malfunction is severe and iv) market/customer size has to be sufficient. The next step is to make sure that the decision making to check if a Product-Service System is a good alternative financially, is to make sure decision making is aligned with that of Schiphol. Schiphol uses a Total Cost of Ownership tool to calculate the costs it needs to carry across the lifetime of an asset. This financial data is used together with an uncertainty assessment of a supplier to get a price indication of what Schiphol should be willing to pay to get a service, instead of an asset. This pricing model is validated using the Light-as-a-Service pilot case, which Schiphol embarked on together with Cofely/Philips. From this validation case, the following results are obtained. The PSS price which Schiphol should be willing to pay is €441k and the offer Cofely/Philips made is €425k. The pricing tool shows that the offer of Philips was a good one and that the price difference could also be explained, thus validating the model.

PSS Price	Offer Cofely Philips
€ 441.397,-	**€ 425.770,-**

The last two steps of the decision framework are that good KPIs are developed and that all agreements and performance agreements are agreed upon in a Service Level Agreement. The last two steps are already present in the decision making of Schiphol, while the first two steps are an addition tailored to the Product-Service Systems as an alternative to a traditional asset ownership solution. Besides the benefits, there are a few challenges which must be addressed by Schiphol in order to have a successful implementation of Product-Service Systems and therefore more Circular Economy. The main challenges are new accounting rules regarding leases and the potential impact on the Regulatory Asset Base, the ability for Schiphol to deal with the increased complexity of a supplier as an asset owner and Schiphol as a user and the fact that asset developers at Schiphol need to consider Product-Service Systems as a suitable alternative. The conclusion of this Master Thesis is that Product-Service Systems can help Schiphol in the transition towards Circular Economy. But in order to make sure that it is successful, the decision framework has to be used in order to make sure that implementation is well substantiated, that the decision process fits with the Function, Risk and Euro framework Schiphol uses, the asset meets the requirement of being converted into a Product-Service System as well as to get a price indication to help in the negotiation process with the supplier.

3. Abbreviations

CE	Circular Economy
ACM	Dutch Authority for Consumer and Markets
ASM	Aviation Asset Management
BA	Business Area
CAPEX	Capital Expenditure
CEC	Cost Expertise Centre
CPS	Consumers, Products and Services
CR	Corporate Responsibility
DCF	Discounted Cashflow
EAC	Equivalent Annual Cost
EoL	End-of-Life
GDP	Gross Domestic Product
HU	Heijmans Utilities
IAS	International Accounting Standards
IFRS	International Financial Reporting Standards
KPI	Key Performance Indicator
L.a.a.S.	Light-as-a-Service
LCC	Life Cycle Costing
NPV	Net Present Value
OPEX	Operational Expenditure
OPS	Airport Operations
PSS	Product-Service Systems
PV	Present Value
RAB	Regulatory Asset Base
RQ	Research Question
SLA	Service Level Agreement
SMART	Specific, Measurable, Accountable, Realistic and Timesensitive
SQ	Sub Question
SSE	Safety, Security & Environement
TCO	Total Cost of Ownership
TEC	Technical Expertise Centre
TRE	Terminal Real Estate (Former ASM)
WACC	Weighted Average Cost of Capital

4. Introduction

4.1 Problem Introduction

The earth is faced with continuous, accelerated and unprecedented growth in both the number of people, as well as people who have obtained, or want to obtain a certain degree of wealth. To get an idea of what it actually implies, is that currently mankind asks around 1,5 earths in its annual need for consumption, this will grow to 3 or 4 earths in 2050 when the earth's population is expected to hit 9 billion people (Bastein, Roelofs, Rietveld, & Hoogendoorn, 2013). The current linear approach of achieving this growth is incapable of sustaining this growth, because the earth simply cannot keep up with replenishing its natural resources. Circular Economy aims to be restorative and regenerative by design, and aims to keep products, components, and materials at their highest utility and value at all times in a fully sustainable matter. It aims to provide sustainable value creation, which is decoupled from the increased consumption of resources (Ellen MacArthur Foundation, 2013a).

Circular Economy (CE) is a sustainability term which has increased in usage over the last few years in the media and within businesses(Bastein *et al.*, 2013) (Ellen MacArthur Foundation, 2013a) (Ellen MacArthur Foundation, 2013b) (Ellen MacArthur Foundation, 2013c) (NU.nl, 2016) (Rabobank, 2014) (Tegenlicht, 2015). It might also be a term which one would not expect to pop up at an organisation such as Schiphol, due to Schiphol's role in the aviation value chain. But being part of this value chain does not mean Schiphol is not working on sustainability, on the contrary. In 2016, Schiphol joined the Ellen MacArthur Foundation, which strives to accelerate the transition towards a CE (Ellen MacArthur Foundation, 2016).

From a growing understanding that standing idle will not solve these problems, Schiphol incorporated sustainability into its strategic and corporate responsibility goals. Especially CE is mentioned explicitly (Schiphol Group, 2016). Schiphol has the desire to grow, maintain and improve its status as one of Europe's biggest Europe and its strive to be Europe's Preferred Airport, which it needs to pursue in order to stay a strong competitor in the fierce European and global aviation market. Furthermore, within the Netherlands Schiphol fulfils a main port function and has a major place in the Dutch economy, not just as an economic powerhouse, but also as a facilitator for businesses around the country (Schiphol Group, 2015). Uniting these goals, growth and sustainability, seems as a mission impossible, but CE promises to be the next big sustainability step mankind could take. By decoupling growth from resource usage. For Schiphol, CE offers the possibility to grow in a sustainable manner, while striving to become Europe's Preferred Airport. A complex and daunting challenge, where Schiphol needs to invest in capacity, quality, while become more efficient with their resources such that airlines have an incentive, via low tariffs, to use Schiphol as their gateway.

In order to introduce more CE, Schiphol is searching for ways of supporting the transition. One of the ways it can take the next step is by not becoming owner of asset or product, but user of its functionality. It looks like the old buy or lease decision, but its purpose is much different. Schiphol and Philips took the risk together to start a pilot project called Light-as-a-Service (L.a.a.S.), in order to see how such a more CE business model would influence doing business. From this pilot project, the question was raised how can we further facilitate this pilot project and what can be learned from it. Is it suitable to support the transition? Solutions such as the L.a.a.S. are called Product-Service Systems (PSS) and are considered a tool which might help the transition. This Master Thesis will explore CE and PSS, check their applicability and what is needed for a successful implementation to support such a transition. In order to gain a better understanding of where this research was performed, Schiphol and its Business Areas will be introduced.

4.1.1 Schiphol

Schiphol Group is the Dutch airport firm which is responsible for the exploitation of, mainly, Schiphol Amsterdam Airport since 1916. In 2015, Schiphol was responsible for the handling of 58,2 million passengers (Nijhuis, 2016) and in order to handle all these passengers in a good and sufficient manner, Schiphol has 4 Business Areas (BA), each responsible for the specific tasks required to operate Schiphol. These four BA's are Aviation, Consumers Products and Services, Real Estate and Alliances & Participations (Schiphol Group, 2015). Consumers Products and Services (CPS) operates the parking, retail and advertise facilities. Real Estate manages the commercial property of the Schiphol excluding airside, such as; office locations, hotels and other types of real estate. Alliances & Participations is responsible for managing the interest of Schiphol in other (regional) airport, such as Lelystad and Eindhoven, and the exploitation of the Airport City concept outside Schiphol.

4.1.2 Business Area Aviation

The Business Area Aviation can be considered as the core business of Schiphol. It is the business area where all aviation related activities are performed. These activities can be split into three parts; Safety, Security & Environment (SSE), Airport Operations (OPS) and Asset Management (ASM).

SSE is responsible for the safety of the passengers, quality of the surface water, incident investigation and the lobby in Europe. SSE's goal is to minimise the risk of endangering safety of everything which happens in and around Schiphol. OPS is responsible for the operational aspect of the aviation activities. Baggage handling, airside operations such as airplane handling, bird control, maintenance and terminal logistics and so on. ASM is the department which is the actual owner of all the aviation related assets, e.g. runways, taxiways, terminals and so on. Furthermore, ASM is responsible for the development and management of those assets. Finally, ASM is responsible for determining the tariffs for airlines for their usage of Schiphol's facilities. Due to its economic relevance, the nature of its business and its market power over the airlines, Schiphol is regulated by the Dutch Authority of Consumers and Markets (ACM) which is granted the power by the Dutch Aviation Act to act as a regulator. This regulation has far reaching consequences on operations of ASM and is meant to ensure a non-discriminatory environment for aviation activities at Schiphol (Ministerie van Verkeer en Waterstaat, 2006), (Luchtvaartwet, 2016). To get sense of the magnitude of these consequences, 50% of the costs to airlines is directly related to regulated assets (Asset Wise! Team Schiphol, 2015).

4.1.3 Context

In order to have a clear picture of the context of this Master Thesis and where the research will be conducted, the following points have to be taken into account when reading this Master Thesis, to make sure that the reader is aware of the context.

1. This Master graduation assignment will primarily be executed within Schiphol Aviation Asset Management. This due to the initiator and supervisor of this research, Ir. Huub Hofstede RC, Sr. Manager Control and Pricing Business Area Aviation.
2. Due to the strict regulation by the ACM, normal applied business methods within real estate and asset management could be prohibited by the regulator and therefore, asset management is performed within tighter accounting principles than commercial asset management.
3. Schiphol is compliant with IFRS ruling for accountancy, however, where an issue arises between the 'Luchtvaartwet' and the IFRS, the Dutch Aviation Law is leading. This mainly has to do with the activation of Asset on the Balance sheet.
4. The 2016-2018 ACM approved 'toerekeningssysteem', the cost allocation system of Schiphol for setting tariffs for airlines, will be used as the basis for any Aviation Asset related information on internal accounting

5. Internal practices and guidelines of Schiphol will act as the basis for (possible) decision making, due to the clear Asset Management guidelines Schiphol has put forth. Furthermore, any decision processes need to be aligned with the current decision processes, in order to ensure transparency in decision making and consequences on airline tariffs.

4.2 Problem Statement

Within this Master Thesis, Schiphol is the problem owner for not being able to oversee on how a successful implementation of PSS could be performed, as well as, how it would contribute to CE for Schiphol. Therefore, the following problem statement has been formulated:

It is unclear whether Product-Service Systems are suitable to support the transition towards Circular Economy at Schiphol.

4.3 Research Goal

Given the problem statement, the research goal is primarily to shed light on how PSS can be implemented and therefore contribute to a CE at Schiphol. As can be imagined, it is therefore important to first know what CE is exactly, how it is currently applied within Schiphol, what PSS are, what a fair price is for a PSS and how the decision process of the acquisition of a PSSs should look like. Furthermore, it is always important to research what kind of barriers exist within Schiphol and with PSS themselves.

4.4 Research Questions

4.4.1 Research Question

Based on the problem statement, combined with the research goals, the main Research Question (RQ) can be formulated. This question reflects the problem statement and its answer should satisfy the stated research goals

4.4.1.1 RQ Are Product-Service Systems suitable to support the transition towards a Circular Economy at Schiphol?

4.4.2 Sub Questions

In order to fully answer the Research Question, a number of Sub Questions (SQ) have been formulated. By systematically answering the SQ, a fully substantiated answer to the RQ can be provided, as well as making sure that all relevant aspect of CE, PSS and it applications have been covered. This allows for clear conclusions and recommendations for Schiphol to use in the future and therefore maximise the usability of this Master Thesis, something which is of the utmost importance for an Industrial Engineering and Management student’s graduation internship, in the author’s opinion.

4.4.2.1 SQ1 What is Circular Economy?

The first sub question is posed in order to gain a better understanding of CE. What its fundamentals are and therefore provide a clear basis for the rest of this Master Thesis.

4.4.2.2 SQ2 What are Product-Service Systems?

The second sub question is regarding PSS. What are they, how can they be beneficial for Schiphol and its CE goals. By answering this question, it becomes clear on how PSS contribute, as well as how their implementation should be given shape in order to make it successful.

4.4.2.3 SQ3 What is the current status of Schiphol, especially regarding decision making?

The third sub question examines how asset management is performed at Aviation Asset Management and what its ambitions are. This to ensure that the context is perfectly clear for any next steps on how and where they should fit in. Furthermore, it assesses which CE initiatives are already started at

Schiphol. Schiphol has clear processes which ensures that decision making is performed well, any solutions which are put forth in this thesis must fit in with this in mind.

4.4.2.4 SQ4 What is needed for good decision making with Product-Service Systems at Schiphol?

The fourth sub question deals with what is needed for good decision making PSS. The two previous sub questions are combined in order to facilitate clear decision making, which is suited for Schiphol. Furthermore, it needs to deal with how the conditions of PSS are translated in decision making tool(s).

4.4.2.5 SQ5 How can a price for a Product-Service System be determined?

The fifth sub question is focussed on how a price determination can be performed. Because a PSS is a service which is acquired and paid for by a yearly fee, Schiphol needs a tool which can determine what a fair price would be for supplier to ask, given the fact that the supplier remains owner of the Asset, for which they need to carry new uncertainties they previously did not need to bear. With the help of such a tool Schiphol can check what price they find reasonable and enable a good comparison between doing it the traditional way, as an asset owner, or acquiring such a PSS.

4.4.2.6 SQ6 What are possible barriers for the implementation of Product-Service Systems?

The sixth and last sub question will be dealing with what implementation barriers are discovered throughout the research. Implementation barriers can exist anywhere in the organisation and Schiphol needs to be aware that they exist and that they have the potential to slow down development. In order to fully enable the transition via PSS, the barriers, limitations and properties of PSS need to be compared to the current way of doing business of Schiphol, in order to point out where chances and challenges are present.

4.5 Research Approach

4.5.1 Data Collection

Data collection can roughly be divided into two categories, primary sources and secondary sources of information (Figure 4.1). The primary sources will be mainly used to capture Schiphol's perspective in Sub Questions 3 and 6, whilst the secondary sources can provide excellent means for answering Sub Questions 1, 2. Sub questions 4 and 5 will draw form both primary and secondary sources.

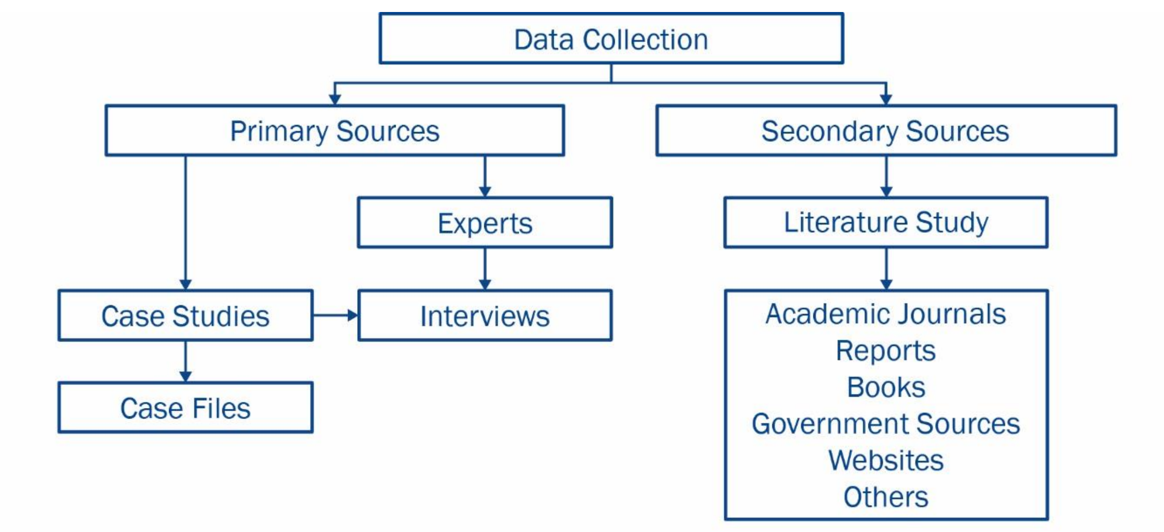


Figure 4.1 - Schematic Overview of Data Collection

4.5.1.1 Primary Sources

Primary sources of information consist of experts on different areas and case studies. The experts can provide relevant information on a wide spectrum related to this research. By consulting relevant experts for their opinion and perception of the matter, valuable information can be obtained. The current list of experts can be found in Table 4.1.

Table 4.1 - Primary sources; Experts

Expert	Firm	Area of Expertise
Sustainability Development Manager	Schiphol (internal)	Sustainability goals & strategy
Sustainability Advisor	Schiphol (internal)	Sustainability goals & strategy
Cost experts	Schiphol (internal)	Cost estimation and modelling
Asset management experts	Schiphol (internal)	Asset data
Project Management L.a.a.S.	Schiphol (internal)	Information on the Light-as-a-Service project at Schiphol
Control Aviation Asset Management	Schiphol (internal)	Accounting and control principals of Schiphol, financial landscape, financial advice
Treasury Department	Schiphol (internal)	Internal financing and risk assessment, financial landscape, financial advice and uncertainties
Circular economy experts	Various	Sources on information of circular economy and the application on businesses and real life cases

4.5.1.2 Secondary Sources

The secondary sources of information mainly consist of academic literature and other types of external sources which can be accessed. A literature study will provide a solid basis for the research. By systematically studying literature and other sources, a view of the current status of affairs can be formed which enables to see where current literature provides clues on how CE affects Schiphol, as well as identify knowledge gaps within either Schiphol or the literature itself. If a knowledge gap at Schiphol is found, the research allows Schiphol to obtain knowledge on CE. If a knowledge gap is found in the academic literature, the research might shed new light and enrich the academic literature on the impact of CE on service providers and regulated companies.

The literature search will be conducted on well-established academic research platforms such as, Sciencedirect, Web Of Science and Scopus. The structured search with search terms, number of hits and usable articles will be provided in the appendix of the thesis. Other sources of information will also be used, this could include websites, reports of CE organisations, reports about CE, government sources, news articles and other sources which might be found.

4.5.2 Research Methodology

The research methodology and structure of this Master Thesis can be found in Figure 4.2. It clearly shows show one subject leads to the next and how the Thesis' structure and scope are build. On the left the source of information is presented and on the right the flow of how the thesis is build up.

This Master Thesis will commence by answering the question of what CE is, what benefits, challenges it has. This provides the basis for the Thesis. By using academic literature and other secondary sources of information, a clear view is constructed. In the second chapter, the current situation of Schiphol will be discussed. This will discuss current business practices, to make sure that the rest of the Thesis will align properly with Schiphol, as well as what CE initiatives are already starting at Schiphol. PSS is one option in the transition towards CE. Therefore, it is important to lay a solid foundation upon which to build using academic literature. Furthermore, the Cost Estimation Model is introduced which is going to be used for price indication for a PSS. This will all be combined in to a Product-Service System Decision Framework, which helps to structure the decision process for choosing a PSS. This framework together with the Cost Estimation model will be validated to check both their validity as well as the applicability. This is done via a case study within Schiphol, using the Light-as-a-Service project. Further applications will also be discussed and mentioned within the case study. Finally, this will lead to the results, conclusions, recommendations and implementation guidelines.

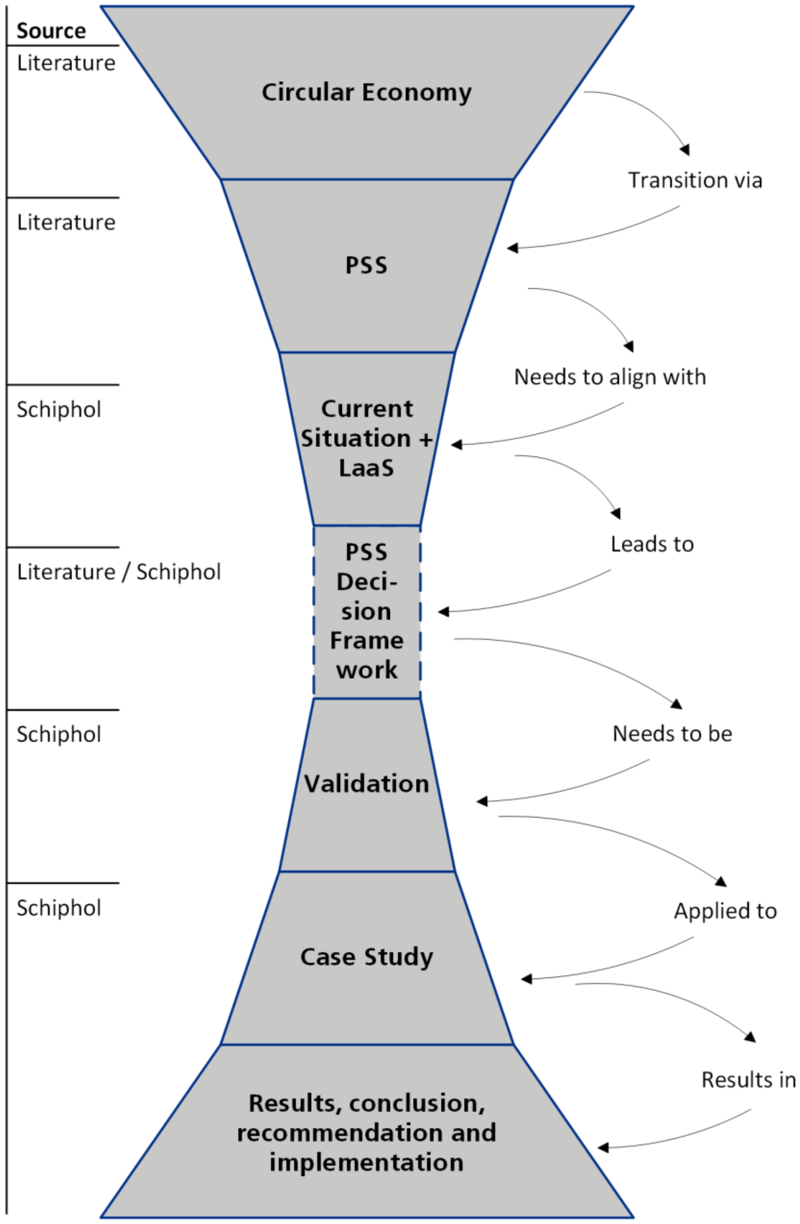


Figure 4.2 - Research Methodology

4.5.3 Reflection and future research

The final conclusion and recommendation will also contain a reflection of the author on his impression on the business of Schiphol. This will provide the possibility to provide an academic edge to the Master Thesis, as well as reflect on lessons learned, obstacles which had to be overcome, how CE and Schiphol are moving towards each other via PSS and other point worth of discussing.

Lastly, future research will put forth point which Schiphol or the academic community needs to address in order to be able to take the next step towards CE.

4.6 Scope

In order to make sure the research is doable and that the right expectations are introduced, the scope is provided. The scope makes sure that the intention is clear and that it is clear what is and what isn't included within this thesis.

1. The content of this thesis will not provide a complete overview of how CE can be implemented at Schiphol, due to the width of CE. Therefore, the main focus is operationalising the proper implementation of Result-Oriented Product-Service Systems.
2. As stated before in 4.1.3, the main focus is at Schiphol's Aviation Asset Management Business Area. Therefore, if the framework or the pricing model are used outside this business area, deviations from what is to be expected might occur.
3. Practical usage and ease of use are very important. In the author's opinion, usability is very important for an Industrial Engineering and Management student's graduation work, when executed at a company.
4. The study is initially intended as an exploratory research, therefore, the scoping starts wide (CE as a whole) and then narrows down (PSS). This allows Schiphol to gain more knowledge on what CE is about.
5. Decisions made, or opinions expressed are mostly the authors and do not necessarily reflect Schiphol's point of view.
6. In the public version of this master thesis, monetary figures are made fictitious in order to protect Schiphol's and its supplier's interest and confidentiality of contractual agreements. However, this is done in such a manner that the figures can still be used and are in proportion to the real figures.
7. In the public version of this master thesis, some projects might be mentioned without any specificity on the nature of the project, what kind of asset it is, or any other information which might distort potential procurement. This is due to the sensitivity of the information, the status of the project which might or might not have been offered for tendering yet.

4.7 Deliverables

Based on the previously stated paragraphs, the following deliverables are to be expected of this Master Thesis's graduation thesis:

1. Answer to the posed Research Question and related Sub Questions
2. Validated Product-Service System Decision Framework
3. Validated PSS Pricing Tool for determining a price indication for a Product-Service System
4. Case Study to validate and test both the framework and the PSS Pricing Tool.
5. Conclusion and recommendations on PSS at Schiphol to support the transition towards a Circular Economy at Schiphol
6. Challenges which are to overcome or need to be accounted for, in order to have a successful PSS implementation.

5. Theoretical Framework on Circular Economy and Product-Service Systems

5.1 Introduction

This chapter will provide the theoretical framework for answering the first two sub questions.

SQ1 What is Circular Economy?

SQ2 What are Product-Service Systems?

In order to structure the approach on how Product-Service Systems (PSS) can support in the transition towards CE, it is first important to get a brief overview of what CE is. The question will be answered in the context of the scope of the Master Thesis as presented in the previous chapter. The information presented in the next part is a summary of a more elaborate theoretical framework that can be found in 1.1 - Appendix A.

Secondly, PSS are explored to check how PSS can contribute to CE. Its characteristics, what types and what is needed to contribute. Only the most important point of PSS are given, for a more elaborate exploration of PSS, the reader is suggested to read Appendix B – Product-Service Systems. Once the main points are treated, the value proposition is explored which is needed for any project, how much will it cost.

5.1.1 Reading Guide

5.2 Circular Economy

5.2.1 Sustainability

In order to prevent confusion on how the transition of CE is going to influence sustainability, it is useful to clearly define how sustainability is defined by ISO26000 (Marcelino-Sádaba, González-Jaen, & Pérez-Ezcurdia, 2015):

"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs, integrating social, economic and environmental goals to mutually reinforce each other"

5.2.2 Linear economy

The current economic model can be considered a linear model, which is based around take, make and waste principle (Figure 5.1). While this model has been very successful the last two centuries, it puts big stress on earth as a resource provider. Currently mankind is using 1,5 earths, which is expected to rise towards 3 or 4 earths in 2050 resources (Bastein, Roelofs, Rietveld, & Hoogendoorn, 2013). The earth is unable to sustain such a usage, due to the finite resources (Sauvé, Bernard, & Sloan, 2015).

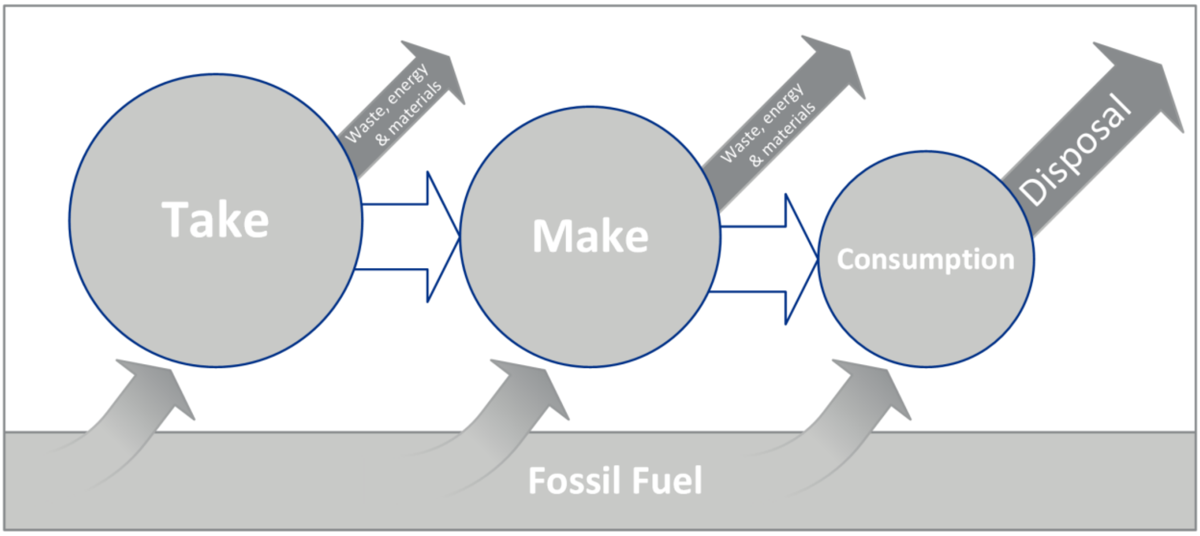


Figure 5.1 - Linear Economy model, adapted from the Ellen Macarthur Foundation (2014)

The major problem of the linear economy is that profit is a private gain, while pollution is a public problem and not bore by those who cause it (Sauvé, Bernard, & Sloan, 2015) (Anderson, 2007). Furthermore, the rise in GDP is no longer supported by a decline in resource prices (Schulte, 2013). A solution is needed in order to provide future generations with the equal opportunity to live and thrive on earth.

5.2.3 Circular Economy

In order to tackle this problem, Circular Economy (CE) comes into the picture. CE has gained considerable attention lately as a possible solution to the problems posed by the current economic model, while tackling the environmental problems in a sustainable matter at the same time, harmonising economic growth and environmental protection (Lieder & Rashid, 2015). CE can be split into two components, biological nutrients (nutrients/resources which enter the biosphere) and technical nutrients (nutrients/resources which cannot enter the biosphere without treatment). Due to the nature of operation at Schiphol, technical nutrients are the main focus. Figure 1.2 shows how technical nutrients move within the CE. Each circle represents how a product can circulate throughout the economy, and the larger the circle the lower the added value and effectiveness is (Ellen MacArthur Foundation, 2013a) (Guidat, Barquet, Widera, Rozenfeld, & Seliger, 2014) (Schulte, 2013) (Witjes & Lozano, 2016).

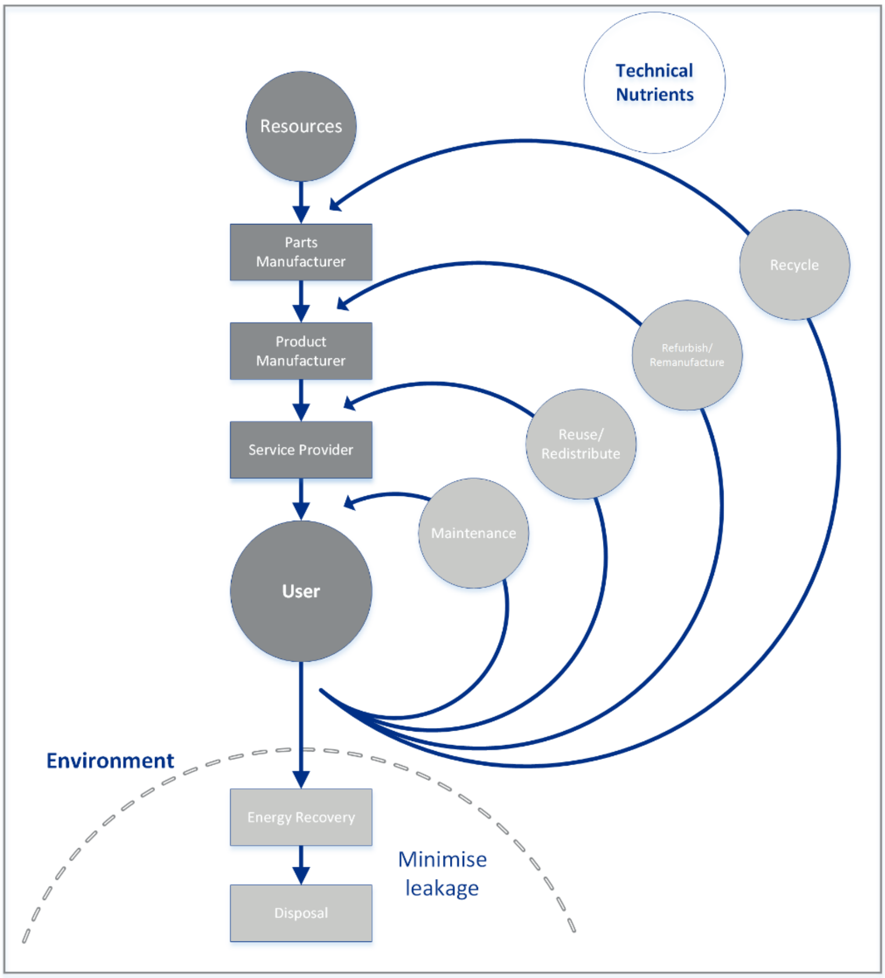


Figure 5.2 - The Circular Economy, adapted from the Ellen Macarthur Foundation (2014)

CE can be summarised into 7 main points:

1. Design out waste
2. Build resilience through diversity
3. Rely on energy from renewable sources
4. System or value chain optimisation
5. Maximise energy efficiency
6. Customers want performance/functionality, not a product
7. Continued ownership is cost efficient.

But as with any transition, there are challenges to overcome. The main challenges are that system optimisation is needed across the whole value chain and that any organisation needs to be ready to cope with the different economical model of CE.

To conclude on Circular Economy, the following defintion is used:

"Circular Economy is a sustainable economic and industrial system, where environment and economy are regenerative by design, aimed at maximising value of a product while minimising the resource usage"

5.2.4 Conclusion Circular Economy

As stated in the previous chapter, the current linear economy style is unsustainable in the long run. The perceived gains are mostly focussed on maximising production at minimum cost, using ever more non-renewable resources and where the producer is not responsible of the disposal at the End-of-Life, with all consequences attached. CE could be a solution, which allows mankind to tackle these problems. CE builds upon closing resource loops, optimising on systems level and using the fact that it is the function and not the product itself which is demanded. The last statement implies that ownership should no longer be attached to the user of a product. This could be a way of enabling the transformation towards a CE. The current problem is, that most literature uses a manufacturing point of view and therefore a knowledge gap in the literature can be identified on how this change in ownership is perceived from the customer point of view, instead of the manufacturer point of view.

For an extensive answer please consult Appendix A – Circular Economy.

5.3 Product-Service Systems

One of the tools in the transition towards CE are Product-Service Systems (PSS), as suggested by Adrodegari., *et al.* (2015), Bastein, T. *et al.* (2013), Beuren, Ferreire, & Miguel (2013) Lieder., *et al.* (2015), Tukker (2015), Van Ostaeyen (2014) and Witjes & Lozano (2016). It is important, with the focus on sustainable development, to understand the characteristics of PSS. Because using a PSS concept does not automatically produce sustainable development (Guidat, Barquet, Widera, Rozenfeld, & Seliger, 2014) (Kuijken, Gemser, & Wijnberg, 2016) (Pigosso & McAloone, 2015) (Sousa & Cauchick Miguel, 2015).

In order to create a clear picture of what is meant by a PSS, the definition of van Ostaeyen (2014) is used, which is in line with Beuren, Ferreire & Miguel (2013) and Sassenelli, Pezzotta, Rossi, Terzi, & Cavalieri (2015):

> *'A Product-Service System (PSS) is an integrated offering of products and services with a revenue mechanism that is based on selling availability, usage or performance'*

Several types of PSS can be identified (See Appendix REF), but only one can be considered a good alternative for the transition towards CE, being Result-Oriented Product-Service Systems. The PSS concept should create the need for sustainability, that it is beneficial for both the manufacturer as well as the customer. Tukker (2015) indicates that only result-oriented is able to fulfil this sustainable development, because with a result-oriented PSS not a product is sold, but functionality (Van Ostaeyen, Van Horenbeek, Pintelon, & Duflou, 2013). It is performance driven and the ownership remains with the manufacturer, who is responsible for the product throughout the life cycle. This means that the disposal is the responsibility of the manufacturing, who then has a strong incentive for reduction of resource usage, reuse of products and the recycling during the disposal phase (Ghisellini, Cialani, & Ulgiati, 2015) (Beuren, Ferreire, & Miguel, 2013) (Fernandes de Castro Rodrigues, Nappi, & Rozenfeld, 2014). Performance agreements could include more than just functional performance, for instance sustainability targets. Furthermore, all materials and consumables needed for delivering the performance are now cost factors for the manufacturer, it therefore it has a stronger incentive to reduce the use of those resources (Tukker, 2015), which is positive because reduction is one of the key principles of CE in terms of sustainability.

5.3.1 Criteria for Product-Service Systems

Drawing on the work of Scheepens *et al.* (2016), the nature of the product determines whether PSS is a suitable solution for lowering the environmental burden. In order to gain a better understanding on when PSS is suitable for a customer, the following criteria are identified (van Ostaeyen, 2014):

1. **Material, labour and energy intensity**
   For customers that use products more intensively, a PSS would be interesting, because in theory a larger cost reduction could be achieved, which would result in a higher value of the product.
2. **Primary process**
   PSS shift the responsibility towards the provider of the product/service. Therefore, PSS is interesting for customers who do not regard the operation or maintenance of the asset as essential part of their primary process.
3. **Consequences of malfunction**
   A PSS is more interesting for a customer if the consequence of malfunction of an investment asset are more important and cause greater discomfort, because (theoretically) the provider will be able to offer a larger value improvement by investing in the quality and reliability of the product. Especially because the service provider/manufacturer is (financially) responsible for the performance issues of the service.
4. **Market/customer size**
   The implementation of a PSS requires investment in service capabilities and infrastructure. Therefore, only large enough customers with large enough projects are interesting, because they should be able to bear the investment cost and be able to recuperate the investment over time.

5.3.2 Conditions for success for Product-Service Systems

There are a few conditions which must be taken into account in order to make Result-Oriented PSS a success. The first is that performance management is at the heart of Result-Oriented PSS. Key Performance Indicators (KPIs) are needed in order to track the performance of the PSS and these KPIs need to be SMART; Specific, Measurable, Accountable, Realistic and Time sensitive (Wilberg, Hollauer, & Omer, 2015). The next important condition that it is clear that all stakeholders are clear. It is essential, because the relationship supplier and customer are embarking upon is longer and more intertwined then before and therefore more important (Ghisellini, Cialani, & Ulgiati, 2015) (Tukker, 2015). Both KPIs and the stakeholder relationship should be covered by a good Service Level Agreement (SLA), which needs to cover the following aspects (Heidel, 1997):

1. Function of the service
   a. The functions offered
   b. Possible time of usage
   c. Needed support from Schiphol
2. Performance of the required service
   a. KPIs
   b. Norm of the KPIs
   c. Bonus/Malus rules
3. Possible restrictions on the usage of the service
4. Administrative details of the SLA
   a. Duration of the contract
   b. Arrangements on the prolongation of the SLA
   c. Arrangements on proposed changes to the SLA
   d. Arrangements for cost calculation and invoice arrangements

e. Arrangements for possible disputes and the roles of a potential third party as a mediator
f. Arrangements for End-of-Life disposal
g. Possible financing arrangements
h. Legal liabilities of both parties
i. Description of scenarios in which force majeure are at play
j. Reporting and frequency of reporting
k. Clear definition on possible conflict of interpretation of certain words, passages, etc.
l. Possible sections of contract which might be changed without renegotiating the whole contract
m. Evaluation moments and possibilities of the SLA
n. If needed; paragraph on customer experience, measurements of customer experience and perception of quality of service
o. If needed; paragraph on innovation and continuous improvement of performance

One of the issues with PSS is that it is unclear what the value is of a PSS for an organisation (Kuijken, Gemser, & Wijnberg, 2016), together with the fact that the new, long relationship between supplier and customer introduces new challenges on stakeholder management, responsibility shift, dependencies increase, financial risks change and the need for information exchange increases (Beuren *et al.,* 2013) (Schnürmacher, Haka, & Stark, 2015) (Lockett, Johnson, Evans, & Bastl, 2011) (Witjes & Lozano, 2016). The last issue is that it is of utmost important to be able to estimate the value of a PSS in order to support decision making with PSS involved.

5.4 Decision making and valuation of Product-Service Systems.

But how does one value a PSS. The adding of a service layer on top of a product adds a complication in valuation. Even though a PSS is different from a normal product, it is still compared to a normal product, or asset given Schiphol. In order to value the PSS and make a fair comparison, Cost Estimation under Uncertainty is used, as proposed by Erkoyuncu (2011). His model revolves around the question, how much should a supplier of a Product-Service System charge for the extra risks and uncertainty it needs to carry as owner of the product/asset. In order to align this model to the scope of this thesis, which is from the perspective of Schiphol as a customer for PSS, the model is reversed and proposed as how much should Schiphol accept as a fair price for a PSS.

The model of Erkoyuncu (2011) is based on the well-known Net Present Value technique. This will first be treated, before we will continue with the Cost Uncertainty part.

5.4.1 Net Present Value

One of the most well know valuation technique within project valuation is the Net Present Value (NPV) technique using Discounted Cash Flow (DCF). Using the NPV all future cash flows are taken into account and therefore a value can be determined. In order to capture all financial aspects of the life of an asset with regards for the influence of time on monetary value, discounting is used. The NPV is a wide spread method to value projects and can be calculated using the following formula (Brealey, Myers, & Allin, 2011) (Samis, Davis, Laughton, & Poulin, 2006):

$$NPV(\mathrm{t}, N) = \sum_{t=0}^{N} \frac{CF_t}{(1+r)^t}$$

where,

$$CF_t = Net\ Cash\ Flow\ at\ time\ t$$

$$t = time\ of\ the\ Cash\ Flow$$

$$r\ = discount\ rate$$

$$N = number\ of\ periods$$

The basic theory behind the NPV is that the project with the highest NPV should be accepted, because it adds the most value to a firm. If a project has a negative NPV is should be rejected, because it subtracts value from the firm. If the NPV would be zero, one should be indifferent between accepting or rejecting the project and decision making needs to be based on other criteria.

Expanding this to the perspective of the customer, e.g. Schiphol, the standard NPV valuation of a project at Schiphol is as follows (Rese, Karger, & Strotmann, 2009):

$$NPV_0 = \ -I_0 + \sum_{t=1}^{N} E_t * \frac{1}{(1 + WACC)^t}$$

$$where,$$

$$I_0 = Investment\ at\ t = 0$$

$$E_t = Expenses\ at\ t$$

$$WACC = Weighted\ Average\ Cost\ of\ Capital\ of\ Customer$$

Within Schiphol, the Net Present Value technique is used to determine the Total Cost of Ownership (TCO). The TCO is in principle nothing else than an extended NPV where all costs and benefits over the life time of an asset or project are taken into account. This allows to capture the full value and make an informed decision about an asset over its complete (useful) lifetime. As stated in the current situation, Schiphol uses the Equivalent Annual Cost to transform the NPV to an annuity, in order to see what the cost per year would be. This will be introduced in 6.4.

The deficiency of a straight forward NPV analysis, is that risk and uncertainties are not captured. This will be countered by the introduction of the uncertainty cost estimation.

5.4.2 Cost Estimation under Uncertainty

5.4.2.1 Risk and Uncertainty Management in Product-Service Systems

In order to better grasp how cost estimation under uncertainty can be performed, it is important to get a better understanding of what risk and uncertainties are. Everything is inherently connected with risks and uncertainties, PSS's are no exception. Product-Service Systems introduce different types of risks and uncertainties compared to traditional asset ownership and usage. In order to better understand what kind of risk and uncertainties exist, the relationship between uncertainty and risk is defined as well as what an uncertainty is. For uncertainty, the following definition is used (Herzog, Meuris, Bender, & Sadek, 2014):

> *"Uncertainty is the stochastic behaviour of any physical phenomenon that causes the indefiniteness of outcomes meaning the expected and actual outcomes are never the same."*

Within the scope of Product-Service Systems, risk can be defined as follows (Erkoyuncu, 2011):

"Risk is a special outcome of uncertainty, where the outcome of a specific event or a number of events have a negative effect on the overall performance of a project."

Thus risks follow from uncertainties and therefore the focus will be on uncertainty, because accounting for uncertainty will automatically cover the risks.

As stated earlier, it is important to account for risks and uncertainties, because when acquiring a PSS, risks and uncertainties become inherently connected to the price and therefore the value of a PSS. In order to make a comparison between traditional asset purchase and ownership and a PSS, the assessment of such uncertainties is needed to be made in order to know whether the price offered by a supplier is fair.

5.4.2.2 The Cost Uncertainty Estimation Model

In order make a fair comparison between the traditional purchase of an asset and the purchase of a service, it is necessary to account for the increased risk and uncertainty for the supplier, due to the retained ownership and the responsibilities which are connected with being owner. In order to price in these uncertainties, the cost estimation procedure of Erkoyuncu (2011) will be used. It consists of roughly 8 phases, which allows for a systematic assessment of uncertainties related to any project valuation. Each phase consists of an activity which needs to be performed, this activity will be explained as well as the technique used in how it contributes to the cost estimation under uncertainty. In Figure 5.3, a visual representation of his model can be seen. In the next section, the various phase will be further explained.

5.4.2.3 Cost Estimation under Uncertainty Model

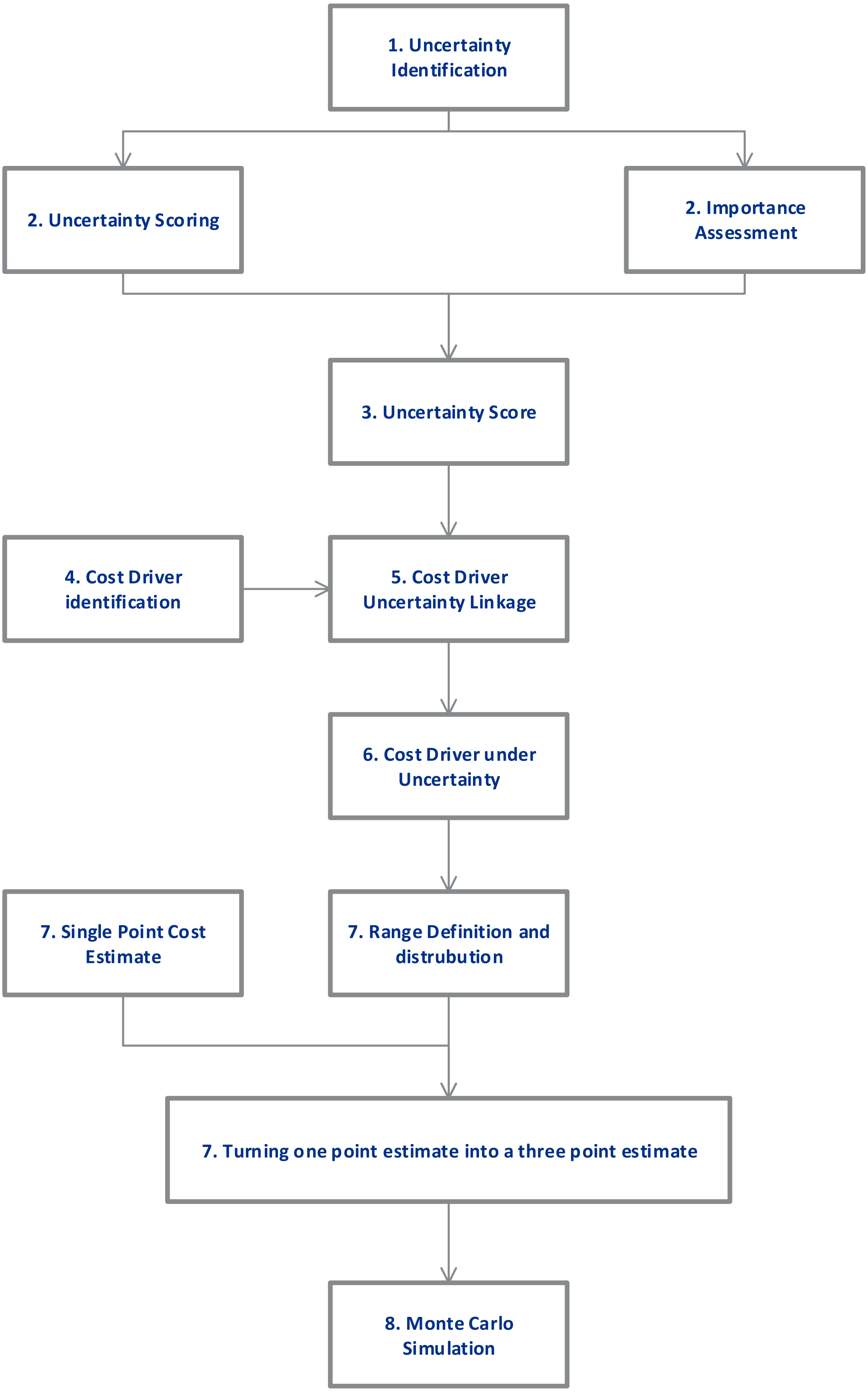


Figure 5.3 - Cost Estimation under Uncertainty adapted from Erkoyuncu (2011)

5.4.2.3.1 Uncertainty identification

Erkoyuncu (2011) distinguished 6 main categories of uncertainty. His research focusses on the uncertainties as experienced by manufacturers in the defence industry in their effort to determine a good price for offering a service. These main categories can be used as a guideline in assessing the main categories of uncertainty for suppliers of Schiphol.

	Category	Description
1.	Commercial Uncertainty	Factors that affect the contractual agreement, driven by requirements of the customer. However, the supplier is responsible for defining these requirements based on the capability.
2.	Affordability Uncertainty	Factors that affect ability to predict customer's and/or supplier's funding capabilities.
3.	Performance Uncertainty	Factors that affect the achievement in reaching the performance goals (KPI).
4.	Training Uncertainty	Factors that affect achievement in reaching customer's needs for the delivery of training.
5.	Operation Uncertainty	Factors that affect achievement in reaching the required level of service and support delivery. Focusses on equipment level (e.g. maintenance etc.).
6.	Engineering Uncertainty	Factors that affect the achievement in managing strategic decisions with regards to the future service and support requirement (e.g. End-of-Life etc.).

These 6 main uncertainties categories consist of many uncertainties. A complete list of these uncertainties can be found in Appendix K – List of Uncertainties. Besides the uncertainties of Enkoyuncu, the following uncertainties are also identified by Reim *et al.*, (2013):

1. Hard to communicate value
2. Inappropriate organisational structure
3. Cultural antipathy
4. Monitoring and information sharing
5. Too extensive or difficult contracts
6. Lack of resources and capabilities
7. Lack of financial resources
8. Complex supply chain
9. Adverse behaviour
10. Breakdown risk

Given the uncertainties provided, the actor has to assess which uncertainty is relevant for the project and should therefore be included in the uncertainty assessment.

5.4.2.3.2 Uncertainty assessment and relative significance

The next step is to determine the score of each uncertainty. Erkoyuncu (2011) uses 3 categories for which the actor has to determine a score (1, 3, 5 or 7). The three categories are:

1. Basic Estimate
2. Rigour in Assessment
3. Level of Validation

Basic estimate regards on the basic estimate of uncertainty taken into account how experienced the firm and/or actor is in assessing the given uncertainty. The Rigour of Assessment regards the accuracy of the basic estimate and whether it can be based on internal knowledge on the uncertainty. The level of validation regards on how well the score can be validated outside the firm.

These three categories can be assessed using the following scoring using the guideline from Figure 5.4

Basis of Estimate	Rigour of Assessment	Level of Validation
7: No Experience in the area 5: Incomplete data, small sample, educated guesses, indirect approximate rule of thumb estimate 3: Small sample of historical data, parametric estimates, some experience in the area, internally verified data 1: Best possible data, large sample, use of historical field data, validated tools and independently verified data	7: No established assessment of processes 5: Limited experience of applied process with lack of consensus on results 3: Sufficiently experienced and benhmarked internal processes with consensus on results 1: Best practice in well established discipline	7: No validation 5: Limited internal validation, no independent validation 3: Internally validated with sufficient coverage of models, processes and verified data. Limited independent validation 1: Best available, independent validation within domain, full coverage of models and processes.

Figure 5.4 - Uncertainty Scoring Guidelines based on Erkoyuncu (2011)

The next step is to assess the relative importance of each uncertainty against the whole project. This is done within each category of uncertainty. A score from 1 to 9 is given to each uncertainty and using a partial Analytical Hierarchy Process (Saaty, 1990), the significance score is transformed into a pairwise comparison and normalised weights using a priority vector, which is the principal eigenvector of the score matrix, which is produced by scoring each uncertainty. Then the score is normalised to a scale relative to the most importance and significant uncertainty (given the weight of 1 and the others are compared to this score). The significance categories from 1 to 9 can be found in Figure 5.5.

Pairwise Comparison

The following significance/relevance can be assigned to each uncertainty. This will be automatically translated in a relative weighted importance of each uncertainty via the AHP process.

1: Not significant/relevant. 2: Not significant/relevant to moderately significant/relevant. 3: Moderately significant/relevant. 4: Moderately to strongly significant/relevant. 5: Strongly significant/relevant. 6: Strongly to very strongly significant/relevant. 7: Very strongly significant/relevant. 8: Very strongly to extremely significant/relevant. 9: Extremely significant/relevant.

Figure 5.5 - Significance Categories based on Erkoyuncu (2011)

An example can be found in Table 5.1, the input significance score is provided in the green column for each uncertainty. Using the matrix from Table 5.2 the normalised weights are calculated and expressed again in Table 5.1. The normalised weights are the final scores for significance which are used for the calculation of the uncertainty score for each uncertainty in the next step.

Table 5.1 – Example Input Significance input

Pairwise Comparison	Input Significance	Percentage Significance	Normalised Weights
Type			
Customer equipment usage	1	0,01	0,06
Labour availability	7	0,08	0,4
Work share between partners	2	0,02	0,1
KPI Specification	9	0,21	1
Interest Rates	2	0,02	0,1
Environmental impact	7	0,08	0,4

Table 5.2 - Example Matrix for Calculation Normalised Weights

	Customer equipment usage	Labour availability	Work share between partners	KPI Specification	Interest Rates	Environmental impact
Customer equipment usage	1	0,14	0,33	0,11	0,33	0,14
Labour availability	7	1	5	0,33	5	1
Work share between partners	3	0,2	1	0,14	1	0,2
KPI Specification	9	3	7	1	7	3
Interest Rates	3	0,2	1	0,14	1	0,2
Environmental impact	7	1	5	0,33	5	1

5.4.2.3.3 Calculation of the Uncertainty score

These 2 separate assessments are now combined in order to produce the uncertainty score of each relevant uncertainty. The score is calculated in the following manner.

$$Uncertainty\ Score = \left(\frac{1}{3} * (Basic\ Estimate + Rigour\ of\ Assessment + Level\ of\ Validation)\right) * Normalised\ Importance\ Score$$

This results in an uncertainty score for each relevant uncertainty. An example list can be found in Table 5.3. Where high scores indicate a high uncertainty and significance, while low score indicate a low uncertainty and significance.

Table 5.3 - Example of an Uncertainty Score list

	Category	Type	Uncertainty Score
1	Commercial	Customer equipment usage	0,1
2	Commercial	Labour availability	1,7
3	Commercial	Work share between partners	0,5
4	Commercial	KPI Specification	5,7
5	Commercial	Interest Rates	0,1
6	Commercial	Environmental impact	1,7
7	Commercial	Warranty Scope	0,9
8	Commercial	Relationship with customer	1,5
9	Commercial	Stability of customer requirements	4,9

5.4.2.3.4 Cost Driver identification

The next step is to identify all cost drivers. Purchase price, maintenance, repair, replacement, energy are all cost drivers which add cost to a project. These need to be identified in order to know what cost are going to be incurred over the life time of a project.

5.4.2.3.5 Cost Driver and Uncertainty Linkage

Now that all cost drivers have been identified, all relevant uncertainties have to be linked to these cost drivers. The actor must decide which uncertainty is relevant for each cost driver in a yes or no manner. A cost driver can be influenced by many uncertainties, but it is essential that each uncertainty has at least one cost driver link, otherwise the uncertainty can be deemed irrelevant or indicate a missing cost driver.

By linking the uncertainties to each cost driver, an uncertainty score for the cost driver can now be calculated by adding all uncertainty scores and averaging the result. For the sake of comparability, the score is then divided by 7 (the maximum uncertainty score possible) to gain a cost driver's uncertainty score from a scale of 0 to 1.

5.4.2.3.6 Determination of cost range

In order to capture uncertainty given a cost driver's estimate, it is important that ranges are given to a cost estimate. The method of Erkoyuncu (2011) allows to transform a single figure cost estimate for a cost driver, as can be provided by the CEC of Schiphol, into a three-point range, where the single cost estimate acts as the most likely and the ranges of the cost is determined by the uncertainty scores which a deemed of influence of each cost driver. Based on the Cost Drivers' Uncertainty scores a range is assigned to the respective cost driver. The ranges from Table 5.4 are assigned to each uncertainty score.

Table 5.4 - Cost Range Classification based on Erkoyuncy (2011)

ESTIMATE CLASS	LEVEL OF PROJECT DEFINITION	METHODOLOGY	LOWER UNCERTAINTY VALUE	UPPER UNCERTAINTY VALUE	RANGE MIN	RANGE MAX
1	50% -100%	Deterministic	0	0,3	-10	15
2	30% - 70%	Primarily Deterministic	0,3	0,5	-15	20
3	10% - 40%	Mixed but Primarily Deterministic	0,5	0,7	-20	30
4	1% - 15%	Primarily Stochastic	0,7	0,9	-30	50
5	0% - 2%	Stochastic or Judgement	0,9	1	-50	100

The next step is to check whether the actor agrees to the cost range or that it want to manually adjust the range of each cost driver. Together with the cost range a distribution is assigned to each cost driver. This distribution is initially a triangular distribution, because it is one of the easiest distributions to work with in cost estimation and provides a good base to start with (Erkoyuncu, 2011). If the distribution of a cost driver is known, this distribution can be used, but the assumptions for this distribution must be checked against the available data on the respective cost driver.

5.4.2.3.7 Single Cost estimation to Cost Range Estimation

The next step is to enter the single cost estimate for each cost driver. Using the cost driver and uncertainty linkage, this single cost estimation is transformed to cost estimation range

This is then transformed to a cost estimation range, consisting of three points (Lower limit, Most likely and Upper limit). Where the single cost estimate acts as the most likely, and the ranges assigned to the cost driver based on the uncertainty act as the lower and upper limit.

5.4.2.3.8 Simulation and determination of price.

The last step in order to determine the price is to add all cost drivers into a simulation Monte Carlo model and let it run for a certain number of times. Monte Carlo is a tried and proven concept, which is used in many fields, especially in financial modelling. By drawing random numbers from the distributions linked to the different cost drivers, with their respective ranges for numerous times, the power of numerical scenario exploration can be exploited and numerous scenarios can be explored. This will result in a distribution of possible project cost. From this distribution a confidence level can be chosen (e.g. 95% or 99%) and from the distribution the associated cost level of can be determined and stated that, given the cost structure and distribution, that with a certainty of the chosen confidence level, the cost will not be higher than € *X*. A visual stylised example of a Cost Estimation under Uncertainty can be seen in Figure 5.6.

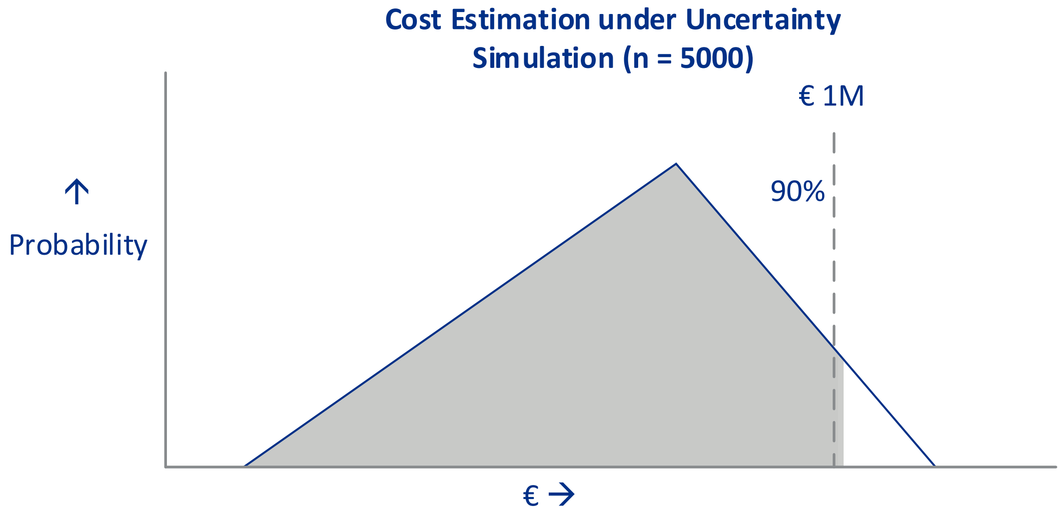


Figure 5.6 - Stylised example outcome of a Simulated Cost Estimation under Uncertainty

Because the model compares the relationship between the traditional NPV and an uncertainty weighted NPV, the difference between them can be seen as an implied risk premium the supplier should ask for carrying the risks and uncertainties associated with remaining owner. This can be reversed for Schiphol as the max risk premium a supplier should be allowed to ask for carrying such risk and is for Schiphol the premium it pays to mitigate the risks of the asset ownership towards asset user.

5.4.2.4 Validation of Cost Estimation under Uncertainty

The usage of Cost Estimation under Uncertainty sounds very promising and useful. In order to make sure that the usage of such a model is valid, a validation must be performed. Luckily, the validation for such a model is quite straight forward. Because the goal of the model to provide an estimate on a fair price, given the uncertainties as experienced by a supplier. Therefore, the user should use the model and determine the outcome of the model against the offering of a supplier. So, in order to validate the outcome of the model needs to be checked against the offering of a supplier for a PSS. If the outcome of the model delivers a price which is higher

5.5 Conclusion

Using the summary of the main finding of the literature review, an extensive one can be found in Appendix B – Product-Service Systems, the second sub question can be answered. First, a definition will be presented:

'A Product-Service System (PSS) is an integrated offering of products and services with a revenue mechanism that is based on selling availability, usage or performance'

PSS are a good way to facilitate the transition towards a CE within Schiphol. But, a PSS alone will not be sustainable all by itself. Of the three types of PSS, only the result-orientation is well suited to incorporate sustainability. PSS has clear benefits such as, higher quality of products, improved (sustainable) performance, lower cost for the whole value chain and therefore a win-win situation for both supplier and customer. Besides these benefits, there are barriers and uncertainties which affect the performance.

In a result-oriented PSS, ownership remains with the supplier of an asset. This increases the dependency between the user and supplier. Besides this dependency also the financial risks shift from user towards supplier. Because a supplier becomes more important in the development of the service, the whole procurement strategy is different than traditional purchasing. Suppliers become stakeholders and therefore need to be involved earlier on in the project. This becomes more apparent when one thinks about the uncertainties which are attached to PSS. Commercial, performance, operational and engineering uncertainties are all of importance to have a clear understanding of roles and responsibilities between buyer and supplier early in the process. When these uncertainties turn into uncontrollable risks, the benefits associated with PSS will not be reached and the relationship between buyer and supplier will be put under pressure, something which is highly unwanted given the long interaction and dependency between the two parties.

Besides the relationship, it is important to take into account the criteria which need to be met in order to make sure that a product/asset is suitable for being converted into a PSS. These four criteria can be seen as a safety net. The four criteria are; material/energy/labour intensive, the product should not be a core competence of the buyer, the consequence of malfunction should be severe to make sure that the supplier delivers quality and the market/investment size should be substantial.

If a product/asset is suitable to be transformed into a service, a few condition apply which are to be taken into account to make sure that it is a success. The first is that there needs to be a synergy added value by combining the tangible product, with the intangible service component. The second is that the product should be technically advanced, this allows to steer on performance. The latter is the most important condition for success for a PSS.

Steering on performance requires performance measurement. Performance measurement requires information gathering and this information is also important for the relationship between buyer and supplier. Because the customer requires a certain performance, it is important that clear KPIs are established, which cover the flow of money, products, services and information within the relationship of the stakeholders. These KPIs should be SMART and reflect the responsibilities both parties have. To make sure that all flows are covered, it is important to map stakeholders and visualise the flow between them. This increases the effectiveness of stakeholders and allows a validation of the established KPIs for both the customer as well as the supplier.

All these criteria, conditions and performance steer measures should be covered by a Service Level Agreement (SLA) which provides clear and unambiguous rules on responsibilities for both parties.

What can be concluded from the academic literature is that it in order to make a PSS a success, risks and uncertainties should be clear and the process of purchasing a PSS must be in place. Otherwise, the uncertainties will lead to uncontrollable risks which endangers not only the benefits of a PSS, but also the relationship between buyer and supplier, as well as the possible failure of the required function.

The last issue which needs to be addressed is the process of cost modelling under uncertainty. Due to the longer relationship between buyer and supplier, there is a need for both sides to have clear estimates on what the cost is of such provided service. Erkoyuncu (2011) has developed a framework from a manufacturer/supplier point-of-view, which can be easily transformed into a framework from a customer’s point-of-view due to the same uncertainties the asset is subjected to.

6. Current Situation

6.1 Introduction

SQ 3. What is the current situation at Schiphol, especially regarding decision making?

Schiphol is divided into 4 business areas (BA). Two of those BA's are actively managing assets. Schiphol Real Estate (SRE) and Schiphol Aviation. As given in the scope, Schiphol Aviation is the business area in which this research takes place. Schiphol Aviation is responsible for all aviation related activities. This comes down to three main pillars, which are Airport Operations (OPS), Safety, Security & Environment (SSE) and Asset Management (ASM). The main focus will be on ASM. A more elaborate description of ASM can be found in Appendix C - Asset Management at Schiphol Aviation.

Within the description of the current situation, it is important to keep in mind that the scope of this thesis is towards CE and the transition towards it via Product-Service Systems. Therefore, the sub question's answer will be more focussed towards PSS and not solely on the current situation at Schiphol.

6.1.1 Reading Guide

This chapter will provide an answer to the sub question on the current situation at Schiphol (SQ3). Paragraph 6.2 will provide information on Asset Management at Schiphol. Paragraph 6.3 will provide sustainability initiatives at Schiphol. Paragraph 6.4 provides information on how project valuation is performed at Schiphol. This provides a basis later on to sufficiently compare Product-Service Systems to traditional solutions. Paragraph 6.5 will treat sustainability at Schiphol, within the scope of CE. This results in paragraph 6.6, where the Light-as-a-Service case is further explained and evaluated. Finally, the conclusion and answer to SQ3 is given in 6.7.

6.2 Asset Management at Schiphol

The most important aspects of Aviation Asset Management (ASM) will be summarised, more information can be found in Appendix C - Asset Management at Schiphol Aviation.

1. There is a strict separation between Aviation and Non-Aviation assets. This separation is obliged by the Dutch Aviation Law (Luchtvaartwet, 2016).
2. Aviation asset are added to the Regulatory Asset Base (RAB). Schiphol can make a fictitious profit on this RAB, with a maximum of the regulated Weighted Average Cost of Capital (WACC) of Schiphol. This WACC is set every year in the 'toerekeningssysteem', or allocation system which has to be approved by the Authority for Consumers and Markets (ACM). The 'Toerekeningssysteem' describes how cost from Aviation are charged to the airlines via the airport tariffs.
3. 52% of all costs levied to airlines are directly asset related (Asset Wise! Team Schiphol, 2015). Therefore, reducing these costs would benefit airlines (lower tariffs) and Schiphol (more attractive due to lower tariffs).
4. Schiphol uses the principles of IFRS accounting, but where it is not aligned with the Aviation Law, the Aviation Law prevails. Main points are; the regulatory fixed depreciation scheme, controlled WACC, residual value is not allowed and assets are only added to the RAB once completely activated.

The conclusion of ASM at Schiphol, is that Schiphol is subjected to quite strict regulation, which limits the amount of movement it has in exploring new business models such as CE.

6.3 Sustainability at Schiphol

6.3.1 Corporate Responsibility Goals

Schiphol feels it has a strong responsibility on the corporate responsibility (CR) level. For quite some time now, Schiphol has incorporated CR into their strategic goals on many levels. Every BA is responsible for operationalising these CR goals which are set every year by the board. The last few years, CE has become a bigger part of the CR strategy and multiple objectives have been set. CE is mentioned in the annual report as one of the subjects which attributes directly to the CR goal of sustainable & safe performance (Schiphol Group, 2016).

6.3.2 CE Projects

Schiphol advocates CE through different projects. As stated before, the CR goals incorporate CE and design. A few projects have been initiated over the past years. Some of these initiatives will be elaborated upon, to see if the proposed transition with Product-Service Systems has a link with one of the already ongoing projects. One project, Light-as-a-Service will be further explained here, for the other CE projects, the reader can read

6.3.2.1 Zer0 Waste

One of the goals of Schiphol is to remove all waste streams and convert them into sustainable revenue streams. The so called Zer0 Waste plan aims at reaching zero waste from operations in 2030.

6.3.2.2 Blue Conveyor

Schiphol has developed a so called blue conveyor system which uses recycled and non-toxic materials for the baggage reclaim conveyer belts. Besides the recycled material, the belt is engineered as such that it uses considerable less energy than a conventional belt and that it can be completely recycled at its End-of-Life (Schiphol Group, 2016).

6.3.2.3 True Price

Within Schiphol, the need arose to have an insight in what the environmental impact of certain projects would be. In order to facilitate the decision making with a tool which contributes towards this, a True Price model has been developed. It monetises the effect a project has on the environment using shadow prices of the environmental impact. Furthermore, it helps to look further than just the internal financial gain, by showing what the societal effects are, if Schiphol would have to pay for the caused impact. Finally, this contributes to the awareness of Schiphol of their environmental impact and it is currently being implemented as an extension of the standard decision making procedure at Schiphol.

6.3.2.4 Light-as-a-Service

Schiphol is renewing its Lounge 2 area at the terminal. During the initial phase of this project, the idea was born to do a pilot project with the lighting. Together with Philips and Cofely, it was decided to try out the new Light-as-a-Service (L.a.a.S.) concept from Philips. The initial idea was that L.a.a.S. could offer an answer to the problem of increasing resource scarcity, provide Schiphol with a tool to grow towards a professional asset management organisation and support Schiphol goal of being Europe's preferred airport. L.a.a.S. is characterised as a Product-Service System, due to the fact that it is a product which is normally purchased and managed internally, but is now outsources and used as a service.

6.3.3 Conclusion

There are several sustainability and CE initiatives within Schiphol. Some are proposed from the CR goals, others have been proposed to improve decision making by putting a price on the whole environmental impact of a project. There is one project which has the clearest link with the scope of this master thesis and the proposed way of enabling the transition from linear towards CE. The Light-as-a-Service (L.a.a.S.) can be classified as a Product-Service System, as it is a product/asset which normally would be purchased and separately maintained, disposed etc., but is now purchased as a service and not as a product. L.a.a.S. will be further examined in the next paragraph, as well as evaluated based on the knowledge obtained from literature, together with the information obtained from Schiphol. By analysing the project, more information can be obtained on how the project has been given shape, how such a project develops in real life and if the underlying processes are sufficient, efficient and effective.

6.4 Project valuation

In order to gain a better understanding of the financial implications of CE, it is important to know how Schiphol valuates its projects. This will provide a basis on which the comparison between current projects and a PSS can be performed. Furthermore, the current techniques used will be evaluated using academic literature, to see whether they are still good techniques to compare projects or alternatives, as well as take it into account in a recommendation if needed.

6.4.1 TCO

Schiphol uses a Total Cost of Ownership (TCO) approach in order to value the project as well as alternatives within a project. The definition which Schiphol uses for a TCO is that all costs over the lifetime of an asset are taken into account. The idea is that alternatives can be better compared if every aspect of its life cycle is accounted for and that not only CAPEX but also OPEX and End-of-Life (EoL) costs are used.

6.4.2 NPV

Schiphol uses the NPV technique to value projects and calculate the TCO of a project. The theory behind NPV is explained in 5.4.11.2.4.1.

6.4.3 EAC

In order to gain a better idea between different projects with possible different life times, it could be beneficial to transform the NPV to an annuity in the form of an Equivalent Annual Cost (EAC). It shows the cost per year of owning and operating an asset over its life time. However, it is important to state that project which are compared to one another should have similar risks. Therefore, EAC is not ideally suited for one time decisions, due to the fact that risks are different. (Emery, Finnerty, & Stowe, 2004), but it can be very insightful in determining the annual cost of a project. The EAC can be calculated using the following formula (Brealey, Myers, & Allin, 2011):

$$EAC = \frac{NPV}{A_{t,r}}$$

where,

$$A_{t,r} = \frac{1 - \frac{1}{(1+r)^t}}{r}$$

The main advantage of using EAC is that it can easily be compared over the years for different solutions what the annual cost would be and this can be used in the calculations for the airline tariffs.

6.4.4 Decision Making

Decision making at ASM has been given shape by the Asset Wise! program which has been launched in 2013. It formalised the process, which was needed to let ASM operate efficient and effectively. The main points for decision making will be explained using Asset Wise! documentation (Asset Wise! Team Schiphol, 2015).

Asset Wise was launched in order to facilitate better asset management, gaining better control over cost and therefore contribute to being Europe's preferred airport with a long term vision. Furthermore, Schiphol wants to utilise the expertise available in the market and gain experience in being an asset manager, instead of being a pure asset owner and maintainer.

Asset Wise introduces five principles for ASM.

1. Every asset should create value for Schiphol mission and strategy.
2. Therefore, every project should be evaluated on function, risk and euros (TCO).
3. The strategic decision making process is top-down oriented, which calls for clear processes.
4. Clear processes result in facts and figures on which proper decisions can be based.
5. Together with clear roles and responsibilities within the organisation, decision making should be thorough and support the best solution, in the broadest sense.

Given the business environment of Schiphol, there is one very important principal which needs to be taken into account for decision making. Due to the nature of Schiphol's operation and the separation between Aviation and Non-Aviation it is very hard to directly link revenue and costs to one another on a project basis. The direct contribution of a project on the revenue of Aviation is nearly impossible to know and therefore direct link between costs and revenue is regulated through the allocation system. The impact this has on decision making is that projects are valued at on costs and not on the associated revenue. In order to make sure that decision making accounts for the needed functionality, taken into account risks and uncertainty the decision making process is based on functionality (Value for customers), TCO (Costs) and risks.

6.4.5 Conclusion

With the introduction of the Asset Wise program at Schiphol, the Total Cost of Ownership (TCO) has gained a central position in ASM at Schiphol. By incorporating all cost throughout the life of an asset, decision making supports the best solution. Using the well-known NPV to value future cash flows and converting them to a single figure annualised cost (EAC) provides the tools to compare different solutions and projects. The risk however is that EAC only works if the project basis is the same. Overall can be concluded that by balancing the function, risk and euros against each other, effective decision making will be supported and should provide the proper incentives to deliver the best result.

When PSS are put against the current project evaluation, it can be concluded that it will fit within the strategy put forth by the Asset Wise program. The cost of a service can be compared to the EAC of doing it the traditional way. Because both are annualised costs of a project. Furthermore, PSS can help to transition towards effective asset management, because it requires to define the needed function, assess the associated risks and to get a competitive price for the required service. Thus can be concluded that PSS as an alternative within a project, should be easy to integrate into the normal decision making process of any Schiphol project. Furthermore, PSS could result in lower cost and higher quality, which would contribute in being Europe's preferred airport, as well as, lowering the asset related cost. One thing is not clear and that is how the process of a PSS in the decision making is given shape. This could be a potential issue, because in a top-down decision making process, a clear and transparent process is key in order to ensure quality.

6.5 Sustainability at Schiphol

6.5.1 Corporate Responsibility Goals

Schiphol feels it has a strong responsibility on the corporate responsibility (CR) level. For quite some time now, Schiphol has incorporated CR into their strategic goals on many levels. Every BA is responsible for operationalising these CR goals which are set every year by the board. The last few years, CE has become a bigger part of the CR strategy and multiple objectives have been set. CE is mentioned in the annual report as one of the subjects which attributes directly to the CR goal of sustainable & safe performance (Schiphol Group, 2016).

6.5.2 CE Projects

Schiphol advocates CE through different projects. As stated before, the CR goals incorporate CE and design. Over the years there is a variety of projects which have been initiated, for more information on other CE projects the reader can read Appendix D - Circular Economy Project at Schiphol. One project will be elaborated more, which is Light-as-a-Service. This project closely resembles a Product-Service System.

6.6 Light-as-a-Service

Schiphol is renewing its Lounge 2 area at the terminal. During the initial phase of this project, the idea was born to do a pilot project with the lighting. Together with Philips and Cofely, it was decided to try out the new Light-as-a-Service (L.a.a.S.) concept from Philips. The initial idea was that L.a.a.S. could offer an answer to the problem of increasing resource scarcity, provide Schiphol with a tool to grow towards a professional asset management organisation and support Schiphol goal of being Europe's preferred airport. L.a.a.S. is characterised as a Product-Service System, due to the fact that it is a product which is normally purchased and managed internally, but is now outsources and used as a service.

In this paragraph the Light-as-a-Service (L.a.a.S.) project will be further examined and evaluated. Schiphol expressed the need for an evaluation due to the novelty of L.a.a.S. as well as problems which have arose during the project. First, the project set up will be explained. Second the project will be evaluated and using knowledge from Schiphol and literature problems will be pointed out. Lastly, solution on how to avoid these problems will be presented. This will contribute in a later stage for assessing the barriers which exist within Schiphol on the adaptation of PSS as a CE enabler.

6.6.1 Project set up

The L.a.a.S. project originated from a meeting between Schiphol and Philips. The idea to turn the product light into a service is one which crossed Schiphol's mind for quite some time. The innovation was given more shape when the renovation of Lounge2 at Schiphol was being planned. Schiphol and Philips set the first steps towards a corporation on the project. Furthermore, the step towards essentially outsourcing a non-core competence of Schiphol fitted in the view that Schiphol needs to transform towards a management organisation. Together they decided to start a pilot project to see whether Light-as-a-Service would add value.

From Schiphol's point of view L.a.a.S. could support the following goals and ambitions of ASM.

1. Sustainability ambition
    a. Energy reduction (20% in 2020)
    b. Resource scarcity
    c. Collaboration with stakeholders for more energy reduction measures
2. Quality and cost efficiency

a. Not more expensive than traditional lighting
b. Increase of efficiency management; complete care taking of daily operation of lighting during the life cycle of Lounge 2 (10 years)
c. Management: completely certain cost for management and maintenance of lighting.
d. Replacement cost reduction possible on large maintenance operations

3. Growth of the Asset Management organisation
   a. ASM does not seek warranty of 10 years, but a guarantee on energy usage and cost level over the upcoming 10 years, with preservation of quality and increase of performance
   b. Focus on customer satisfaction. Learning the impact of adjustable lighting on the customer experience and flow with the help of the market
   c. Knowledge; learning effect due to new contract form as well as collaboration. (Goal is not to change contract management).
4. Collaboration
   a. Showcase for all parties involved; image, promotion and marketing possibilities.

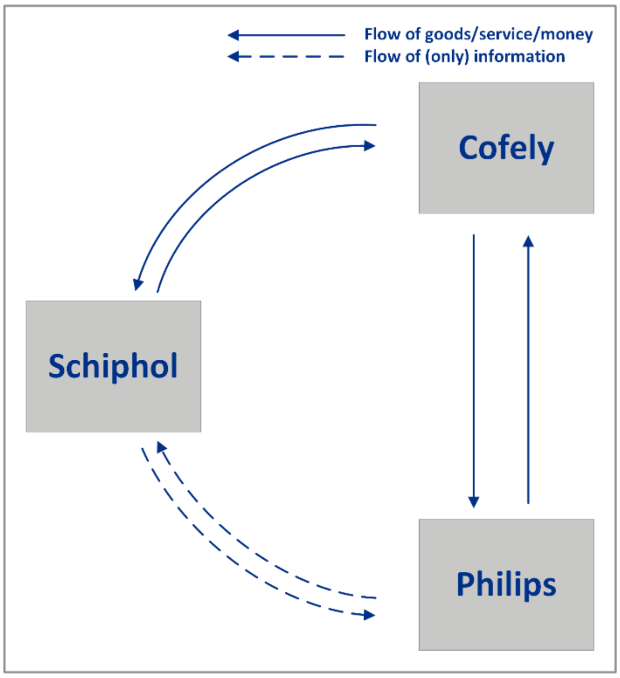


Figure 6.1 - Structure of parties involved

Due to the fact that Schiphol already outsourced their maintenance towards a separate party, the maintenance of the lights needed to be done by this contractor. This complicates the situation. In order to gain a clear understanding on the relationships, the basic structure can be seen in Figure 6.1. It is important to know that Cofely, as the main contractor maintenance for Schiphol, is the party which is charged with the installation and maintenance of the light at Schiphol and that Philips is the supplier of the lights.

6.6.2 Project evaluation

Due to the novelty of the project from the sides of Cofely, Philips and Schiphol, it is important to evaluate the project to see how it developed and were lessons can be learned. Furthermore, it can be checked whether the criteria and condition for a good Product-Service System are being fulfilled.

The first analyses from the checklist is that light as a service is suitable as a PSS. It meets all four criteria, but it is important to state that even though lighting is not necessarily operation critical, it is critical if to many lights fail together.

The second conclusion which can be drawn is that the current L.a.a.S. does not meet the condition which are necessary to guarantee success. This comes down to several points which are essential and are not completely present in the current project and contract.

The first point which is clearly missing is that good, clear and SMART KPIs are missing in the current contract and agreements with both Philips and Cofely. As stated previously, because partially a party loses control over an asset when it is not the owner anymore, clear KPIs have to be introduced in order to retain the means to steer on performance. The KPIs should cover the complete interest from Schiphol's side, as well as provide ways to the supplier to deliver performance. From discussion with Schiphol it became clear that currently only one KPI is present, which is lux/m2. As one can imagine this does not cover the complete interest Schiphol has at L.a.a.S.. Furthermore, in order for a PSS to be successful, in a sustainable matter, the contract and the service have to be result-oriented. With only one real KPI in a contract, this orientation can never be reached and the contract is function oriented. Function oriented services do not add real value to both parties, let alone on a sustainability point of view.

The second point is that there are several situations which are inadequately addressed in the agreements. The lights have been lit in the new Lounge 2 for almost a year as of march 2016. But due to construction delays, the official completion and handover of the lounge is not done yet. The contract is activated only when the lounge is handed over. This is also the moment the warranty becomes of effect as well as the yearly payments of Schiphol for the service provided by Cofely. This means that the lights have been turned on the cost of Cofely/Philips without a fee from Schiphol. Furthermore, the warranty which has been agreed upon is based upon that the light will be turned on when the official handover is there. The warranty is 10 years, which means that the warranty start at the moment the lounge is handed over and then 10 years the supplier will cover any warranty related problems. Now the lights have been turned on for a year already, while the handover was not yet done. This implies that the warranty is stretched to 11 years, which puts additional risks towards the supplier which weren't foreseen. This puts stress on the customer/supplier relationship, which is not beneficial for either, as a good relationship is key.

The third point is that the sustainability goals of the project are not anchored properly in the contract. While one of the reasons to initiate the project was sustainability, the project itself does not have the necessary incentives for the supplier to invest in sustainability. KPIs are necessary in order to make sure that energy efficient lighting is used (W/m2), demands on End-of-Life disposal is necessary, as well as insight in the CO2 usage at production and usage of the lighting. The sustainability need to be addressed before hand, because production can't be reversed afterwards. It could undermine the complete sustainability goals. As stated in the previous, system optimisation is necessary and clear contract with proper KPIs could be the key for all parties to reach such an optimisation.

Mentioning system optimisation, it is important to state that Heijmans Utilities (HU), which is the main contractor for all basic utilities (e.g. electricity), was not included in the design of the lighting. This resulted in additional work by HU, which was done at a significant higher cost level than necessary, which could have been avoided if they were involved earlier on in the process.

6.6.3 Conclusion Light-as-a-Service

The Light-as-a-Service project was initiated with good intention and ideas for Schiphol to answer a growing resource scarcity, facilitate the growth towards being an asset management organisation and support being Europe's preferred airport. However, the project suffered a few problems, which causes the project to be considered not successful as it should. When it comes down to where the actual problem came from and why Schiphol, Cofely and Philips were unable to overcome them, it can be concluded that the development process was unclear and unclear guidelines or project structure was in place which could guarantee a good outcome. While this is unfortunate for all parties, it does allow Schiphol to learn from the current project and therefore support the growth towards an asset management organisation. The key issue with such a conclusion is that in order for Schiphol to not make the mistakes a second time, the lessons learned need to be formally recorded and used for future products. It can therefore be stated that Schiphol needs a framework which can be used for Product-Service Systems and that such a framework is currently missing in the tools provided.

6.7 Conclusion

The current situation at Schiphol given the scope presented in the previous chapter on CE and PSS, shows that Schiphol is transforming from a pure asset owner to an asset management organisation. Throughout the launched Asset Wise program, Schiphol has formalised this intention with a more thorough process on decision making for assets. But the environment for Schiphol to manoeuvre is restricted due to the aviation regulation, which poses strict rules on how project may be valuated using a regulated WACC, how accounting needs to be performed on assets with depreciation, residual value, IFRS exceptions. Furthermore, the necessity of proper asset management is underpinned by the fact that half of all aviation cost are directly related to assets. When seen within the scope of PSS as a transition enabler for CE, it becomes clear that a framework for PSSs, such as Light-as-a-Service, is needed in order to create customer value, enable top-down decision making and support effective decision making over the life time of the required asset/function balancing risk, function and cost, as prescribed by the Asset Wise! program. Due to the fact that ASM is responsible for the development of assets and the associated contract management, it is recommended to have such a framework in place, if a new project comes along which can be classified as a PSS. By structuring the process, the market can be fully utilised and Schiphol can focus on its core competence instead of supporting functions. Lastly, the L.a.a.S. project clearly showed that proper data management, clear contractual agreements on the measurement of performance are needed, if Schiphol want to be able to successfully implement PSS. A framework contributes to such a success. With this conclusion sub question 2 is answered, as well as a next step is presented with which the thesis will continue.

7. Product-Service Systems Framework

7.1 Introduction

SQ4 What is needed for good decision making with Product-Service Systems at Schiphol?

SQ5 How can a price indication for a Product-Service System be determined?

CE, PSS, decision making at Schiphol, and especially within ASM, together with the Light-as-a-Service pilot project have been explored. This allows to combine this knowledge into the next step needed for Schiphol for PSS. This is done by answering sub questions 4 and 5. This chapter will introduce a decision framework, together with a Pricing tool

7.1.1 Reading Guide

Paragraph 7.2 will treat the foundation of the framework. What needs to be included in the framework to prevent mistakes and provide a basis of a successful implementation to a Product-Service System. Paragraph 7.3 will treat the main elements of the framework. Paragraph 7.4 introduces the Product-Service System Decision Framework (PSS-DF). Following from the framework, paragraph will provide guidelines and manuals for using the framework, together with Appendix B – Product-Service Systems. Paragraph 7.5 will introduce the PSS Pricing Tool and paragraph 7.6 will treat the outcome of the PSS Pricing Tool. Paragraph 7.7 will treat on how the framework will be validated in order to make sure that it is complete and validated to use for ASM and Schiphol. Finally, paragraph 7.8 will concluded this chapter.

7.2 Foundation

7.2.1 Origin

From the previous chapters it can be concluded that a clear decision process is needed in order to facilitate that As-a-Service becomes an alternative within the ASM organisation. By providing a clear process, the alternative can be put forth in an early stage. Secondly, from the literature in chapter 5, it is concluded that Result Oriented Product-Service Systems can be a transition tool for Schiphol towards a more CE business model, which is one of the CR goals of Schiphol. Due to the strict regulatory nature of Schiphol's Aviation Business Area, a clear process is needed in order to show to their internal and external stakeholders the added value of a PSS both in business sense, as well as a sustainability sense. From the Light-as-a-Service pilot case, it can be concluded that in order to guarantee effectiveness and full benefits, the process should be clear so that every stakeholder involved has a clear understanding of the project's specifics, expectations from other parties and how the long term relationship will be given shape. The set up and expectations need to be clear for PSS to succeed and provide a good tool for Schiphol to become more circular. When all these steps are clear, the decision process fits in neatly with the Asset Wise! program and provide an extra asset solution to make ASM a more effective asset management organisation which can focus more on performance and results. Thus, it is clear that a decision process is needed. The next paragraph will treat the most important points from the previous chapters regarding the content of the decision framework. It will draw upon the necessities from a CE point of view, the properties of Product-Service Systems all aligned with the business environment of Schiphol, in order to smoothen the implementation.

7.2.2 Circular Economy

CE focusses on regenerative by design, aiming at maximising the value throughout the whole value chain, while reducing resource usage. In order to achieve this, it is important that the optimisation as such is not confined to just Schiphol, or just the supplier of Schiphol, but at both parties. In order to achieve this, it is important that both Schiphol and its suppliers work together more closely in order to achieve a joint goal and not just two individual goals. A joint goal requires clear expectations from both parties and clear expectations require a transparency and corporation from both parties.

7.2.3 Product-Service Systems

Product-Service Systems could be an excellent tool for Schiphol to facilitate the transition towards a more CE as well as an effective Asset Management organisation. In order to guarantee a success, it is important that the PSS is set up as a result oriented PSS, which allows for both Schiphol and the supplier to have the same goal and maximise the effectiveness of the asset both on performance as well as on the environment. 5.3.1 gives 4 criteria which act as a first guideline to see whether a certain asset can be acquired as a (Result Oriented) Product-Service System. The need for result orientation of the PSS can help Schiphol to set the next step towards performance contracts, which is the final contractual goal of the Asset Wise! program given the maintenance of assets. A Result Oriented PSS has maximum effectiveness if the ownership remains at the supplier, but this complicates the ability for Schiphol to determine what a fair price is to pay for the service, because there exists a transfer of responsibilities and associated risks from Schiphol towards the supplier. Risks required return and thus, a supplier will include a risk premium into its price. Thus, using Cost Estimation under Uncertainty, Schiphol is able to estimate a fair price for the service and therefore enable a fair comparison between a traditional asset solution where Schiphol becomes owner and an As-a-Service solution.

7.2.4 Business Environment

Schiphol Aviation Asset Management has a rather unique position due to the deep involvement of the ACM (Dutch Competition Authority) and the Aviation Law which puts a restriction on how ASM is able to put its investment to work. There is a clear distinction between Aviation and Non-Aviation related activities and if necessary an allocation scheme is in place to divide costs between them. Furthermore, all Aviation related OPEX costs are directly incorporated in the Airlines Tariffs. For CAPEX the assets are added to the Regulatory Asset Base (RAB) and a fictional rate of return may be earned on those assets. This rate of return has as a maximum a regulated and by the ACM controlled WACC. The impact of this regulation is that a new difference in earning capacity may come into existence when there is a big difference between a traditional asset owner (and therefore adding to the RAB) solution and a PSS, where the CAPEX is replaced by OPEX and no extra earning capacity is allowed due to the strict regulation, which might endanger the position of Schiphol in the future.

As stated in 6.4.4, the most important impact of the business environment on the framework is that costs and revenue are very hard to directly link to one another. A projects outcome is hard to convert into figures which show a direct increase in revenue. Therefore, projects are, mostly, evaluated on costs and not on whether the NPV is positive. Furthermore, all costs which are incurred by ASM are transferred, via the cost allocation keys, towards the users of their assets. So, in short it can be stated that the NPV of a project is always zero, because all costs incurred are always earned via the allocation. Therefore, decision making is on costs and not on revenue and this is very important for decision making and explains why Schiphol puts so much emphasis on the TCO, risks and functionality triangle in the decision making process.

7.2.5 Light-as-a-Service evaluation

The following points are identified as not sufficient in the evaluation. For each point the solution to cope with the point is given, which is either based on previously mentioned literature, new literature or information from Schiphol.

1. There is no clear indication of what potential risk and impact of purchasing a service compared to a traditional asset

2. There are no criteria used on whether a product/asset is suitable to be purchased as a service
3. There are no conditions provided which ensure success
4. There is a mismatch between stakeholder relationships and their respective contractual agreements
5. No proper KPIs were developed and therefore only one KPI made it into the contract, which is insufficient to effectively steer on performance
6. There is no clear monetary incentive for the supplier to deliver results, because i) the KPIs are missing, ii) no clear norm, bonus and/or malus setting is contractually agreed upon.
7. The structuring of the contract was not well due to the novelty of such a service contract. There was no proper Service Level Agreement.

7.3 Framework elements

The proposed solutions to the abovementioned points can be considered elements which need to be incorporated into the framework. For each point, a solution will be put forth and substantiated if necessary.

7.3.1 Product-Service Criteria

The current Light-as-a-Service has been put forth from a novelty, and innovative point of view, as a pilot project. While this is a good starting position, it is however important to check which criteria there are to determine whether a project is actually feasible. As stated, this was not checked beforehand. The reason for this is unclear, but with the knowledge obtained in paragraph 5.3.1, it is possible to state four criteria which need to be met in order to safely say that a certain product/asset is suitable to be purchased as a service instead of the traditional ownership. These four criteria are:

1. **Labour, resource and/or energy intensive**
2. **Not part of a critical primary process**
3. **Severity of malfunction**
4. **Market/Investment size sufficient**

7.3.2 Performance Steering

As stated in 7.2, to ensure maximum effect of a PSS, Result Orientation is needed. In order to have the capability to make results count, performance steering is required. If the operation of an asset does not allow for performance steering and/or improvement, it is hard for either Schiphol or the supplier of the service to provide continuous improvement and therefore increasing results. Therefore, some form of performance steering is necessary for both parties to reach the full value adding effects of a PSS.

7.3.3 Risks and Impacts

If one buys an asset and operates it in the traditional way of being full owner, the associated risks and impact are different from when Schiphol purchases a service from a supplier.

The first thing which needs to happen that the potential financial impact is to be determined. This needs to be done via the TCO methodology already in use at Schiphol. The traditional way and as an alternative the service. By comparing the annual service fee with the Equivalent Annual Cost (EAC) of the traditional way. This allows to get an idea of how the annual cost compare.

Furthermore, this can be used in order to assess the risks. The traditional way has maintenance, energy and other asset usage related costs, these cost also have risks, but also certainty because Schiphol has full control compared to the dependency of a service and other involved parties. All these kinds of risks and their potential impact need to be visualised, so that not only a financial comparison is performed, but also functional and risk comparison. This is in line with the Asset Wise decision making on the triangle of function, risks and euros.

7.3.4 Stakeholder relations

The first condition is that stakeholder relations need to be clear and mapped. Due to the new environment of taking on a service with much broader possible consequences due to increased dependency, it is vital to get a clear picture of which stakeholders are involved in the respective project. Besides these relationships, it is important to map which type of goods, services, information and monetary flows there exist between the stakeholders on the given project. Due to the change of ownership compared to traditional asset management, there is the possibility that this could lead to decreased transparency in functionality, product and information flow. In order to tackle this, it is important that the contractual relationship between stakeholders also needs to be clear. Usually, the contractual relationships are different than the informal relationships. For the Light-as-a-Service case, the official contract is with Cofely, while Philips is nonetheless an important stakeholder in the project. This is important to map beforehand, because a good and stable relationship between buyer and supplier is essential. By having an overview of both situation, the legal and actual dependencies between different stakeholders is clear and can be acted accordingly.

7.3.5 KPI development

Key Performance Indicators (KPI) are at the base of modern contractual agreements and business models. They are quintessential in order to measure performance and exert and manage control over assets. The problem with the current Light-as-a-Service contract is that while constantly mentioned in the trajectory of development of L.a.a.S., they were never formally agreed upon. There is only one KPI which is actually in the current contract and that is Lux/m2. As can be imagined, one KPI is not enough to actively steer on performance and therefore contribute to the CE. Therefore, how basic it may sound, it is explicitly identified as one of the reason the current L.a.a.S. project has not been the success it could be. Given the increased dependencies between stakeholders on a variety of relationships, whether goods, services, information or data, KPIs are the tools to produce common grounds, derive clear expectation for all parties and cover the potential loss of control by mutually agreeing on KPIs. From Schiphol's perspective, KPIs are the performance agreements for which it pays its service fee. Function, result and performance and risk coverage all come down to proper KPIs.

7.3.6 Contractual Incentives

KPIs alone are not enough to persuade a supplier to deliver the best possible service it can. With KPIs, a norm is needed which is the minimum performance required by Schiphol. Together with this minimum performance, contractual incentives can boost constant innovation and improvement. Therefore, a bonus can be agreed upon if the supplier outperformance the expectations. What is necessary is that it should not invoke strategic behaviour, however a bonus for (long term) performance can push the supplier the extra mile to deliver. On the contrary, due to the increase dependency of Schiphol, it is important that a malus is also included. If the required performance is not met, the consequence of this failure to meet promises should be penalised. This to ensure that a supplier will deliver the minimum required performance. The dependency of the two parties puts additional risks at both of them, but by setting a minimum performance together with sufficient means to steer on performance, these risks can be dealt with. A mutual beneficial solution for both parties and a potential basis for a long and healthy relationship between them.

7.3.7 Service Level Agreement

The final point which needs to be addressed in the framework is that within the contract all the above mentioned points need to be firmly represented in the contract with the supplier. Therefore, a Service

Level Agreement (SLA) part needs to be part of the contract in which all these kinds of measures and agreements are put forth. In order to make sure that the SLA covers the needs completely, the points provided in Conditions for success for Product-Service Systems5.3.2 are followed.

7.4 Product-Service System Decision Framework (PSS-DF)

From the combination of the foundation, the literature study, internal and external talks and the need for a formalised decision process, a Product-Service System Framework (PSS-DF) has been developed, which can be seen in Figure 7.1. The PSS-DF consists of the following parts, which will all be explained in the coming paragraphs, together with the accompanied files and tools needed for usage

1. Compact Framework (Size A4)
    a. Guidance Manual
2. Extensive Framework (Size 4 A4)
    a. Clear overview of Inputs, Outputs, Decisions, Actors and Affected Stakeholders
3. PSS Criteria Matrix
4. PSS Pricing Tool
    a. Guidance Manual
    b. Excel Tool

The framework can be regarded as an easy to follow action plan with steps which need to be taken. If all steps are taken, one can state that a thorough and complete decision process has been used in order to come to a complete contract, KPIs and decision to implement a Product-Service System at Schiphol. By applying the framework from the first moment a project is started which might be purchased as a service instead of a product/asset, all associated risks and impact become clear and the co-creation of buyer/supplier can be optimal put to work in order to make it a success for both sides. Furthermore, due to the road taken by Schiphol to become an effective asset management organisation, it is necessary to formalise the process, which is effectively done by the framework. Lastly, the framework takes into account all relevant aspects as put forth by the ASM strategy as well as the Asset Wise! strategy, which are both essential in the operation of ASM.

7.4.1 Compact Product-Service System Decision Framework (PSS-DF)

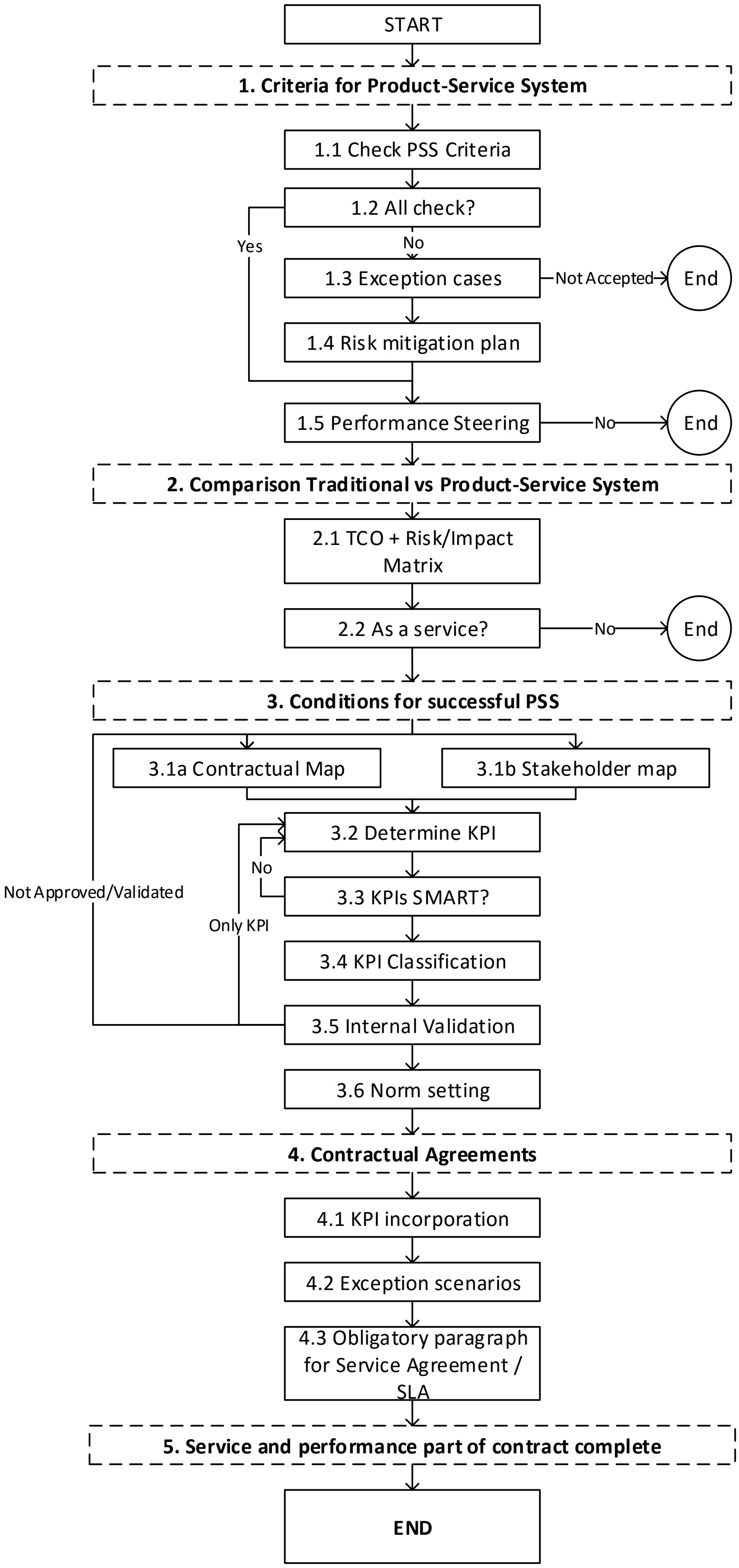


Figure 7.1 - Product-Service System Decision Framework

Figure 7.1 shows the compact framework. It consists of 17 steps, which are clustered into five stages. The whole framework, including manual can be found in Appendix G - Manual Compact Product-Service Systems Decision Framework. This section acts as the explanation of the framework, which steps are present. For a quick overview the compact framework offers enough structure, for a more extensive framework on the different roles, the extensive framework of Appendix J – Extensive PSS Decision Framework is the better option.

7.4.1.1 Stage 1 – Product Service System Criteria

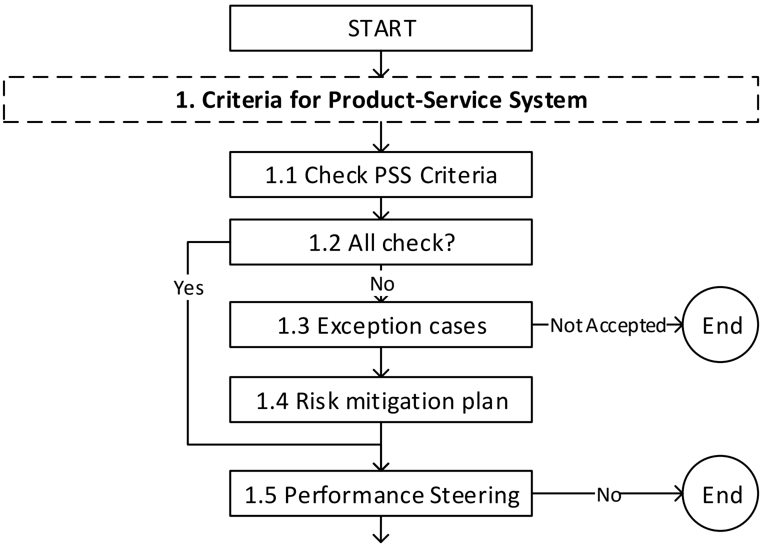


Figure 7.2 - Stage 1

The first stage, criteria of PSS Systems consists of 5 steps. The first step, **1.1**, is to check whether the product/asset meets all four criteria which are considered essential by literature. The PSS Criteria Matrix in Figure 7.3 can be used in order to easily see whether all are met and what are possible exception scenarios.

1. Labour, resource and/or energy intensive
2. Not a core competence
3. Severity of malfunction
4. Market/Investment size sufficient

The second step, **1.2**, is to check if all criteria are met using the criteria matrix in Figure 7.3. If all are met, the user may proceed to step 1.5, otherwise step **1.3**, is next in line. Step 1.3 check which criteria are not met. If criterion 1 or 4 are not met, the advice is given to not proceed with trying to implement a PSS, due to the unfitness of the nature or size of the product/asset. If criterion 2 and/or 3 are not met, it is still possible to continue, but it requires a clear assessment of whether Schiphol want to bear the risk. If criterion 2 is not met, which means that the product is part of the primary process of Schiphol, one needs to question whether the severity of malfunction is acceptable for Schiphol. If the influence of malfunction is too severe, Schiphol must check whether it is willing to take the risk. Due to the loss of ownership, Schiphol loses control and if it influences the primary process to much, it is advised not to pursue a PSS. If the severity of malfunction, criterion 3, is not enough, Schiphol lacks the means to gain an effective negotiation position. These two criteria on itself should not have to mean the end of a PSS, but if not met, a risk mitigation plan must be written which puts forth the possible effects of the PSS on Schiphol, which is step **1.4**. This to make sure that there is given proper thought to it and that possible risks are accounted for. If these plan are considered to cover the risks sufficiently, one may continue to step 1.5. Step **1.5** checks whether performance steering is possible. For an effective result orientation, performance steering is necessary. A contract for result orientation is usually a performance contract, where improvement of performance during the contract duration is required. This to make sure that the supplier keeps the proper incentives to perform.

PSS Criteria	**1. Labour, resource and/or energy intensive?**	**2. Not part of primary proces?**	**3. Impact on operation severe?**	**4. Market/ Investment Size sufficient?**
Place Check if Applicable				
Option 1: Suitable for PSS	✓	✓	✓	✓
Option 2: Conditional Suitability for PSS	✓			✓
Option 2: Conditional Suitability for PSS	✓	✓		✓
Option 2: Conditional Suitability for PSS	✓		✓	✓
Other check combinations are not Suitable for PSS				

Figure 7.3 - PSS Criteria Matrix

7.4.1.2 Stage 2 – Comparison Traditional Asset vs Product-Service System

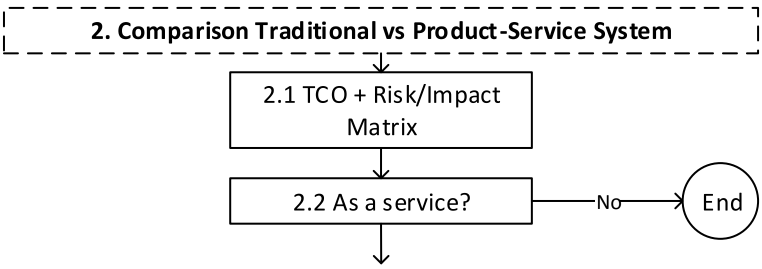


Figure 7.4 - Stage 2

If these steps are all met, the first stage is concluded. The second stage, Comparison Traditional vs. Product-Service Systems, accounts for the project valuation. The first step, step **2.1**, is to check the Total Cost of Ownership (TCO) vs the cost of a PSS and to assess the associated risks versus impacts.

For the traditional asset ownership case, the TCO tool already available at Schiphol is used in order to assess the value and costs of the project. The cost information is usually obtained from the Technical Expertise Centre (TEC) department of ASM and the Cost Expertise Centre (CEC) of the Corporate Procurement department. The TCO tool gives several outputs, NPV, impact on tariffs and the Equivalent Annual Costs (EAC). This figure is used for the comparison with the PSS price.

For the PSS pricing, the same cost inputs can be used by TEC and CEC. In addition, the project team needs to assess the uncertainties. This procedure is further explaine. With the uncertainty assessment of these costs, a fair price for the PSS can be determined. Using the Excel tool, a price can be extracted and used to compare to the EAC of the traditional TCO.

The last step is to fill in the risks versus impacts matrix to determine the different risks and impacts of traditional ownership versus PSS. This is to ensure that the project team makes a clear assessment of the risks and impacts, such that an informed decision is to be made by the project team members and stakeholders involved.

When both the monetary valuation as well as the risks/impacts are assessed, a decision can be made which is the more suitable alternative in step 2.2. If the decision is made that a PSS is the best alternative the process moves to step 3.1, if the decision is made that a traditional asset ownership is the better solution, the PSS process comes to a stop.

7.4.1.3 Stage 3 – Conditions for a successful Product-Service System

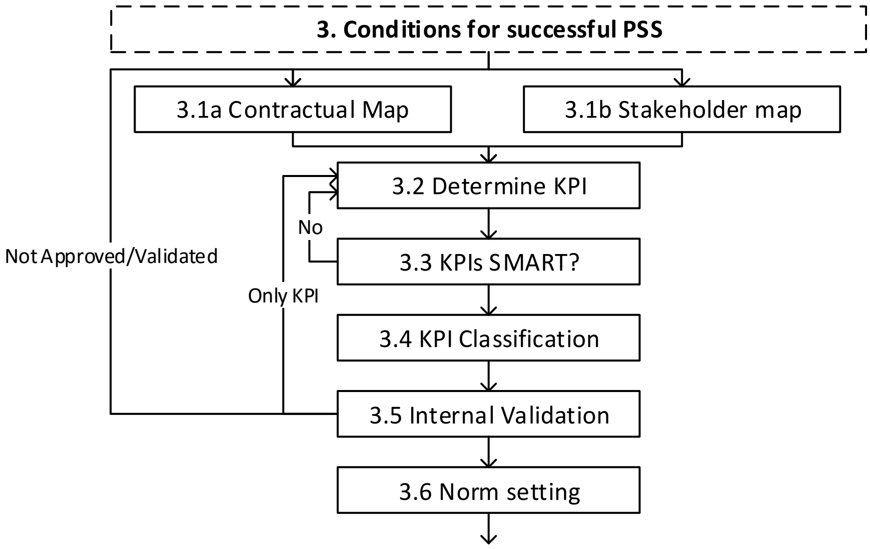


Figure 7.5 - Stage 3

The third stage is about what conditions are there to be met to make sure that a PSS becomes a success. In order to make sure that the PSS is to be a success, six steps are to be taken to make sure that everything is accounted for.

The first steps are step 3.1a, contractual map, and step 3.1b, stakeholder map. In order to gain a good understanding of how the dependency between Schiphol and its supplier is structured, it is wise to construct two maps. The first map is the contractual map, which shows which party has a contract with whom. This is a formal mapping and shows how the relationship is formally given shape. The second map is a stakeholder map which needs to contain the following pieces of information.

1. All involved stakeholders. This includes supplier of Schiphol's suppliers and needs to provide a clear picture which parties are involved
2. The flow of money, information, products and services between these stakeholders. This is to get a visual representation of how stakeholders are dependent on one another and how the monetary compensation flows through the involved parties.

By visualising both the formal contractual relationship, as well as the flow of information, products and money between the involved stakeholder, Schiphol get a good overview of what needs to be covered contractually and how this act trough all involved stakeholders.

These relationships can be covered by the development of Key Performance Indicators (KPIs) in step 3.2. By developing and determining good KPIs, all relationships and their respective flows should be covered. This ensures that the dependability between all parties are covered, visible, measurable and accounted for.

When the KPIs are developed, the next step, step **3.3**, is to check whether they are SMART (Specific, Measurable, Accountable, Realistic, Timely). There is a control loop present in the framework, to make sure that the KPIs are check thoroughly whether they are SMART and therefore of added value. The next step is to classify the KPIs in step **3.4**. This classification lets Schiphol to assess which KPIs are most important, have the most impact on performance, in which phase of the project and where initial performance steering is preferred. The classification matrix in Figure 7.6 can help visually classifying the KPIs according to the perceived impacts and the amount of risk. The classification is not of the utmost importance, but it can help structuring priorities and make the involved employees rethink what is important, what is the perceived impact and what is the associated risk.

KPIs

Impact \ Risk	Low	Medium	High
Low			
Medium			
High			

Figure 7.6 - KPI Classification Matrix: Risk vs Impact

The next step is to validate the KPIs with internal and the external stakeholders and involved parties in step **3.5**. Internal stakeholders of Schiphol are departments who are assigned to work with the parties when the asset comes into operation, who are responsible for contract management, maintenance, energy suppliers etc., or the project team. External stakeholders are for instance the suppliers who need to deliver the required performance. If one of the parties does not approve the KPIs, the loop requires the actor to check again if the contractual and stakeholder maps are sufficiently comprehensive, KPIs are well determined and SMART. This to ensure that all stakeholders agree on the KPIs.

The next step, **3.6**, is where the required performance is set for the KPIs. By determining a norm, a minimum performance level is determined which the supplier needs to deliver with its PSS. Because performance is stimulated and necessary, it is important to state what the minimum performance level should be and agree upon a malus if this level is not met. Besides this malus, it is important to agree upon a (long term) bonus for making performance agreements or when performance increases during duration of the contract. This makes sure that the supplier receives proper incentive to deliver and therefore contribute towards sustainable performance.

7.4.1.4 Stage 4 – Contractual Agreement

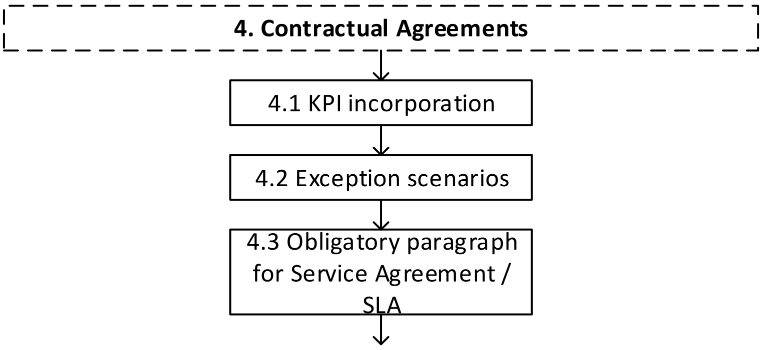


Figure 7.7 - Stage 4

The next stage is about contractual agreements. It is to ensure that all agreed KPI are properly integrated in the contract which Schiphol signs with the PSS supplier. Step **4.1** ensures that the determined KPIs as well as the norm, bonus and malus for each KPI are clear and incorporated in the contract.

Step **4.2** is to think about exception scenarios which might causes that either Schiphol or the supplier is unable to deliver the agreed performance of the PSS. Usually, assets which are used as PSS are part of a bigger projects and delay in construction or other force majeure could lead that the performance can't be delivered. It is important to think about possible scenarios beforehand, because it can put strain on the relationship between Schiphol and the supplier and the relationship is one of the fundamentals of a successful PSS implementation. The impact of such events on warranty, norm/bonus/malus, service fee and contract breach need to be described.

The last step in the fourth stage is step **4.3**. This step is about the SLA paragraph in the contract where every aspect of the PSS is described on a contractual level. The following aspects need to be included in the SLA in order to make sure that it is complete, this is the same list as in Conditions for success for Product-Service Systems5.3.2 on page 19.

7.4.1.5 Stage 5 – Service and performance part of contract completed

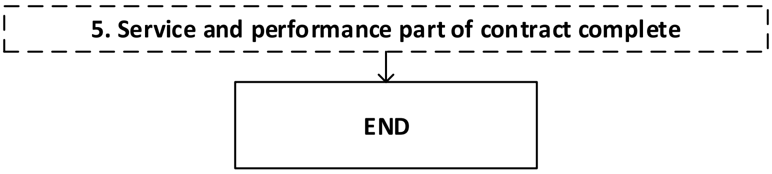


Figure 7.8 - Stage 5

When all these steps are taken and signed of, it can be stated that a thorough process has been followed, which included all relevant stakeholders, made a fair comparison between traditional ownership and a Product-Service System and includes the necessary KPIs to mitigate the loss of control by Schiphol and motivate both parties to perform with a clear contractual agreement which covers all flows of money, products, services and information between the involved parties. This stage is the end of the Product-Service System Decision Framework.

7.4.2 Extensive Product-Service System Decision Framework (PSS-DF)

The framework given in 7.4.1 and Figure 7.1 is a compact version, which only the bare essentials displayed. In Appendix J – Extensive PSS Decision Framework a comprehensive version is shown. With this extensive version, the process is more elaborated and detailed. Furthermore, for each step it is shown which inputs are needed, which outputs need to be generated, which decision are to be made at a step, which actors are involved and finally which stakeholders are affected by this decision by these actors. This information clearly shows the role of each stakeholder and actor in the decision process and this ensures that a clear and transparent process is to be followed.

To get a better understanding of the extensive framework, a small example is provided of the framework. Figure 7.9 shows stage 1, step 1.1. On the left, the inputs, outputs, decision, actor and stakeholders affected are shown. On the right extra information about the step is presented.

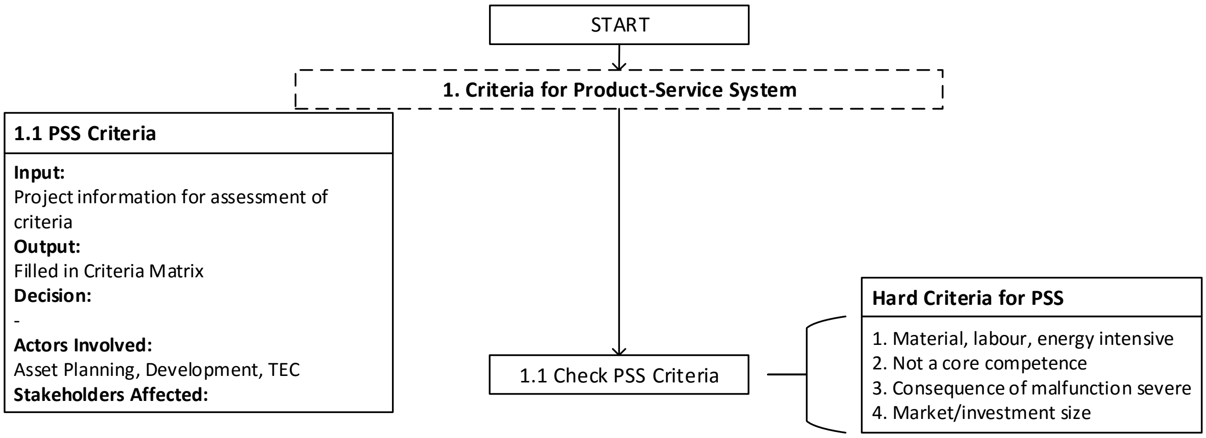


Figure 7.9 - Example of the extensive framework

7.5 PSS Pricing Tool

The next big part of the framework is the tool which enable the value comparison between a traditional asset ownership and the acquiring of a PSS. As stated, continued ownership is beneficial, but it also introduces new risks and uncertainties for the supplier of the PSS, which it previously did not had. As with any risk, those who carry it, want a return for it, a risk premium. A supplier would not reveal its risk premium, because then it would diminish any leverage it has in the negotiations. In order to tackle this problem, the PSS Pricing Tool has been developed to get a price indication on what price is reasonable for Schiphol to pay a supplier.

The following input is needed:

1. TCO Tool with financial information on how much it will cost to purchase and use an asset in the traditional way.
2. A specialist who knows the supplier and is able to assess the risks and uncertainties the supplier will gain when remaining owner and provide the PSS to Schiphol. The tool will be described in a short manner, for a longer description the reader may read REF appendix, or the case study in the next chapter, which will show the usage of the tool.

7.5.1 Dashboard

The final Dashboard with all relevant information can be seen in Figure 7.10 . How the user can interpret the information will be provided in paragraph 7.6.

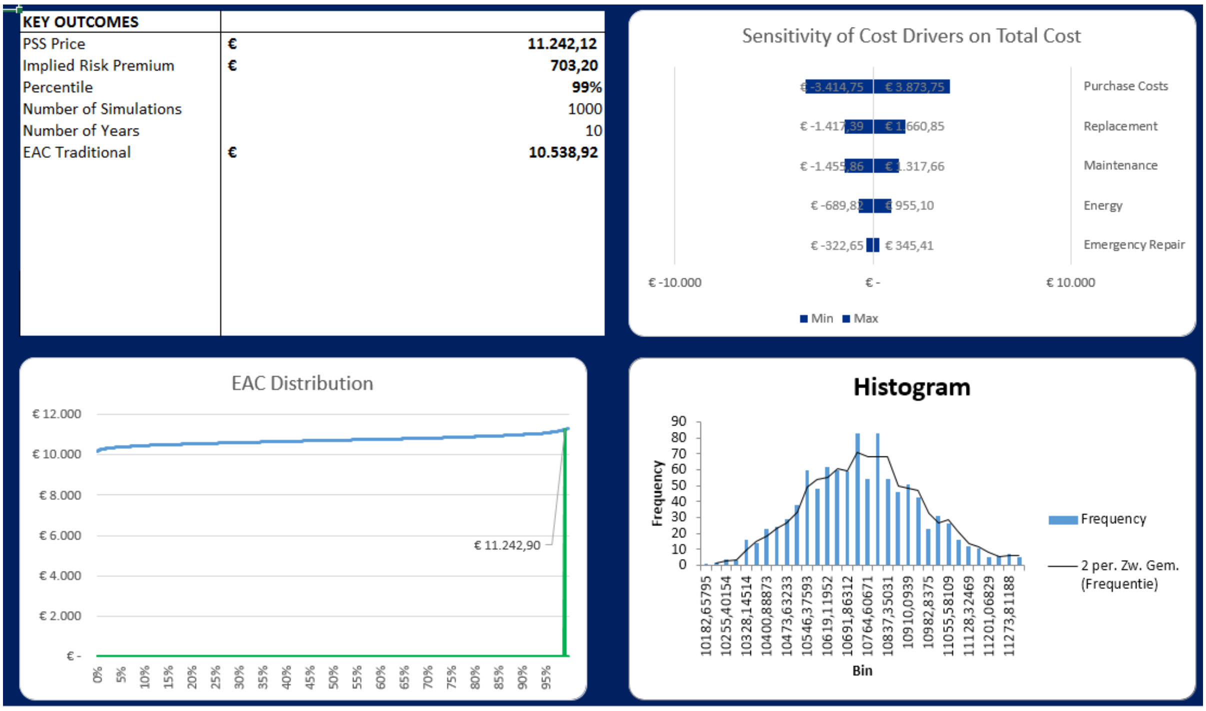


Figure 7.10 - PSS Dashboard Overview

7.5.2 PSS Pricing Tool steps

7.5.2.1 Uncertainty identification

Schiphol's supplier experience different kinds of uncertainty in the business processes. In this step, the user of the model identifies different uncertainties. Five categories are used from Erkoyuncu (2011) the sixth was not deemed relevant:

1. Commercial Uncertainty
2. Affordability Uncertainty
3. Performance Uncertainty
4. Operation Uncertainty
5. Engineering Uncertainty

The complete list of uncertainties (+/- 70 uncertainties) of these 5 categories can be found in Appendix K – List of Uncertainties. The user of the model needs to identify which of these uncertainties are applicable to the project. It is important that if the uncertainty is of influence it is marked as relevant.

7.5.2.2 Uncertainty Scoring and Importance Assessment

The next step is to score the uncertainties on the three categories as mentioned in 5.4.2.3.2 to; i) Basic Estimate, ii) Rigour of Assessment and iii) Level of Validation. Each needs to be scored on the scale of 1, 3, 5 or 7. Where 1 is low in uncertainty and 7 is high.

The next step is to assess the importance of the uncertainty. Which can be seen as the amount of impact the uncertainty might have on the whole project. This is scored on a scale from 1 to 9, where 1 is not relevant and 9 is extremely important and thus a high impact.

7.5.2.3 Uncertainty score

This leads to an uncertainty score for each uncertainty.

7.5.2.4 Cost Driver Identification

Based on the TCO Tool of Schiphol, the cost drivers of the project can be determined. These cost drivers are the identical to those in the TCO tool, such as initial purchase and maintenance etc. This step does not require any new information, because it is based on the alternative where Schiphol purchases the asset, which is an alternative which is almost always considered.

7.5.2.5 Cost Driver Uncertainty Linkage

The next step is to link the uncertainties to each cost driver. The options are 'Yes' or 'No'.

7.5.2.6 Cost Driver under Uncertainty

The next step is that the model calculates the uncertainty score of each cost driver. The final score ranges from 0 to 1, where 0 is no uncertainty and 1 is a very high uncertainty.

7.5.2.7 Distribution and Range Definition

The next step is to check if the distribution is correct. The standard used distribution is the triangular distribution, which the model is highly suitable for. If and only if known, the user may opt for another distribution. Weibull, Normal, Lognormal or Uniform distribution are all an option (see Table 7.1 for parameter conditions). But the user needs to have information on the needed parameters. Table 7.2 shows where the input may be given.

Table 7.1 - Distribution parameter conditions

Distribution	Parameter	Meaning	How to input
Normal Distribution	Sigma	Volatility	0-100%
	Mu	Average	0-100%
Weibull	Lambda	Scale	0,..
	K	Shape	0,..
Lognormal	Sigma	Volatility	0-100%
	Mu	Average	0-100%
Uniform	High Range		No input required
	Low Range		No input required

Table 7.2 – Example of required Distribution Parameters for Cost Drivers

Uncertainty score (divided by 7)	0,25	0,39	0,31
Lower Range	-0,10	-0,15	-0,15
High Range	0,15	0,20	0,20
Distribution	Weibull	Normal	Lognormal
Sigma (Normal Distribution)			
Mu (Normal Distribution)			
Lambda (Weibull Distribution)			
K (Weibull Distribution)			
Sigma (Lognormal Distribution)			
Mu (Lognormal Distribution)			

The user now has the possibility to adjust the ranges, if the ranges are over or understated in the opinion of the user.

7.5.2.8 Single cost estimate to three-point cost estimate

The user now needs to fill in the NPV sheet. The cost drivers are similar to the TCO tool and the figures need to be added to the NPV sheet. Important is that the cost entered need to be the non-discounted costs and that the user needs to pay attention to which year the costs are added in order to make sure that the discounting goes correctly. When all costs are added, the traditional EAC and NPV should be identical to that of the TCO Tool.

Using the triangular distribution, or other distribution by the user, the single cost estimate is now transformed into a cost distribution. This cost distribution is used in the next step.

7.5.2.9 Monte Carlo

Using the cost distribution and the power of Monte Carlo, a simulation is performed. The 95% mark represents the mark which is used for the price indication.

7.6 Outcome

This procedure is repeated for e.g. 1000 times and this will lead to the following example result which is visually represented in the following three graphs in Figure 7.11, Figure 7.12 and Figure 7.13.

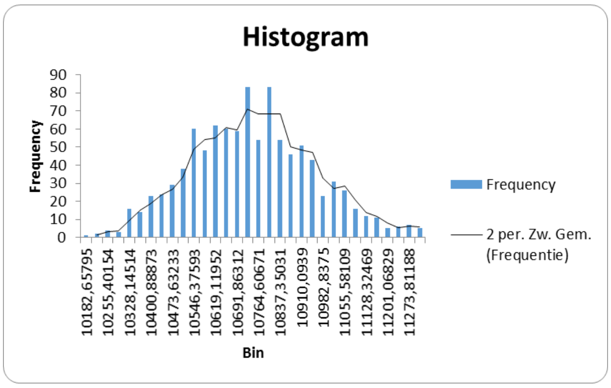


Figure 7.12 - Histogram of Monte Carlo Outcome

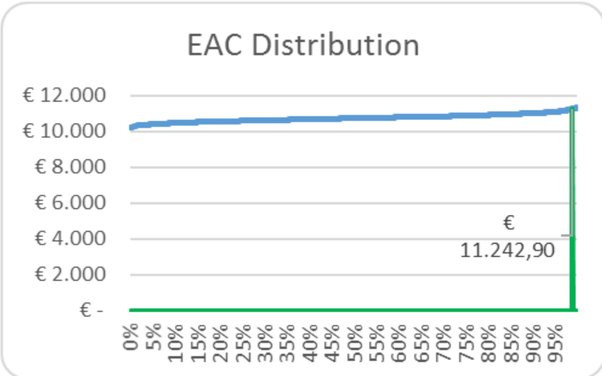


Figure 7.11 - EAC Distribution

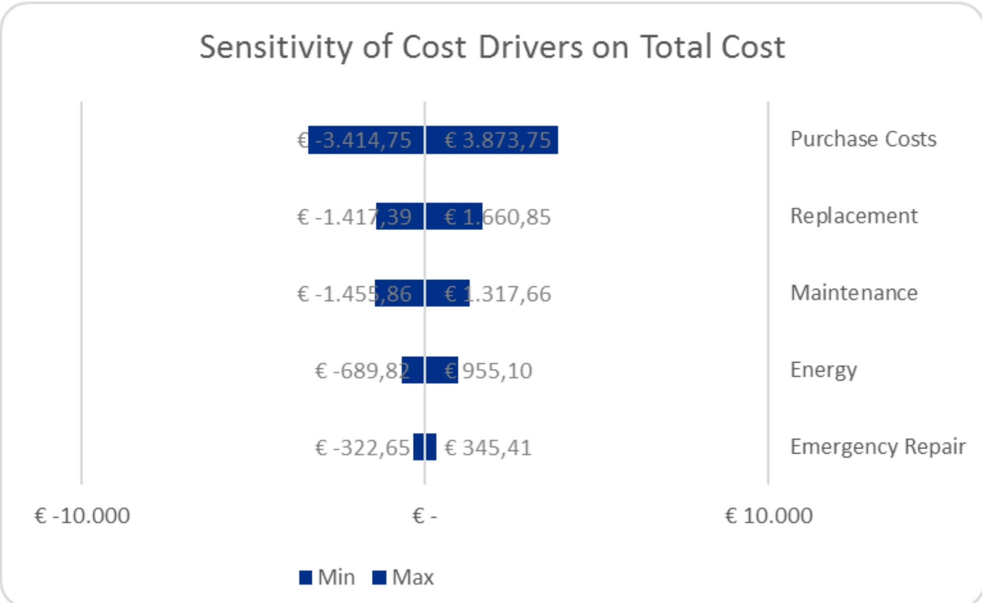


Figure 7.13 – Sensitivity of Cost Drivers

Figure 7.12 shows the histogram of the simulation, which depicts the frequency (y axis) of costs (x axis). Figure 7.11 shows the distribution of EAC across all outcomes.

Table 7.3 - Key Outcomes

KEY OUTCOMES		
PSS Price	**€**	**11.242,12**
Implied Risk Premium	**€**	**703,20**
Percentile		**99%**
Number of Simulations		1000
Number of Years		10
EAC Traditional	**€**	**10.538,92**

What is important to know is how the dashboard can be read and used in order to extract the necessary information needed for good judgement. The first thing which needs to be checked is the Key Outcome table (Table 7.3). In this table one will find the PSS Price (annual service fee), which is the 95% figures of the Monte Carlo. The difference between the PSS Price and the Traditional EAC of the project (which is identical to the TCO outcome), it the implied risk premium which is calculated on the basis of the Uncertainty Assessment.

The next step can be to see where the biggest sources of sensitivity lay. This can be distilled from the tornado graph in Figure 7.13. It shows which Cost Drivers is subjected to the biggest uncertainty combined with the cost magnitude. This can provide an indication of where a lot of uncertainty is, or where the biggest impact can be found. This can help in the negotiations with the supplier to get a better price.

The Histogram of Figure 7.12 shows the overall cost distribution of the whole project. It can help to assess how skewed the cost distribution. In line with the skewness, Figure 7.11 shows the distribution of the EAC across the outcome of all simulations. The more skewed the line is, the more uncertainty is present in the project. Both can help in determining if a project is subjected to a lot of uncertainty (skewed line and wider histogram) or that it is certain (flat line and relatively narrow histogram).

It can be seen that the lowest outcome of the simulation is around €8,5k and the highest outcome is an EAC of around €14k. The most important outcome of the simulation is the 95% percentile figure. This figure is the EAC which 95% of the outcomes of the simulation will not surpass. In this example case the 95% figure is around **€11,2k**. This is the final outcome of the fair price determination for a PSS. This figure is the uncertainty incorporated cost determination of a PSS, based on the inputs known by Schiphol.

7.7 Validation

As with any framework or model, validation is a point which must not be omitted. By validating the framework, the conclusion can be drawn whether the model is suitable for real life application of Product-Service Systems, or what needs to be adjusted in order for it to be used. As described in 5.4.2.4, the validation can be done by doing a case study where the framework is used by people who were involved in the L.a.a.S. project. All the missing points should be covered by the framework and this should be the outcome. That the framework results in a clear process, where no steps are omitted and that the end result is a clear picture of why a PSS is a good option and what is needed in order to make it into a success. The outcome of such a process would be that Schiphol is able to make the next step towards a CE.

The validation will be given described in the next chapter.

7.7.1 Usability and limitations

One of the most important things with any model and framework, after validation, is to explicitly clarify what the usability and limitations are of the framework. The framework has been developed given a specific set of information, regulation, context, academic literature and scope. The framework is initially developed for Product-Service Systems, such as Light-as-a-Service. The criteria provided are directly extracted from academic literature on PSS. The conditions and KPI development are developed with PSS in mind. The technical condition is meant with the fact that in order to facilitate the transition towards a CE, improvement is needed and technical products are more suited to be optimised and improved over time. Lastly, the TCO impact has been described using the fact that there is a second issue on not only the TCO itself on cost level, but also the potential impact on aviation tariffs due to the Regulatory Asset Base. This means that the framework is meant, and therefore the recommendation given, to use it only for Product-Service System related projects.

Given the recommendation of strict usability for PSS only, it might appear that the framework is not suitable for other types of products and/or asset. This is not the case, but what must be emphasised is that for PSS the framework will be validated and for other types not within this Master thesis. This limits the strength of the framework if it is not a pure PSS according to the definition given in paragraph 5.2.4.

7.8 Conclusion

Schiphol has set its first small step towards CE via performance economy. With the start of the Light-as-a-Service project in Lounge2, it expressed the direction which it wants to take. However, as became clear from the previous chapters, in order to succeed, one needs to have a clear idea on how to achieve. Therefore, a framework has been presented in this chapter. It uses all the knowledge gained from academic literature, L.a.a.S. project evaluation and internal sources of information to create a framework which is aligned with the strategy of ASM and the decision making of the Asset Wise! program of Schiphol. Sub question 3 is therefore answered. The framework should help to make sure that a next time, there is a clear process available which supports and facilitates the successful implementation of a Product-Service System at Schiphol. In order to validate the framework, the framework will be used and discussed with all relevant people which have helped in the initial L.a.a.S. case and the outcome of the framework should contain everything which was missing the first time, as well as a complete picture and guidance on the business case, KPIs and Service Level Agreement to make sure that it becomes a success.

8. Validation and Case Study

8.1 Introduction

In the previous chapter the Product-Service System Decision Framework has been introduced, together with the PSS Pricing Tool. As with any new model or framework, it is vital to validate in order to show that the model is up for the task it is intended and that it is therefore validated to use. This chapter will deal with the validation of both the Decision Framework, as well as the PSS Pricing Tool for a price indication. Furthermore, the question whether both the Framework as well as the estimation model are clear and straight forward for usage will be answered. Lastly, possible future improvement possibilities will be provided, which enable both the framework as well as the estimation model to be improved in the future.

8.1.1 Reading Guide

First the set-up will be explained in 8.2. In paragraph 8.3 the validation of the decision framework will be described. Next is the validation of the PSS Pricing Tool in paragraph 8.4. Lastly, in paragraph 8.5 the number of simulations will be checked.

8.2 Validation set-up

In order to validate both the Product-Service System Decision Framework (PSS-DF) and the PSS Pricing Tool, first a set-up is determined which allows for the validation to take place. As stated in 5.4.2.4, a case study is an excellent way of testing a framework or model in a real life setting. A number of questions need to be answered during the validation to make sure that all necessary steps are present in the PSS-DF and that the Pricing Tool is able to produce a workable estimate.

1. Are all necessary steps covered?
2. Are the different roles for Stakeholders/Actors clear in the PSS-DF?
3. Are all needed Inputs, Outputs, Decisions, Actors and Stakeholders present and clear at each step?
4. Does the PSS Pricing Tool deliver a fair input for the decision making process based on the Function, Euro, Risk consideration?
5. What is the price according to the tool compared to the offer by Cofely/Philips on the Light-as-a-Service case and what can be concluded of the potential difference?
6. What is the relationship between the number of simulations and the confidence level percentile chosen?

Lastly, the question is raised whether both the PSS-DF and the PSS Pricing Tool are clear and the usage is easy, straight forward and understandable. This to ensure that future implementation should be as smooth as possible.

The first three question will be answered in paragraph 8.3, the fourth and fifth question will be answered in paragraph 8.4. The sixth question will be answered in paragraph 8.5.

8.2.1 Confidentiality

Because the figures mentioned in the next section are confidential and sensitive for competitors of Schiphol, Philips and Cofely as well as could provide (unwanted) insight into the agreements in the main contracts, the figures are made fictitious in the public version of this thesis. In this way it can be assured that sensitive figures are confidential.

8.3 Validation of Decision Framework

The answering of the first three questions will be performed by interviewing and discussing the framework with relevant employees who have worked on the Light-as-a-Service project in the development phase, where similar steps were taking as presented in the framework and the outcomes of the actual process is discussed and reflected upon given the framework to see if the framework would provide the user with a complete decision process , if all relevant steps are accounted for, that a clear decision structure is present and that at the end of the process, using the framework, all stakeholders can agree that a thought trough decision has been made whether an As-a-Service alternative is a good solution and that all relevant aspect for a proper contract are all in place, agreed upon and that the added value of As-a-Service is clear for all parties involved. In Table 8.1, an overview can be found of employees who have been asked to comment on the framework, besides these employees, other Schiphol employees have been asked on their opinion on certain pieces of the framework.

Table 8.1 - Involvement for Framework Validation

Function	Role
Strategic Advisor	Involved in L.a.a.S. Project
Manager Innovation & Sustainability	Involved in L.a.a.S. Project
Sr. Manager Pricing & Control	First Supervisor
Cost Engineer	Modelling

8.3.1 Are all necessary steps covered?

From the discussion and meetings with the employees, it became clear that all necessary steps are present in the current framework. The third and fourth phase, KPI development and SLA, can be considered already present in the current decision making and project development. The first two steps, checking the criteria and determining a price for the PSS are new and were missing previously in the decision making process. It was stated that it is important to formally check if an asset is suitable for being converted into a PSS, because no guidelines are present at the moment.

8.3.2 Are the different roles for Stakeholders/Actors clear in the Product-Service System Decision Framework?

The framework provides clear roles for the involved stakeholders and actors. It is clear who is involved when and whether they are affected by, or have an active part in the framework. Due to the novelty of the project it was not always clear what was needed from parties. Especially during the development of the business case and the Life Cycle Costing, a lot of uncertainties came forth. Issues like big adjustments to the proposed pricing, uncertainties of what is included in the contract and what will happen if the Lounge was getting an upgrade after 7 years, while the contract lasted for 10, popped up during the process and unclear was how to act accordingly and what the eventual influence was on the process remained unclear. By mapping the stakeholders visually, much of this accounted for, because the dependencies become clear. Furthermore, if changes occur, it can easily be figured out how it affects the whole value chain of stakeholders. Because the roles are clear it can be easily seen which department or stakeholder needs to be informed of such a change and whether action is required.

The first 2 section of the framework are clearly new and dedicated for PSS, the last two sections, Conditions for success and SLA are already used methods, which are now also embedded if a PSS is considered.

8.3.3 Are all needed Inputs, Outputs, Decisions, Actors and Stakeholders present and clear at each step?

By discussing the Inputs, Outputs, Decisions, involved actors and affected stakeholders with the various employees it can be concluded that it is clear that everyone who is in need to be involved is involved and that it is clear what is needed, in what stage, to which outputs the decisions lead. Furthermore, the structure of the framework allows the decision maker to take into account the Function, Euro, Risk triangle of Schiphol, because the framework explicitly needs functionality as a basis, presents a Euro outcome and let the user think of what kind of uncertainties are involved in the project and thus not account for them let them lead to risks.

8.4 Validation of PSS Pricing Tool

Table 8.2 - Involvement Validation PSS Pricing Tool

Function	Role
Strategic Advisor	Involved in L.a.a.S. Project
Manager Innovation & Sustainability	Involved in L.a.a.S. Project
Sr. Manager Pricing & Control	First Supervisor
Cost Engineer	Modelling
Business Controllers Schiphol	Presentation with discussion

In order to validate the PSS Pricing Tool, the following procedure will be followed. Together with the involved employees, uncertainties will be identified and scored. The uncertainty weighting will then be assigned to the Cost Driver which are present in the Light-as-a-Service project. It is very important to state that the financial data used is from the traditional alternative where Schiphol purchases lights and does the maintenance according the traditional way. The financials of Cofely/Philips are not used in this part of the price indication, only at the last stage to compare the outcome of the model against the offer from Cofely/Philips. The last version of the TCO of the L.a.a.S. project will be used, as it is also the TCO which is used in the decision to execute the project. This TCO will provide the financial data needed for the model. These will all be used in the tool which leads to the following outcome of a good price, according to the tool, for the PSS/L.a.a.S.. The outcome of the tool will be compared to the contractual agreed price for the Light-as-a-Service project. The outcome of the tool will then be compared to the offer Philips and Cofely made to Schiphol. In order to validate the tool, the difference between the tool and the offer needs to be explained. If this reasoning holds, the tool can be considered validated and therefore fit to use for determining a price for a PSS, the implied risk premium for the service with the standard TCO tool as a basis.

Furthermore, a comparison will be done with 1000 simulation at 95% and 5000 simulations at 95%, to compare the results and speed. This to determine if 1000 simulations are sufficient, or that a higher number of simulations is required.

8.4.1 Information sources

The following documentation is used:

Table 8.3 - Documentation used for Validation

Documentation	Comment
LCC L.a.a.S. GHA V4.4	Final LCC documentation of the Life Cycle Costing calculation of the L.a.a.S. project. Used in the final Decision Document of Schiphol.
Other project related files	Used for explaining price differences and the overall development of the project.

This Life Cycle Costing (LCC) document contains two LCC calculations. The first is the Cofely/Philips case as provided by Philips in order to determine the price for the service. The second is a traditional alternative of lights and was performed in collaboration with Deerns (engineering consultant).

For the PSS Pricing Tool, the input figures from the traditional alternative will be used and the uncertainty scored. This will provide a risk weighted PSS price and this can be compared to the offer Philips has made. This will provide insight in whether the price is fair, how much the implied risk premium is and what the offer of Philips means in the light of the tool.

8.4.2 The PSS Pricing Tool

The PSS Pricing Tool consists of several steps; the next sections will take the L.a.a.S. case through each of the steps to determine a price.

8.4.2.1 General parameters

The first step is to fill in the general parameters needed for the model. Using the LCC L.a.a.S. GHA V4.4 TCO calculation file, the needed parameters are extracted:

Parameter	Value	Comment
WACC	5,05%	Auke (Controller TRE)
Project Duration	10 Years	Project Duration

The number of simulations is 1000 and the confidence level will be set at 95%. This lead to the following general parameters of the Light-as-a-Service case study as can be seen in Table 8.4.

Table 8.4 - General Parameters

Parameter	Value	Comment	Source
Number of simulations	1000	Enter the number of simulation you want (more is slower)	
Confidence Level Percentile	95%	Enter the confidence level required (95% is normal, 99% is extreme)	
Years	10	Enter the duration of the PSS contract	TCO Tool
WACC	5,05%	Enter the WACC	TCO Tool

8.4.2.2 Uncertainties and Cost Drivers

The next step is to assess which uncertainties are applicable on Schiphol, if the perspective of Philips is assumed and then to score these on the three categories; i) basic estimate ii) rigour of assessment and iii) level of validation.

This leads to the list in Table 8.6 on page 60, where the uncertainties which are deemed relevant for the L.a.a.S. have been listed and scored. The colour indication provides the first clue which uncertainties may have a big impact on the price for the PSS.

The next step is to add the cost drivers which are present in the project. These cost drivers are again extracted from the LCC sheet from the documentation. The following cost drivers are present:

1. Initial Investment
2. Replacement
3. Maintenance
4. Energy
5. Removal Cost/Service

These are added in the Pricing tool and the next step is initialised which is linking uncertainties with the cost drivers. The linkage can be seen in Table 8.7 on page 62. This results in that the following uncertainty score of each Cost Driver (Table 8.5).

Table 8.5 - Uncertainty Score for each Cost Driver

	Initial Investment	Replacement	Maintenance	Energy	Removal Cost/Service
Uncertainty score (divided by 7)	0,33	0,22	0,27	0,22	0,30
Lower Range	-0,15	-0,10	-0,10	-0,10	-0,15
High Range	0,20	0,15	0,15	0,15	0,20
Distribution	Triangular	Triangular	Triangular	Triangular	Triangular

8.4.2.3 NPV Sheet

The uncertainty score of each cost driver of the L.a.a.S. project is now known and can now be used to add an uncertainty weighting to the TCO calculation for pricing purposes. By using the costs as provided in the LCC the following outcome can be seen in Table 8.8.

Table 8.6 - List of Scored Uncertainties

	Category	Type	Uncertainty Score
1	Commercial	Customer equipment usage	1,9
2	Commercial	Work share between partners	1,4
3	Commercial	KPI Specification	5
4	Commercial	Environmental impact	2,3
5	Commercial	Relationship with suppliers	0,3
6	Commercial	Warranty Scope	0,7
7	Commercial	Relationship with customer	2,7
8	Commercial	Stability of customer requirements	2,7
9	Commercial	Commodity and energy prices	0,3
10	Commercial	Inflation/deflation	0,2
11	Commercial	Material cost	2,1
12	Affordability	Customer ability to spend	0,5
13	Affordability	Project life cycle cost	5,7
14	Affordability	Equipment Availability	1,3
15	Affordability	Customer willingness to spend	2,8
16	Performance	IT	1,3
17	Performance	Performance against KPIs	5
18	Operations	Complexity of equipement	0,7
19	Operations	Quality of component(s)	1
20	Operations	Quality of manufacturing	0,6
21	Operations	Maintainer performances	3,7
22	Operations	Equipment utilisation rate	1,6
23	Operations	Rate of repairability	0,6
24	Operations	Mean time between failure data	3
25	Operations	No fault found rate	0,9
26	Operations	Location fo maintenance	0,2
27	Operations	Availability of maintenance support resources	1,9
28	Operations	Operating parameters	3
29	Operations	Effectiveness maintence policy part level	0,5
30	Operations	Failure rate of hardware	1
31	Operations	Customer equipment utilisation	0,5
32	Engineering	Rate of capabilities upgrades	2,2
33	Engineering	Rate of system integration issues	4,1
34	Engineering	Rate of rework	0,9
35	Engineering	failure rate for software	3,7
36	Engineering	Rate of severity of obsolescence	0,7
37	Engineering	Cost estimating data reliability or quality	5
38	Engineering	Effectiveness of managment of risk and opportunities	0,3

Table 8.7 - Cost Driver/Uncertainty Link

	Initial Investment	Replacement	Maintenance	Energy	Removal/Service Costs
Customer equipment usage	No	No	Yes	Yes	Yes
Work share between partners	No	No	Yes	No	Yes
KPI Specification	Yes	No	No	No	Yes
Environmental impact	Yes	Yes	No	Yes	Yes
Relationship with suppliers	Yes	Yes	No	No	No
Warranty Scope	No	No	Yes	No	Yes
Relationship with customer	Yes	Yes	Yes	No	Yes
Stability of customer requirements	Yes	Yes	Yes	No	Yes
Commodity and energy prices	No	Yes	Yes	Yes	No
Inflation/deflation	No	Yes	Yes	Yes	No
Material cost	Yes	Yes	No	No	No
Customer ability to spend	Yes	Yes	Yes	Yes	Yes
Project life cycle cost	Yes	No	Yes	No	No
Equipment Availability	No	Yes	Yes	No	Yes
Customer willingness to spend	Yes	Yes	No	No	Yes
IT	Yes	No	Yes	No	No
Performance against KPIs	No	Yes	Yes	Yes	Yes
Complexity of equipement	Yes	Yes	Yes	No	Yes
Quality of component(s)	Yes	Yes	Yes	Yes	No
Quality of manufacturing	Yes	Yes	Yes	Yes	No
Maintainer performances	No	Yes	Yes	No	Yes
Equipment utilisation rate	No	No	Yes	Yes	Yes
Rate of repairability	No	Yes	Yes	No	Yes
Mean time between failure data	No	No	Yes	No	Yes
No fault found rate	Yes	No	Yes	No	Yes
Location fo maintenance	No	No	Yes	No	Yes
Availability of maintenance support reso	No	No	Yes	No	Yes
Operating parameters	Yes	Yes	Yes	Yes	Yes
Effectiveness maintence policy part leve	No	No	Yes	No	No
Failure rate of hardware	No	No	Yes	No	No
Customer equipment utilisation	No	Yes	Yes	Yes	Yes
Rate of capabilities upgrades	No	Yes	No	No	Yes
Rate of system integration issues	Yes	No	Yes	No	Yes
Rate of rework	Yes	Yes	No	No	Yes
failure rate for software	Yes	No	Yes	No	Yes
Rate of severity of obsolescence	No	Yes	No	No	Yes
Cost estimating data reliability or quality	Yes	No	Yes	No	Yes
Effectiveness of managment of risk and	Yes	Yes	No	No	Yes

Table 8.8 - NPV Calculation with simulation values

To PSS Dashboard

	Year	0	1	2	3	4	5	6	7	8	9	10	NPV
	Initial Investment												
		€ 2.000.000,00											
	PV Sum	**€ 2.000.000,00**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	€ 2.000.000,00
	PV Sum for Simulation	€ 1.988.716,59	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ 1.988.716,59
	Replacement												
							€ 490.545,20						
	PV Sum	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ 383.441,17**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	€ 383.441,17
	PV Sum for Simulation	€ -	€ -	€ -	€ -	€ -	€ 407.357,16	€ -	€ -	€ -	€ -	€ -	€ 407.357,16
	Maintenance												
		€ 11.368,14	€ 11.595,51	€ 11.827,42	€ 12.063,97	€ 12.305,24	€ 12.551,35	€ 12.802,38	€ 13.058,42	€ 13.319,59	€ 13.585,98		
	PV Sum	**€ 11.368,14**	**€ 11.038,08**	**€ 10.717,61**	**€ 10.406,43**	**€ 10.104,30**	**€ 9.810,93**	**€ 9.526,08**	**€ 9.249,50**	**€ 8.980,95**	**€ 8.720,20**	**€ -**	€ 99.922,23
	PV Sum for Simulation	€ 11.565,99	€ 10.996,69	€ 11.736,93	€ 11.036,48	€ 10.551,87	€ 9.352,86	€ 9.414,77	€ 9.541,60	€ 9.120,50	€ 9.017,63	€ -	€ 102.335,31
	Energy												
		€ 64.028,52	€ 61.127,29	€ 56.320,56	€ 57.506,76	€ 59.008,99	€ 60.189,17	€ 61.392,96	€ 62.620,82	€ 63.873,23	€ 65.150,70		
	PV Sum	**€ 64.028,52**	**€ 58.188,75**	**€ 51.035,79**	**€ 49.605,60**	**€ 48.454,49**	**€ 47.047,67**	**€ 45.681,70**	**€ 44.355,38**	**€ 43.067,58**	**€ 41.817,16**	**€ -**	€ 493.282,64
	PV Sum for Simulation	€ 59.079,09	€ 65.984,08	€ 47.121,16	€ 46.246,58	€ 53.512,89	€ 46.806,19	€ 49.194,70	€ 46.863,80	€ 42.999,61	€ 44.977,57	€ -	€ 502.785,66
	Removal/Service Costs												
		€ 8.078,76	€ 8.240,34	€ 8.405,15	€ 5.655,14	€ 5.768,24	€ 5.883,60	€ 6.001,27	€ 6.121,30	€ 6.243,73	€ 6.368,60		
	PV Sum	**€ 8.078,76**	**€ 7.844,21**	**€ 7.616,46**	**€ 4.878,15**	**€ 4.736,52**	**€ 4.599,00**	**€ 4.465,47**	**€ 4.335,82**	**€ 4.209,94**	**€ 4.087,70**	**€ -**	€ 54.852,02
	PV Sum for Simulation	€ 8.441,57	€ 7.794,98	€ 7.617,65	€ 5.226,24	€ 4.984,55	€ 4.979,85	€ 4.555,33	€ 4.416,84	€ 4.152,53	€ 4.160,76	€ -	€ 56.330,30
	PV per year	€ 2.083.475,43	€ 77.071,05	€ 69.369,86	€ 64.890,18	€ 63.295,30	€ 444.898,76	€ 59.673,25	€ 57.940,71	€ 56.258,47	€ 54.625,07	€ -	
Simulation	PV per year	€ 2.067.803,24	€ 84.775,75	€ 66.475,74	€ 62.509,30	€ 69.049,30	€ 468.496,06	€ 63.164,80	€ 60.822,24	€ 56.272,63	€ 58.155,97	€ -	

Traditional	Net Present Value	€ 3.031.498,07
	Equivalent Annual Cost	€ 427.451,85
Simulation	Net Present Value	€ 3.057.525,02
	Equivalent Annual Cost	€ 431.121,74

This concludes the final inputs for the Monte Carlo simulation. The final step is to let the PSS Pricing Tool determine the fair price for the PSS and therefore the implied risk premium for this project.

8.4.2.4 Outcome of the PSS Pricing Tool

Table 8.9 - Key Outcomes of Pricing Tool

KEY OUTCOMES		
PSS Price	€	**470.898,66**
Implied Risk Premium	€	**43.446,81**
Percentile		**95%**
Number of Simulations		1000
Number of Years		10
EAC Traditional	€	**427.451,85**

In Table 8.9 the key outcomes can be seen and it can be seen that the price determined by the Tool is: **€ 470,8k**. Compared to the original EAC there is a **€ 43,3k** difference, which is the implied risk premium for carrying the uncertainties. This number may appear large, so in order to know where it comes from, a further analysis can be executed on where the biggest sensitivity of the cost drivers is.

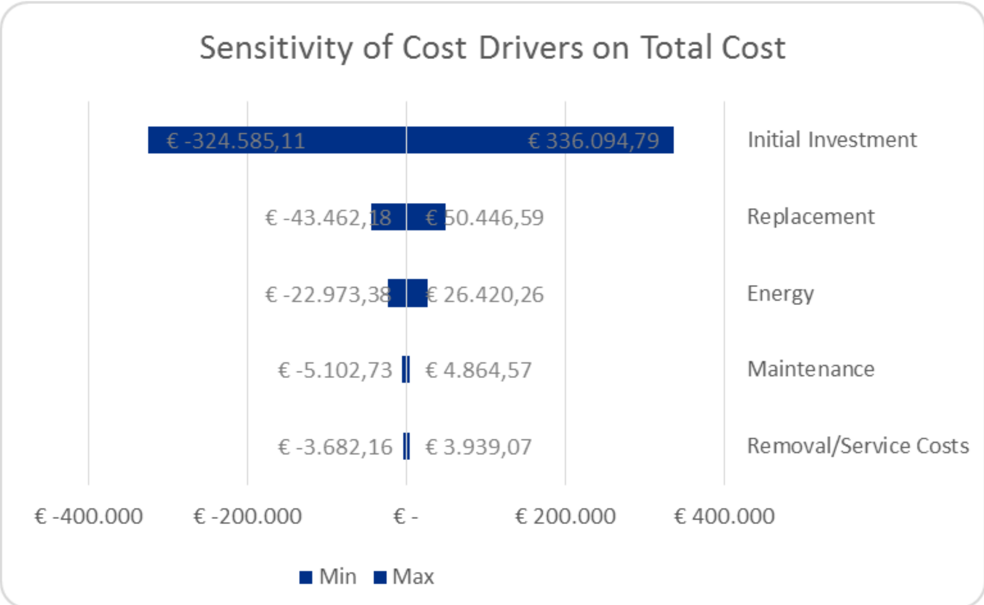


Figure 8.1 - Sensitivity of Cost Drivers

From Figure 8.1 it is very clear that the biggest variation comes from the initial purchase costs. As can be seen in the NPV sheet in Table 8.8, these represent the biggest cost driver by far and given the high uncertainty score in Table 8.5, the uncertainty of the initial purchase price is high. The question which can then be raised is whether this big variation is true, where this uncertainty comes from or that it is overstated and to many uncertainties are coupled to initial investment, while this might not influence it that much.

8.4.2.5 Revising the ranges

Given the fact that Philips' main business is delivering lighting solutions and that they know very well how much lighting will cost them, it can be stated that the initial range for the initial investment is high. However, there was uncertainty involved with the initial purchase in the financing arrangements. This was extensively discussed with Philips and a solution was found. This allows to manually lower the range of the uncertainty from -15/+20% to -5/+5%. The readjustment is a vital part of the model. Because the initial outcome can be used as means of discussion to lower the uncertainty for certain cost drivers, because it can be seen what the impact is, as shown in Figure 8.1. The range from the initial purpose is adjusted as can be seen in Figure 8.3a and Figure 8.3b, to a lower range which fits much more with the lowered uncertainty.

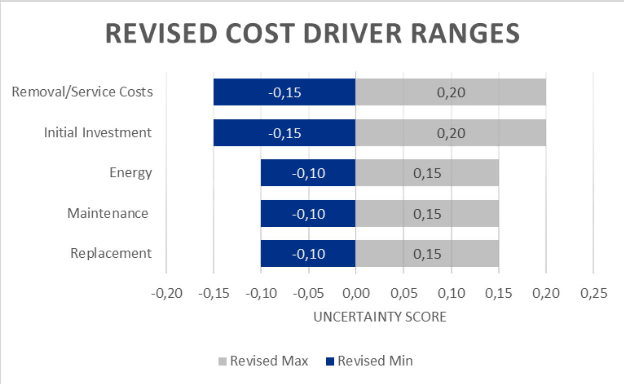


Figure 8.3a - Initial Cost Range

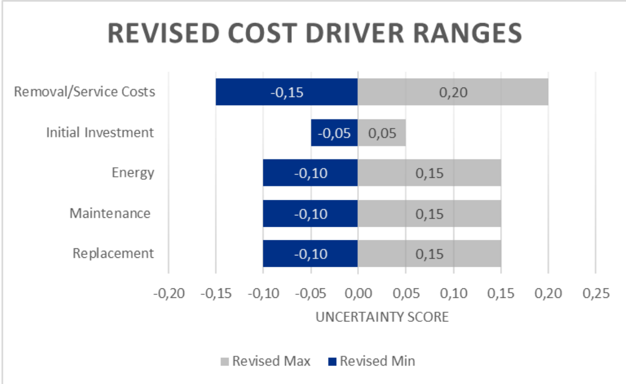


Figure 8.3b - Revised Cost Range

8.4.2.6 Outcome with Revised Ranges

With the adjusted ranges, the simulation is run again and this results in the following outcome (Table 8.10). The implied risk premium is now **€ 13,9k** with a PSS Price of **€ 441,4k**. This figure will be used for the comparison with the offer Cofely/Philips have put forth.

Table 8.10 - Key Outcomes Revised Ranges

KEY OUTCOMES		
PSS Price	**€**	**441.396,64**
Implied Risk Premium	**€**	**13.944,79**
Percentile		**95%**
Number of Simulations		1000
Number of Years		10
EAC Traditional	**€**	**427.451,85**

In Figure 8.6 the sensitivity of the Cost Drivers can be seen. The huge sensitivity of the initial investment is much more in line with the other Cost Drivers.

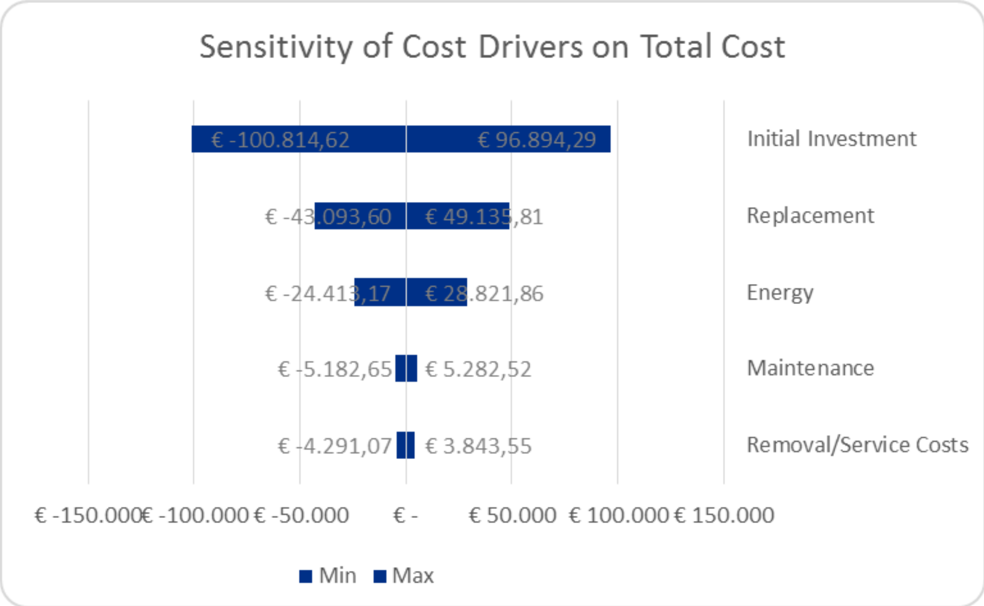


Figure 8.6 - Sensitivity of Cost Drivers with Revised Ranges

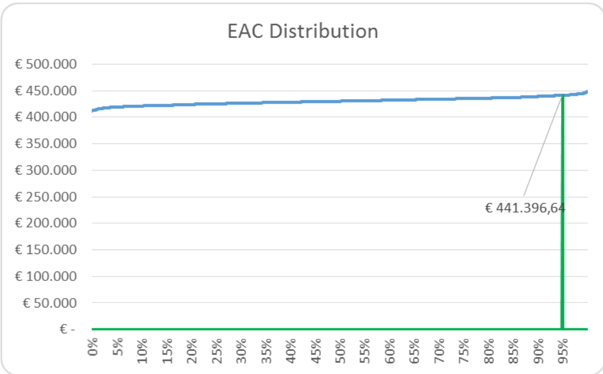


Figure 8.5a - EAC Distribution

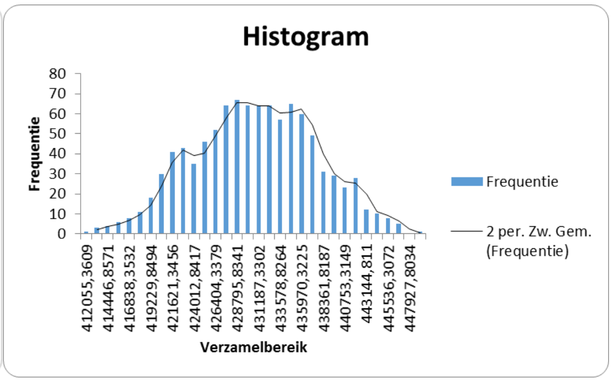


Figure 8.5b – Histogram of PSS Price

The last two graph can also be analysed, because they can tell something about the distribution of the simulated costs and therefore the (potential) skewness of the cost estimation, which can be seen in Figure 8.5a and Figure 8.5b. It can be seen that the distribution is fairly normal which can be confirmed by the EAC distribution which is fairly flat except for the extreme regions (<5% and >95%). The amount of steepness is an indication of the amount of uncertainty present in the project.

8.4.3 Comparison PSS Price to Cofely/Philips Offer

The last step is to compare the PSS Price to the offer which Philips and Cofely have made, which is shown in Table 8.11.

Table 8.11 - Comparison PSS Price and offer Cofely/Philips

PSS Price	Offer Cofely Philips
€ 441.397,-	€ 425.770,-

As can be seen the offer of Philips is lower than the PSS Price and even lower than the TCO price Schiphol has calculate. This indicates that this is a very good offer. Further research in the documentation learns that this is because Philips has also taken the opportunity to make it a show case project and therefore it was able to subtract some costs such as marketing. Furthermore, it can be stated that given the uncertainty, the implied risk premium Philips has, is €8,3k per year for bearing the associated risk of ownership.

8.5 Validation Number of Simulations

Monte Carlo is a powerful technique to assess all kinds of scenarios by using the computing power of random numbers. The basic assumption is that around 1000 simulations is usually enough to make sure that enough randomness is included in the model. This is checked and the outcome is that 1000 simulations is sufficient. For the validation of the number of simulations, the reader may consult Appendix F – Validation of the number of simulations.

8.6 Conclusion

In order to validate the framework and the PSS Pricing Tool, the Light-as-a-Service pilot project has been used as a validation case. It is the ideal case to test the framework to see whether all necessary steps are present in the framework to make sure that decision making is thorough, as well as that it provides the opportunity to test the PSS Pricing Tool, due to the availability of both the LCC/TCO of Cofely/Philips and Schiphol. Furthermore, extensive documentation is available which helps to draw the context in which the prices of Cofely/Philips was determined. This led to the validation case, where it is shown that the framework has all necessary steps to provide the user with thorough decision making in whether a PSS is a suitable alternative to be taken into account in the project. Furthermore, the PSS Pricing Tool provides the user with a tool which forces the user to map uncertainties and to score them. This adds a sanity check for the user to see which uncertainties and therefore potential risks, are involved in the project. This leads to an implied risk premium the supplier of the should ask from Schiphol, which is also the maximum implied risk premium Schiphol should accept from a supplier to take over its uncertainties in being owner. Therefore, it can be concluded that the framework and PSS Pricing Tool have been validated and can be used to support decision making within Schiphol when a PSS is a potential option, to check whether it is worth in taken into consideration as a viable alternative.

9. Challenges for Product-Service Systems at Schiphol

9.1 Introduction

SQ 6 What are possible barriers for implementation of Product-Service Systems?

The last sub question of this thesis will explore what potential barriers exist which could introduce problems in implementing Product-Service Systems at Schiphol or which could undermine the successful use of PSS. In the light of the research and especially the research question it is good to raise the question and shed light on those barriers.

9.2 Challenges

Based on literature, the research itself, discussions with employees and the case study several challenges are identified which exist or could present themselves when implementing PSS or during the process to determine whether PSS is a suitable alternative.

The first challenge which will be treated has to do with accounting. The current ruling on accounting is the IAS 17 *Leases*. This ruling will be surpassed by IFRS 16 *Leases*. This new accounting standard has a potential big impact on the advantage of not being owner. Because Schiphol uses the asset, it is effectively leasing them. Usually, this was not an issue, but the issue which presents itself with the new accounting is that all leases need to be accounted for on the balance sheet. In a normal firm this isn't a problem, except that it is clear how much one leases. For Schiphol on the other hand, due to the 'Toerekeningssysteem', the allocation system, assets leased by Aviation are also added to the Regulatory Asset Base. Which means that these leases will be charged to the airlines, but in the service fee the ownership is also charged. Which means that potentially, one asset will be double charged to airlines, which is not in line with the vision as set forth by the direction to let the airport tariffs decline or keep at the same level.

The second challenge is that introducing PSS is introducing complexity with PSS. A normal relatively simple asset becomes more complicated to control, due to the extended performance required by the supplier of the PSS. Schiphol needs to be able to cope with this extra complexity. This should not be a problem, if clear arrangements are made before the contract becomes effective.

The third challenge is the change in procurement. Suppliers require more information earlier on in the process in order to design not only an asset, but also the service layer. This requires more than just specification, because the service is bound by different means. This barrier co-exists with the second barrier.

The fourth challenge is that KPIs need to be specified sufficiently to overcome the loss of control by not being owner. The KPIs need to provide well enough information for Schiphol to be able to monitor performance by the supplier, so it can effectively steer on performance and make sure that it gets the required performance. This barrier emphasises the importance of a good relationship with the supplier, due to the newly introduced dependency on one another.

The fifth challenge is that PSS should be seen as an alternative by project developers. If they don't consider it an alternative worth exploring, it will not be put forth as a suitable alternative. It is important to state that PSS are not the best solution there is, but in cases it can be a very suitable alternative. If the framework is used with the matrix to check suitability and the PSS Pricing Tool for a price indication.

10. Results, Conclusion and Recommendations

10.1 Introduction

This chapter will treat the results, conclusion and recommendation based on the previous chapter and outcome of the case study. It will answer the Research Question as well as the summarise the answers on the Sub Questions, which have been treated in the previous chapters. Based on the outcome of the case study, a definitive answer can be given on the combination of Schiphol, Circular Economy, Product-Service Systems, suitability and usability.

Research Question:
Are Product-Service Systems suitable to support the transition towards a Circular Economy at Schiphol?

Sub Questions:
1. What is Circular Economy?
2. What are Product-Service Systems?
3. How is the current situation at Schiphol, especially regarding decision making?
4. What is needed for good decision making with PSS at Schiphol?
5. How can a price for a PSS be determined?
6. What are possible barriers for implementing PSS at Schiphol?

10.1.1 Reading Guide

Firstly, answers on the sub questions will be given in paragraph 10.2. This will refresh the memory and help to answer the main question in the main conclusion in paragraph 10.3. Lastly, the recommendations will be given in paragraph 10.4.

10.2 Results

10.2.1 Sub Questions

In order to answer the Research Question, firstly the sub questions will be answered. They will provide the basis for the RQ to be answered and make sure that all relevant aspects are covered.

10.2.1.1 Sub Question 1: What is Circular Economy?

The question on what Circular Economy is answered by the following definition:

"Circular Economy is a sustainable economic and industrial system, where environment and economy are regenerative by design, aimed at maximising value of a product while minimising the resource usage"

This definition gives a clear guideline on what needs be taken into account for Schiphol when Circular Economy is on the agenda. One of the ways to ensure that this guideline is followed is by asking the question, do you need to be owner of a product/asset? From a CE point of view, the answer is "No". Functionality and performance what Schiphol needs from a product/asset. From literature one of the possible transition enablers would be to lease product, to use functionality while not being owner, so called Product-Service Systems.

This leads to the next question which is how can Schiphol cope with not being owner, but user? Historically Schiphol has been owner of many assets, but given the developments both in CE as well as Schiphol's own goals of becoming an asset manager instead of owner, the need arises to explore how Schiphol can make sure that the decision process for being asset manager and user of the functionality.

10.2.1.2 Sub Question 2: What are Product Service Systems?

As stated earlier, Product-Service Systems (PSS) is a suitable transition tool towards CE. But in order to know how it can be fully utilised, the question was answered in chapter 5. Firstly, the definition of PSS is given:

'A Product-Service System (PSS) is an integrated offering of products and services with a revenue mechanism that is based on selling availability, usage or performance'

With this in mind, the following characteristics of PSS are important to mention. By implementing a PSS, success is not guaranteed. In order to guarantee success, the following aspects should be taken into account. PSS come in different flavours and the one which supports Circular Economy is the Result-Oriented PSS. With this type of PSS, the ownership remains at the supplier and the user uses functionality. This has a few important consequences, which need to be taken into account in order to be successful. The relationship between user and supplier intensifies due to the increased dependency on one another. The supplier changes from a mere supplier into a stakeholder, the procurement changes because a supplier must be involved earlier on and the loss of control due to the lack of ownership of the user must be counteracted by proper KPIs for monitoring performance of the asset which has turned into a service. Four basic criteria have been identified as being essential in checking if an asset is suitable for being acquired as a PSS, being; i) labour, resource and/or energy intensive, ii) Not part of primary process, iii) Impact of malfunction on operation has to be severe enough and iv) Market/investment size should be sufficient. Using the matrix of 7.3.1, it can easily be checked if an asset meets the necessary criteria. Next to these criteria it is important to know which conditions are important to ensure PSS is a good alternative compared to a traditional asset solution. The most important success condition is that there is a clear picture of which stakeholders are involved and what product, service, information and monetary flow exist between them and compare this to the contractual and formal relationship. This helps to develop proper KPIs which account for every aspect. These KPI have to be internally validated to see if everyone agrees and checked with the supplier that they can meet such demands. Here the importance of the relationship with the supplier is underlined. The next questions which are raised with these success conditions is, if ASM would go for the PSS solution: what is needed for PSS at Schiphol as an asset solution and how can a price for a PSS be determined? Before these questions are answered, another question is needed to be answered. This to make sure that the business context of Schiphol is clear and that the procedure for decision making is followed.

10.2.1.3 Sub Question 3: How is the current situation at Schiphol, especially regarding decision making?

In order to understand how Schiphol can become an asset user instead of owner, it is important to understand how decision making takes place and how the business environment of Schiphol and of Aviation Asset Management is influencing decision making.

Schiphol has introduced a few Asset Management programs over the last few years, all aimed at increase the structure of decision making and make sure that decisions are made with good argumentation and can be substantiated. The most important decision rule is the balance between Function, Euro and Risk. Especially within ASM this balance is very important, due to the nature of business of ASM. The relationship between revenue and cost of a project are very hard to make explicit. Therefore, the projects are valued on their costs (the Euro in decision making). Because costs are the main financial driver, Schiphol has introduced the TCO methodology, which makes sure that all costs during the lifetime of an asset are taken into account in decision making. The TCO is based on the well-known NPV technique and is usually translated in an EAC to get an insight in what an asset will cost if translated to yearly costs. From this question it can be concluded that what is needed for the transition towards a CE in asset management is that the functionality is clear (Function), that it is known what it should cost (Euro) and that it is clear what risks are present in a project (Risks). If these three aspects are captured, the transition to CE could take the next step. This leads to the next sub question.

10.2.1.4 Sub Question 4: What is needed for good decision making with Product-Service Systems at Schiphol?

As stated in the previous sub question, the key to success is to balance Function, Risk and Euro. But how can ASM balance those three decision makers in the light of Product-Service Systems? In order make sure that decision making support the triangle, fits within Schiphol and takes into account the characteristics of PSS. A framework has been developed which support decision making in a structured and consistent way. It makes sure that step for step the properties of a PSS are assessed an in a structured way decision making is supported. Is the asset suitable for being acquired as a PSS. What stakeholders are involved. How does the product/service/information/monetary flow between them look like, which can be used for KPI development in order to make sure that all relationships are sufficiently covered. What is to be included in the Service Level Agreement. All this is captured in the PSS Decision framework (Figure 10.1).

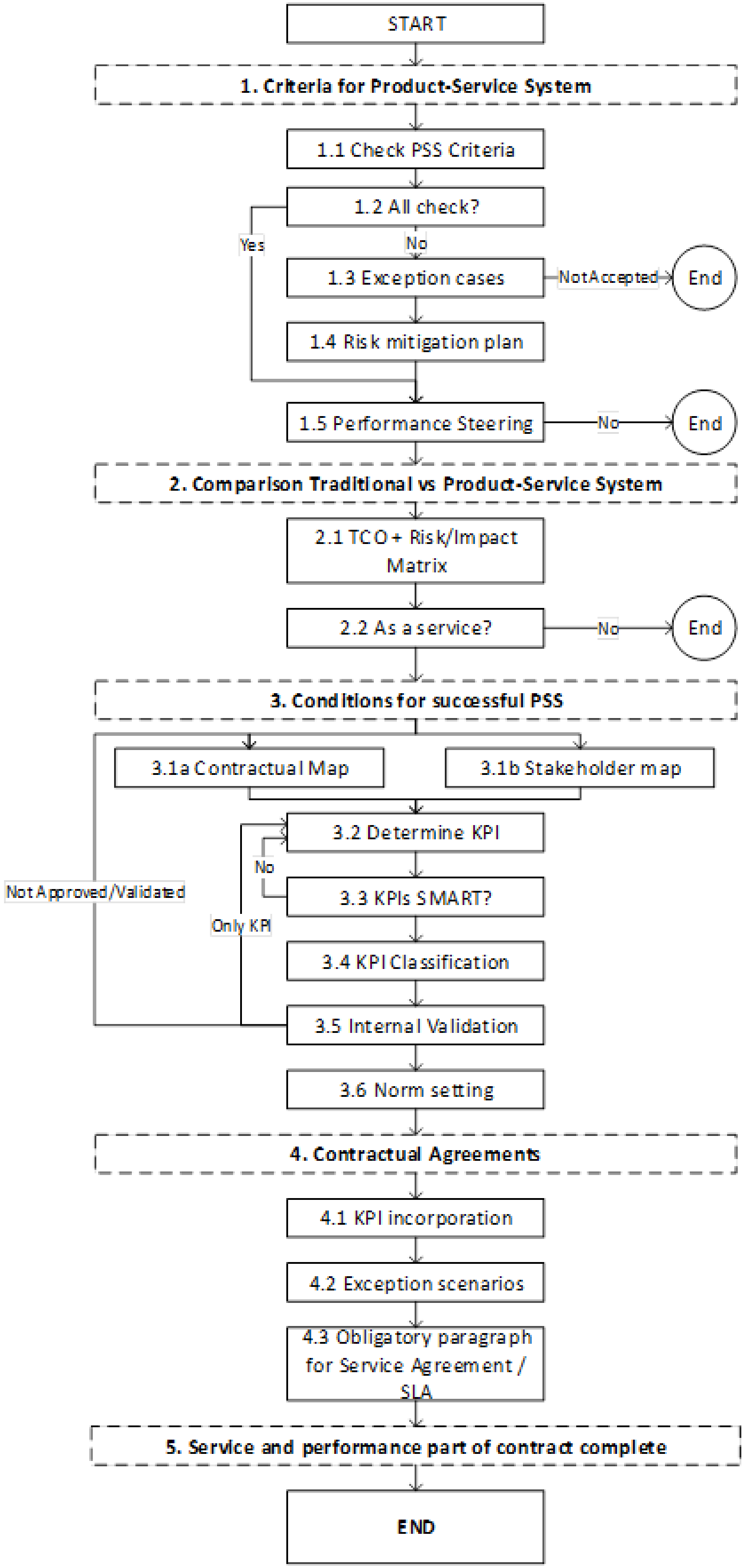


Figure 10.1 - PSS Decision Framework

10.2.1.5 Sub Question 5: How can a price for a Product-Service System be determined?

The next step to make sure that PSS is a suitable and worthy alternative in the decision making process of ASM is that from the three main decision makers (Function, Risk and Euro), the Euro can be determined. The difficulty with a PSS on the cost part, is that there is a loss of transparency when Schiphol acquires a service instead of an asset. With an asset, there is the need to perform maintenance, deliver energy, replace broken parts etc. With the purchase of a service all these activities, and especially the associated costs, become more opaque. This increases the ability to judge the offer of a supplier, because it will bring forth the argument of being an asset owner brings risks, and risks require a reward. This can be counteracted using the PSS Pricing Tool. The tool is based on the already in use TCO tool for calculating the NPV and EAC of a project. In order to incorporate the uncertainty of a supplier, the user enters which uncertainties are experienced by a supplier and scores them on three different criteria: i) basic estimate of uncertainty, ii) rigour of assessment and iii) level of validation. Next the uncertainty is given an importance against the whole project. Next, each uncertainty is linked to cost driver in the project (initial purchase, maintenance, etc.) who are affected by the uncertainty. This produces an uncertainty weighted cost range estimate, which can then be used in a simulation to determine the 95% percentile and determine the implied risk premium. This risk premium + the normal TCO EAC is the maximum price Schiphol should be willing to pay. If a supplier offers a price lower than this indication, it is a good offer worth taken into consideration. Is the offer higher, Schiphol can reply to the supplier that given the uncertainties perceived the offer is too expensive and needs to be lowered or more information is needed to be provided on why the cost is so high. For the L.a.a.S. case, it has shown that the offer from Philips was well within the maximum price, which was confirmed by the project team from L.a.a.S., that Philips dropped significantly for marketing and pilot project purposes. Using the L.a.a.S. case the model was validated.

For the Light-as-a-Service case this yields the following result (Table 10.1s).

Table 10.1 - Key Outcomes Revised Ranges

KEY OUTCOMES		
PSS Price	**€**	**441.396,64**
Implied Risk Premium	**€**	**13.944,79**
Percentile		**95%**
Number of Simulations		1000
Number of Years		10
EAC Traditional	**€**	**427.451,85**

When this outcome is compared to the offer made by Philips, it can be concluded that Philips offered a good price, because the price it offered was lower than the PSS Price which was calculated. This shows that Philips' offer was well enough to continue with.

10.2.1.6 Sub Question 6: What are possible barriers for the implementation of Product-Service Systems?

Several barriers have been identified. New accounting rules on leases could undermine one the not being owner in a financial way. Due to that leases need to be on the balance sheet and therefore included in the RAB which is charged to the airlines. Furthermore, PSS introduce complexity compared to the old asset owner situation. This complexity and the loss of control by the not being owner needs to be tackled by good KPIs which allow Schiphol to steer this performance. Procurement and development need to be aware that the procurement process is different due to the service layer, which has different demands than asset specifications in the old situation. Lastly, project developers need to see PSS as an alternative solution in a project. If it is not proposed, it will not be used.

10.3 Conclusion

With all the sub questions answered, the research question can be answered. Furthermore, the relevance for Schiphol and the academic relevance are described. As these are both important parts of any thesis.

10.3.1 Research Question: Are Product-Service Systems suitable to support the transition towards a Circular Economy at Schiphol?

With the answer to all sub questions, the research question can be answered. The transition towards CE can be done with many tools. In this Master Thesis, Product-Service Systems have been explored as a tool for this transition. Bases on the literature review of sub questions 1 and 2, it can be concluded that Product-Service Systems are suitable to support the transition towards a Circular Economy. But in order that this transition can be supported within Schiphol, it is also important to know how Schiphol's decision making is performed and how PSS can fit in the decision making process. Schiphol, and especially ASM, takes decisions based on the balance between Function, Risk and Euros. The function is assumed to be clear with any project together with the PSS Criteria Matrix (paragraph 7.3.1), which checks if an asset is suitable to be converted into a PSS. Next, the risk and Euro part are covered by the PSS Pricing Tool (paragraph 7.5), which gives a price indication of what Schiphol should want to pay (Euro), given the assessed uncertainties a supplier has of remaining owner and offering the PSS (risk). The PSS Pricing Tool is based on the already use TCO tool within Schiphol for the financials and it relies on the knowledge and expertise of the employees of Schiphol to assess the risks and uncertainties. This complete the decision triangle Schiphol uses within ASM where Function is covered by functional specifying, the Euro is the price determination and the Risk is covered by the uncertainty assessment.

The price which comes from the tool can be used to assess the offer made by a supplier to check whether it's fair and just. It strengthens the negotiation position of Schiphol in the tender process and can be used to determine the biggest variation in the cost drivers of the PSS, which can then be returned to the supplier in negotiation of how the price is structured. This prevents the supplier to simply revert to the argument of remaining owner and carrying the risk, because it has to better substantiate its argumentation.

10.3.2 Relevance for Schiphol

The relevance for Schiphol is clear. This Master Thesis explores the suitability of PSS as a transition tool for Schiphol towards CE. During the research many aspects are mentioned in making the support as clear and strong as possible. For Schiphol, it provides a guideline in what is needed to implement a PSS, how to make sure that it is successful and that Schiphol pays the right price. Furthermore, the case study of Light-as-a-Service shows that is applicable, but also that the decision to continue with L.a.a.S. was correct if the tool was available earlier. Especially the PSS Pricing Tool was seen as a good extension to the already present TCO tool, if leasing is one of the alternative to get a price indication.

Lastly, the Master Thesis helps Schiphol in reaching their Corporate Responsibility goals. It helps to structure the process to see if PSS is a suitable alternative. By standardising the process, Schiphol is able to substantiate better how projects can help in reaching circularity (CR goal) and explain why a certain solution is chosen.

10.3.3 Academic relevance

Another aspect of each graduation research is the academic relevance. This Master Thesis explores how PSS can be implemented in practise and which aspects are needed to make into a success. The operationalisation of such can be seen as relevant for the academic community. The formal modelling of a decision framework, which takes into account the characteristics of PSS as described in literature, in order to make sure that PSS is a good alternative for an asset related project, which has been validated within a firm, can be considered a good application of academic knowledge in a real life setting. Furthermore, to the knowledge of the author, no previous PSS pricing tool from a customer perspective has been developed earlier. While the model is nearly identical to cost estimation under uncertainty model of Erkoyuncu (2011), the perspective is very different. The pricing tool can be used in negotiations as a stronger reply to the offer made by a potential supplier. Furthermore, it can help procurement and developers into asking the right questions on the amount of uncertainty, using the sensitivity outcome and therefore help to take uncertainty away at the supplier and therefore get a better price.

10.4 Recommendations

One of the deliverables of this Master Thesis are recommendations for Schiphol to help in getting more Circular Economy by Product-Service Systems.

The first recommendation is that PSS should be considered an alternative in asset relation projects. This recommendation is mend for the departments Asset Planning, Development and Technical Expertise Centre (TEC) of ASM. It essential that they consider PSS as an alternative, because they are responsible for proposing alternatives. The matrix must be used in order to check for suitability.

The PSS Pricing Tool can be used when a price indication is needed of what the potential costs are. Therefore, the second recommendation is that the PSS Pricing Tool should be used, when PSS is considered. This can also be used later when a potential supplier is contacted and asked what fee it would charge for such a service. Furthermore, the uncertainty assessment helps in structuring the uncertainties present in the project, because the project members are forced to assess and therefore think about what risks and uncertainties are present.

The PSS Pricing Tool can be used by the Cost Expertise Centre (CEC) when they are asked to estimate the potential cost. Together with a specialist from TEC, they can make a price indication.

The fourth recommendation is that Control of (initially) ASM should be get used to the methodology of PSS and have a clear understanding of its impact financially. Due to the role business controllers have, they are asked to judge the financials and the financials are different with a PSS. They should check if the process is followed by Developers/Asset planners, to check if the PSS is a suitable alternative, before they check the financials.

The fifth recommendation is that Developers should know that the procurement process is different with a PSS than with a traditional asset purchase. They should provide the proper information to the supplier to allow him to design a service layer which fits both the asset as well as Schiphol. Furthermore, they should keep in touch more when they hand over the project to Procurement, to ensure the KPIs which have been developed are sustained, because they are at the Centre of the relationship with the supplier as well as at the heart of the functionality and performance required by Schiphol.

11. Further usability, Limitations, Discussion & Reflection and Future Research

11.1 Further usability

One of the aspect worth discussing in this thesis are other possible usability's for parts of this Master Thesis. One of the first parts which is well suited for possible other usage is the PSS Pricing Tool. In principle, the tool can be used for any kind of service where Schiphol is able to perform a TCO calculation and an uncertainty assessment. This could be a tool to check whether a price of a service is fair, in the same manner the tool is intended for the PSS.

Another possible usage is in software and IT solutions. Within IT, many products are sold as services to firms such as Schiphol, from Oracle systems to website design. The tool can be used, but gaining the proper inputs much more difficult, because IT and software are very intangible compared to an ordinary asset. This makes it difficult to assess the uncertainties and when TCO is available for a traditional solution, the financials are missing. Therefore, it may be hard to use it and more research is required on how the model can be translated that it fits IT-as-a-Service. This is however a point which was explicitly mentioned during the presentation and discussion with Business Control of Schiphol.

11.2 Limitations

It is always good to take into account the limitations the answer to the research question may introduce. Within this Master Thesis, a framework and a PSS Pricing Tool are developed. It is important to check what limitations there are, in order to take them into account.

The first limitation has to do with Product-Service Systems. It is good to know that PSS are not the ultimate solution. Not for introducing complete CE within Schiphol or ASM, not for all new assets, or to become an effective Asset Management organisation. It is one of the tools to help in the transition process, but common sense and judgement should always prevail in decision making.

The second limitation has to do with the complexity which is introduced in using PSS. Due to the different nature of PSS, the cooperation with suppliers in delivering performance and the monitoring needed for proper function, a usual simple asset might become more complex than necessary. The service layer on top of the asset is an extra investment.

The third limitation is a model risk in the PSS Pricing Tool. Uncertainties are scored and are assigned to different cost drivers. These cost drivers are thus sort of correlated with uncertainties. This could induce an unexpected correlation between cost drivers. This effect has not been quantified or examined, but it is present and therefore good to mention.

11.3 Discussion & Reflection

11.3.1 Discussion

There are a few point worth mentioning as a discussion point given this Master Thesis and the direction it is written. As with any research, there are point which remain unclear and open for interpretation. One of the points has to do with the fact that Schiphol has opted to reduce Operational Expenditure (OPEX). Usually this translates into investing more into Capital Expenditure (CAPEX), which can be spread out more easily over time. PSS is an OPEX solution, because one does not invest in assets, but pays a fee for a service. While this support Schiphol's wish to become more an asset management organisation, due to the fact that you let the firms who are specialised in their business actually execute it, it does not stroke with the wishes to also reduce OPEX. This is an issue which will pop up more often, if PSSs are introduced more at Schiphol and the management of ASM needs to think if they can agree with it or not. This problem is further complicated because one of the uses of a PSS, financially, could be to be able to not let the asset be added to the RAB, and therefore the tariffs. By paying a service fee, Schiphol is able to keep the shock of an asset added to the RAB to a minimum. Not adding to the RAB is a non-CAPEX solution.

The second point worth discussion is that the model is based on the fact that the financials come from the already used TCO model for a traditional asset purchase. One could think of a hypothetical scenario where Schiphol no longer has any experience with the purchase of a specific asset, because it all acquired it as a service. This would render the pricing tool useless. Hopefully, Schiphol has by that time enough experience in the acquiring of PSS and has develop another set of tools to judge the price.

The last point has to do with one of the barriers as posed in paragraph 9.2. The new accounting rules under IFRS 16 *Leases* are going to be much stricter on lease accounting. Every single lease needs to be on the balance sheet. This has a potential big effect for Schiphol, compared to other firms, not because one can see how much is leased, but more because Schiphol is obliged by law to charge airlines for the asset using a controlled WACC. This could introduce a double charging mechanism which can be considered unwanted. Airlines are always tough in negotiations for airline fees and they know better than anyone else that the new lease rulings are coming (airlines are one of best well known users of leases with airplanes). In order to avoid discussion on this point during the negotiations, it is best for Schiphol to already have a plan on how to tackle this issue. Not only for PSS, but for all leases which are currently not on the balance sheet.

11.3.2 Reflection

During my research at Schiphol, I was granted the opportunity to have a peek inside on of the most complex and biggest operations in the Netherlands. In my opinion the complexity and 24 hour operations with complete dependency of the customer (the air traveller, 60 million of them in 2016) can only be compared to a big hospital. The operation never stops and the effect of any work on the operation must be kept to a minimum, also due to the scarcity of capacity. On the other hand, the need to invest and continually improve the operation is very strong. This puts pressure on project to deliver the best result, with the least amount of spending, while not disturbing operation and with continuing shifting demands on what is considered the best for the customers and clients. This combined with the fact that cost and revenue are not directly related within ASM provided me with a very interesting picture. All around me the call for more commercial thinking was heard more than once, but now that I have experienced how thorough decision making needs to be, combined with the fact that ASM is not able to directly appoint revenue to a specific project, I can understand why the process is slow and appears to stay slow, despite the efforts. Plans keep on shifting and changing and important and powerful stakeholders (airlines, LVNL (air traffic control NL), government) are constantly changing their point-of-view and position. I did my best to come up with a solution which would fit within the modus operandi of ASM. I listened well to what was needed and translated it into, hopefully, an easy to use tool which allows for informed decision making. If my pricing tool and the matrix would be used in checking if a PSS or lease construction would be a suitable alternative, I am more than happy. Schiphol thought me that a big and complex organisation is hugely interesting and slow at the same time and proved to me once again that I find such a working field very intriguing.

11.4 Future Research

The most important future research point is that it needs to be clear for Schiphol what the potential impact is of the new IFRS ruling on leases. This could undermine the financial benefits of not only PSS, but on leasing all together. A graduation project on itself, which is the most important potential research which I could identify.

12. References

(2014). Retrieved 1 28, 2016, from Rabobank: https://www.rabobank.com/nl/about-rabobank/in-society/sustainability/circular-economy-challenge/afrap-circular-economy-challenge.html

(2015, 11 8). (VPRO) Retrieved 1 28, 2016, from Tegenlicht: http://tegenlicht.vpro.nl/afleveringen/2015-2016/einde-van-bezit.html

(2016). Retrieved 1 28, 2016, from NU.nl: http://www.nu.nl/ondernemen/4201294/banken-zetten-in-circulair-ondernemen.html

ACM. (2015, 7 14). *Goedkeuring toerekeningssysteem Schiphol 2016-2018*. Retrieved 1 27, 2016, from ACM: https://www.acm.nl/nl/publicaties/publicatie/14494/Goedkeuring-toerekeningssysteem-Schiphol-2016-2018/

Adrodegari, F., Alghisi, A., Ardolino, M., & Saccani, N. (2015). From ownership to service-oriented business models: a survey in capital goods compnaies and a PSS typology. *Procedia CIRP, 30*, 245-250.

Anderson, M. S. (2007). An Introductory Note on the Environmental Economics of the Circular Economy. *Sustain. Sci.*, 133-140.

Asset Wise! Team Schiphol. (2015). *Blauwdruk Assetmanagement Versie 3.0.* Internal Report.

Aurich, J. C., Fuchs, C., & Wagenknecht, C. (2006). Life cycle oriented design of technical Product-Service Systems. *Journal of Cleaner Production*(14), 1480-1494.

Aurich, J. C., Mannweiler, C., & Schweitzer, E. (2010). How to design and offer services successfully. *CIRP Journal of Manufacturing Science and Technology, 2*, 136-143.

Bastein, T., Roelofs, E., Rietveld, E., & Hoogendoorn, A. (2013). *Kansen voor de circulaire economie in Nederland.* TNO. TNO-rapport.

Beuren, F. H., Ferreire, M. G., & Miguel, P. A. (2013). Product-service systems: a literature review on integrated products and services. *Journal of Cleaner Production, 47*, 222-231.

Brealey, R. A., Myers, S. C., & Allin, F. (2011). *Principles of Corporate Finance 10th Edition.* McGraw-Hill.

Costa, F., Prendeville, S., Beverley, K., Teso, G., & Brooker, C. (2015). Sustainable product-service systems for an office furniture manufacturer: How insights from a pilot study can inform PSS design. *Procedia CIRP, 30*, 66-71.

Ellen MacArthur Foundation. (2013a). *Towards the Circular Economy 1.* Ellen MacArthur Foundation.

Ellen MacArthur Foundation. (2013b). *Towards the Circular Economy 2.* Ellen MacArthur Foundation.

Ellen MacArthur Foundation. (2013c). *Towards the Circular Economy 3.* Ellen MacArthur Foundation.

Ellen MacArthur Foundation. (2014). *Handeling Collection*. Retrieved 2 9, 2016, from Ellen MacArthur Foundation: http://www.ellenmacarthurfoundation.org/news/handling-collection

Ellen MacArthur Foundation. (2016, 1 28). *Amsterdam Airport Schiphol joins the CE100 programme*. Retrieved 2 8, 2018, from Ellen MacArthur Foundation: http://www.ellenmacarthurfoundation.org/news/amsterdam-airport-schiphol-joins-the-ce100-programme

Emery, D. R., Finnerty, J. D., & Stowe, J. D. (2004). *Corporate Financial Management.* Upper Sadle Rivers, NJ:: Printice-Hall.

Erkoyuncu, J. A. (2011). *Cost Uncertainty Management and Modelling for Industrial Product-Service Systems.* PhD Thesis, Cranfield University .

Exner, K., & Stark, R. (2015). Validation of Product-Service Systems in Virtual Reality. *Procedia CIRP, 30*, 96-101.

Exner, K., Lindow, K., Buchholza, C., & Stark, R. (2014). Validation of Product-Service Systems - A Prototyping Approach. *Procedia CIRP, 16*, 68-73.

Fernandes de Castro Rodrigues, K., Nappi, V., & Rozenfeld, H. (2014). A proposal to support the value proposition in Product Oriented Service business model of Product Service Systems. *Procedia CIRP, 16*, 211-216.

Gesing, J., Maiwald, K., Wieseke, J., & Sturm, R. (2014). Are IPS2 always a solution? Obstacles towards Buying Industrial Product Service Systems. *Procedia CIRP, 16*, 265-270.

Ghisellini, P., Cialani, C., & Ulgiati, S. (2015). A Review on Circular Economy: the Expected Transition to a Balanced Interplay of Environmental and Economic Systems. *Journal of Cleaner Production*, 1-22. doi:http://dx.doi.org/10.1016/j.jclepro.2015.09.007

Guidat, T., Barquet, A. P., Widera, H., Rozenfeld, H., & Seliger, G. (2014). Guidelines for the defintion of innovatie industrial product-service systems (PSS) business models for remanufacturing. *Procedia CIRP, 16*, 193-198.

Heidel, R. V. (1997). Are You Being Served? (Service Level Agreements for I/S Support Organizations). *Proceedings of the Computer Measurement Group's International Conference*.

Herzog, M., Meuris, D., Bender, B., & Sadek, T. (2014). The nature of risk management in the early phase of IPS2 design. *Procedia CIRP, 16*, 223-228.

Hiles, A. N. (1994). Service Level Agreements. *The TQM Magazine, 6*(2), 14-16.

Jackson, S. B., Xiaotao, L., & Cecchini, M. (2009). Economic Consequences of Firms' Depreciation Method Choice: Evidence from Capital Investments. *Journal of Accounting and Economics*(48), 54-68.

Kimita, K., Watanbe, K., Hara, T., & Komoto, H. (2015). Who realises a PSS?: an organizational framework for PSS development. *Procedia CIRP, 30*, 372-377.

Kuijken, B., Gemser, G., & Wijnberg, N. M. (2016). Effective product-service systems: A value-based framework. *Industrial Marketing Management*.

Lieder, M., & Rashid, A. (2015). Towards Circular Economy Implementation: a Comprehensive Review in Context of Manufacturing Industry. *Journal of Clearer Production*, 1-16. doi:http://dx.doi.org/10.1016/j.jclepro.2015.12.042

Lindstöm, J. (2016). Introducing Functional Products in production systems: problems and issues encoutered. *Procedia CIRP, 41*, 45-50.

Lockett, H., Johnson, M., Evans, S., & Bastl, M. (2011). Product Service Systems and Supply Network Relationships: An Exploratory Case Study. *Journal of Manufacturing Technology Management, 22*(3), 293-313.

Luchtvaartwet. (2016). Retrieved 1 22, 2016, from Overheid.nl: http://wetten.overheid.nl/BWBR0002267/geldigheidsdatum_22-01-2016#Opschrift

Marcelino-Sádaba, S., González-Jaen, L. F., & Pérez-Ezcurdia, A. (2015). Using project management as a way to sustainability. From a comprehensive review to a framework definition. *Journal of Cleaner Production, 99*, 1-16.

Matschewsky, J., Sakao, T., & Lindahl, M. (2015). ProVa - Provider Value Evaluation for Integrated Product Service Offerings. *Procedia CIRP, 30*, 305-310.

Ministerie van Verkeer en Waterstaat. (2006). Wet van 29 juni 2006 tot wijziging van de Wet luchtvaart inzake de exploitatie van de luchthaven Schiphol. *Staatsblad van het Koninkrijk der Nederlanden*, pp. 1-9.

Morelli, N. (2006). Developing new product service systems (PSS): methodologies and operational tools. *Journal of Cleaner Production, 14*, 1495-1501.

Moser, U., Maisenbacher, S., Kasperek, D., & Maurer, M. (2015). Defintion of an Approach for the Development of Product-Service Systems. *Procedia CIRP, 30*, 18-23.

Nijhuis, J. (2016, 1 4). *Verwachte groei Schiphol: 60 miljoen reizigers in jubileumjaar*. Retrieved 2 3, 2016, from www.schiphol.nl: http://www.schiphol.nl/SchipholGroup1/NieuwsPers/Persbericht/VerwachteGroeiSchiphol60MiljoenReizigersInJubileumjaar.htm

Pearce, D. W., & Turner, R. K. (1990). Economics of Natural Resources and the Environment. *Johns Hopkins Univ Press*.

Phang, S.-Y. (2016). A General Framework for Price Regulation on Airports. *Journal of Air Transport Management*(51), 39-45.

Pigosso, D. C., & McAloone, T. C. (2015). Supporting the development of environmental sustainable PSS by means of the Ecodesign Maturity Model. *Procedia CIRP, 30*, 173-178.

Qu, M., Yu, S., Chen, D., Chu, J., & Tian, B. (2016). State-of-the-art of design, evaluation, and operation methodologies in product service systems. *Computers in Industry, 77*, 1-14.

Reim, W., Parida, V., & Lindström, J. (2013). Risks for Functional Products - Empirical Insights from two Swedisch Manufacturing Companies. *Procedia CIRP, 11*, 340-345.

Rese, M., Karger, M., & Strotmann, W.-C. (2009). The dynamics of Industrial Product Service Systems (IPS2) - using the Net Present Value Approach and Real Option Approach to improve life cycle management. *CIRP Journal of Manufacturing Science and Technology, 1*, 279-286.

Richter, J. L., & Koppejan, R. (2015). Extended Producer Responsibility for Lamps in Nordic Countries: Best Practices and Challanges in closing Material Loops. *Journal of Cleaner Production*, pp. 1-13. doi:http://dx.doi.org/10.1016/j.jclepro.2016.06.131

Saaty, L. T. (1990). How to make a decision: The Analytical Hierarchy Process. *European Journal of Operational Research*(48), 9-26.

Samis, M., Davis, G. A., Laughton, D., & Poulin, R. (2006). Valuing uncertain asset cash flows when there are no options: A real option approach. *Resources Policy, 30*, 285-298.

Santos, L., Soares, I., Mendes, C., & Ferreira, P. (2014). Real Options versus Traditional Methods to assess Renewable Energy Projects. *Renewable Energy, 68*, 588-594.

Sassenelli, C., Pezzotta, G., Rossi, M., Terzi, S., & Cavalieri, S. (2015). Towars a Lean Product Service Systems (PSS) Design: state of the art, opportunities and challanges. *Procedia CIRP, 30*, 191-196.

Sauvé, S., Bernard, S., & Sloan, P. (2015). Enivornomental Sciences, Sustainable Development and Circular Economy: Alternative Concepts for Trans-disciplinary Research. *Environmental Development*, 1-9. doi:http://dx.doi.org/10.1016/j.envdev.2015.09.002

Scheepens, A. E., Vogtländer, J. G., & Brezet, J. C. (2016). Two Life Cycle Assessment (LCA) based Methods to analyse and design Complex (Regional) Circular Economy Systems. Case: making Water Tourism more Sustainable. *Journal of Cleaner Production*(114), pp. 257-268.

Schiphol Group. (2015). *De kracht van de mainport. Strategie Schiphol Group 2016-2020.* Schiphol Group.

Schiphol Group. (2015). *Schiphol Annual Report 2014.* Schiphol Group.

Schiphol Group. (2015). Toerekeningssysteem. *Luchtvaartactiviteiten Schiphol Group op de luchthaven Schiphol*. Schiphol. Retrieved from https://www.acm.nl/nl/publicaties/publicatie/14494/Goedkeuring-toerekeningssysteem-Schiphol-2016-2018/

Schiphol Group. (2016, 4 25). *Corporate Responsibility; Grondstofschaarste*. Retrieved from Website of Schiphol Group: http://www.schiphol.nl/SchipholGroup1/CorporateResponsibility1/Grondstofschaarste.htm

Schiphol Group. (2016). *Schiphol Annual Report 2015.*

Schmidt, D. M., Malaschewski, O., Fluhr, D., & Mörtl, M. (2015). Customer-oriented Framework for Product-Service Systems. *Procedia CIRP, 30*, 287-292.

Schnürmacher, C., Haka, H., & Stark, R. (2015). Providing Product-Service-Systems - The Long Wat from a Product OEM towards an Orginal Solution Provider (OSP). *Procedia CIRP, 30*, 233-238.

Schulte, U. G. (2013). New Business Models for a Radical Change in Resource Efficiency. *Environmental Innoviation and Societal Transition*, 43-47. doi:http://dx.doi.org/10.1016/j.eist.2013.09.006

Schweitzer, E., & Aurich, J. (2010). Continuous improvement of industrial product-service systems. *CIRP Journal of Manufacturing Science and Technology, 3*, 158-164.

Sousa, T. T., & Cauchick Miguel, P. A. (2015). Product-service systems as a promising approach to sustainability exploring the sustainable aspects of a PSS in Brazil. *Procedia CIRP, 30*, 138-143.

Sundin, E., Nässlander, E., & Lelah, A. (2015). Sustainability indicators for Small and Medium-sized Enterprises (SMEs) in the transition to provide Product-Service Systems (PSS). *Procedia CIRP, 30*, 149-154.

Tukker, A. (2015). Product Services for a Resource-efficient and Circular Economy - a Review. *Journal of Cleaner Production*(97), pp. 76-91.

van Ostaeyen, J. (2014, 3). Analysis of the Business Potential of Product-Service Systems for Investment Goods. *PhD thesis, KU Leuven*, pp. 1-314.

Van Ostaeyen, J., Van Horenbeek, A., Pintelon, L., & Duflou, J. R. (2013). A refined typology of product-service systems based on functional hierarchy modeling. *Journal of Cleaner Production, 51*, 261-276.

Voigt, B.-F. (2015). Coping with the challanges of a heterogeneous working context - a configuration of individual competencies for PSS workers. *Procedia CIRP, 30*, 402-407.

Wilberg, J., Hollauer, C., & Omer, M. (2015). Supporting the Performance Assessment of Product-Service Systems during the Use Phase. *Procedia CIRP, 30*, 203-208.

Witjes, S., & Lozano, R. (2016). Towards a more Circular Economy: Proposing a framework linking sustainable public procurement and sustainable business models. *Resources, Conservation and Recycling, 112*, 37-44.

1. Appendix

1.1 Appendix A – Circular Economy

1.1.1 Linear Economy

In the last two centuries, mankind has experienced unprecedented growth of technology and the subsequent growth of the economy and global wealth. The industrial revolution sparked this growth and it laid the basis economical model on which our current, neo-classical, modern economy is still based upon, the linear economy. While the linear economy has been very successful, it is based on the take, make and waste principle, where natural resources are extracted from the earth using energy, labour and capital (take), are turned into products, using energy, labour and capital (make) and where the products are disposed after consumption (waste) (Ellen MacArthur Foundation, 2013a) (Anderson, 2007). This transformation process is a one-way life cycle in which any product is produced and eventually disposed using fossil fuels and along the way uses resources which can't be retained within the life cycle and are being considered waste (Ghisellini, Cialani, & Ulgiati, 2015). The current linear model can be seen in Figure 1.1.

While mankind has benefitted in a great way in the last two centuries, it is becoming more clear that a linear economy is not able to sustain the global wealth the human race is becoming accustomed to, even stronger, the current economy demands around 1,5 earths in the amount of resources now consumed. With the upcoming middle class and the expectation that the world population will hit 9 billion, the linear economy will demand around 3 or 4 earth's worth of resources (Bastein, Roelofs, Rietveld, & Hoogendoorn, 2013). The current economy, as well as growth, is based on the usage of fossil fuels and finite mineral resources (Sauvé, Bernard, & Sloan, 2015).

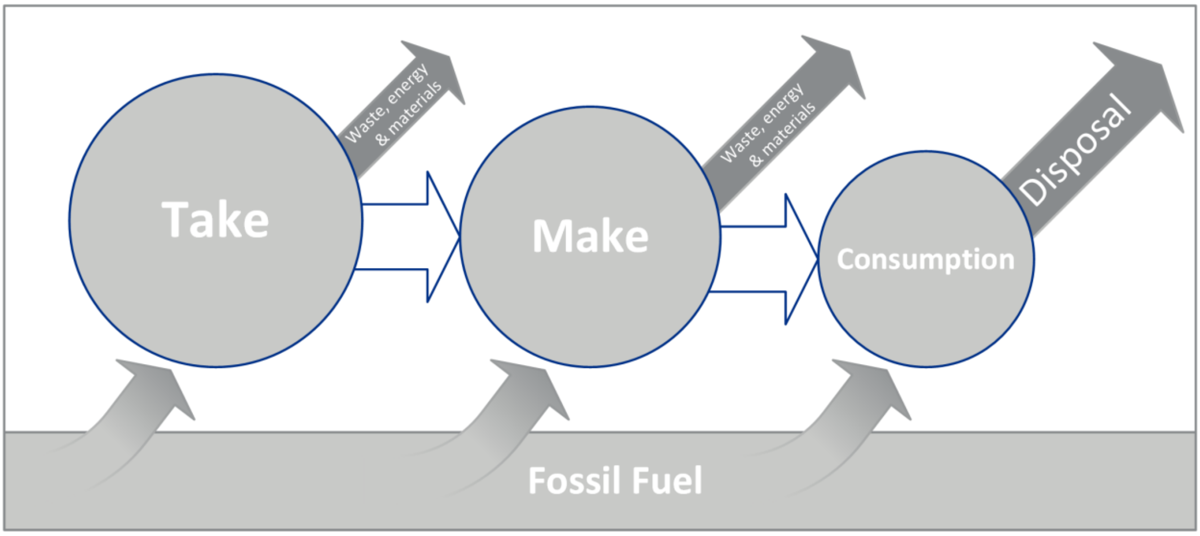


Figure 1.1 - Linear Economy model, adapted from the Ellen Macarthur Foundation (2014)

The linear economy is focussed on an ever more efficient production process which uses more energy, to reduce the amount of labour which is needed. Due to this concept of efficiency, the fact that fossil fuels and virgin mineral resources will never be renewable and the fact that the return or repair of products in the production chain creates extra costs (Schulte, 2013), makes that the consumption of resources and fossil fuels is still ever increasing (Lieder & Rashid, 2015).

The linear economy model is geared to improve the efficiency at every step in the production process, ensuring a maximum out at a minimum of cost for the producing firm and minimum cost of the product for the customer, with minimum regards for the environment. This model puts enormous pressure on the earth, to deliver the resources, on its ability to cope with the waste produced on the environment by the linear production process and by the planned obsolescence of products and the waste which is thus caused by the linear model (Lieder & Rashid, 2015) (Sauvé, Bernard, & Sloan, 2015). Some 60% of all materials used worldwide, is now being discarded as waste and does not enter the value chain (Ellen MacArthur Foundation, 2013a).

This will eventually lead to a scenario were the earth is unable to sustain the global population and wealth levels which are currently enjoyed by humankind, in combination that since 2000 the growth of the global GDP is no longer supported by a drop in the price of commodities. For a long time, the commodity prices have seen a steady decline due to an ever increasing technological advance which was enabling to extract more resources at lower cost. But, scarcity is becoming more and more common in the commodity sector and with the growing demand for rare metals the prices have become much more volatile, exposing firms to more risks. All these risks are purely from an economic point of view (Schulte, 2013).

From an environmental point of view, the linear economy pays virtually no regard towards the environmental impact it has. This is due to the fact that the benefit from productivity gain and growth is private, while the associated pollution of the ever increasing production is carried by society as a whole, because environment is a public good. Thus, the external costs of growth are not borne by those who profit most, therefore the production solution chosen is not the solution which has the minimum total cost, but the decision where the private benefit are the greatest, usually at the cost of the public good, the environment (Sauvé, Bernard, & Sloan, 2015) (Anderson, 2007). As can be concluded from above, the need exists for a solution.

1.1.2 Circular Economy

1.1.2.1 The Concept of Circular Economy

The concept of circular economy (CE) has gained considerable attention lately, for being a possible solution for the limitations the linear economy is facing in both wealth sustainability as well as environmental sustainability and thereby harmonising economic growth and environmental protection (Lieder & Rashid, 2015). The origin of CE can be traced back to the 1990's, where Pearce and Turner (1990) first used the term Circular Economy to describe a closed loop economic system, based on the laws of thermodynamics, that within a closed system, the earth, economy and environment are interconnected and that everything acts as an input for everything else. It is within this notion that the difference between the current linear economy model and CE becomes much clearer. While the linear economy is focussed on optimising the production process, CE is about optimising systems and decoupling growth from increased resource usage. If one takes nature as an example, one can see that waste does not exist in nature. In nature, the waste of one process is a resource for the next and this is performed in an extremely efficient manner (Schulte, 2013). This process can be replicated in our economy by transforming into a circular economy.

1.1.2.2 The Principles of Circular Economy

Circular Economy is a concept which can be seen as a large umbrella. In order to gain a better understanding of the concept, the principles of CE will be explained. This allows to scope this research into the most applicable part of CE for Schiphol. The first distinction which needs to be made, is that there are two kinds of material resource consumption (Ellen MacArthur Foundation, 2013a).

1. Biological nutrients
Resources which are suitable and designed to re-enter the biosphere and help to build natural capital and value.
2. Technical nutrients
High quality resources which are designed to circulate throughout the economy without entering the biosphere.

As can be understood from the above types of resources, the concept of waste is absent. This can however not be completely true, despite all intentions, because some form of waste will always be present (Ghisellini, Cialani, & Ulgiati, 2015). What can be done is to minimise waste by taking disassembly into design. In order to better scope this master thesis, it is important to state that whenever resources are mentioned, these resources consist of technical nutrients. The biological nutrients are outside the scope of this resource, because Schiphol uses mostly technical nutrients in their operation. From a macro point of view, the Circular Economy model can be seen in Figure 1.2. Compared to the linear economy model in Figure 1.1, it is clear that CE is much more aimed at optimising the system as a whole, through maintenance, reuse/redistribute, refurbish/remanufacture and recycle. It is important to know that the added value and the positive impact on the environment are greatest in the smaller circles and tend to lose value the bigger the circle becomes (e.g. reuse adds more value and positive impact on the environment than recycling).

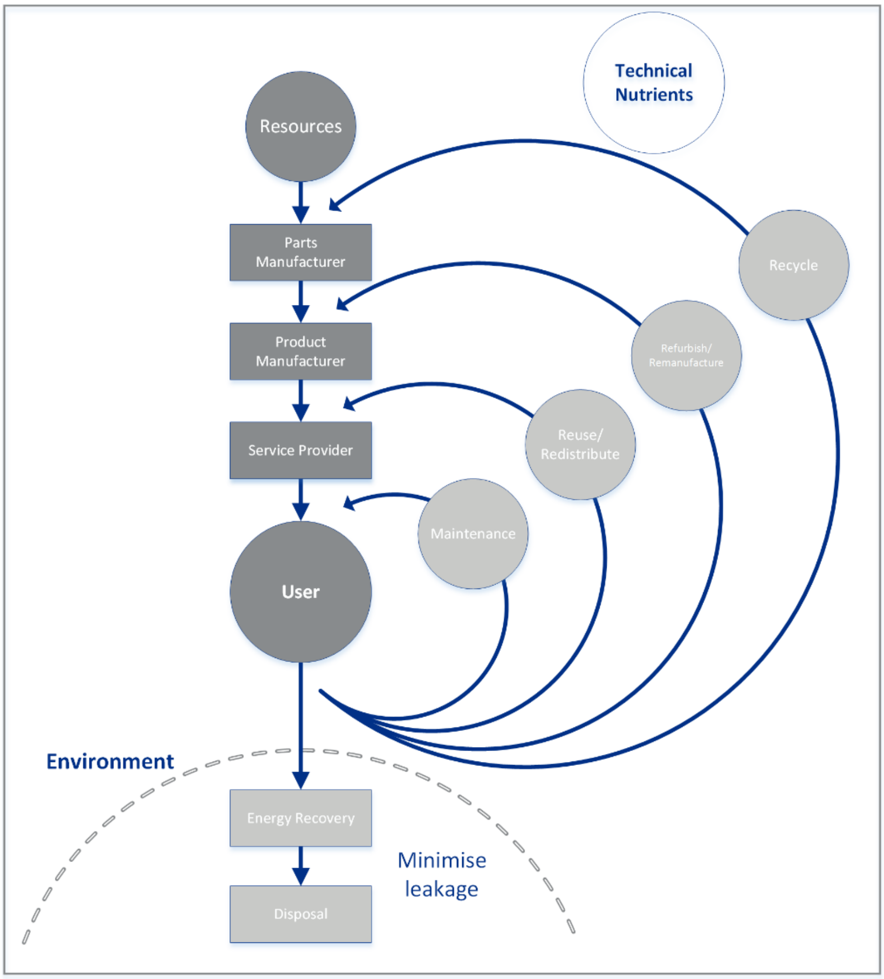


Figure 1.2 - The Circular Economy, adapted from the Ellen Macarthur Foundation (2014)

The next step is to give the key principles of CE. This ensures that it is clear which concept are considered CE and helps to further enhance the concept of CE and the scoping of this master thesis. CE is based on the 3R's; (1) Reduction, (2) Reuse and (3) Recycle. Each principle of CE can be explained throughout one of these terms. As stated earlier, the effectiveness and positive impact on the environment is largest at the first term and smallest at the last term. This can be used to determine the impact of principles which fall under CE and will help in determining further scoping of the research (Ellen MacArthur Foundation, 2013a) (Guidat, Barquet, Widera, Rozenfeld, & Seliger, 2014) (Schulte, 2013) (Witjes & Lozano, 2016).

1.1.2.2.1 Design out waste

Design out waste, or zero emission, is one of the strongest principles which is under CE. By making the right decision at the design phase of any product or process, waste can be virtually eliminated from the product. Furthermore, it can be combined with design to disassemble, in which one takes into account that a product may one day become obsolete and needs to be disassembled. By making sure it can be disassembled, parts reused and other resources recycled, the value can be maximised, while the impact on the environment can be significantly reduced. Design out waste is a strong advocate for CE due to the fact that it combines reduction, reuse and recycling, thus ensuring maximum and sustainable value creation (Witjes & Lozano, 2016).

1.1.2.2.2 Build resilience through diversity

Technology is advancing rapidly nowadays and whilst this brings forth many new and innovative solutions for problems, it can also cause accelerated obsolescence of products. In order to be prepared for such obsolescence, it is important that products and processes are designed to be modular, versatile and adaptive. By incorporating these properties into the design, a product can easily be upgraded or functionality added to be able to cope with future demands. Example could be a building where the façade is modular and can easily be replaced when future demand asks for it. This allows a reduction of materials, because a solid base is not needed to be completely replaced and it allows for reuse of this already existing base.

1.1.2.2.3 Rely on energy from renewable sources

Energy is one of the big enablers of the huge leap mankind has made the last two centuries. By using more energy, processes could be enlarger and made more labour efficient. The problem with using more energy is that it is usually produced from fossil fuels. As can be seen in Figure 1.1, fossil fuels are at the base of each step of the linear economy and the energy is usually transformed into heat and CO2. The impact of this transformation is a debate which is ongoing for many years and which will continue. As energy is at the base of many products and processes, it is important to get the energy needed from renewable sources. Fossil fuels are finite resources, which will become scarce. Scarcity will trigger high cost and will not contribute to value creation. Thus it is important to incorporate renewable energy into the business processes. Furthermore, CE looks upon how business process are performing nowadays. Currently, the taxation is on labour. Shifting this taxation towards finite resources, such as non-renewable energy and materials and of infinite resources such as labour and renewable energy, could spark an acceleration towards a circular economy (Ellen MacArthur Foundation, 2013a).

1.1.2.2.4 System optimisation

The current linear economy is focussed on a single process which it tries to optimise. The consequence of such action is that systems are used suboptimal or worse. In a circular economy, one should not think on a process level, but on a systems level. Everything is connected and this feedback rich systems should be optimised. This will produce optimisation on a large scale across the value chain and enhances the circular thought that everything is connected. If one looks upon a product as the product alone, it misses everything which is connected to it. From resource extraction, to waste management.

1.1.2.2.5 Maximise energy efficiency

The last principle is that a product should be designed that it uses the least amount of energy needed. Not only when it is operating, but the total energy content of the product or service throughout the whole life cycle needs to be minimised. This ensure a reduction of resources needed and will force producers of the product to think about their footprint. What can help to achieve this energy minimisation is the Extended Producers Responsibility and to incorporate external cost into the decision making. Which both enable the principle of polluter pays and therefore increase informed decision making.

1.1.2.2.6 Customers want performance not a product

A key ingredient of CE is that people tend to forget that they actually don't want a product, but that they want the performance of that product and that is the reason why they purchased it. Within this idea, one could state that this allows a shift towards selling a service instead of a product.

1.1.2.2.7 Continued ownership is cost efficient

Whenever a product change of ownership, transaction costs are applied. By reuse, repair and remanufacturing, while the ownership does not change, an increase in cost efficiency could be realised, because transaction costs are prevented. This principle, together with the need of customers for performance, not product, is the ideal basis for a service based industry, where one party remains owner and therefore keeps control over (cost) efficient use of the product.

1.1.3 Transformation

The promises CE has, could revolutionise the world. But, as with any great change, the change itself, the transformation is the hardest part. While the benefits of CE are apparent, it is hard for people, businesses and governments to decide to switch towards CE. This is because while the environmental benefits are clear, the risks and the transformation process towards CE, in corporation with the economic benefits are not. That is why it is necessary to explore what kind of process is best suited to enable the transformation.

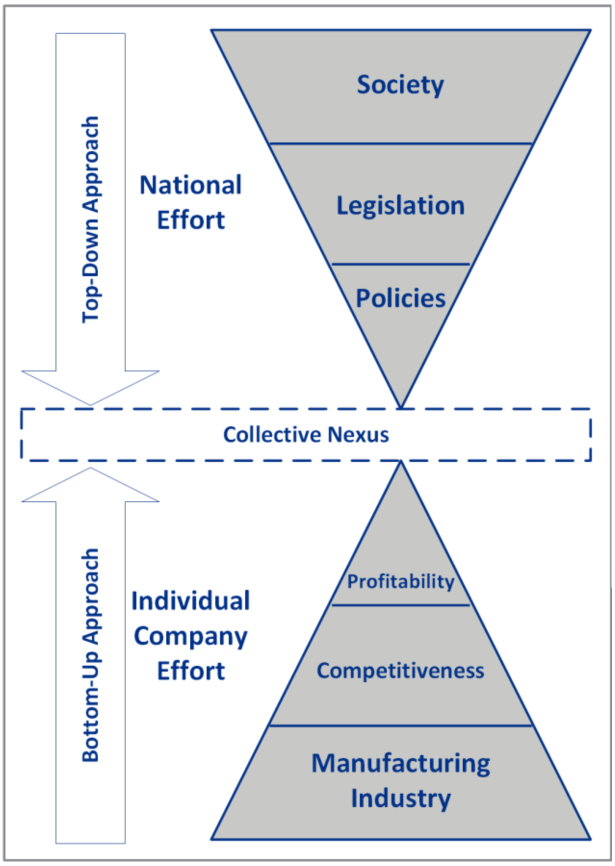
The first notion which is made, is that transformation enablers can roughly be divided into two categories. The first is a top down approach and the second is a bottom up approach. The approaches both have their advantages and disadvantages in their ability to implementation of CE in businesses. Important to know is that the choice of approach, heavily depends on the view uphold by the stakeholder involved.

Governmental and regulatory bodies together with policy makers benefit more from a top down approach, where through legislation a collective consciousness can be implemented (Lieder & Rashid, 2015).

A bottom up approach is more suited for business in order to motivate them to incorporate collaborative business models, product design, supply chain and IT into their business processes and benefit from the economic benefits from CE, becoming more resilient against resource scarcity and reduce the environmental impact.

As can be seen in Figure 1.4, both approaches meet in the middle and form a collective nexus, a mind-set which enables the transformation towards a circular economy. It shows that both the willingness from the governmental bodies, as well as the drive from individual business is needed to succeed.

In order to succeed towards CE, it is important to understand what will be at the source of a successful business model. Based upon Lieder & Rashid (2015), one can see that there are two approaches. Within this thesis the bottom up approach will be the basis, due to the fact that Schiphol is an individual company and a service provider.



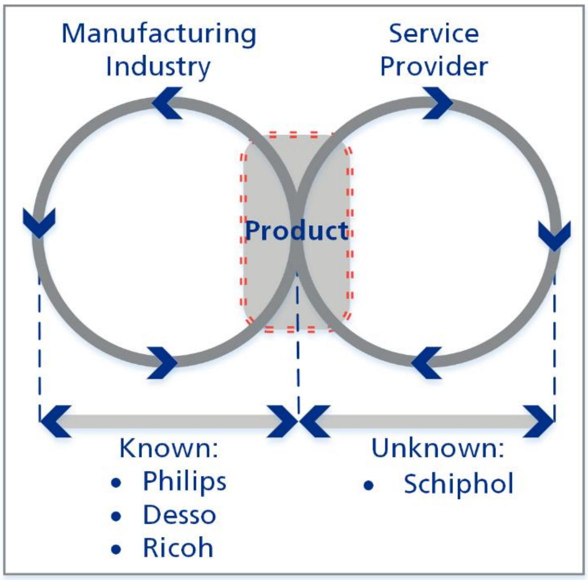


Figure 1.3 - Knowledge gap CE on service providers

Figure 1.4 - CE Implementation Approach, based upon Lieder & Rashid (2015)

The problem is that most literature on CE is from a manufacturer point of view. This is due to the nature of how CE is currently being researched. In Figure 1.3, a visualisation can be seen on how the manufacturing industry and service providers are working in collaboration. Products are the main source of energy and resource used and are therefore at the centre of research on CE. There are a few cases where manufacturing firms have been successful at shifting towards becoming a service provider, e.g. Philips, Desso and Ricoh (Ellen MacArthur Foundation, 2013a) (Ellen MacArthur Foundation, 2013c) (Adrodegari, Alghisi, Ardolino, & Saccani, 2015). The business models for manufacturing companies are easier to grasp, because they are more likely to retain the ownership and therefore complete control during the life cycle of their product. For a service provider, like Schiphol, it is clear that they use the performance of the product, but how performance adds value to their organisation is unclear from academic literature. Therefore, it can be stated that a knowledge gap exists within the current literature on CE on the effects of performance economy on service providers.

Despite the knowledge gap, the transformation towards CE can still draw upon knowledge on how manufacturers should change. As Lieder & Rashid (2015) state, the current step manufacturers take is the transition of selling goods towards providing service. It can therefore be stated that a transition towards a performance economy will facilitate the transformation towards a circular economy, because manufacturers are becoming more aware of their impact in a performance economy, than in the old linear product selling economy (Guidat, Barquet, Widera, Rozenfeld, & Seliger, 2014) (Fernandes de Castro Rodrigues, Nappi, & Rozenfeld, 2014).

Transformation towards a performance economy is however not a step which is easily made, because once again the economic benefits are not entirely clear, nor is the process towards it. This demands a solution on how performance economy could be implemented successfully, keeping in mind the principles of CE. As Adrodegari., *et al.* (2015), Bastein, T. *et al.* (2013), Beuren, Ferreire, & Miguel (2013) Lieder., *et al.* (2015), Tukker (2015), Van Ostaeyen (2014) and Witjes & Lozano (2016) suggest, Product-Service Systems (PSS) could be the tool in this transition.

1.1.3.1 Challenges for CE

Besides the benefits of CE, there are also challenges which need to be addressed if CE is to succeed in its mission to change the way our economy operates. Because CE is about system optimisation, it is important that the whole value chain steps in. Especially end users have a big influence as final customers, because they can demand that their products need to become more sustainable. Next, the legislators should provide the tools to facilitate circular economy. The current regulation is largely focussed on linear economy and using energy and resources to reduce labour, which is taxed the highest. Furthermore, one needs to become aware that (potential) revolutions are not always completely the best and most efficient solution at the starting point. The efficiency of the first steam engine, which powered mankind into the modern era, was very inefficient, its effects unprecedented (Ghisellini, Cialani, & Ulgiati, 2015).

Another challenge of CE is that the organisation has to be ready to facilitate. Especially if the transition is going via performance economy, the organisational challenges have to be clear and thought about. Especially the new relationship with stakeholders, as well as new organisational demands could have consequences on the transition (Kimita, Watanbe, Hara, & Komoto, 2015) (Lindstöm, 2016) (Voigt, 2015).

1.2 Appendix B – Product-Service Systems

1.2.1 Definition of Product-Service Systems

In order to create a clear picture of what is meant by a Product-Service System, the definition of van Ostaeyen (2014) is used, which is in line with Beuren, Ferreire & Miguel (2013) and Sassenelli, Pezzotta, Rossi, Terzi, & Cavalieri (2015):

'A Product-Service System (PSS) is an integrated offering of products and services with a revenue mechanism that is based on selling availability, usage or performance'

1.2.2 Product-Service Systems Types

Besides a clear definition of a PSS, it is clear that there are different PSS typologies (van Ostaeyen, 2014). It is important that the categorisation is clear, because it can have a large impact on whether PSS is successful and a good transformation enabler for CE, or not. Van Ostaeyen (2014) defines three different PSS types, which are widely accepted within the academic PSS literature (Van Ostaeyen, Van Horenbeek, Pintelon, & Duflou, 2013):

1. Product-oriented PSS
2. Use-oriented PSS
3. Result-oriented PSS

It is important with the focus on sustainable development to understand the differences between these three types. Because using a PSS concept does not automatically produce sustainable development (Guidat, Barquet, Widera, Rozenfeld, & Seliger, 2014) (Kuijken, Gemser, & Wijnberg, 2016) (Pigosso & McAloone, 2015) (Sousa & Cauchick Miguel, 2015).

The first type, product-oriented, the ownership of the product is transferred to the customer. The transfer of ownership is not optimal and thus product-oriented PSS is unsuitable for enabling the transition towards CE. This is underpinned by van Ostaeyen (2014), who also stated that this transfer of ownership discerns it from the other two types of PSS. It is still focussed on selling the largest amount of products, which in itself is certainly not the most sustainable solution (Costa, Prendeville, Beverley, Teso, & Brooker, 2015) (Schweitzer & Aurich, 2010).

With a use-oriented PSS, the ownership remains at the producer of the product and the right to use the product are sold to the customer. Classic use-oriented PSS is for instance the leasing of products. Although this might seem like a sustainable development, it can often produce a counter effect which cancels out any environmental advantages (Scheepens, Vogtländer, & Brezet, 2016)s. For instance, lease cars are not driven with greater fuel efficiency or greater care, because the customer does not bear the direct cost or benefit of doing so (Aurich, Mannweiler, & Schweitzer, 2010) (Costa, Prendeville, Beverley, Teso, & Brooker, 2015) (Schweitzer & Aurich, 2010).

The last type is a result-oriented PSS. As stated earlier, PSS does not automatically provide sustainable development. The PSS concept should create the need for sustainability, that it is beneficial for both the manufacturer as well as the customer. Tukker (2015) indicates that only result-oriented is able to fulfil this sustainable development, because with a result-oriented PSS not a product is sold, but functionality (Van Ostaeyen, Van Horenbeek, Pintelon, & Duflou, 2013). It is performance driven and the ownership remains with the manufacturer, who is responsible for the product throughout the life cycle. This means that the disposal is the responsibility of the manufacturing, who then has a strong incentive for reduction of resource usage, reuse of products and the recycling during the disposal phase (Ghisellini, Cialani, & Ulgiati, 2015) (Beuren, Ferreire, & Miguel, 2013) (Fernandes de Castro Rodrigues, Nappi, & Rozenfeld, 2014). Performance agreements could include more than just functional performance, for instance sustainability targets. Furthermore, all materials and consumables needed for delivering the performance are now cost factors for the manufacturer, it therefore it has a stronger incentive to reduce the use of those resources (Tukker, 2015), which is positive because, as stated in (1.1.2.2), reduction is one of the key principles of CE in terms of sustainability.

1.2.3 Benefits, barriers and best practices of Product-Service Systems

1.2.3.1 Benefits

Result-oriented PSS may benefit consumer, supplier, the environment and society as a whole in a variety of ways. Due to the lasting relationship between customer and supplier, the potential to continuously improve performance, competitiveness and environmental performance. If successfully, this could lead to a long lasting relationship and alliance which benefit both and cause a win-win scenario (Beuren *et al.,* 2013). In turn, this will lead to high quality assets and customer satisfaction (Aurich *et al.*, 2010). Due to the good relationship, new innovations and systems are more easily developed with the customer involved (Tukker, 2015). Furthermore, by better quality, longer lifetime of the product/asset and the incentive for smart disposal, the amount of waste can be reduced. This reduces the need for new material for new products and increases the usage of old products. Which is one of the pillars of circular economy (Baines *et al.*, 2007). Lastly, PSS has the potential to break the link between production volume and profit, therefore seamlessly supporting what circular economy tries to achieve (Pigosso & McAloone, 2015).

1.2.3.2 Barriers

Besides the benefits, there are also barriers which have to be overcome in order to implement a PSS successfully (Kimita, Watanbe, Hara, & Komoto, 2015). The whole process of a PSS compared to traditional buying of a product is different. It requires a change of all stakeholders involved in the process, especially due to the increased involvement in one another. Responsibilities shift, dependency increases, financial risks changes and information exchange increase (Beuren *et al.,* 2013) (Schnürmacher, Haka, & Stark, 2015) (Lockett, Johnson, Evans, & Bastl, 2011) (Witjes & Lozano, 2016). The increased dependency can also be interpreted by the customer as a perceived loss of know-how (Gesing, Maiwald, Wieseke, & Sturm, 2014). However, the biggest barrier is, as always, the cultural barrier within an organisation (Schmidt, Malaschewski, Fluhr, & Mörtl, 2015) (Voigt, 2015). In the case of Schiphol, Schiphol has to move away from the practise of full ownership of an asset towards an user of an asset and being able to steer on performance. This requires a focus on the use of the product/asset together with a clear view of the planning of the service needed (Moser, Maisenbacher, Kasperek, & Maurer, 2015). The last barrier which exists within organisations is that the value of a PSS compared to a traditional way of purchasing an asset, is hard to show upfront and on the short term (Kuijken, Gemser, & Wijnberg, 2016).

1.2.3.3 Procurement

The last thing which may cause a problem is the traditional way of procurement, which is standardised in the EU Public Procurement Directive, which is also applied within Schiphol with projects larger than predetermined amounts, depending on which main contract the project is within. The traditional procurement process, as is also present at Schiphol, can be schematically seen in Figure 1.5.

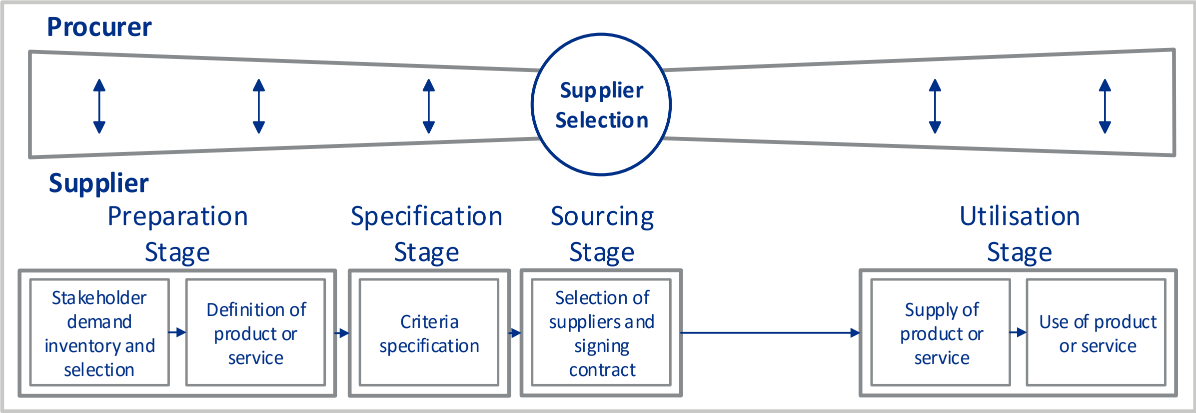


Figure 1.5 - Traditional Procurement based on Witjes & Lozano (2016)

The problem with traditional procurement, is that the supplier selection is relatively late in the process. With traditional product or asset purchase, this is not an issue, mainly because the price is per product unit. But with PSS, the collaboration between procurer/purchaser and supplier is essential and the price will change to price for a service or function. Therefore, the traditional process no longer suffices.

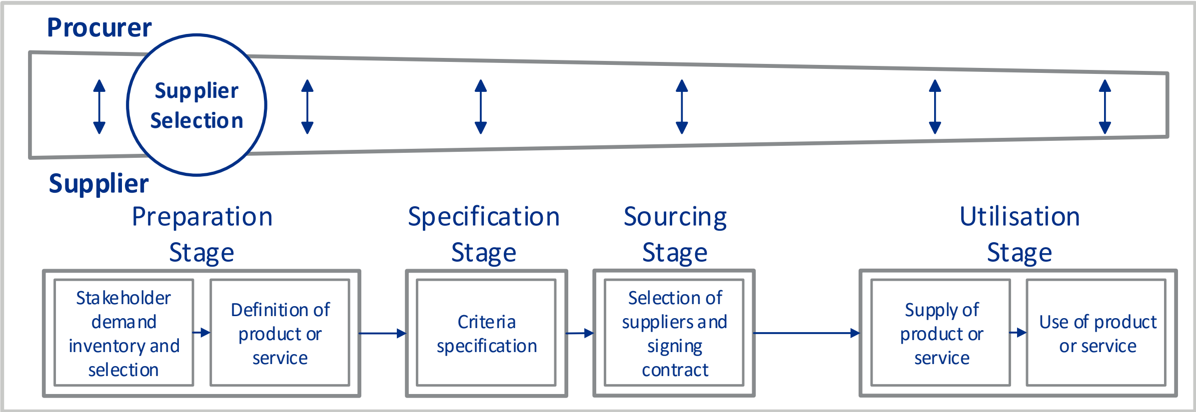


Figure 1.6 - CE Procurement based on Witjes & Lozano (2016)

The procurement process which supports circular economy and PSS can be seen in Figure 1.6. Due to the increased dependence, the supplier needs to be involved earlier on in the process. This causes that the supplier selection needs to be earlier on. In order to properly select a supplier, the procurer needs to have clear selection requirements. The requirements should reflect the change from purely technical specifications to a collaboration of technical and non-technical specifications, combined with sustainability goals, such as disposal, resource usage, closing the loop and energy performance, from the procurer and the feasibility assumptions of the supplier regarding those goals (Aurich, Fuchs, & Wagenknecht, 2006) (Witjes & Lozano, 2016).

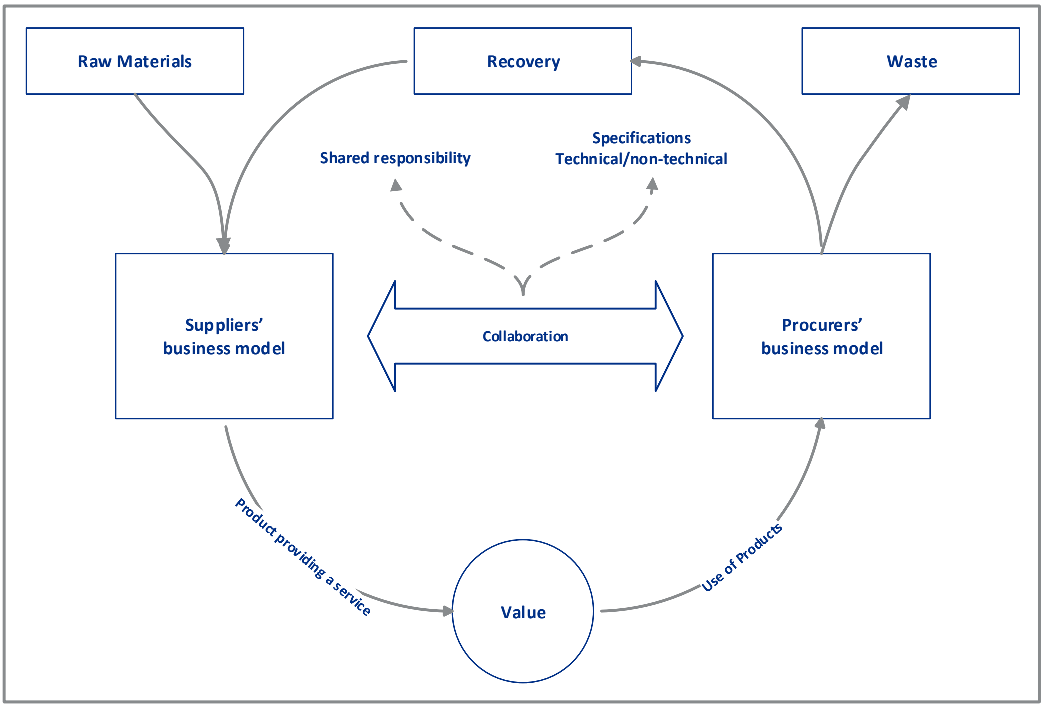


Figure 1.7 - Collaboration between Procurer and Supplier based on Witjes & Lozano (2016)

In the traditional procurement, specifications are determined by the procurer alone. With an more PSS oriented procurement process, the business model during procurement with product flow looks like Figure 1.7. Where there is close collaboration between supplier and procurer and that this leads to shared responsibilities as well as specifications determined together. This maximises the result, because the supplier can check whether it regards the (sustainability) goals of the procurer as feasible.

Due to the changes in procurement, it can be concluded that the stakeholder involvement and management becomes much more important, due to the change of moment when a supplier becomes involved, as well as the increased dependency between both parties.

1.2.3.4 Best Practices

Within literature several best practices have been identified. These practices can help to better shape the transition towards PSS. The best practices are defined from a manufacturing point of view, but nonetheless, they can help to structure the thinking of a procurer, because it can help to steer and demand certain actions from their supplier. Pigosso & McAloone (2015) have provided a clear list of all best practices:

1. Develop a business model that can support the transition towards PSS
2. Create networks that foster innovation and promote customer resource integration
3. Define PSS offerings and value propositions to be provided to customers and stakeholders
4. Add service elements to the portfolio of offerings
5. Understand customer value creation processes to develop suited and specific value propositions
6. Co-create value together with the customers by developing service- and customer- oriented offerings
7. Identify available offerings in the market
8. Understand the life cycle of the offerings
9. Map and visualise the actual activities of the users of the company's offerings

10. Focus on value-driven communication of offerings – clearly communicate the value associated with the PSS offer.
11. Increase the extent of interactions with customers through the PSS offerings
12. Collect PSS data through increased interaction with customers
13. Align physical product characteristics with service offer characteristics and vice-versa
14. Identify preferable product properties to increase the value of the PSS business
15. Define the level of customization of the PSS offering
16. Assess strengths and weaknesses of the current product portfolio and markets
17. Identify the market value of the PSS compared to the competing product in term of tangible and intangible value

1.2.4 Decision making for a PSS value proposition

Compared to traditional asset valuation, a PSS consists of a tangible component, the asset, and an intangible component, the service component. To make sure that value is clear, the following definition is used (Rese, Karger, & Strotmann, 2009):

"Value is the worth in monetary terms of economic, commercial, technical service and social benefit of customer's firm receives in exchange for the price it pays for a market offering."

However, the introduction of a service component in the valuation of an asset causes a new problem with valuation. How does one value a service component? The intangible part of the PSS is much harder to value and therefore it is more difficult for the customer to know if the price stated by a service provider is proper value for money, or not. This results in the problem that a value is needed for decision making, because as stated in Blauwdruk Assetmanagement (Asset Wise! Team Schiphol, 2015), Schiphol uses a TCO model to value alternatives on their monetary properties and it is a core component of the decision making process. Therefore, being able to value a PSS is important, if a fair and well comparison is to be made.

Before exploring how the value of a PSS can be determined, different valuation techniques will be treated. This to strengthen the understanding of the decision making process, as well as provide the tools for making the PSS valuation possible.

1.2.4.1 Net Present Value

One of the most well know valuation technique within project valuation is the Net Present Value (NPV) technique using Discounted Cash Flow (DCF). Using the NPV all future cash flows are taken into account and therefore a value can be determined. In order to capture all financial aspects of the life of an asset with regards for the influence of time on monetary value, discounting is used. The NPV is a wide spread method to value projects and can be calculated using the following formula (Brealey, Myers, & Allin, 2011) (Samis, Davis, Laughton, & Poulin, 2006):

$$NPV(i,N) = \sum_{t=0}^{N} \frac{C_t}{(1+r)^t}$$

where,

$$CF_t = Net\ Cash\ Flow\ at\ time\ t$$

$$t = time\ of\ the\ Cash\ Flow$$

$$r\ = discount\ rate$$

$$N = number\ of\ periods$$

The basic theory behind the NPV is that the project with the highest NPV should be accepted, because it adds the most value to a firm. If a project has a negative NPV is should be rejected, because it subtracts value from the firm. If the NPV would be zero, one should be indifferent between accepting or rejecting the project and decision making needs to be based on other criteria.

Expanding this to the perspective of the customer, e.g. Schiphol, the standard NPV valuation of a project at Schiphol is as follows (Rese, Karger, & Strotmann, 2009):

$$NPV_0 = -I_0 + \sum_{t=1}^{N} E_t * \frac{1}{(1+WACC)^t}$$

$$where,$$

$$I_0 = Investment\ at\ t = 0$$

$$E_t = Expenses\ at\ t$$

$$WACC = Weighted\ Average\ Cost\ of\ Capital\ of\ Customer$$

Within Schiphol, the Net Present Value technique is used to determine the Total Cost of Ownership (TCO). The TCO is in principle nothing else than an extended NPV where all costs and benefits over the life time of an asset or project are taken into account. This allows to capture the full value and make an informed decision about an asset over its complete (useful) lifetime. As stated in the current situation, Schiphol uses the Equivalent Annual Cost to transform the NPV to an annuity, in order to see what the cost per year would be.

The deficiency of a straight forward NPV analysis, is that risk and uncertainties are not captured. This problem can be overcome by several techniques and this is where the valuation of PSS will become more substantial.

1.2.4.2 Sensitivity Analysis

One of the best known techniques for checking uncertainties is sensitivity analysis. With sensitivity analysis, one checks what will happen if one of the parameters changes, or the assigned weight of a parameter changes. There are several parameters which can change during the course of an asset. Maintenance costs, replacement cost, energy, WACC, all can change during the lifetime of an asset and they all can have an effect on the value of a project. With sensitivity analysis, one parameter is changed and seen what kind of effect it has on the NPV. The limitation of sensitivity analysis is, that it only allows for one parameter to change. This limits the exploratory effect and it does not allow for the change of multiple parameters, therefore making it difficult to check on this effect (e.g. strengthening or dampening the effect of the changes). But it can give an idea of the sensitivity of the NPV to parameters.

1.2.4.3 Scenario Analysis

Another way of testing the NPV is by scenario analysis. Scenario analysis allows for multiple parameter to change according to the scenario specified. It calls upon the knowledge of the user to come up with possible or likely scenarios, both best and worst cases, which might occur and see what kind of effect it may have on the project valuation. It can therefore be considered more advanced than sensitivity analysis. The downside of scenario analysis is that every scenario must be thought of and implemented in to the NPV calculation in order to check it. This can be cumbersome and tedious work, especially if projects are larger and more complex. Common scenarios often include, different interest rates, life span, residual value, replacement moments and maintenance costs.

Scenario analysis can be used in order to value PSS, because it allows to think about different states of an asset and which risks could occur (Sundin, Nässlander, & Lelah, 2015). This can then be used to make an assessment of what scenarios are possible for a supplier of a service and therefore assess which risks and uncertainties a supplier will be faced with. This can be used to explain why a supplier is offering a higher price, because it wants to be compensated for carrying the risks as were identified using scenario analysis.

1.2.4.4 Real Options

Real option (RO) theory is often presented as an alternative to the Discounted Cash Flow, or NPV, to value a project. Every project brings forth a number of options which might be executed in the future, or not. This managerial flexibility can be of great value, especially in the replacement or extra maintenance decision making. The parallel to the PSS and the traditional asset purchase and maintaining is easily made. Therefore, a part on Real Option Theory will contribute to a possible understanding and valuation of possibilities in the future.

The main difference between a NPV and a Real Option approach is that uncertainty in future cash flow and the risk which comes with it can be adjusted for, while in the NPV it can only be aggregated in the bigger picture, thus losing the flexibility or the ability to differentiate on the different risks involved. RO is able to distinguish between different options present in future time. Whether to irreversibly invest, or to postpone the investment (Santos, Soares, Mendes, & Ferreira, 2014).

Besides the difference, there are similarities between the DCF and the RO approach of valuing a project. Both see assets as uncertain cash flows received over a period of time. Both recognise that the value of an asset depends on the cash flow and it respective timing and summed gives the value of the asset, given the underlying assumptions. While the standard NPV approach uses one discount rate, in Schiphol's case the WACC, to discount the cash flow for the appropriate risk and time, the Real Option approach uses a twostep approach.

Because every cash flow timing brings forth different risks, the first thing RO approach does is a risk adjustment. Each cash flow is adjusted for the its uncertainty, before it is discounted and added to the sum to value the respective asset. To put it more clearly, what RO does is valuing an asset as a portfolio of claims to individual cash flow elements and adjusting for uncertainty and the discounting for time (Samis, Davis, Laughton, & Poulin, 2006).

The problem with a Real Option approach, is that it is hard to make a proper assessment on the size of the cash flow. This allows for much noise to be added to the project valuation, which makes it hard to state that the estimate using Real Options is trustworthy.

1.2.4.5 Monte Carlo Simulation

Monte Carlo simulation is considered a very powerful technique to get an insight into all kind of possible scenarios via simulation. By randomly picking different changes in parameters and repeating this numerous times, many different scenarios can be assessed. These are then represented with a certain possibility and likelihood for which one can state that, given the probability distribution of the parameters, with an e.g. 95% level of certainty the NPV is not higher than a certain amount. The problem with Monte Carlo simulation is that certain assumptions lay underneath it. Parameters have to be assigned a certain probability distribution in order to randomly vary them. This probability distribution is usually based upon historical data, where a distribution can be fitted on. The problem which this poses regarding PSS, is that the usage of PSS is quite often not a well-established discipline for both customer and supplier. This causes that there is often little historical information on the costs incurred from including the service layer. This poses a problem with using Monte Carlo, despite the advantages simulation has (Fernandes de Castro Rodrigues, Nappi, & Rozenfeld, 2014).

While the assessment of the service part is often a problem, due to the lack of historical data, the assessment of the tangible component part can often be well executed and is done on a regular scale, especially within Schiphol, which has a lot of asset on its balance and therefore quite some experience with the purchase, usage and maintenance of such assets. The uncertainties related to this ownership are transferred to the supplier, if a PSS is requested. While this may not sound like the solution to the problem of little historical data on service costs, it opens up a possibility to overcome the problem of little knowledge on service costs.

It is hard to put a figure on the risk premium a supplier adds to the service cost, because it needs to carry additional risks and uncertainties compared to traditional product selling. Also, it is not difficult to imagine that a supplier would never just give such a number, because it is also an extra earnings potential and therefore a leverage position towards a customer in price negotiations. But, it can be understood, that for a supplier of such a service it is also hard to assess what a decent risk premium is, to carry the risks of ownership.

Schiphol and its supplier are not the first who have encountered this problem. The defence industry struggled with the same question. The military just wanted to use their assets for their primary process, providing safety and protection. They did not want to purchase a war ship and then also needed to be able to do the maintenance. They wanted outsource such services to a long term partner, preferably the supplier of the ships, due to its expertise on the ship. The question which was raised by the supplier was, what is a sensible figure for such a service, given the uncertainties and risk it had to carry, due to the ownership. Erkoyuncu (2011) developed a model which allowed to perform Cost Estimation under Uncertainty in order to determine a fair price for providing such a Product-Service System with the associated risks and uncertainties. While the focus of his model is on a fair price setting for suppliers of Product-Service Systems, one can think of reversing the model and use the model as a check on whether the price offered by a supplier is a fair price for the customer, given the uncertainties the customer can perceive at the supplier for carrying the additional risks and uncertainties.

1.2.4.6 Risk and Uncertainty Management in Product-Service Systems

In order to better grasp how cost estimation under uncertainty can be performed, it is important to get a better understanding of what risk and uncertainties are. Everything is inherently connected with risks and uncertainties, PSS's are no exception. Product-Service Systems introduce different types of risks and uncertainties compared to traditional asset ownership and usage. In order to better understand what kind of risk and uncertainties exist, the relationship between uncertainty and risk is defined as well as what an uncertainty is. For uncertainty, the following definition is used (Herzog, Meuris, Bender, & Sadek, 2014):

"Uncertainty is the stochastic behaviour of any physical phenomenon that causes the indefiniteness of outcomes meaning the expected and actual outcomes are never the same."

Within the scope of Product-Service Systems, risk can be defined as follows (Erkoyuncu, 2011):

"Risk is a special outcome of uncertainty, where the outcome of a specific event or a number of events have a negative effect on the overall performance of a project."

Thus risks follow from uncertainties and therefore the focus will be on uncertainty, because accounting for uncertainty will automatically cover the risks.

As stated earlier, it is important to account for risks and uncertainties, because when acquiring a PSS, risks and uncertainties become inherently connected to the price and therefore the value of a PSS. In order to make a comparison between traditional asset purchase and ownership and a PSS, the assessment of such uncertainties is needed to be made in order to know whether the price offered by a supplier is fair.

How does this relate to Schiphol is the next question which needs to be answered. Schiphol is well experienced in assessing the costs related to the purchase and ownership of an asset. It has a Cost-Expertise-Centre (CEC), which can offer cost estimates on many different assets and products and is used in order to make a TCO for decision making. So, when Schiphol is carrying the risks and uncertainties, a cost estimation can be made. But how can Schiphol use its own cost estimation knowledge in determining a fair price for acquiring a service instead of an asset.

This is where the model of Erkoyuncu (2011) comes into play. Using the cost estimation from the CEC and the model of Erkoyuncu, an uncertainty layer can be added to the cost estimation and it can take into account the risk premium a supplier adds, in order to carry the additional risk and uncertainty. By combining these to, a fair comparison can be made between traditional ownership and therefore NPV valuation and the PSS NPV valuation where it can be stated that the valuation accounts for the different risk profiles of each alternative. Secondly, it provides Schiphol with a tool to assess the offer of a supplier of an PSS. By taking into account the uncertainty a supplier is faced with and using the internal TCO model, an estimate can be determined for what Schiphol regards as a fair price for the required service from a supplier.

1.2.4.7 Cost Estimation under Uncertainty

In order make a fair comparison between the traditional purchase of an asset and the purchase of a service, it is necessary to account for the increased risk and uncertainty for the supplier, due to the retained ownership and the responsibilities which are connected with being owner. In order to price in these uncertainties, the cost estimation procedure of Erkoyuncu (2011) will be used. It consists of roughly 8 phases, which allows for a systematic assessment of uncertainties related to any project valuation. Each phase consists of an activity which needs to be performed, this activity will be explained as well as the technique used in how it contributes to the cost estimation under uncertainty. In Figure 1.8, a visual representation of his model can be seen. In the next section, the various phase will be further explained.

1.2.4.8 Cost Estimation under Uncertainty Model

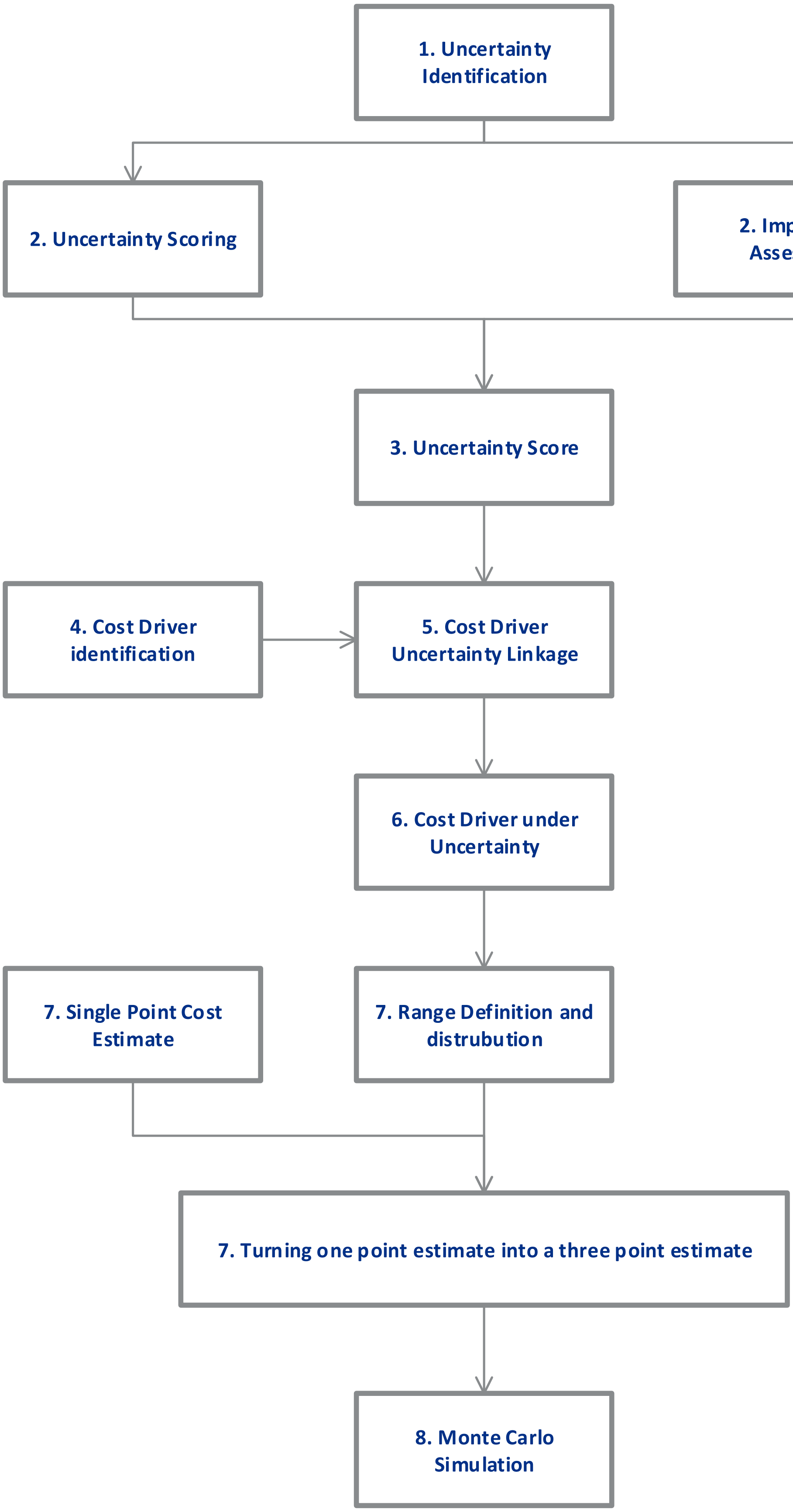


Figure 1.8 - Cost Estimation under Uncertainty adapted from Erkoyuncu (2011)

1.2.4.8.1 Uncertainty identification

Erkoyuncu (2011) distinguished 6 main categories of uncertainty. His research focusses on the uncertainties as experienced by manufacturers in the defence industry in their effort to determine a good price for offering a service. These main categories can be used as a guideline in assessing the main categories of uncertainty for suppliers of Schiphol.

1.	Commercial Uncertainty	Factors that affect the contractual agreement, driven by requirements of the customer. However, the supplier is responsible for defining these requirements based on the capability.
2.	Affordability Uncertainty	Factors that affect ability to predict customer's and/or supplier's funding capabilities.
3.	Performance Uncertainty	Factors that affect the achievement in reaching the performance goals (KPI).
4.	Training Uncertainty	Factors that affect achievement in reaching customer's needs for the delivery of training.
5.	Operation Uncertainty	Factors that affect achievement in reaching the required level of service and support delivery. Focusses on equipment level (e.g. maintenance etc.).
6.	Engineering Uncertainty	Factors that affect the achievement in managing strategic decisions with regards to the future service and support requirement (e.g. End-of-Life etc.).

These 6 main uncertainties categories consist of many uncertainties. A complete list of these uncertainties can be found in Appendix X. Besides the uncertainties of Enkoyuncu, the following uncertainties are also identified by Reim *et al.*, (2013):

1. Hard to communicate value
2. Inappropriate organisational structure
3. Cultural antipathy
4. Monitoring and information sharing
5. Too extensive or difficult contracts
6. Lack of resources and capabilities
7. Lack of financial resources
8. Complex supply chain
9. Adverse behaviour
10. Breakdown risk

Given the uncertainties provided, the actor has to assess which uncertainty is relevant for the project and should therefore be included in the uncertainty assessment.

1.2.4.8.2 Uncertainty assessment and relative significance

The next step is to determine the score of each uncertainty. Erkoyuncu (2011) uses 3 categories for which the actor has to determine a score (1, 3, 5 or 7). The three categories are:

1. Basic Estimate

2. Rigour in Assessment
3. Level of Validation

Basic estimate regards on the basic estimate of uncertainty taken into account how experienced the firm and/or actor is in assessing the given uncertainty. The Rigour of Assessment regards the accuracy of the basic estimate and whether it can be based on internal knowledge on the uncertainty. The level of validation regards on how well the score can be validated outside the firm.

These three categories can be assessed using the following scoring using the guideline from Figure 1.9.

Basis of Estimate	Rigour of Assessment	Level of Validation
7: No Experience in the area	7: No established assessment of processes	7: No validation
5: Incomplete data, small sample, educated guesses, indirect approximate rule of thumb estimate	5: Limited experience of applied process with lack of consensus on results	5: Limited internal validation, no independent validation
3: Small sample of historical data, parametric estimates, some experience in the area, internally verified data	3: Sufficiently experienced and benhmarked internal processes with consensus on results	3: Internally validated with sufficient coverage of models, processes and verified data. Limited independent validation
1: Best possible data, large sample, use of historical field data, validated tools and independently verified data	1: Best practice in well established discipline	1: Best available, independent validation within domain, full coverage of models and processes.

Figure 1.9 - Uncertainty Scoring Guidelines based on Erkoyuncu (2011)

The next step is to assess the relative importance of each uncertainty against the whole project. This is done within each category of uncertainty. A score from 1 to 9 is given to each uncertainty and using a partial Analytical Hierarchy Process (Saaty, 1990), the significance score is transformed into a pairwise comparison and normalised weights using a priority vector, which is the principal eigenvector of the score matrix, which is produced by scoring each uncertainty. Then the score is normalised to a scale relative to the most importance and significant uncertainty (given the weight of 1 and the others are compared to this score). The significance categories from 1 to 9 can be found in Figure 1.10.

Pairwise Comparison

The following significance/relevance can be assigned to each uncertainty. This will be automatically translated in a relative weighted importance of each uncertainty via the AHP process.

1: Not significant/relevant. 2: Not significant/relevant to moderately significant/relevant. 3: Moderately significant/relevant. 4: Moderately to strongly significant/relevant. 5: Strongly significant/relevant. 6: Strongly to very strongly significant/relevant. 7: Very strongly significant/relevant. 8: Very strongly to extremely significant/relevant. 9: Extremely significant/relevant.

Figure 1.10 - Significance Categories based on Erkoyuncu (2011)

An example can be found in Table 1.1, the input significance score is provided in the green column for each uncertainty. Using the matrix from Table 1.2 the normalised weights are calculated and expressed again in Table 1.1. The normalised weights are the final scores for significance which are used for the calculation of the uncertainty score for each uncertainty in the next step.

Table 1.1 – Example Input Significance input

Pairwise Comparison	Input Significance	Percentage Significance	Normalised Weights
Type			
Customer equipment usage	1	0,01	0,06
Labour availability	7	0,08	0,4
Work share between partners	2	0,02	0,1
KPI Specification	9	0,21	1
Interest Rates	2	0,02	0,1
Environmental impact	7	0,08	0,4

Table 1.2 - Example Matrix for Calculation Normalised Weights

	Customer equipment usage	Labour availability	Work share between partners	KPI Specification	Interest Rates	Environmental impact
Customer equipment usage	1	0,14	0,33	0,11	0,33	0,14
Labour availability	7	1	5	0,33	5	1
Work share between partners	3	0,2	1	0,14	1	0,2
KPI Specification	9	3	7	1	7	3
Interest Rates	3	0,2	1	0,14	1	0,2
Environmental impact	7	1	5	0,33	5	1

1.2.4.8.3 Calculation of the Uncertainty score

These 2 separate assessments are now combined in order to produce the uncertainty score of each relevant uncertainty. The score is calculated in the following manner.

$$Uncertainty\ Score = (\frac{1}{3} * (Basic\ Estimate + Rigour\ of\ Assessment + Level\ of\ Validation)) * Normalised\ Importance\ Score$$

This results in an uncertainty score for each relevant uncertainty. An example list can be found in

Table 1.3. Where high scores indicate a high uncertainty and significance, while low score indicate a low uncertainty and significance.

Table 1.3 - Example of an Uncertainty Score list

	Category	Type	Uncertainty Score
1	Commercial	Customer equipment usage	0,1
2	Commercial	Labour availability	1,7
3	Commercial	Work share between partners	0,5
4	Commercial	KPI Specification	5,7
5	Commercial	Interest Rates	0,1
6	Commercial	Environmental impact	1,7
7	Commercial	Warranty Scope	0,9
8	Commercial	Relationship with customer	1,5
9	Commercial	Stability of customer requirements	4,9

1.2.4.8.4 Cost Driver identification

The next step is to identify all cost drivers. Purchase price, maintenance, repair, replacement, energy are all cost drivers which add cost to a project. These need to be identified in order to know what cost are going to be incurred over the life time of a project.

1.2.4.8.5 Cost Driver and Uncertainty Linkage

Now that all cost drivers have been identified, all relevant uncertainties have to be linked to these cost drivers. The actor must now decide which uncertainty is relevant for each cost driver in a yes or no manner. A cost driver can be influenced by many uncertainties, but it is essential that each uncertainty has at least one cost driver link, otherwise the uncertainty can be deemed not relevant or indicate a missing cost driver.

By linking the uncertainties to each cost driver, an uncertainty score for the cost driver can now be calculated by adding all uncertainty scores and averaging the result. For the sake of comparability, the score is then divided by 7 (the maximum uncertainty score possible) to gain a cost driver's uncertainty score from a scale of 0 to 1.

1.2.4.8.6 Determination of cost range

In order to capture uncertainty given a cost driver's estimate, it is important that ranges are given to a cost estimate. The method of Erkoyuncu allows to transform a single figure cost estimate for a cost driver, as can be provided by the CEC of Schiphol, into a three-point range, where the single cost estimate acts as the most likely and the ranges of the cost is determined by the uncertainty scores which a deemed of influence of each cost driver. Based on the Cost Drivers' Uncertainty scores a range is assigned to the respective cost driver. The ranges from Table 1.4 are assigned to each uncertainty score.

Table 1.4 - Cost Range Classification based on Erkoyuncy (2011)

ESTIMATE CLASS	LEVEL OF PROJECT DEFINITION	METHODOLOGY	LOWER UNCERTAINTY VALUE	UPPER UNCERTAINTY VALUE	RANGE MIN	RANGE MAX
1	50% -100%	Deterministic	0	0,3	-10	15
2	30% - 70%	Primarily Deterministic	0,3	0,5	-15	20
3	10% - 40%	Mixed but Primarily Deterministic	0,5	0,7	-20	30
4	1% - 15%	Primarily Stochastic	0,7	0,9	-30	50
5	0% - 2%	Stochastic or Judgement	0,9	1	-50	100

The next step is to check whether the actor agrees to the cost range or that it want to manually adjust the range of each cost driver. Together with the cost range a distribution is assigned to each cost driver. This distribution is initially a triangular distribution, because it is one of the easiest distributions to work with in cost estimation and provides a good base to start with (Erkoyuncu, 2011). If the distribution of a cost driver is known, this distribution can be used, but the assumptions for this distribution must be checked against the available data on the respective cost driver.

1.2.4.8.7 Single Cost estimation to Cost Range Estimation

The next step is to enter the single cost estimate for each cost driver. Using the cost driver and uncertainty linkage, this single cost estimation is transformed to cost estimation range

This is then transformed to a cost estimation range, consisting of three points (Lower limit, Most likely and Upper limit). Where the single cost estimate acts as the most likely, and the ranges assigned to the cost driver based on the uncertainty act as the lower and upper limit.

1.2.4.8.8 Simulation and determination of price.

The last step in order to determine the price is to add all cost drivers into a simulation Monte Carlo model and let it run for a certain number of times. Monte Carlo is a tried and proven concept, which is used in many fields, especially in financial modelling. By drawing random numbers from the distributions linked to the different cost drivers, with their respective ranges for numerous times, the power of numerical scenario exploration can be exploited and numerous scenarios can be explored. This will result in a distribution of possible project cost. From this distribution a confidence level can be chosen (e.g. 95% or 99%) and from the distribution the associated cost level of can be determined and stated that, given the cost structure and distribution, that with a certainty of the chosen confidence level, the cost will not be higher than € *X*. A visual stylised example of a Cost Estimation under Uncertainty can be seen in Figure 1.11.

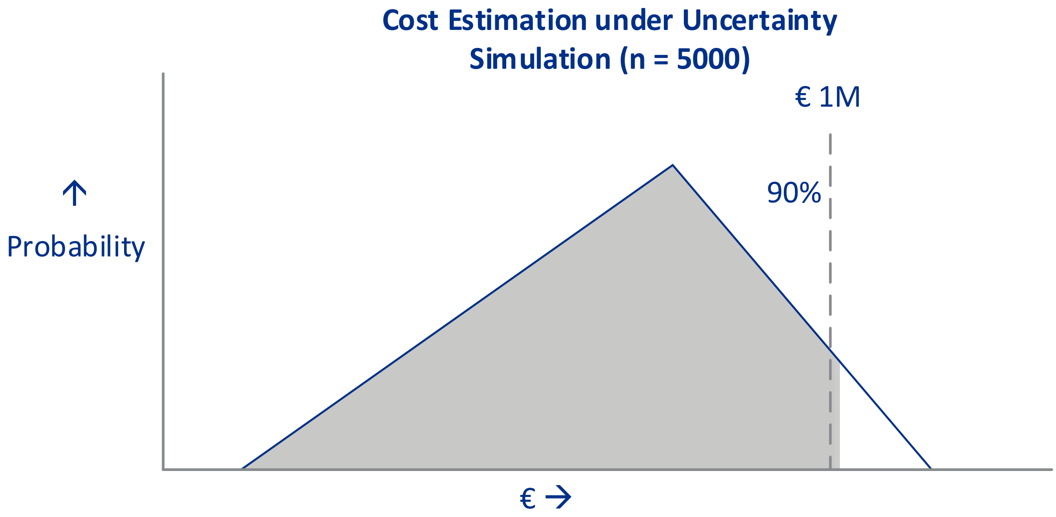


Figure 1.11 - Stylised example outcome of a Simulated Cost Estimation under Uncertainty

Because the model compares the relationship between the traditional NPV and an uncertainty weighted NPV, the difference between them can be seen as an implied risk premium the supplier should ask for carrying the risks and uncertainties associated with remaining owner. This can be reversed for Schiphol as the max risk premium a supplier should be allowed to ask for carrying such risk and is for Schiphol the premium it pays to mitigate the risks of the asset ownership towards asset user.

1.2.4.9 Validation of Cost Estimation under Uncertainty

The usage of Cost Estimation under Uncertainty sounds very promising and useful. In order to make sure that the usage of such a model is valid, a validation must be performed. Luckily, the validation for such a model is quite straight forward. Because the goal of the model to provide an estimate on a fair price, given the uncertainties as experienced by a supplier. Therefore, the user should use the model and determine the outcome of the model against the offering of a supplier. So, in order to validate the outcome of the model needs to be checked against the offering of a supplier for a PSS. If the outcome of the model delivers a price which is higher

1.2.5 Principles of Product-Service Systems

Result-oriented PSS could be used for enabling the transformation towards CE via performance economy. But, PSS is not a solution for every sustainability product. It is therefore important to know when PSS could work, and probably even more important, when it will not work.

1.2.5.1 Criteria for Product-Service Systems

Drawing on the work of Scheepens *et al.* (2016), the nature of the product determines whether PSS is a suitable solution for lowering the environmental burden. In order to gain a better understanding on when PSS is interesting for a customer, the following criteria are used (van Ostaeyen, 2014):

5. **Material, labour and energy intensity**

For customers that use products more intensively, a PSS would be interesting, because in theory a larger cost reduction could be achieved, which would result in a higher value of the product.

6. **Primary process**

PSS shift the responsibility towards the provider of the product/service. Therefore, PSS is interesting for customers who do not regard the operation or maintenance of the asset as essential part of their primary process.

7. Consequences of malfunction

A PSS is more interesting for a customer if the consequence of malfunction of an investment asset are more important and cause greater discomfort, because (theoretically) the provider will be able to offer a larger value improvement by investing in the quality and reliability of the product. Especially because the service provider/manufacturer is (financially) responsible for the performance issues of the service.

8. Market/customer size

The implementation of a PSS requires investment in service capabilities and infrastructure. Therefore, only large enough customers with large enough projects are interesting, because they should be able to bear the investment cost and be able to recuperate the investment over time.

These criteria will be used in order to determine which case study is most suited to be executed and helps to structure the choice on what Schiphol could do to make the transition towards circular economy. Not just within this master thesis, but also in the future.

1.2.5.2 Conditions for Product-Service Systems

These four criteria are the first step in order to check whether a product is suitable as a PSS. The next step is see what other conditions must be either satisfied or taken into account in order to successfully implement a PSS.

As mentioned before, the nature of the product is important. Not all products are suitable for being converted into a PSS. It is necessary that products which are used for a PSS are product which are typically expensive, technically advanced, require maintenance and repair, are relatively easy to transport, may be used infrequently by the customer and are not heavily influenced by branding and fashion (Tukker, 2015). The most important conditions to take into account is that the products are usually expensive and technically advanced and that they are not very susceptible to fashion.

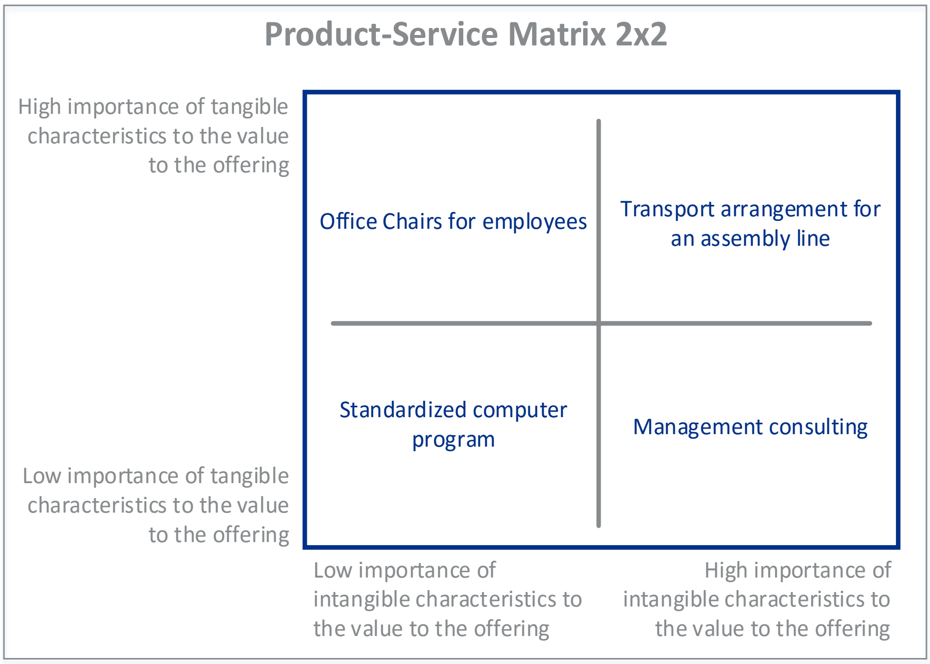


Figure 1.12 - Product-Service Matrix based upon Kuijken et al., (2016).

A PSS can be seen as a tangible product supplemented with an intangible service component. As is clear, some products are more suitable than other to be offered as a PSS. Besides the earlier mentioned criteria and the condition on a technical product, the value added of a PSS compared to a normal product can also be examined using the Product-Service Matrix as shown in Figure 1.12. It can help to determine whether a product is suitable for a service. Kuijken *et al.* (2016) argue that a PSS should consists of a tangible product and an intangible service which could also be offered separately. In order to add a synergy value, the two should cover two different quadrants of the Product-Service Matrix. Because the two components each offer a different value, they complement each other and by combining the two in one PSS, there should be value added.

The expensive and technically advanced are usually strongly related. This is important, because the service layer added should act as a value added layer upon a material intensive product (Scheepens, Vogtländer, & Brezet, 2016). If this is not the case, with a technical simple and inexpensive product for instance, the value added layer of the service is not big enough to justify the added investment in the infrastructure needed at both the provider of the service layer as well as the customer. The second statement is that the product should not be very susceptible to fashion. In other words, the risk should be minimised that products become obsolete, (long) before their technical life is reached. Especially combined with the infrastructure investment needed for a PSS. The only way this could be done, is when modularity is integrated from the start which allows for easy upgrading, together with reusability for the old parts, as stated in 1.1.2.2.2. Furthermore, modularity provides the possibility of upgrading the product during its life, expanding its functionality, extending its technical life and introduce new technology which could reduce energy usage for instance. Furthermore, it could reduce the risk that products only get out of fashion, but also become technically obsolete (Richter & Koppejan, 2015). The problem is with upgrading, that the parts taken out could have a negative side effect that while the upgraded product is better for the environment, the disposal of the old parts is (much) worse. So manufacturers should have clear plans for how to deal with such a disposal and aim for reuse of the parts, because it has the highest contribution to the value. This clearly shows that PSS extends the responsibility of both the manufacturer as well as the customer.

1.2.5.3 Performance Measurement in Product Service Systems

One of the fundamental principles of result-oriented PSS is performance measurement, it is a necessary condition for success. Due to the new situation where two parties are dependent on one another, performance measurement is the tool to check whether the required function is delivered, and the wanted performance standards can be met. Performance measurement is executed via performance indicators, where the most important indicators are called Key Performance Indicators (KPIs). By determining good KPIs, the performance of the PSS can be measured and acted upon, therefore monitoring and improving performance. Good KPIs are SMART; Specific, Measurable, Accountable, Realistic and Time sensitive (Wilberg, Hollauer, & Omer, 2015). In order to make sure that the proper KPIs developed, the following PSS KPI process scheme can be kept in mind to make sure that the process is well structured and thorough.

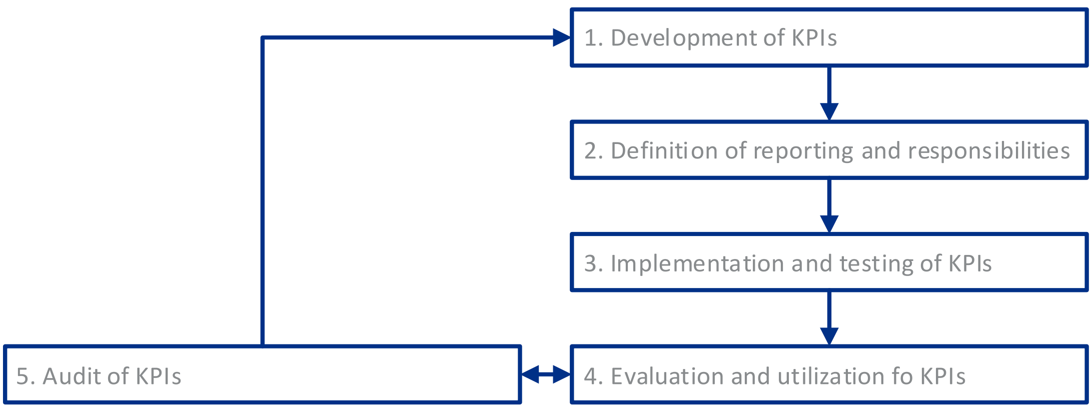


Figure 1.13 - Process of KPI implementation, based upon Wilberg et al., (2015).

1.2.5.4 Stakeholder Relationships

Proper KPIs should enable Schiphol to steer on performance, monitor sustainability goals and provide a clear overview on responsibilities. This aligns with paragraph 1.2.3.3, where it is stated that the changes in roles and responsibility of both parties change significantly and stakeholder management becomes more important. Therefore, a clear overview of responsibilities requires a clear overview of all parties, and therefore stakeholders.

Due to the shift between supplier and buyer in a PSS, the relationship between them intensifies and dependencies increases (Lockett, Johnson, Evans, & Bastl, 2011). The dependency during the life cycle of the product increases and the responsibilities shift from buyer towards supplier for maintaining and guaranteeing performance. This shift, if not properly accounted for, puts pressure on the relationship between stakeholders. Therefore, it can be clearly stated that the relationship between buyer and supplier is important (Ghisellini, Cialani, & Ulgiati, 2015) (Tukker, 2015). Identifying all actors within the affected network is therefore essential in order to, i) get a clear overview of all stakeholders involved, ii) get a clear picture of which information, product, service and monetary flows exist between stakeholders, iii) see where dependencies exist which need to be covered with KPIs (Morelli, 2006).

From this condition, one can conclude that not only contract management and KPI's are important, but also the relationship between supplier and buyer. Being able to steer on performance as well as clear arrangements on the roles of both parties could induce a mutual benefit for both parties.

Besides the mutual benefits, there are two other important reasons why a good supplier and buyer relation is essential. The first is maintenance. Because the ownership changes, the maintenance also changes. The producer is responsible for the maintenance with a PSS, but the customer is the one who feels the effects on either good or bad maintenance. Besides clear contractual agreements and steering on KPI's, a good relationship between the two is essential for keeping operation going for the customer, especially for a service provider as Schiphol, an operational risk.

The second reason is financing. The relation between producer and customer becomes more entangled, due to the fact that selling a service includes much more than selling a product. When selling a product, the customer is responsible for the financing. When selling a service, the producer becomes responsible for the financing. This change in financing could have consequences for any project. Now the CAPEX is at the manufacturer, while the OPEX will rise for the customer, because it now needs to pay, usually in instalments, for the financing at the producer (Tukker, 2015). This implies two potential problems. Firstly, the producer must be able to bear such investment for a prolonged period of time, especially compared to the earlier situation. The ability to carry such financing, puts additional pressure on meeting the arranged KPI's and contractual agreements, otherwise, any additional costs are purely for the producer. This in itself isn't a problem, because it provides producers an incentive for higher quality.

The second potential problem is that the overall financing cost of a project could become higher, even when the total cost minus financing cost remain the same. The cause would be that the producer has a lower credit rating than the customer. This difference in rating produces a higher interest rate for financing by the producer, compared to the rate of the customer. This could cause an extra barrier for the customer to implement a PSS and thus CE. Potential solution could be to make additional finance agreements where the customer finances the manufacturer upfront, or where the financers finance the project, instead of an individual firm. This could be based on the contract were financial payments are regular and for a long term and where the project cash flow as well as contractual agreements act as collateral. The question is whether it is still a full PSS if the customer is actually financing and therefore carrying the investment instead of paying an all-inclusive service fee.

Besides these conditions, it is clear that it can be beneficial for both parties if the producer retains the ownership. It allows the producer to fully utilise the in-house knowledge it possess on their product, if the right incentives are provided from their customers. Customers experience a better product and better care taking by their product provider, all with a simplified usage of the product due to the service layer and a single service fee.

1.2.5.5 Service Level Agreements and Contract Management

In order to guarantee that the required performance by the buyer, Schiphol, is delivered by the supplier of the service, it is important that all relevant aspects of their relationship is captured and secured in a proper Service Level Agreement (SLA). To make the concept perfectly clear. The following definitions of the words in SLA are used (Hiles, 1994):

- It is an agreement – that is, it is negotiated and involves a growing understanding of the needs and constraints on each side, probably resulting in compromise.
- It quantifies the level of service – that is, metrics are designed which both parties to the SLA agree represent the quality of service as delivered.
- Delivered quality is the minimum acceptable. Minimum is not pejorative: higher quality usually costs more money. Anything above the minimum may be excess and therefore probably result in unnecessary cost. But the quality delivered has to be acceptable to the customer.

A clear SLA could benefit both parties, by having a clear understanding between both about targets, measurement, reporting, roles and responsibilities (Heidel, 1997). To make sure that a SLA is complete, the following aspects should be treated:

5. Function of the service
    a. The functions offered
    b. Possible time of usage
    c. Needed support from Schiphol
6. Performance of the required service
    a. KPIs
    b. Norm of the KPIs
    c. Bonus/Malus rules
7. Possible restrictions on the usage of the service
8. Administrative details of the SLA
    a. Duration of the contract
    b. Arrangements on the prolongation of the SLA
    c. Arrangements on proposed changes to the SLA
    d. Arrangements for cost calculation and invoice arrangements
    e. Arrangements for possible disputes and the roles of a potential third party as a mediator
    f. Arrangements for End-of-Life disposal
    g. Possible financing arrangements
    h. Legal liabilities of both parties
    i. Description of scenarios in which force majeure are at play
    j. Reporting and frequency of reporting
    k. Clear definition on possible conflict of interpretation of certain words, passages, etc.

l. Possible sections of contract which might be changed without renegotiating the whole contract
m. Evaluation moments and possibilities of the SLA
n. If needed; paragraph on customer experience, measurements of customer experience and perception of quality of service
o. If needed; paragraph on innovation and continuous improvement of performance

Lastly, it is important to state that trust between both parties is most important of all before given ways of ensuring a good implementation of a PSS. The measures given should all contribute in earning and maintaining trust and a good relationship between buyer and supplier in a Product-Service System.

1.2.6 Validation of a Product-Service System

A Product-Service System brings forth a lot of benefits for both the customer and supplier of such an asset turned into a service. But in order to be sure that those benefits are achieved, it is important to know how to validate a PSS when one decided to buy one. The best way to validate a PSS is by performing a Case Study on the purchased PSS and check whether it fulfils all relevant criteria and conditions as given for a successful implementation (Exner & Stark, 2015) (Exner, Lindow, Buchholza, & Stark, 2014) (Matschewsky, Sakao, & Lindahl, 2015) (Qu, Yu, Chen, Chu, & Tian, 2016). By checking a case against the required criteria, condition and other prerequisites with the involved employees and stakeholders, it can be checked whether a complete process has been followed and that no loose ends are left at the end of the process.

1.3 Appendix C - Asset Management at Schiphol Aviation

ASM is responsible for the management and development of all aviation related assets at Schiphol. Due to the uniqueness of Schiphol within the Netherlands, a special law, 'The Aviation Law', has been installed which describes the framework which Schiphol is subjected to (Luchtvaartwet, 2016). The law has a double purpose. Firstly, it aims at providing a level playing field for all airlines at Schiphol. This to ensure that competition is fair and that no airline has special advantages, or that the airport abuses its market power. The second purpose is to make sure that Aviation does not subsidises non-aviation activities and therefore that all revenues from Aviation are to be invested in Aviation. This strict separation between aviation and non-aviation is also known as the dual till approach. The dual till approach treats aviation and non-aviation as two separate financial entities (Phang, 2016). This has as a consequence that only aeronautical activities are regulated and non-aviation activities can be treated as an efficient market where strict regulations are deemed unnecessary. The Dutch law explicitly uses a dual till system (Luchtvaartwet, 2016).

Within the Netherlands, the Authority for Consumer and Markets (ACM) is responsible for the execution of the Dutch Aviation law (Luchtvaartwet, 2016). This control on the market is done by a central document which is called 'Toerekeningssysteem' (Allocation system). This document is prepared by Schiphol, in conjunction with its stakeholders and the ACM. The ACM has the authority to legally approve or disapprove the document and therefore granting Schiphol the precedent to act according the document. In the Toerekeningssysteem, a detailed and thorough explanation is given on how the allocation is performed, which costs are passed on, how benefits are accounted for and how certain activities are allocated if non-aviation is involved and on what grounds. Furthermore, it clearly states on how the airline tariff is composed. The allocation system (Toerekeningssysteem) which his used within this master thesis is the ACM approved allocation system for 2016-2018 (ACM, 2015) (Schiphol Group, 2015). The actual allocation keys are determined every year, based on the most recent estimates of usage and costs within Schiphol.

1.3.1 Stakeholder roles

Before moving on to more details on the allocation system, it is important to clearly describe the roles which the different stakeholders have in the allocation system. A clear view on the different roles stakeholders have contributes to clear conclusions and recommendations. These roles have been discussed within Schiphol.

1.3.1.1 Schiphol Airport

Schiphol is the main composer of the document. Based upon the aviation law it writes its allocation system in which it clearly defines how and which costs are passed on towards the airlines. Schiphol proposes changes to its allocation system, to better reflect business opportunities or other changes for which it sees the need to change in order to better suit the cost allocation to the actual usage of airport facilities by various business areas. These changes are discussed internally and the consequences of these changes to their customers has an important role in these discussions. The document is proposed within the legal framework the Dutch Aviation Law provides. It submits the revised version to the ACM.

1.3.1.2 ACM

The ACM checks whether the allocation system meets the demands on market conformity, proportionality and integrity (Schiphol Group, 2015). It then informs airlines of the proposed changes. It receives any complaints about the document and relays it back to Schiphol the parts which airlines subject and whether the ACM finds it fair arguments to either approve or disapprove. Once the airlines agree or the ACM is of the opinion the document fulfils all requirements, they give their sign of approval and state that with the power invested by Dutch law the document is granted legal approval for usage.

1.3.1.3 Airlines

The airlines get informed by the ACM of the proposed changes Schiphol has in mind. They are allowed to oppose or approve these changes and motivate why these changes might affect fair competition or abuse of market power by Schiphol. They send this feedback to the ACM, which will check whether it is a fair statement.

1.3.1.4 Overview

To have a clear picture of how the roles are distributed and how one stakeholder relates to another, a graphical overview can be seen in Figure 1.14. It shows the relationship between the airlines and Schiphol, as well as the different steps within the process of determining the allocation system.

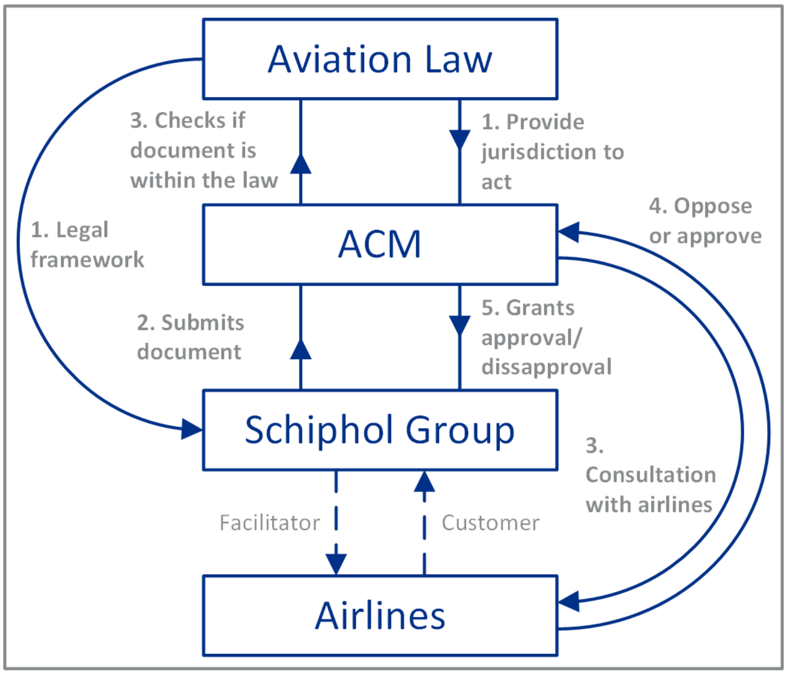


Figure 1.14 - Overview of stakeholder roles

1.3.2 Schiphol's allocation system

In order to gain a better understanding on the impact of the regulatory environment on Schiphol. A few key characteristics of the allocation system will be discussed. It will bring forth the tension it raises with different aspects, as well as illustrate that the scope of this master thesis is more narrow then one would expect in normal circumstances. All information given in the next section is extracted from the allocation document (Schiphol Group, 2015) and complemented with information from Schiphol.

1.3.2.1 Separation of operation aviation/non-aviation

The regulatory environment dictates that Schiphol is obliged to keep aviation strictly separated from non-aviation activities. This dual till system has as a consequence that two quite similar BA's exist within Schiphol, being ASM and SRE, in order to meet this rule. This may not be the most efficient way, due to the overlap within certain parts. This separation also has as an effect that the allocation document is needed, because the operation of the two BA's do meet quite often in daily operation, activities and development. Therefore, an allocation system is needed in order to clearly identify whether an activity is aviation or non-aviation.

1.3.2.2 Double accounting

Due to the separate BA's and the fact that it needs to be transparent how aviation costs are passed on towards the customers, the airlines, it is necessary to have a separate accounting for BA Aviation. This accounting is used to track all costs and benefits related to aviation activities and to show that there is no cross subsidisation.

1.3.2.3 IFRS exceptions

Since 2005, Schiphol is obliged to use the IFRS guidelines for their accounting practises. The problem with IFRS is, is that there are a few rules which contradict with what the Aviation Law prescribes. In this case, the Aviation Law is leading. There are four points in which the accounting practices from Schiphol deviate from the IFRS guidelines, regarding the Regulatory Asset Base (RAB)[1].

1. Assets, other than tangible fixed assets, may not be taken into RAB
2. Tangible fixed assets are only allocated to aviation, after the moment the asset is activated.
3. For the accounting value of asset and depreciation, which are linked with very large investments, special calculation methods apply.
4. The way in which construction interest is calculated according to the Dutch Aviation Law, deviates from the calculation of construction interest as applied for the purpose of composing the annual statements. Based upon the Aviation law, the construction interest is calculated over the entire average capital invested in the asset under construction. The annual statements only take into account the debt component of the capital costs.

The financial accounting of Schiphol uses in daily operation the methods as described by IFRS for the annual report. Only for determining the tariffs, a correction is applied which takes into account these four abovementioned points.

1.3.2.4 Controlled WACC

The rate of return which Schiphol can make on its RAB is controlled. Schiphol is allowed to have a rate of return on its assets which is at maximised at the Weighted Average Cost of Capital (WACC), as prescribed in the Toerekeningssyteem. This WACC is regulated and the composition is determined by fixed rules. This provides fixed rate of return can be disputed, because due to its fixed nature it isn't a true representation of the actual hurdle rate of Schiphol. Furthermore, with the current low interest rate, the WACC is declining, while the interest paid by Schiphol on some of its long term debt obligation is higher than the WACC implies. For internal purposes, the treasury department of Schiphol determines the internal WACC for the different BA's. This allows for a better and more tailored project valuation.

1.3.2.5 Fixed depreciation scheme

Any asset which is activated and added to the RAB will be depreciated linearly from historical cost price over the life time of the asset towards zero. No residual value can be assigned to any asset, nor is it possible to use the fair value valuation principles to get an insight into the actual market value of any aviation related asset. A linear depreciation scheme is not by itself a bad thing, because there is less tendency in excessive capital investments, compared to other depreciation methods (Jackson, Xiaotao,

[1] The Regulatory Asset Base (RAB), is, as defined by Dutch Aviation Law, the average book value of aviation and security related assets, which can be attributed to tangible fixed assets. The RAB is composed of only tangible fixed assets, all other assets are excluded.

& Cecchini, 2009). The original idea is that aviation assets are hard to sell, due to their nature. The life time of an asset can be adjusted if deemed necessary, but only the depreciation time span can be adjusted, no value adjustment of the asset is allowed.

1.3.2.6 Residual value

Residual value is not allowed to be taken into account. Only for vehicles a residual value can be determined, due to a bigger market where these kind of asset can be sold. The initial idea is that due to the nature of the aviation assets, these assets can't be sold easily, nor will they be easily sold by Schiphol. The problem is that these assets are thus seen as a whole asset. If these assets are made more modular, which is becoming more common, the components of assets can be sold. This makes residual value a potential which to account for, but due to the regulation can't be accounted for.

1.3.2.7 Tariff structure

The tariff structure is determined by the cost incurred by Schiphol in order to facilitate aviation. These costs are mostly incurred at Aviation, but Non-aviation activities are also a part of the cost structure, as well as corporate cost which are incurred on a corporate level in order to facilitate the organisation Schiphol. This leads to the following cost structure (Schiphol Group, 2015):

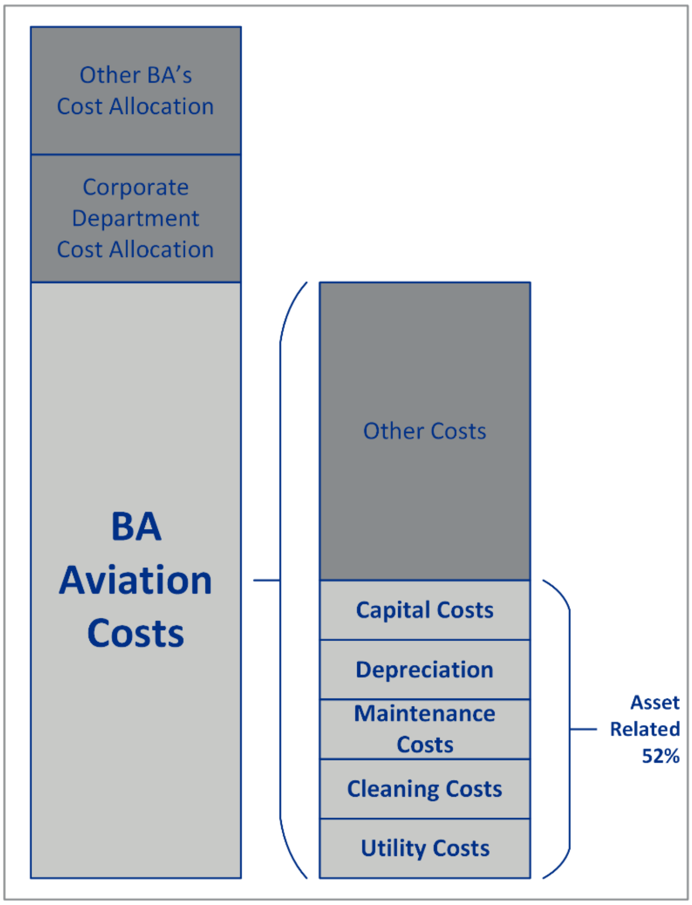


Figure 1.15 - Stylised cost structure, based on Toerekeninssysteem 2016-2018 (Schiphol Group, 2015), annual report 2016 (Schiphol Group, 2016) and internal Asset Wise! Documentation (Asset Wise! Team Schiphol, 2015)

As can be seen from Figure 1.15, 52% of the BA Aviation costs, divided into 5 main cost categories, are all direct asset related (Asset Wise! Team Schiphol, 2015). In the current situation it is easy to distinguish between these different costs. However, would a PSS be implemented this becomes opaquer, as these costs are replaced by a single service fee where it is not possible anymore to distinguish. It is important to mention this side effect, because it is one of reasons why clear KPIs need to be implemented in order to keep insight in what activities are introducing costs.

1.4 Appendix D - Circular Economy Project at Schiphol

1.4.1.1 Zer0 Waste

One of the goals of Schiphol is to remove all waste streams and convert them into sustainable revenue streams. The so called Zer0 Waste plan aims at reaching zero waste from operations in 2030.

1.4.1.2 Blue Conveyor

Schiphol has developed a so called blue conveyor system which uses recycled and non-toxic materials for the baggage reclaim conveyer belts. Besides the recycled material, the belt is engineered as such that it uses considerable less energy than a conventional belt and that it can be completely recycled at its End-of-Life (Schiphol Group, 2016).

1.4.1.3 True Price

Within Schiphol, the need arose to have an insight in what the environmental impact of certain projects would be. In order to facilitate the decision making with a tool which contributes towards this, a True Price model has been developed. It monetises the effect a project has on the environment using shadow prices of the environmental impact. It helps to look further than just the internal financial gain, by showing what the societal effects are, if Schiphol would have to pay for the caused impact. This contributes to the awareness of Schiphol of their environmental impact and it is currently being implemented as an extension of the standard decision making procedure at Schiphol.

1.5 Appendix E – PSS Pricing Tool example

1.5.1.1 Uncertainty Identification

Schiphol's supplier experience different kinds of uncertainty in the business processes. In this step, the user of the model identifies different uncertainties. Five categories are used from Erkoyuncu (2011) the sixth was not deemed relevant:

6. Commercial Uncertainty
7. Affordability Uncertainty
8. Performance Uncertainty
9. Operation Uncertainty
10. Engineering Uncertainty

The complete list of uncertainties (+/- 70 uncertainties) of these 5 categories can be found in Appendix (REF). The user of the model needs to identify which of these uncertainties are applicable to the project. It is important that if the uncertainty is of influence it is marked as relevant.

1.5.1.2 Uncertainty Scoring and Importance Assessment

The second step is the assessment of each uncertainty. For each uncertainty the following three assessments have to be made with a score from 1 to 7, as can be seen Figure 1.16. This assessment is analogue to the method as introduced in 7.5.

Basis of Estimate	Rigour of Assessment	Level of Validation
7: No Experience in the area	7: No established assessment of processes	7: No validation
5: Incomplete data, small sample, educated guesses, indirect approximate rule of thumb estimate	5: Limited experience of applied process with lack of consensus on results	5: Limited internal validation, no independent validation
3: Small sample of historical data, parametric estimates, some experience in the area, internally verified data	3: Sufficiently experienced and benhmarked internal processes with consensus on results	3: Internally validated with sufficient coverage of models, processes and verified data. Limited independent validation
1: Best possible data, large sample, use of historical field data, validated tools and independently verified data	1: Best practice in well established discipline	1: Best available, independent validation within domain, full coverage of models and processes.

Figure 1.16 - Uncertainty Scoring

1.5.1.2.1 Basic Estimate

The Basic Estimate is the estimate of the level of uncertainty. Using Figure 1.16 the user can see how the uncertainty can be asses given the certain data. If the supplier has a lot of data the amount of uncertainty is low, when there is little data the uncertainty is inherently high.

1.5.1.2.2 Rigour of Assessment

The Rigour of Assessment is how experienced the supplier is with assessment of uncertainty. Does it have clear processes on uncertainty assessment. Can it show how accurate it is? The explanation of the score levels can be seen in Figure 1.16.

1.5.1.2.3 Level of Validation

The Level of Validation is on how well cost data can be validated to be true. Ideally an external, independent source can validate cost estimates, but usually this is not true. How far the supplier is with validation, can be given a score in this score. The explanation of the score levels can be seen in Figure 1.16.

The next step is to assess the significance of each uncertainty. As can be imagined, some uncertainties are more relevant than others. For the sake of easiness and usability, the user of the models assesses the relevance compared to the complete project with a score from 1 (not significant) to 9 (extremely significant). For each uncertainty, an assessment is to be made of the amount of influence the uncertainty has on the project. In Figure 1.17, the scoring categories can be seen.

Pairwise Comparison

The following significance/relevance can be assigned to each uncertainty. This will be automatically translated in a relative weighted importance of each uncertainty via the AHP process.

1: Not significant/relevant. 2: Not significant/relevant to moderately significant/relevant. 3: Moderately significant/relevant. 4: Moderately to strongly significant/relevant. 5: Strongly significant/relevant. 6: Strongly to very strongly significant/relevant. 7: Very strongly significant/relevant. 8: Very strongly to extremely significant/relevant. 9: Extremely significant/relevant.

Figure 1.17 - Significance Categories

The scoring given is used to determine a pairwise comparison, which is used to determine the uncertainty significance, which are normalised to a scale from 0 to 1. This is all done automatically, the only input required by the user is the significance assessment.

1.5.1.3 Uncertainty Score

The next step in the model is that the model calculates the uncertainty score of each uncertainty based on the assessment of uncertainty and significance assessment. Each uncertainty will receive a score between 0 and 7, where 0 is no uncertainty and relevance and 7 is highly uncertain and highly relevant. The model automatically calculates these scores.

1.5.1.4 Cost Driver Identification

The fourth step in the price determination uses the inputs which are normally required for the construction of a traditional TCO model within Schiphol. A Cost Driver is a cost which is incurred for an asset when an asset is traditionally purchased and utilised over its lifetime. Costs such as energy usage, maintenance costs, replacement costs etc. are costs which are almost always incurred with every project of an asset. Because for the traditional TCO all these cost drivers are already needed to be known, this step does not require any new information of either the Technical Expertise Centre (TEC) or the Cost Expertise Centre (CEC) at Schiphol, because the information is already required. This eases the use of the model, because these costs drivers and their respective costs can be easily copied.

1.5.1.5 Cost Driver Uncertainty Linkage

When all cost drivers are identified, the next step is to link uncertainties to cost drivers where the uncertainty has a potential influence upon. Within the excel model, this is easily done by either selecting Yes or No from the dropdown menu for each cost driver and its respective uncertainty as can be seen in

Table 1.5, where the uncertainties are given in the first column and the cost drivers in the upper row. If an uncertainty has no cost driver which it influences, the user must ask oneself if the uncertainty is relevant in this case.

Table 1.5 - Cost Driver Uncertainty Linkage Example

	Energy	Maintenance	Replacement
Customer equipment usage	Yes	No	Yes
Labour availability	No	Yes	No
Work share between partners	No	Yes	No
KPI Specification	Yes	Yes	No
Interest Rates	Yes	No	Yes

1.5.1.6 Cost Driver under Uncertainty

When each cost driver has its uncertainties assigned to it, the user can move to the next step, which is the determination of the uncertainty score of each cost driver. The model automatically calculates the uncertainty score of each cost driver. An example is given in Table 1.6. e.g. the last row, Uncertainty score (divided by 7) for the cost driver Energy is 0,25. The uncertainty score is again from 0 to 1, where 0 the lowest score and 1 is the highest score for uncertainty for each cost driver.

Table 1.6 - Cost Driver Uncertainty Score example

Uncertainty	Energy	Maintenance	Replacement
Customer equipment usage	0,1	0	0,1
Labour availability	0	1,7	0
Work share between partners	0	0,5	0
KPI Specification	5,7	5,7	0
Interest Rates	0,1	0	0,1
Environmental impact	1,7	0	1,7
Warranty Scope	0	0	0,9
Relationship with customer	0	1,5	1,5
Stability of customer requirements	4,9	4,9	4,9
Commodity and energy prices	0,4	0	0
Inflation/deflation	1,7	1,7	1,7
Material cost	0	0,4	0,4
Labour Rate	0	1,2	1,2
Labour hours	0	4,9	4,9
Customer ability to spend	0	0	0
Bid success rate	0	3	3
Economy	0,4	0	0,4
Customer willingness to spend	0	0	3,7
IT	0	6,3	6,3
Rate of surge	0,8	0,8	0
Uncertainty score (divided by 7)	0,25	0,39	0,31

1.5.1.7 Range Definition &Distribution and Single Point Cost Estimate

Each uncertainty score is used to determine the appropriate range which is assigned to each cost driver. As can be understood, the higher the uncertainty, the higher the cost range will be. The ranges are the same as in Table 1.4 on page 103.

Again, the model will automatically assign the proper ranges to each cost driver.

If the user disagrees with the ranges for a specific cost driver, because it can accurately estimate the cost, there is the possibility to adjust the ranges to specific levels. However, this must only be done if the user is certain that it has such information about the cost driver. The ranges are needed for a proper price determination and therefore, under estimation of the range due to the alleged knowledge of the costs is to be avoided.

A probability distribution is assigned to each cost driver. This distribution is used in the next two steps for price determination. The standard distribution assigned is the Triangular Distribution, which is an easy to use distribution and well suitable for the usage with the determined ranges. If the user has specific data on the cost driver regarding the distribution, it can change the distribution to the required one. However, this must only be done if the user has detailed knowledge and data available on the cost driver, because every distribution has its own assumptions. An overview of which distributions are usable in the model can be found in Appendix (REF to distri in appendix). The user can choose from the different distribution, which can be filled in with their respective rows, as can be seen in Table 1.7.

Table 1.7 – Example of required Distribution Parameters for Cost Drivers

Uncertainty score (divided by 7)	0,25	0,39	0,31
Lower Range	-10	-15	-15
High Range	15	20	20
Distribution	Weibull	Normal	Lognormal
Sigma (Normal Distribution)			
Mu (Normal Distribution)			
Lambda (Weibull Distribution)			
K (Weibull Distribution)			
Sigma (Lognormal Distribution)			
Mu (Lognormal Distribtuion)			

1.5.1.8 Single Point to Three Point Cost Estimate

Now that the ranges and distribution of each cost driver have been determined, the user can add the actual cost data for the project. This information is entered in the NPV sheet, where the user can enter the expected costs for each year for each cost driver. In Table 1.8 an example is shown where the energy cost for an asset which will be used for 10 years is shown. The energy costs are €1.500 p/y and are yearly index for inflation, in this case equal to the WACC of Schiphol. For each cost driver such a table is available and the user inputs.

Table 1.8 - Example Cost Estimation Input

Year											
0	1	2	3	4	5	6	7	8	9	10	NPV

Energy	€ 1.500	€ 1.545	€ 1.591	€ 1.639	€ 1.688	€ 1.738	€ 1.791	€ 1.844	€ 1.900	€ 1.957	€ 2.015	
PV Sum	**€ 1.500**	**€ 1.500**	**€ 1.500**	**€ 1.500**	**€ 1.500**	**€ 1.500**	**€ 1.500**	**€ 1.500**	**€ 1.500**	**€ 1.500**	**€ 1.500**	**€ 16.500**

These inputs are then used to let the value fluctuate based on the range as determined by the uncertainty scores. An example can be seen in Table 1.9. As can be seen, the value (PV sum) changes for each year due to the including of uncertainty. This will eventually yield a different NPV (last column) €16,5k versus €17,9k. This is the bases of the next step.

Table 1.9 - Example of Cost estimation for simulation

PV Sum	**€ 1.500**	**€ 1.500**	**€ 1.500**	**€ 1.500**	**€ 1.500**	**€ 1.500**	**€ 1.500**	**€ 1.500**	**€ 1.500**	**€ 1.500**	**€ 1.500**	**€ 16.500**
PV Sum for Simulation	€ 1.578	€ 1.805	€ 1.659	€ 1.230	€ 2.085	€ 1.619	€ 1.286	€ 1.199	€ 1.523	€ 1.767	€ 2.183	€ 17.940

1.5.1.9 Monte Carlo Simulation for Price determination

The next step is to use the inputs of the cost estimation and uses it in a simulation model. The basics of a Monte Carlo simulation are explained in (ref to MC). By randomly drawing a cost estimation for numerous time (N >1000), all kinds of scenarios can be automatically explored. The result of this simulation will provide a price determination of what is a fair price for a PSS given the perceived uncertainties the supplier needs to carry by remaining owner and the responsibility of delivering performance.

	Year 0	1	2	3	4	5	6	7	8	9	10	NPV
Energy	€ 1.500	€ 1.545	€ 1.591	€ 1.639	€ 1.688	€ 1.739	€ 1.791	€ 1.845	€ 1.900	€ 1.957	€ 2.016	
PV Sum	€ 1.500	€ 1.500	€ 1.500	€ 1.500	€ 1.500	€ 1.500	€ 1.500	€ 1.500	€ 1.500	€ 1.500	€ 1.500	€ 16.500
PV Sum for Simulation	€ 1.549	€ 2.739	€ 2.548	€ 1.700	€ 836	€ 2.165	€ 1.675	€ 709	€ 1.402	€ 1.740	€ 1.933	€ 18.996
Maintenance	€ 3.000	€ 3.150	€ 3.308	€ 3.473	€ 3.647		€ 3.000	€ 3.150	€ 3.308	€ 3.473	€ 3.647	
PV Sum	€ 3.000	€ 3.058	€ 3.118	€ 3.178	€ 3.240	€ -	€ 2.512	€ 2.561	€ 2.611	€ 2.662	€ 2.713	€ 28.654
PV Sum for Simulation	€ 3.724	€ 2.005	€ 3.297	€ 4.630	€ 2.414	€ -	€ 3.339	€ 2.631	€ 2.464	€ 2.610	€ 4.242	€ 31.356
Replacement						€ 15.000						

PV Sum	€ -	€ -	€ -	€ -	€ -	€ 12.939	€ -	€ -	€ -	€ -	€ -	€ 12.939
PV Sum for Simulation	€ -	€ -	€ -	€ -	€ -	€ 16.760	€ -	€ -	€ -	€ -	€ -	€ 16.760
Purchase Cost	€ 30.000											
PV Sum	€ 30.000	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ 30.000
PV Sum for Simulation	€ 15.173	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ 15.173
PV per year	€ 20.445	€ 4.744	€ 5.845	€ 6.331	€ 3.251	€ 18.925	€ 5.015	€ 3.339	€ 3.865	€ 4.350	€ 6.175	
Net Present Value	**€ 82.285**											
Equivalent Annual Cost	**€ 9.646**											

Table 1.10 shows one of the simulation outcome of for instance 1000 simulations. The cost estimation outcomes for this particular scenario are a project valuation TCO of € 82k. Which over a 10-year lifespan of the project leads to an equivalent annual cost of € 9,6k.

Table 1.10 - Example of NPV Simulation Table

	Year 0	1	2	3	4	5	6	7	8	9	10	NPV
Energy												
	€ 1.500	€ 1.545	€ 1.591	€ 1.639	€ 1.688	€ 1.739	€ 1.791	€ 1.845	€ 1.900	€ 1.957	€ 2.016	
PV Sum	€ 1.500	€ 1.500	€ 1.500	€ 1.500	€ 1.500	€ 1.500	€ 1.500	€ 1.500	€ 1.500	€ 1.500	€ 1.500	€ 16.500
PV Sum for Simulation	€ 1.549	€ 2.739	€ 2.548	€ 1.700	€ 836	€ 2.165	€ 1.675	€ 709	€ 1.402	€ 1.740	€ 1.933	€ 18.996
Maintenance												
	€ 3.000	€ 3.150	€ 3.308	€ 3.473	€ 3.647		€ 3.000	€ 3.150	€ 3.308	€ 3.473	€ 3.647	
PV Sum	€ 3.000	€ 3.058	€ 3.118	€ 3.178	€ 3.240	€ -	€ 2.512	€ 2.561	€ 2.611	€ 2.662	€ 2.713	€ 28.654
PV Sum for Simulation	€ 3.724	€ 2.005	€ 3.297	€ 4.630	€ 2.414	€ -	€ 3.339	€ 2.631	€ 2.464	€ 2.610	€ 4.242	€ 31.356
Replacement												
						€ 15.000						
PV Sum	€ -	€ -	€ -	€ -	€ -	€ 12.939	€ -	€ -	€ -	€ -	€ -	€ 12.939
PV Sum for Simulation	€ -	€ -	€ -	€ -	€ -	€ 16.760	€ -	€ -	€ -	€ -	€ -	€ 16.760
Purchase Cost	€ 30.000											
PV Sum	€ 30.000	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ 30.000
PV Sum for Simulation	€ 15.173	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ 15.173
PV per year	€ 20.445	€ 4.744	€ 5.845	€ 6.331	€ 3.251	€ 18.925	€ 5.015	€ 3.339	€ 3.865	€ 4.350	€ 6.175	
Net Present Value	**€ 82.285**											
Equivalent Annual Cost	**€ 9.646**											

1.6 Appendix F – Validation of the number of simulations

This set up is to show what impact the number of simulations has on the outcome. To verify this, the following verification set up will be used.

Table 1.11 - Set up

Simulation	Comment
1.	Number of simulations: 1000, Percentile: 95%
2.	Number of simulations: 5000, Percentile: 95%

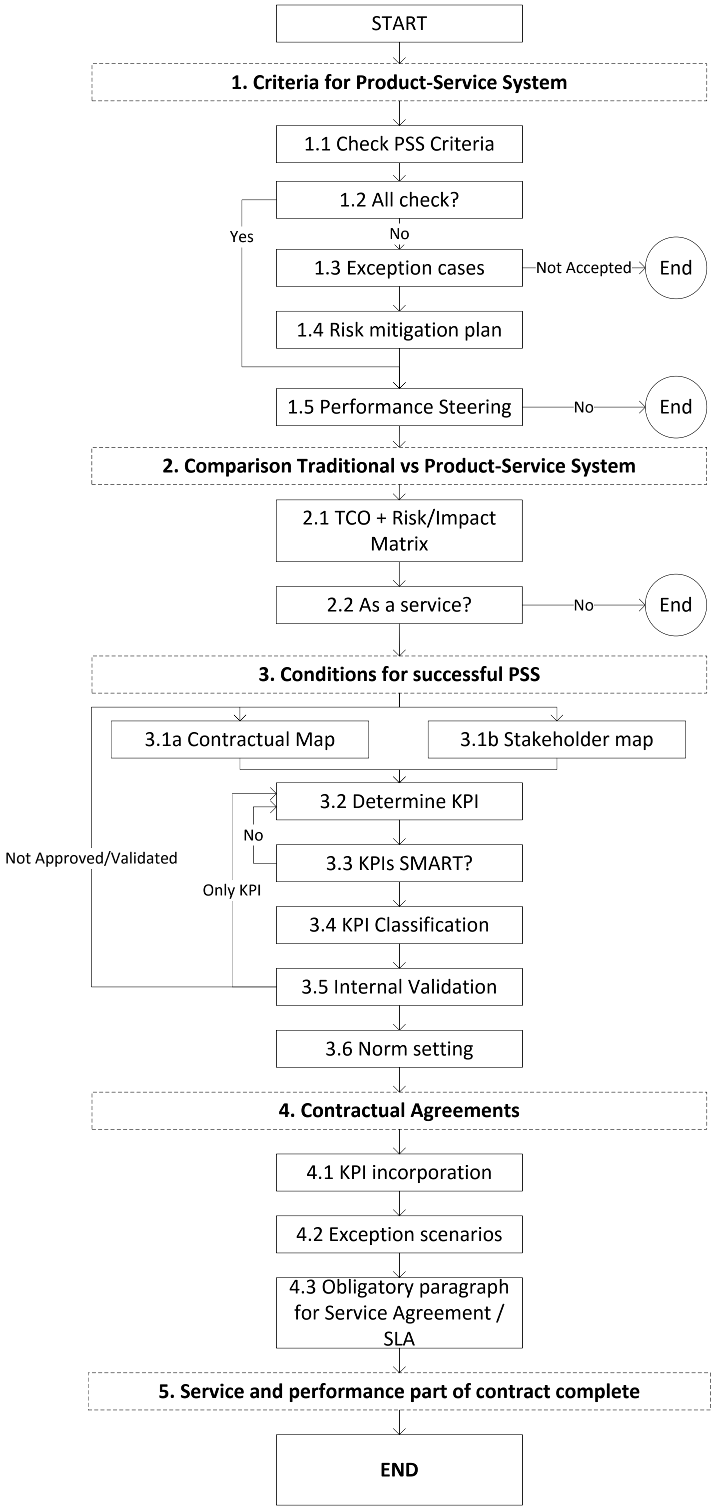
Table 1.12 – Influence of the number of simulations

KEY OUTCOMES	5000 simulations		1000 simulations	
PSS Price	**€**	**440.610,48**	**€**	**440.589,35**
Implied Risk Premium	**€**	**13.158,63**	**€**	**13.137.53**
Percentile		**95%**		**95%**
Number of Simulations		5000		1000
Number of Years		10		10
EAC Traditional	**€**	**427.451,86**	**€**	**427.451,86**

As can be seen Table 1.12 in the number of simulations has no real noticeable effect on the outcome of the Pricing Tool, while it does take longer for the model to run. Therefore, it is best to keep the simulation Tool at 1000 runs.

1.7 Appendix G - Manual Compact Product-Service Systems Decision Framework

Compact Framework



1.7.1 Introduction

This manual provides the user with information on the usage of the compact Product-Service Systems Decision Framework, which is aimed to assist in decision making on whether a Product-Service System is a suitable alternative for the traditional asset solution. In this manual the user will be provided with the necessary information to use the compact framework. If the user needs the extensive framework, which contains more information on the process steps, required inputs etc., the user is suggested to not use this manual and framework and switch to the extensive framework and manual. Furthermore, for the usage of the PSS Pricing Tool, the user is recommended to also get the PSS Pricing Tool manual. This manual provides the user detailed information on the usage of the Excel Tool.

1.7.2 Framework

1.7.2.1 Stage 1 – Criteria for Product-Service Systems

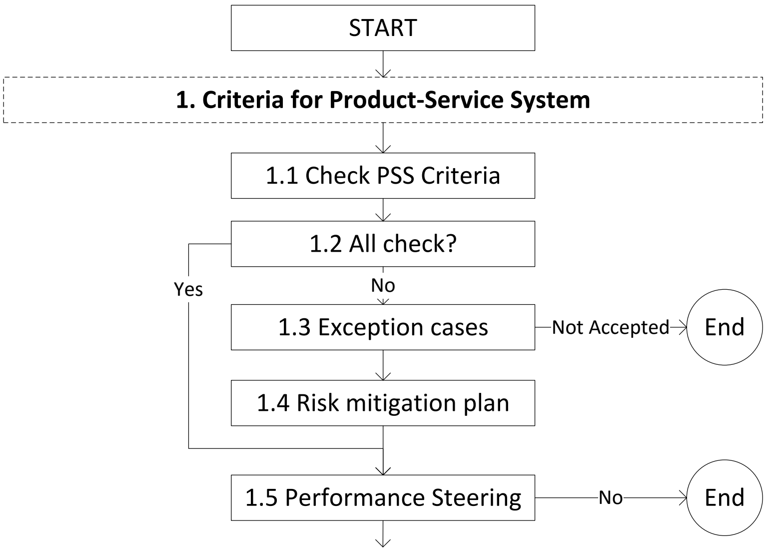


Figure 1.18 - Stage 1

1.7.2.2 Check PSS Criteria

The first step is to check whether a project's asset or product fulfils the criteria associated with Product-Service Systems. The PSS Criteria Matrix from Table 1.13 can be used by the user. The user must assess if the product/asset applies for the four criteria.

1. **Labour, resource and/or energy intensive?** The user must decide if the product/asset is an intensive user of either labour, resource and/or energy. If this is the case, a check is placed in the white checkbox under the first criteria.
2. **Not part of primary process**? The user must decide what the influence of the asset/product is on the primary process of Schiphol. Does it affect airport operation in a critical way, does it have the potential to greatly disturb important primary processes. If this is the case, the user must decide whether to retain control by remaining owner, or is sufficiently able enough to transfer ownership to a supplier and is able to mitigate this loss of control with proper contracting. If the user is not sure whether Schiphol is able to exert such control via contracting, no check should be placed. The scale of severity can be seen in Figure 1.19.
3. **Impact on operation severe?** The user must check whether the malfunction of the product/asset has impact on the operation. If the influence is too small, the question is raised whether Schiphol needs to invest in a service layer on top of the normal product/asset. The scale of severity can be seen in Figure 1.19.
4. **Market/Investment Size sufficient?** The last criterion is that the market or investment size needs to be sufficient in order to justify the investment in a service layer. If the investment size from Schiphol is too small, the needed investment for a service layer is to big compared to the product/asset. If a supplier already has a product with service which it can easily implement, the check may be placed.

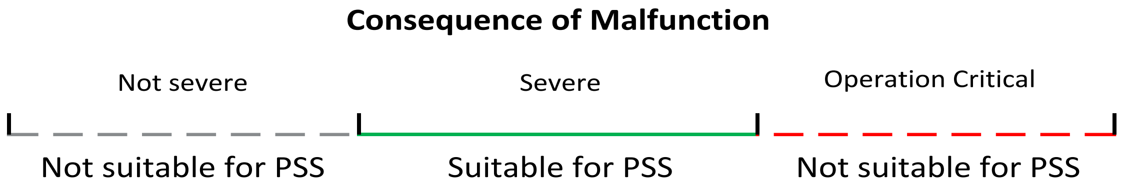


Figure 1.19 - Consequence of Malfunction

Table 1.13 - PSS Criteria Matrix

PSS Criteria	1. Labour, resource and/or energy intensive?	2. Not part of primary proces?	3. Impact on operation severe?	4. Market/ Investment Size sufficient?
Place Check if Applicable				
Option 1: Suitable for PSS	✓	✓	✓	✓
Option 2: Conditional Suitability for PSS	✓			✓
Option 2: Conditional Suitability for PSS	✓	✓		✓
Option 2: Conditional Suitability for PSS	✓		✓	✓
Other check combinations are not Suitable for PSS				

1.7.2.3 All Check

There are 4 possible outcomes which constitute in a continuation of considering PSS as an alternative. The first option is that all criteria are checked. The user may proceed to 1.5, performance steering. If another outcome is present, the user must continue to 1.3.

1.7.2.4 Exception Cases

The second option is that both criteria 1 and 4 are checked, but 2 and/or 3 not. This will cause the user to go 1.4. If either criteria 1 or 4 is not checked, the decision needs to be made that a PSS is not suitable as a solution.

1.7.2.5 Risk mitigation plan

If criteria 2 or 3 is missing, there is a potential risk to the success of the PSS plan. In order to cope with this risk, there needs be thought about what kind of risk Schiphol is exposed to and how it can be mitigated. Two examples will be given in order to show what kind of risk is meant with criteria 2 or 3.

Criterion 2. Part of primary process. If an asset is part of the primary process of Schiphol and is thus operation critical, e.g. platform lighting of a VOP[2], the question is raised whether Schiphol want to lose control over the lighting in case of an emergency, because it can have a big disturbing effect. Risk mitigation to counteract such loss of control can be clear and strict contractual agreements.

[2] VOP (VliegtuigOpstelPlaats), aircraft parking stand in Dutch, commonly used within Schiphol.

Criterion 3. If the severity of malfunction is to mild, Schiphol has no real leverage to demand performance from a supplier. If a floor tile is worn and looks sleazy, Schiphol might want to have it replaced, but it still performs to functional demand, Schiphol can have difficulty to demand that it is replaced by the supplier. Risk mitigation can be to add another criterion in the functional demand that the floor must look sleek and uniform for customer experience.

If the user comes up with proper risk mitigation plans, the user may continue to 1.5. Otherwise, the user needs to decide that a PSS is a no-go.

1.7.2.6 Performance Steering

The next go or no-go decision the user needs to take is to consider whether the product/asset is able to be steered on performance. Because the goal of the usage of a PSS is to enable Schiphol to incorporate more Circular Economy into their business model, improving or altering performance is essential. This allows Schiphol to set demands for performance over many years. Performance can also be viewed more widely, such as customer experience, more comfortable climate, or other performance measures which can be measured and a minimum performance level can be set by Schiphol for the supplier. The performance steering is needed, because the type of contract is a performance contract. Technical installations normally lent themselves well for performance improvement due to new parts/technologies/software updates over time.

1.7.3 Stage 2 – Comparison Traditional TCO vs Product Service Systems

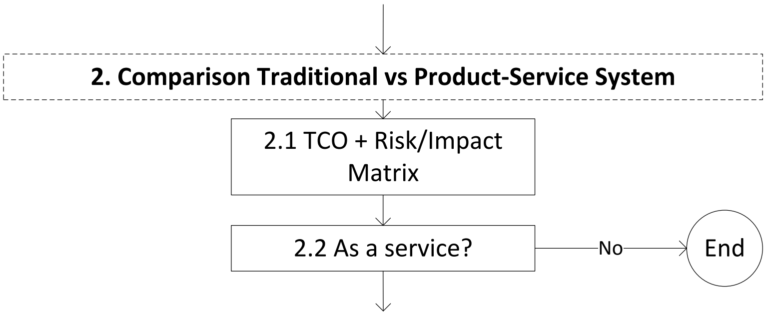


Figure 1.20 - Stage 2

1.7.3.1 TCO + Risk/Impact Matrix

The second stage consists of the financial comparison of a Product-Service Systems against a traditional asset solution, where Schiphol becomes owner of the asset. For this part, the traditional cost assessment with Total Cost of Ownership comes is needed. Together with the cost assessment, a uncertainty analysis needs to be performed. For this step, it is recommended to use the Manual for PSS Pricing.

Once the comparison between traditional ownership and a Product-Service Systems, the user may proceed to 2.2.

To assist in the process, the PSS Pricing Tool also provides an Risk/Impact matrix to assess which uncertainties can cause potentially high impacts and thus induce high risks to Schiphol.

1.7.3.2 As a service

The outcome of the previous step determines whether the user prefers a traditional asset solution where Schiphol becomes owner and therefore responsible for maintaining the asset as well as its performance, or that it acquires a Product-Service System, where a supplier is responsible to deliver functionality to Schiphol. Using the PSS Pricing tool, the user is able to determine a price and a suitable risk premium for the PSS based on its own TCO tool. This figure can be used to judge when a supplier is asked to provide an offer for the PSS.

If the choice is made to go for the PSS, the user may continue to stage 2.

1.7.4 Stage 3 – Conditions for successful Product-Service Systems

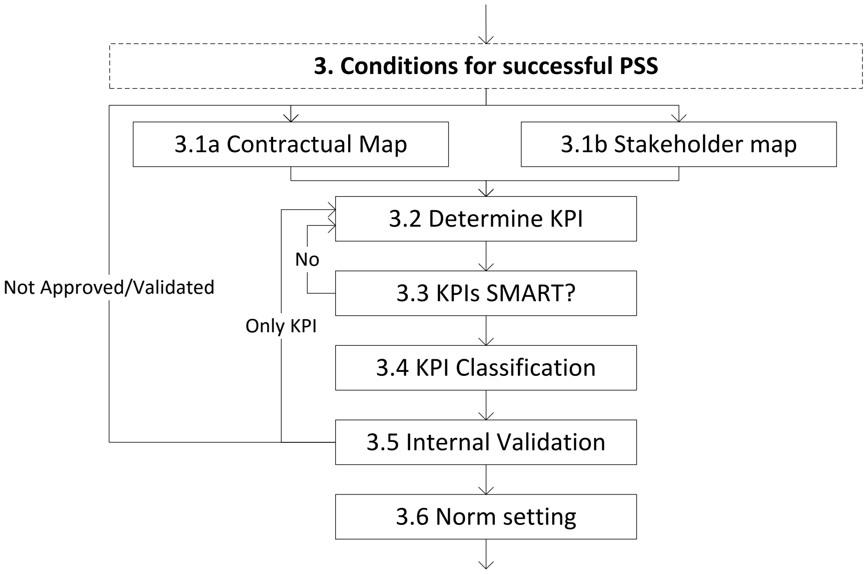


Figure 1.21 - Stage 3

1.7.4.1 Contractual and Stakeholder Map

Now that a decision is made that a PSS is a good alternative in the asset solution, the next step is to make sure that the PSS is implemented well. The first two steps are to make two visual maps of the stakeholders. The first map (3.1a) with the contractual relationships, to make sure that the it is clear for the user how the final contractual, formal, relationship is. The second map (3.1b) is a stakeholder map which contains the flow of money, products, services and data between the different involved stakeholders. This to ensure that the user has a clear overview of which stakeholder is involved with whom and which dependencies exist between them.

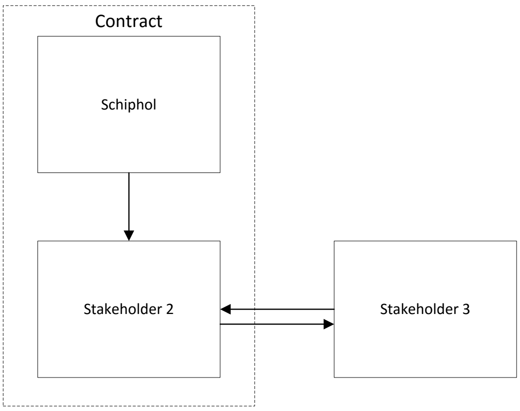


Figure 1.22 - Example of Contractual map

Example of stakeholder map.

When the user has a clear picture of how the different relationships and dependencies are between the stakeholders, the user may continue to step 3.2.

1.7.4.2 Determine KPIs

Using the relationships, the various flows between stakeholder and the formal relationship, the user is now able to develop and determine the proper KPIs which allows Schiphol and the supplier to deliver the optimal performance and sustain a healthy long term relationship. By first mapping the flow of data, products and services the user can develop the KPIs to make sure that these dependencies are covered by them. The compensation for these services and product is the monetary flow, which is determined by how well the performance standards for the KPIs are met. If all relationships are sufficiently covered, the user may continue to 3.3

1.7.4.3 KPIs SMART?

This step is a formal check to make sure that the determined KPIs from the previous step are SMART. KPIs need to be smart in order to be executable and usable.

1. Specific
2. Measurable
3. Accountable
4. Realistic
5. Time

If the conclusion is drawn that one of the KPIs is not, the KPI must be made SMART, which is the line in Figure 1.20 between 3.3 and 3.2. When the user concludes that all KPIs are SMART, the user may continue to 3.4.

1.7.4.4 KPI Classification

The next step is make a classification of the KPI in order to determine which are the most important and which are less, it is important to make a prioritisation. This helps later on in the norm setting and to steer on what's most important for Schiphol. When the KPIs is prioritised, the user may continue to 3.5.

1.7.4.5 Validation

When the user, and thus Schiphol, has determined the KPIs is deems important and essential for the PSS, it is important to validate the KPIs within Schiphol and with the external stakeholders. Internal stakeholders are process owners, or other departments which might become involved with the project.

External stakeholder are stakeholders mapped in both the contractual as well as the stakeholder map. Especially with the most important external stakeholder, the supplier, the KPIs need to be checked and validated with the supplier that it agrees that it can deliver the required functionality and performance according to the proposed KPIs.

1.7.4.6 Norm Setting

When the KPIs are validated by internal and external stakeholders, the user needs to set the norm for the KPIs. What is the minimum performance required, what is the level of performance for which the supplier is penalised and what long term performance goals could provide the supplier with a bonus. These questions need to be answered for each KPI.

When the norm setting has been completed and the user is satisfied with the required performance of the supplier. The user may continue to stage 4.

1.7.5 Stage 4 – Contractual Agreements

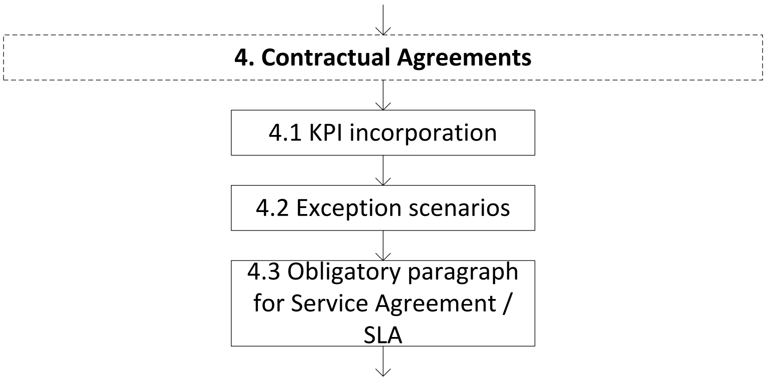


Figure 1.23 - Stage 4

1.7.5.1 KPI Incorporation

The next step is to include the KPIs into the contract with the supplier. This step is explicitly mentioned, to make sure that it is formally done. This ensures that the KPIs, the norm, bonus and malus for each KPI are clear and integrated in the contract.

1.7.5.2 Exception Scenarios

The next step is to think about exception scenarios which might causes that either Schiphol or the supplier is unable to deliver the agreed performance of the PSS. Usually, assets which are used as PSS are part of a bigger projects and delay in construction or other force majeure could lead that the performance can't be delivered. It is important to think about possible scenarios beforehand, because it can put strain on the relationship between Schiphol and the supplier and the relationship is one of the fundamentals of a successful PSS implementation. The impact of such events on warranty, norm/bonus/malus, service fee and contract breach need to be described.

1.7.5.3 Obligatory Paragraph for SLA

For the completeness of the contract, the following aspects need to be incorporated or considered to be incorporated in the SLA to make sure that it is sufficient and covering the requirements needed to for a successful Product-Service System within Schiphol.

1. Function of the service
    a. The functions offered
    b. Possible time of usage
    c. Needed support from Schiphol
2. Performance of the required service
    a. KPIs
    b. Norm of the KPIs
    c. Bonus/Malus rules
3. Possible restrictions on the usage of the service
4. Administrative details of the SLA
    a. Duration of the contract
    b. Arrangements on the prolongation of the SLA
    c. Arrangements on proposed changes to the SLA
    d. Arrangements for cost calculation and invoice arrangements
    e. Arrangements for possible disputes and the roles of a potential third party as a mediator
    f. Arrangements for End-of-Life disposal
    g. Possible financing arrangements
    h. Legal liabilities of both parties
    i. Description of scenarios in which force majeure are at play
    j. Reporting and frequency of reporting
    k. Clear definition on possible conflict of interpretation of certain words, passages, etc.
    l. Possible sections of contract which might be changed without renegotiating the whole contract
    m. Evaluation moments and possibilities of the SLA
    n. If needed; paragraph on customer experience, measurements of customer experience and perception of quality of service
    o. If needed; paragraph on innovation and continuous improvement of performance

1.7.6 Stage 5 – Decision Process complete (title!)

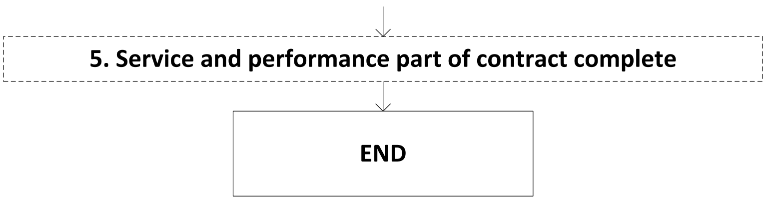


Figure 1.24 - Stage 5

Once the SLA point have been addressed, the user has gone through the complete decision process to check whether a PSS is a good alternative, what a fair price should be and how the development of KPIs is well structured that it sufficiently covers all needed aspects.

1.8 Appendix H - Manual PSS Criteria Matrix

PSS Criteria	1. Labour, resource and/or energy intensive?	2. Not part of primary proces?	3. Impact on operation severe?	4. Market/ Investment Size sufficient?
Place Check if Applicable				
Option 1: Suitable for PSS	✓	✓	✓	✓
Option 2: Conditional Suitability for PSS	✓			✓
Option 2: Conditional Suitability for PSS	✓	✓		✓
Option 2: Conditional Suitability for PSS	✓		✓	✓
Other check combinations are not Suitable for PSS				

Figure 1.25 - PSS Criteria Matrix

1.8.1 Product-Service System criteria check

The user must decide whether the project meets the following four criteria. If so, the user can place a check in the second row and after all four criteria are done, see which criteria have checks and which have not. Based on this outcome it can be decided whether this project is suitable for being a Product-Service System or not.

1. **Labour, resource and/or energy intensive?** The user must decide if the product/asset is an intensive user of either labour, resource and/or energy. If this is the case, a check is placed in the white checkbox under the first criteria.
2. **Not part of primary process**? The user must decide what the influence of the asset/product is on the primary process of Schiphol. Does it affect airport operation in a critical way, does it have the potential to greatly disturb important primary processes. If this is the case, the user must decide whether to retain control by remaining owner, or is sufficiently able enough to transfer ownership to a supplier and is able to mitigate this loss of control with proper contracting. If the user is not sure whether Schiphol is able to exert such control via contracting, no check should be placed. The scale of severity can be seen in Figure 1.25.
3. **Impact on operation severe?** The user must check whether the malfunction of the product/asset has impact on the operation. If the influence is too small, the question is raised whether Schiphol needs to invest in a service layer on top of the normal product/asset. The scale of severity can be seen in Figure 1.19.

4. **Market/Investment Size sufficient?** The last criterion is that the market or investment size needs to be sufficient in order to justify the investment in a service layer. If the investment size from Schiphol is too small, the needed investment for a service layer is to big compared to the product/asset. If a supplier already has a product with service which it can easily implement, the check may be placed.

1.8.2 Feasibility PSS

The project is **only** feasible to be executed as a PSS in the following combination of checks placed.

1. Option 1. All criteria are checked. In this case, the project is well suitable for being executed as a Product-Service System. It fulfils all needs.

Option 1: Suitable for PSS	✓	✓	✓	✓

2. Option 2a. All criteria except criterion 2. This means that the project has a big influence on one of the primary processes of Schiphol. In this case, the user must think how it can mitigate the potential risk of the loss of control due to the lack of ownership. If Schiphol is able to account for this loss of control by good contracting and clear arrangements with the supplier in order to minimise the risk, the project is suitable for PSS.

Option 2: Conditional Suitability for PSS	✓		✓	✓

3. Option 2b. All criteria except criterion 3. This means that the severity if the product does not function according to specifications, the impact is limited. The problem this induces, is that it could potentially undermine the negotiation position of Schiphol. This due to the fact that if something can still deliver the functionality it needs to deliver, for instance a floor tile which is worn, but still allows people to walk across it, it is hard to demand that it is repaired or fixed, because the function is still present. The user must think about alternate ways to secure it negotiation position. Such as performance requirements on the uniformity of looks, perceived quality by customers etc. If the user can account for this, the project is suitable for a PSS.

Option 2: Conditional Suitability for PSS	✓	✓		✓

4. Option 2c. Even though it is highly unlikely, if the situation occurs that the project is both part of the primary process, but still the severity of the malfunction has no real impact on the functionality of the product/or asset, the product or asset can still be suitable for a PSS, but the user must think about possible mitigation of this risk beforehand. If it can't come up with such a plan, the project is unsuitable for a PSS.

Option 2: Conditional Suitability for PSS	✓			✓

Any other combination of placed checks, means that the project is not suitable for being executed as a PSS.

1.9 Appendix I – Manual PSS Pricing Tool

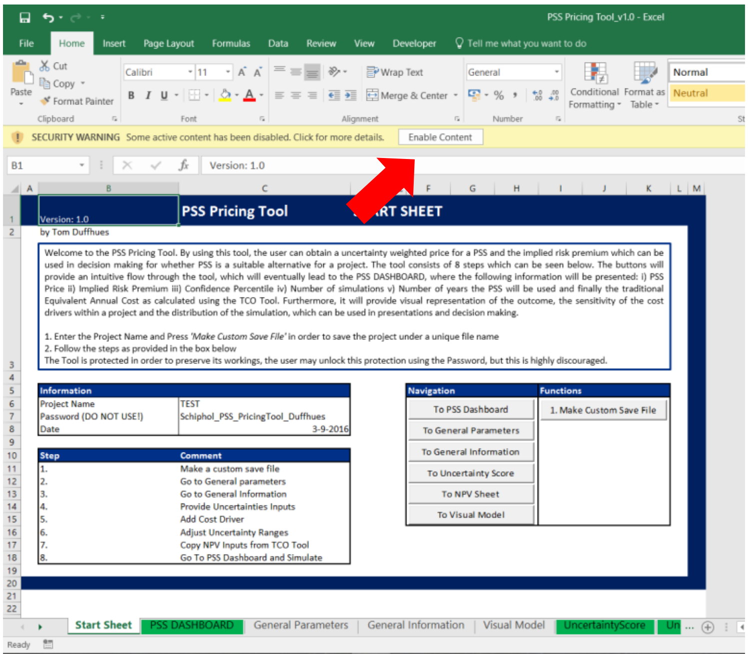
This manual helps the user of the PSS Pricing Tool in using the tool correctly and to get a price indication of what Schiphol should pay for a PSS.

1.9.1 Needed information

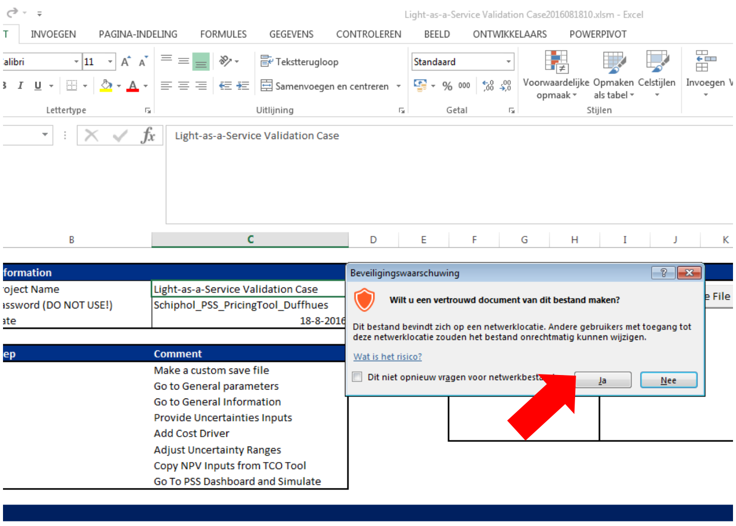
Generally speaking, there are two sources of information required for the usage of the Tool.

1. Complete TCO tool with financial information
2. Specialist from TEC who knows, or can assess a potential supplier

1.9.2 Opening the tool



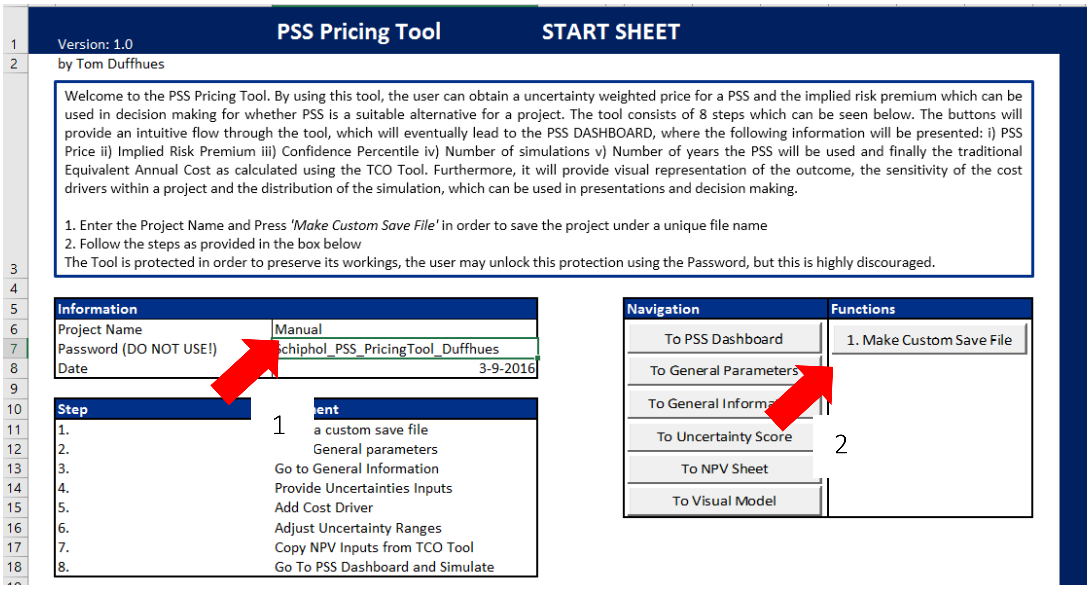
The first important step is to press 'enable content' or 'inhoud inschakelen'. This allow Excel to use the macros embedded in the Tool.



It could also be that Excel gives a second warning. Press 'Yes' or 'Ja'.

1.9.3 Make Custom Save file

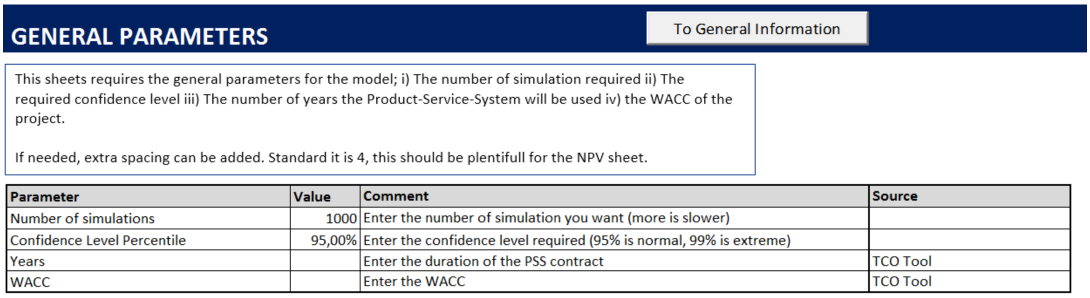
The first thing the user needs to do is to save the Tool under a unique name. This can easily be done by filling in the Project name and press 'Make Custom Save File'.



1.9.4 General Parameters

The next step is to go to general parameters by pressing the 'To General Parameters' button.

Here, the users must enter the following information:



GENERAL PARAMETERS

To General Information

This sheets requires the general parameters for the model; i) The number of simulation required ii) The required confidence level iii) The number of years the Product-Service-System will be used iv) the WACC of the project.

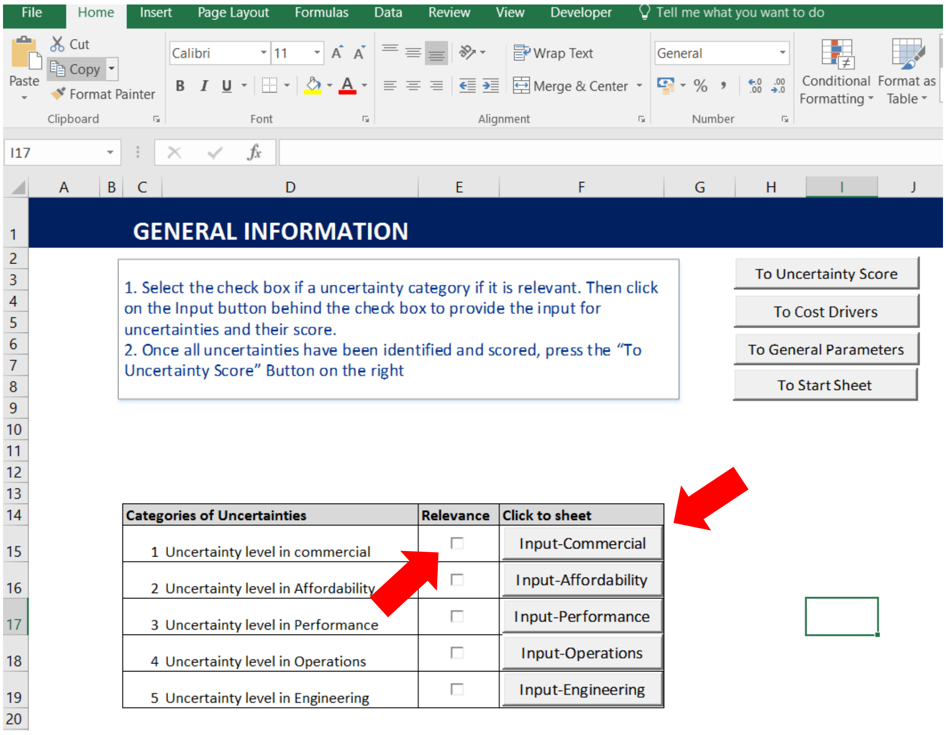
If needed, extra spacing can be added. Standard it is 4, this should be plentifull for the NPV sheet.

Parameter	Value	Comment	Source
Number of simulations	1000	Enter the number of simulation you want (more is slower)	
Confidence Level Percentile	95,00%	Enter the confidence level required (95% is normal, 99% is extreme)	
Years		Enter the duration of the PSS contract	TCO Tool
WACC		Enter the WACC	TCO Tool

The number of simulations (1000) and the confidence level (95%) are already filled in. The user needs to add the number of years the project/PSS will be used and the WACC as used in the traditional asset purchase.

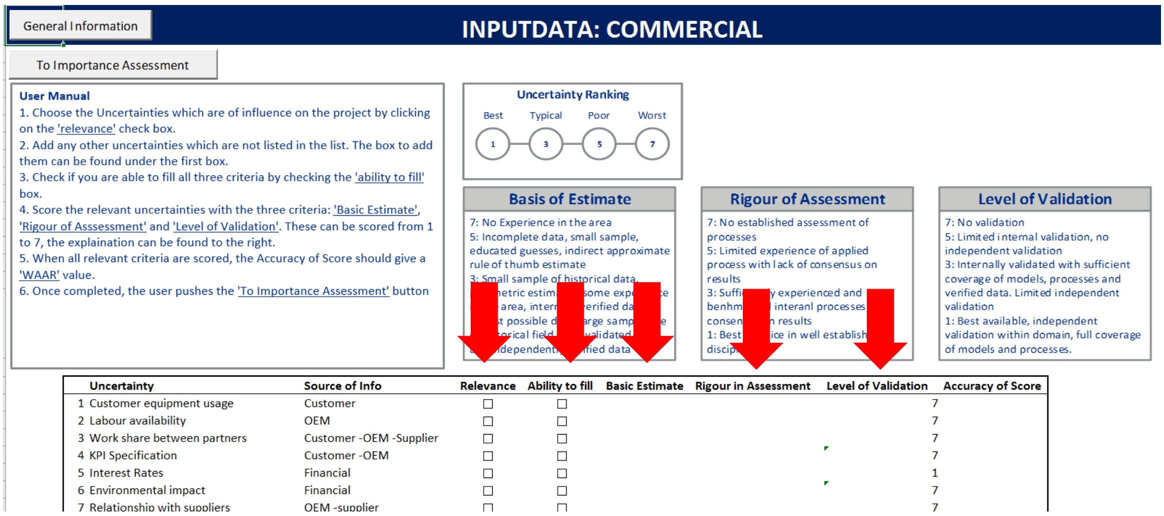
Next, press the 'To General Information Button'

1.9.5 General Information



This is the sheet the user sees when first using the tool. There are 5 categories of uncertainty. For each uncertainty, the user must check the box if they category is relevant. If the box is clicked, the user must then press the 'Input-' button which is next to the box to start the assessment. This is best done with someone from TEC who knows the supplier best.

1.9.6 Uncertainty Assessment



The user needs to follow the 6 steps as presented in the top left.

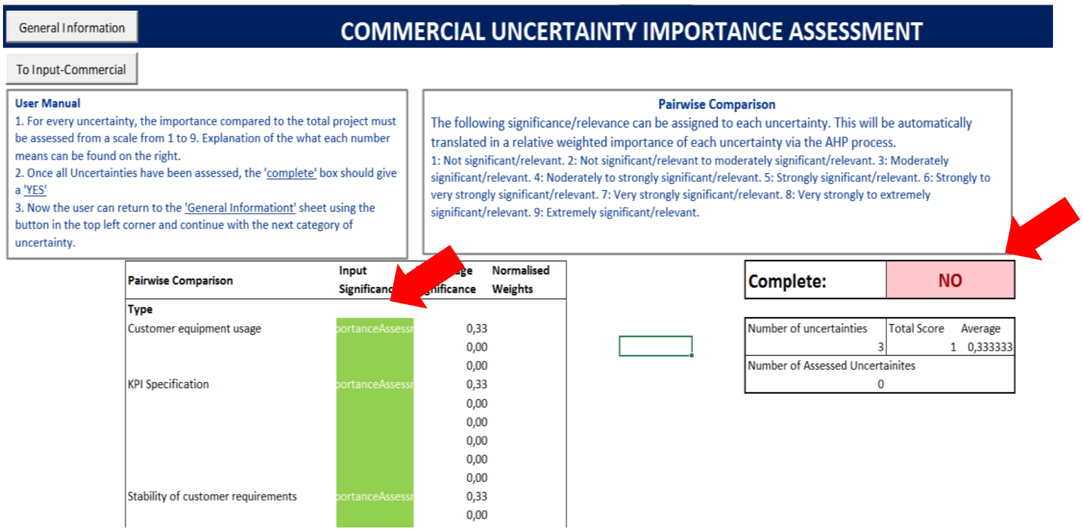
1. Choose which uncertainties are relevant for the supplier. Check the box relevance and the box ability to fill.
2. If an uncertainty is missing, below this list is an empty box of max three uncertainties which may be added by hand.
3. Score each uncertainty on the three criteria on a 4-point scale (1, 3, 5, 7). 1 is no uncertainty, 7 is a high uncertainty.

Basic estimate is the estimate of the amount of uncertainty. *Rigour of Assessment* is the possibility to check it internal for a supplier (for instance, material testing). *Level of validation* is whether the supplier is able to check it outside its own firm (for instance KPI specifications are provided by Schiphol).

4. Once all relevant uncertainties have been scored, the accuracy of score should say 'WAAR' in green.
5. Now press the button 'To Importance Assessment'

1.9.7 Importance Assessment

The next step is to score the uncertainty on the amount of influence it might have on the total project. This score is given for 1-9, where 1 is no influence and 9 is extremely high influence. There is dropdown menu for only the uncertainties which have been selected as relevant. Once the user has scored all relevant uncertainties, the Complete will turn from a Red NO to green YES

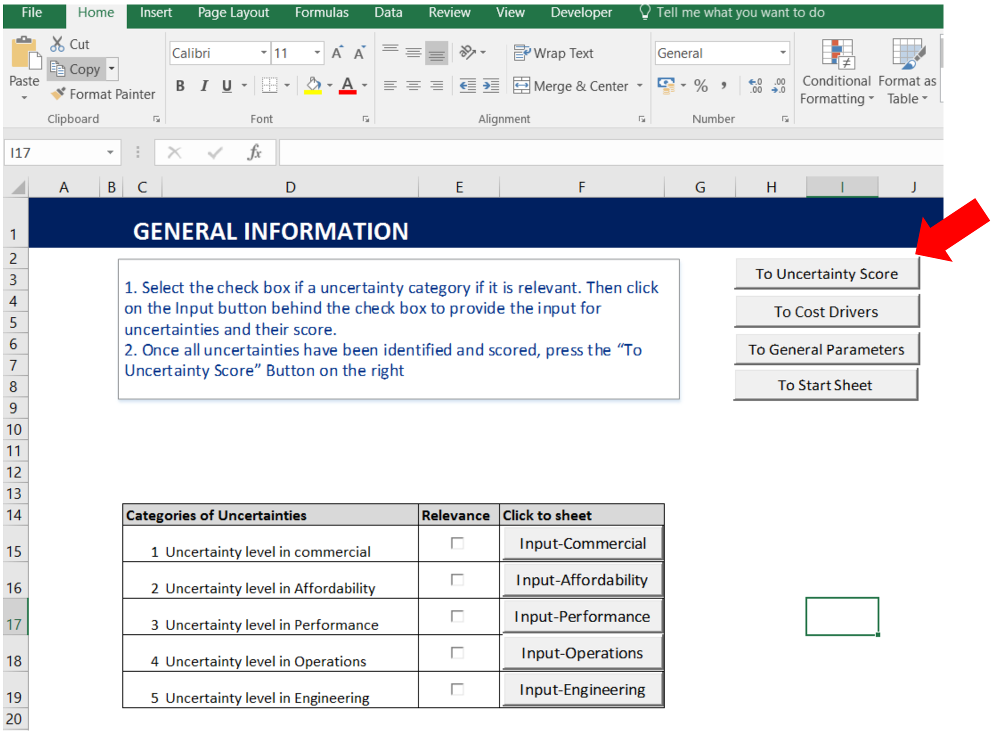


Next click on 'General Information'.

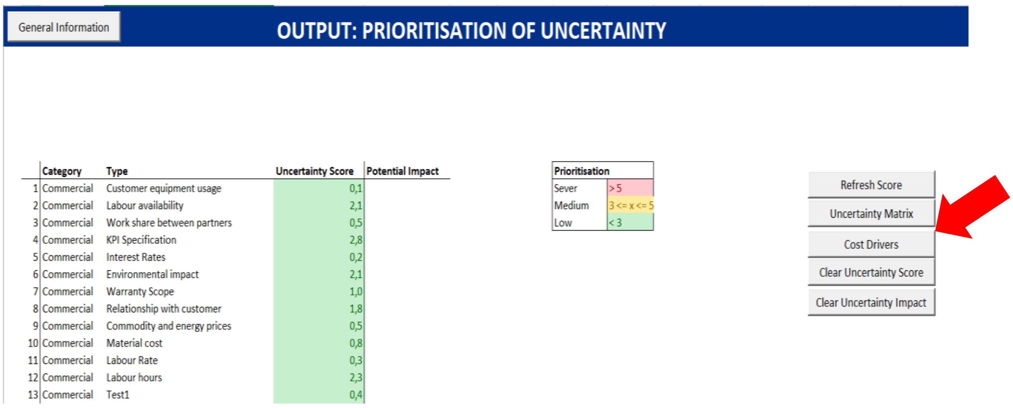
These steps are to be repeated for each category of uncertainty which is relevant. The procedure is identical.

1.9.8 Uncertainty Score

Now Press Uncertainty score in order to let the tool calculate the uncertainty score of each uncertainty.



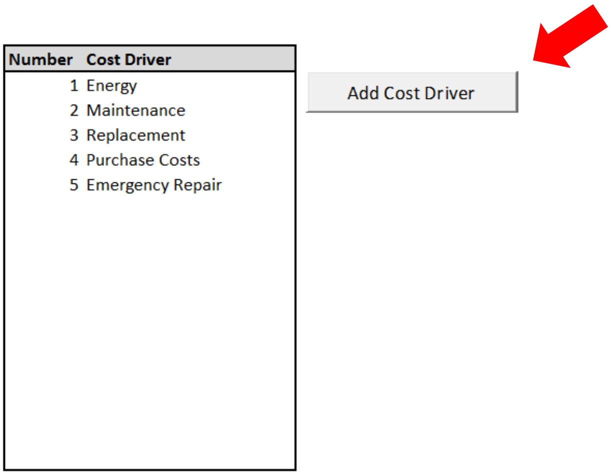
An example of how this could look is given below:

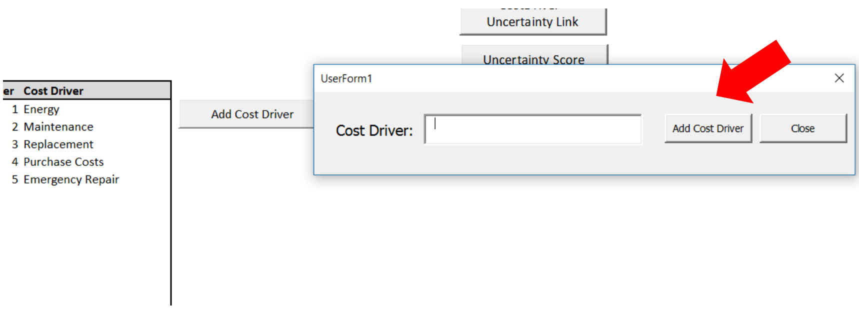


Next press on the Cost Drivers button.

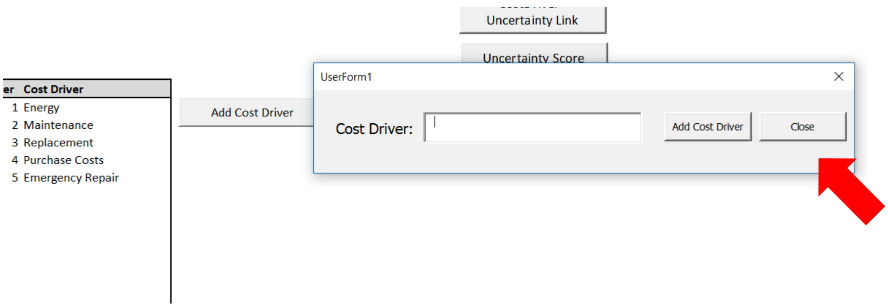
1.9.9 Cost Drivers

Cost drivers are the costs in a project. Think of initial purchase and maintenance costs. These cost drivers come directly from the TCO tool. By pressing add cost driver button, the user can add a cost driver to the list.

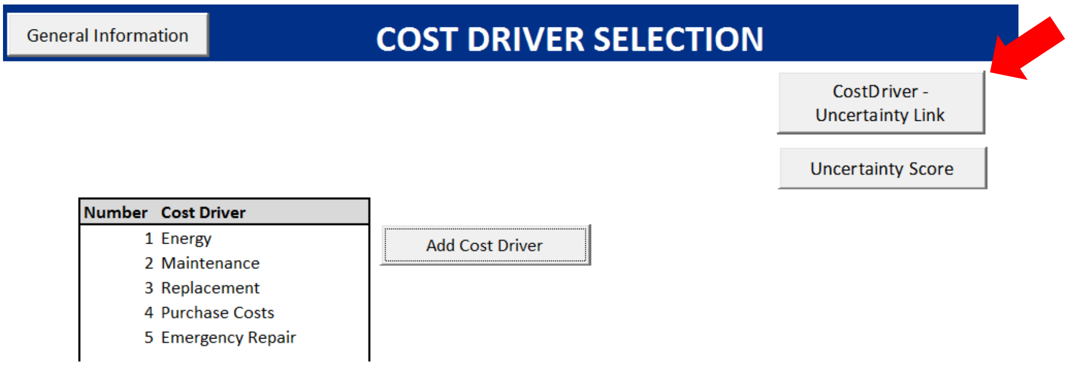




Once all cost drivers have been added, press close.

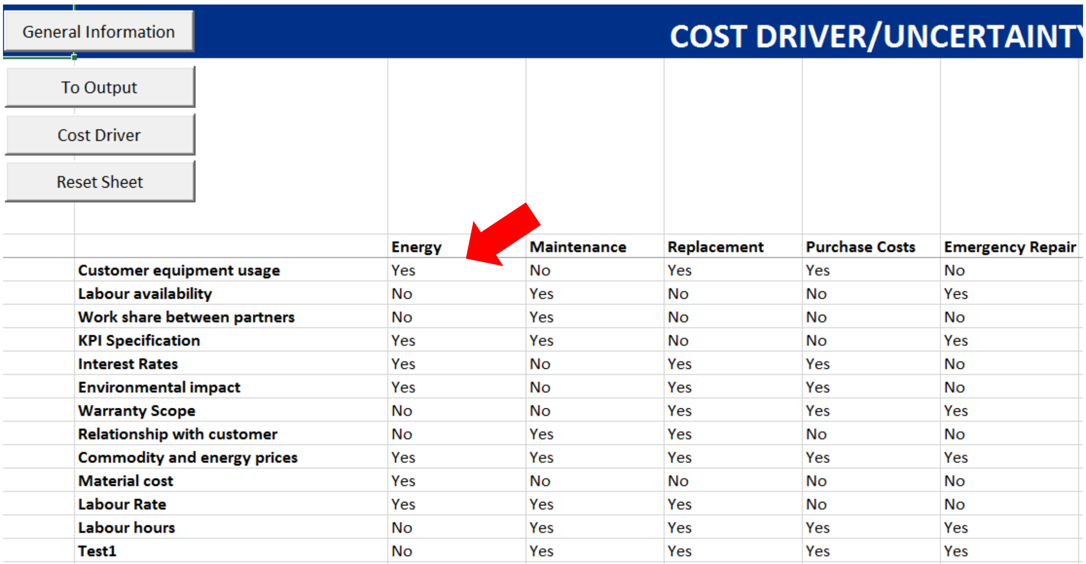


Now press the Cost Driver – Uncertainty link button



1.9.10 Cost Driver Uncertainty Link

The user now needs to indicate whether an uncertainty has influence on a cost driver or not. The options are Yes and No. Once this has been done for all uncertainties, the overview might look like the one below here.



	Energy	Maintenance	Replacement	Purchase Costs	Emergency Repair
Customer equipment usage	Yes	No	Yes	Yes	No
Labour availability	No	Yes	No	No	Yes
Work share between partners	No	Yes	No	No	No
KPI Specification	Yes	Yes	No	No	Yes
Interest Rates	Yes	No	Yes	Yes	No
Environmental impact	Yes	No	Yes	Yes	No
Warranty Scope	No	No	Yes	Yes	Yes
Relationship with customer	No	Yes	Yes	No	No
Commodity and energy prices	Yes	Yes	Yes	Yes	Yes
Material cost	Yes	No	No	No	No
Labour Rate	Yes	Yes	Yes	No	No
Labour hours	No	Yes	Yes	Yes	Yes
Test1	No	Yes	Yes	Yes	Yes

Once finished, press ‘To Output’. The tool will automatically check if all uncertainties are assigned.

1.9.11 Cost Driver Uncertainty Score

General Information

OUTPUT: COST DRIVER AND UNCERTAINTY

Initialise NPV Sheet

Uncertainty	Energy	Maintenance	Replacement	Purchase Costs	Emergency Repair
Customer equipment usage	0,10	0,00	0,10	0,10	0,00
Labour availability	0,00	2,10	0,00	0,00	2,10
Work share between partners	0,00	0,50	0,00	0,00	0,00
KPI Specification	2,80	2,80	0,00	0,00	2,80
Interest Rates	0,20	0,00	0,20	0,20	0,00
Environmental impact	2,10	0,00	2,10	2,10	0,00
Warranty Scope	0,00	0,00	1,00	1,00	1,00
Relationship with customer	0,00	1,80	1,80	0,00	0,00
Commodity and energy prices	0,50	0,50	0,50	0,50	0,50
Material cost	0,80	0,00	0,00	0,00	0,00
Labour Rate	0,30	0,30	0,30	0,00	0,00

The sheet will look something similar like the picture above. When you scroll down the uncertainty score of each cost driver is visible.

Cost estimating data reliability or quality	0,00	4,30	4,30	0,00	4,30
Effectiveness of managment of risk and op	0,50	0,00	0,50	0,50	0,00
Uncertainty score (divided by 7)	0,27	0,29	0,23	0,25	0,35
Lower Range	-0,10	-0,10	-0,10	-0,10	-0,15
High Range	0,15	0,15	0,15	0,15	0,20
Distribution	Triangular	Triangular	Triangular	Triangular	Triangular
Sigma (Normal Distribution)					
Mu (Normal Distribution)					
Lambda (Weibull Distribution)					
K (Weibull Distribution)					
Sigma (Lognormal Distribution)					
Mu (Lognormal Distribtuion)					

If a distribution is known, it can be changed from triangular into a different one. But it is suggested to not change, unless absolutely certain.

Next scroll up again and hit 'Initialise NPV sheet' if it is the first time that you use the tool or when an adjustment has been made to the number of cost drivers. This initialises the NPV sheet for later usage.

1.9.12 Checking the ranges

General Information

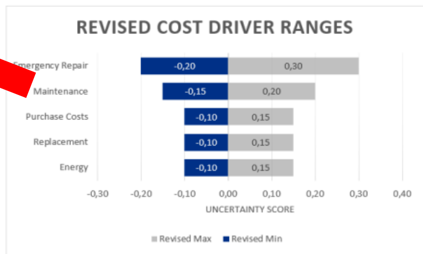
COST DRIVER RANGES: ADJUSTMENT

Get Ranges for Adjustment

Reset/Initiate Revision

Go to NPV-INPUT Sheet

	Uncertainty Score	Suggested Range		Revision	
		Original Min	Original Max	Revised Min	Revised Max
Energy	0,26	-0,10	0,15	-0,10	0,15
Replacement	0,23	-0,10	0,15	-0,10	0,15
Purchase Costs	0,25	-0,10	0,15	-0,10	0,15
Maintenance	0,29	-0,10	0,15	-0,15	0,20
Emergency Repair	0,35	-0,15	0,20	-0,20	0,30



First press 'Get Ranges for Adjustment' and then Reset/Initiate Revision. This will load the ranges into the table.

General Information

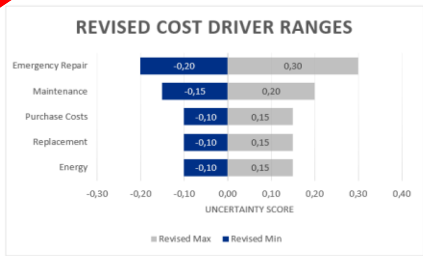
COST DRIVER RANGES: ADJUSTMENT

Get Ranges for Adjustment

Reset/Initiate Revision

Go to NPV-INPUT Sheet

	Uncertainty Score	Suggested Range Original Min	Original Max	Revision Revised Min	Revised Max
Energy	0,26	-0,10	0,15	-0,10	0,15
Replacement	0,23	-0,10	0,15	-0,10	0,15
Purchase Costs	0,25	-0,10	0,15	-0,10	0,15
Maintenance	0,29	-0,10	0,15	-0,15	0,20
Emergency Repair	0,35	-0,15	0,20	-0,20	0,30



Based on the uncertainty score of each cost driver, the cost range is determined. The range assigned to each cost driver can be seen in the figure on the right, which look like a tornado. If no adjustments are needed, the user may press 'Go to NPV-INPUT Sheet'.

1.9.13 NPV INPUT Sheet

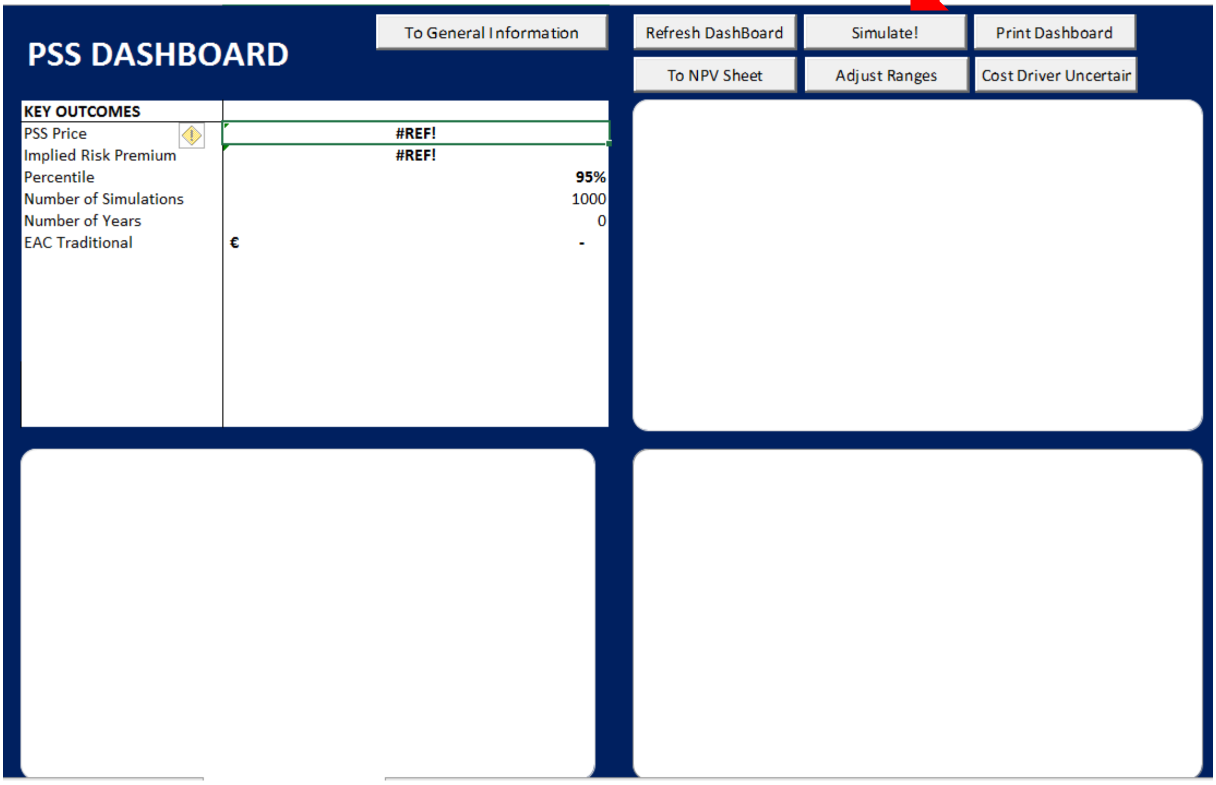
To PSS Dashboard

Year	0	1	2	3	4	5	6	7	8	9	10	NPV
Energy												
	€ 1.500	€ 1.545	€ 1.591	€ 1.639	€ 1.688	€ 1.739	€ 1.791	€ 1.845	€ 1.900	€ 1.957	€ 2.016	
PV Sum	**€ 1.500,00**	**€ 1.501,46**	**€ 1.502,59**	**€ 1.504,29**	**€ 1.505,60**	**€ 1.507,38**	**€ 1.508,70**	**€ 1.510,39**	**€ 1.511,58**	**€ 1.513,05**	**€ 1.514,74**	€ 16.579,77
PV Sum for Simulation	€ 1.620,93	€ 1.594,14	€ 1.490,61	€ 1.489,90	€ 1.443,24	€ 1.634,75	€ 1.426,03	€ 1.464,93	€ 1.517,45	€ 1.643,34	€ 1.514,69	€ 16.840,01
Maintenance												
	€ 3.000	€ 3.150	€ 3.308	€ 3.473	€ 3.647		€ 3.000	€ 3.150	€ 3.308	€ 3.473	€ 3.647	
PV Sum	**€ 3.000,00**	**€ 3.061,22**	**€ 3.124,17**	**€ 3.187,56**	**€ 3.252,93**	**€ -**	**€ 2.527,14**	**€ 2.578,71**	**€ 2.631,74**	**€ 2.685,14**	**€ 2.740,20**	€ 28.788,81
PV Sum for Simulation	€ 2.972,03	€ 3.316,66	€ 3.261,30	€ 3.077,03	€ 3.176,58	€ -	€ 2.834,84	€ 2.499,00	€ 2.617,24	€ 2.677,23	€ 2.926,04	€ 29.357,94
Replacement												
						€ 15.000						
PV Sum	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ 13.002,13**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	€ 13.002,13
PV Sum for Simulation	€ -	€ -	€ -	€ -	€ -	€ 13.504,17	€ -	€ -	€ -	€ -	€ -	€ 13.504,17
Purchase Costs												
	€ 30.000,00											
PV Sum	**€ 30.000,00**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	€ 30.000,00
PV Sum for Simulation	€ 31.264,45	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ 31.264,45
Emergency Repair												
									€ 2.500,00			
PV Sum	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ 1.988,92**	**€ -**	**€ -**	€ 1.988,92
PV Sum for Simulation	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ 2.132,41	€ -	€ -	€ 2.132,41
PV per year	€ 34.500,00	€ 4.562,68	€ 4.626,76	€ 4.691,86	€ 4.758,53	€ 14.509,51	€ 4.035,84	€ 4.089,10	€ 6.132,23	€ 4.198,18	€ 4.254,93	
Simulation PV per year	€ 35.857,41	€ 4.910,80	€ 4.751,91	€ 4.566,93	€ 4.619,82	€ 15.138,92	€ 4.260,87	€ 3.963,93	€ 6.267,09	€ 4.320,57	€ 4.440,73	
Traditional Net Present Value	€ 90.359,63											
Equivalent Annual Cost	€ 10.538,92											
Simulation Net Present Value	€ 93.098,98											
Equivalent Annual Cost	€ 10.858,41											

Above the user sees an example of the NPV sheet. Above the double line, the user copies the cashflow from each cost driver from the TCO tool. If any help is needed, the CEC, Business Controller or Financial Advisor should be able to help. The PV Sum shows the value as it is present in the TCO tool. Check this.

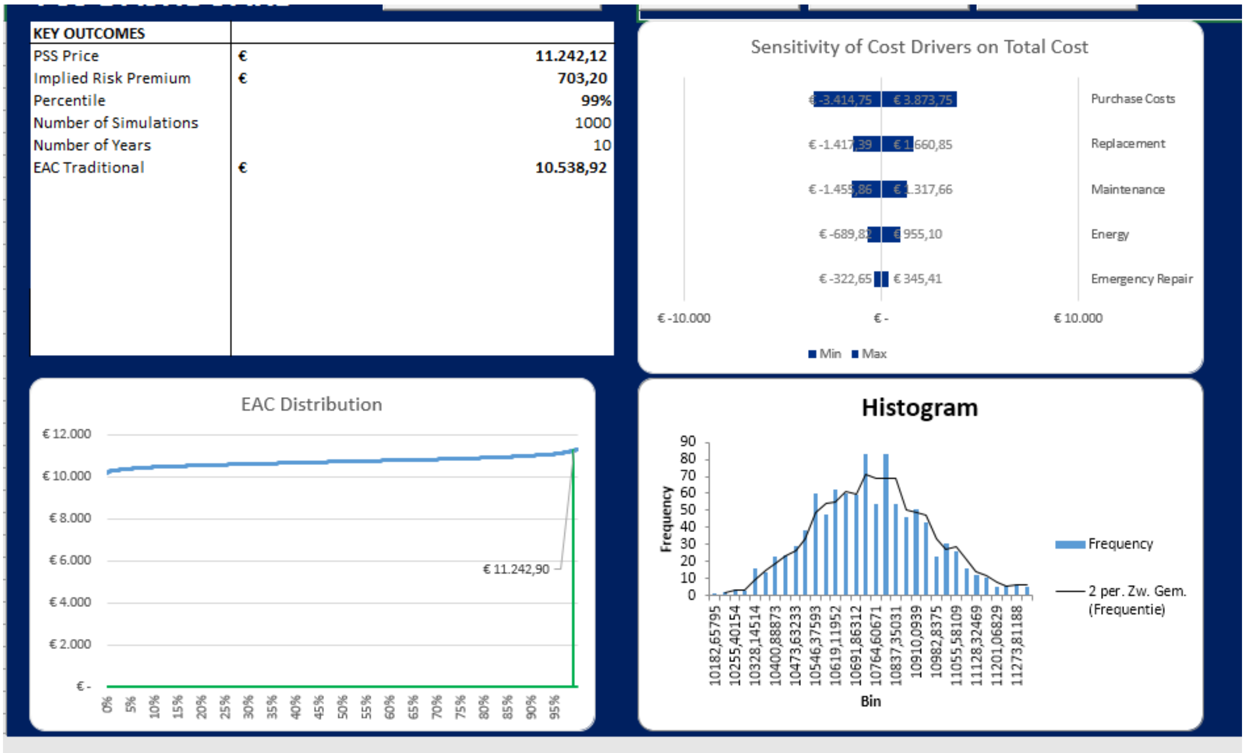
The value in the row of PV simulation is a value which is part of the simulation. Once completely filled in, the user presses on the 'To PSS Dashboard' button.

1.9.14 PSS Dashboard and simulation

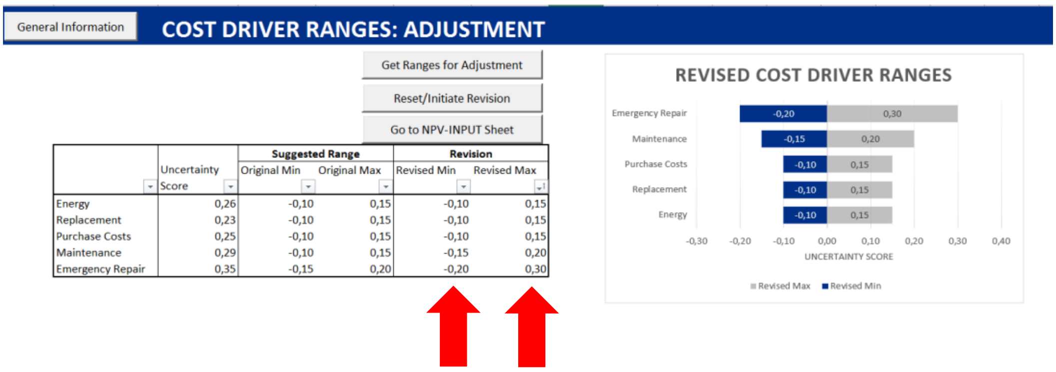


The user then finds this empty dashboard. With all parameters and information set, the user can press Simulate! In order to commence the simulation. The simulation takes can 5 to 30 seconds and the screen may flicker some, let it run until it is completely finished.

After the simulation, the dash board should look like this.



From the overview, an assessment can be made if some of the ranges might be too big or too small. It can be that uncertainty is under or overstated. This can be adjusted by pressing 'Adjust Ranges', which gives the ranges sheet where the ranges can be adjusted.

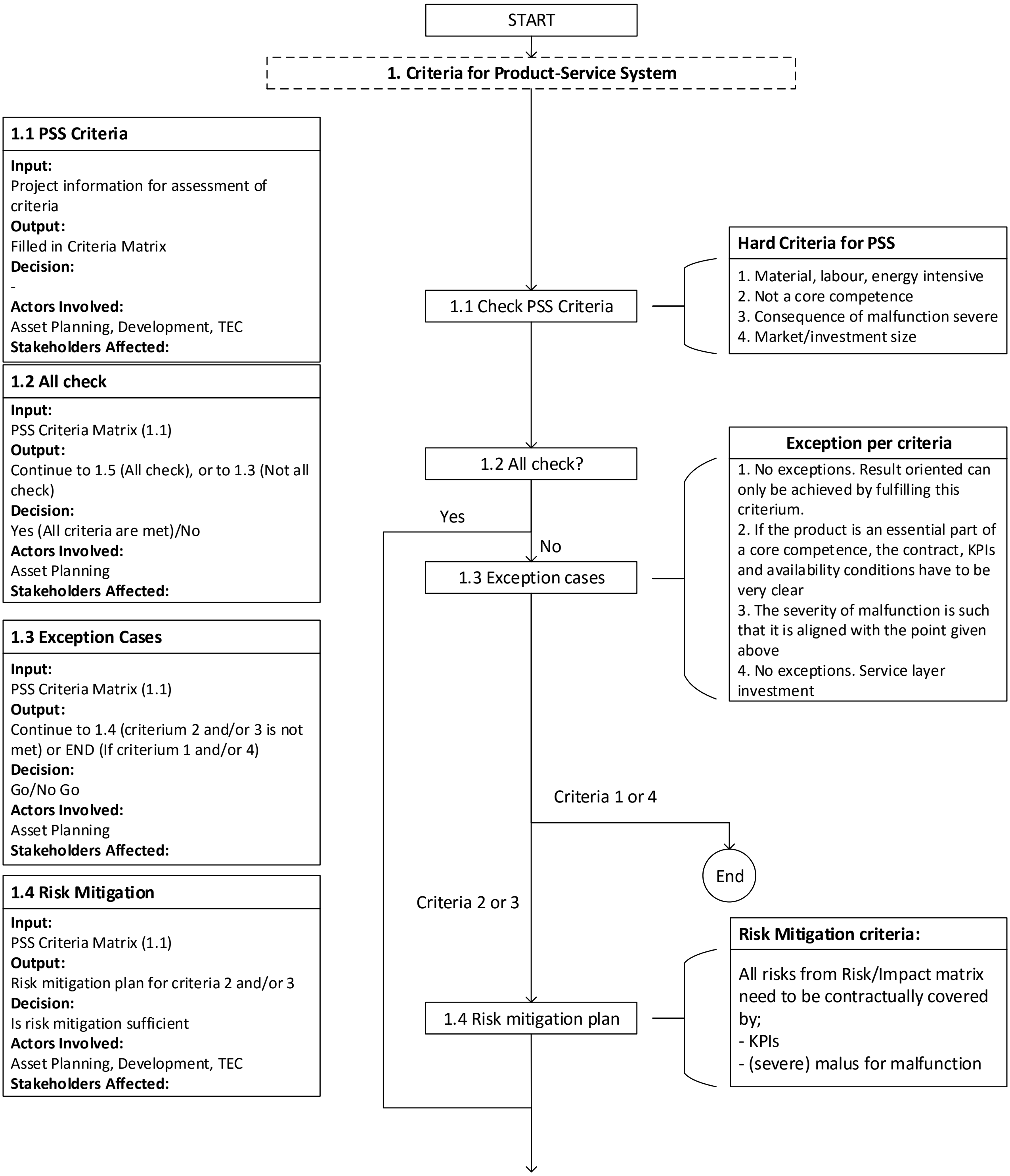


		Suggested Range		Revision	
	Uncertainty Score	Original Min	Original Max	Revised Min	Revised Max
Energy	0,26	-0,10	0,15	-0,10	0,15
Replacement	0,23	-0,10	0,15	-0,10	0,15
Purchase Costs	0,25	-0,10	0,15	-0,10	0,15
Maintenance	0,29	-0,10	0,15	-0,15	0,20
Emergency Repair	0,35	-0,15	0,20	-0,20	0,30

For each Cost Driver, only if needed, the range can be adjusted. The figures need to be for the Revised Min column between -1,00 (-100%) and 0 (0%) and for the Revised max between 0 (0%) and 1,00 (100%). Once finish, click on go to NPV-Sheet and the 'To PSS Dashboard'. Then click again on simulate to let the simulation rerun for the new result.

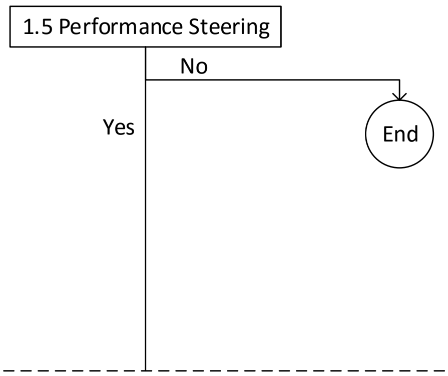
The final output can be used in decision making.

1.10 Appendix J – Extensive PSS Decision Framework



1.5 Performance Steering

Input:
1. Project information 2. PSS Criteria Matrix (1.1)
Output:
Continuation if performance steering is possbile, END if not
Decision:
Go/No Go
Actors Involved:
Asset Planning, Development, TEC
Stakeholders Affected:



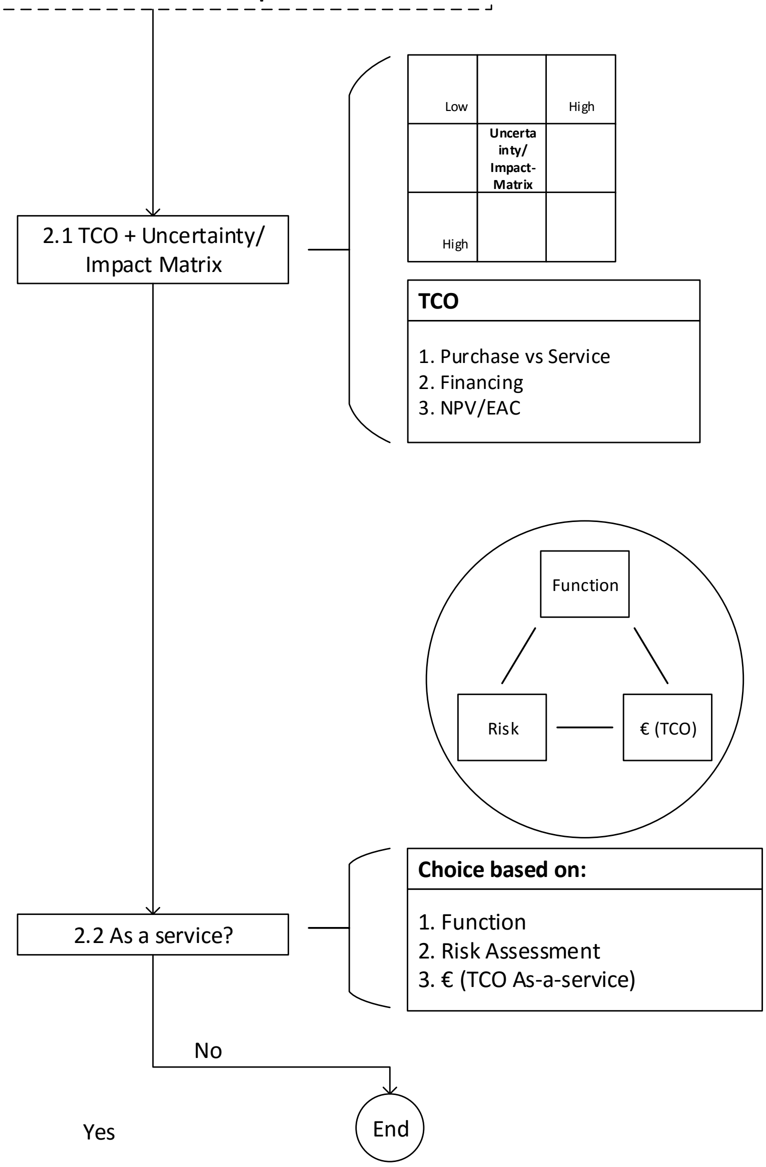
2. Traditional vs Service Comparison

2.1 TCO + Uncertainty/Impact Matrix

Input:
1. Project information 2. Uncertainties 3. CEC Input 4. Project input TEC 5. Uncertainty Assessment
Output:
TCO (traditional asset). TCO (As a Service Cost Estimation). Uncertainty/Impact Matrix
Decision:
1. Uncertainties for project 2. Assessment of uncertainty 3. Link between costs and uncertainty
Actors Involved:
Asset Planning, Development, TEC, CEC
Stakeholders Affected:
All

2.2 As a Service

Input:
1. TCO (traditional and As-a-service(2.1)
2. Uncertainty/Impact Matrix (2.1)
3. Functional Demands
Output:
Decision on As-a-Service
Decision:
Go/No Go As-a-Service based on Function, Risk and €
Actors Involved:
Planning, Development, Change Board
Stakeholders Affected:
ASM, Supplier, Process Owner



3.1 Contract/Stakeholder Map

Input:
3.1a Contractual parties
3.1b Project info on flow of; goods, service, money and information
Output:
1. Contractual Map 2. Stakeholder Map
Decision:
-
Actors Involved:
Development
Stakeholders Affected:
All stakeholders on map

3.2 KPI

Input:
1. Stakeholder Map (3.1a) 2. Project info
3. CR Goals
Output:
KPI
Decision:
What KPIs will be used
Actors Involved:
Development, Process Owner
Stakeholders Affected:
Supplier and Schiphol

3.3 SMART KPI

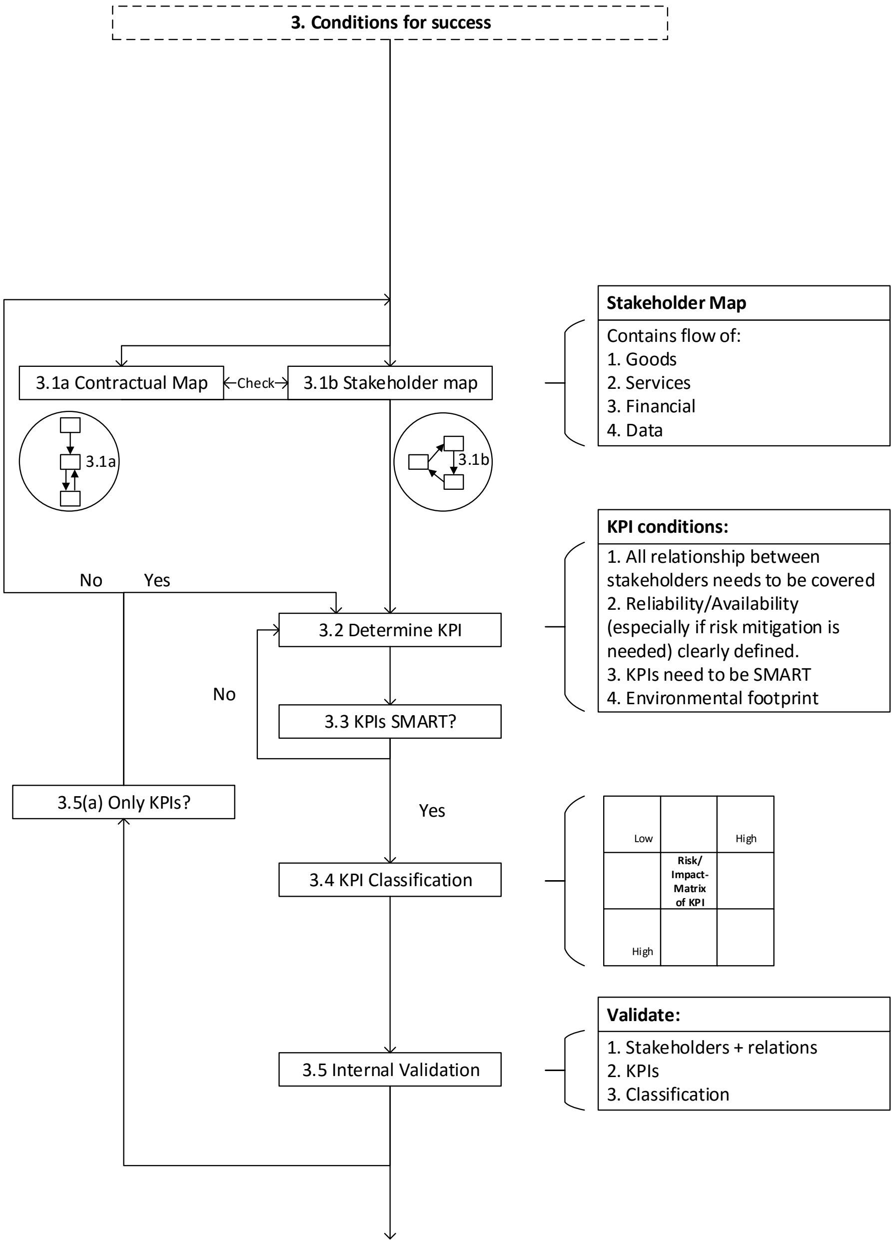
Input:
KPIs (3.2)
Output:
SMART KPIs
Decision:
Are the KPIs SMART?
Actors Involved:
Development
Stakeholders Affected:
Supplier and Schiphol

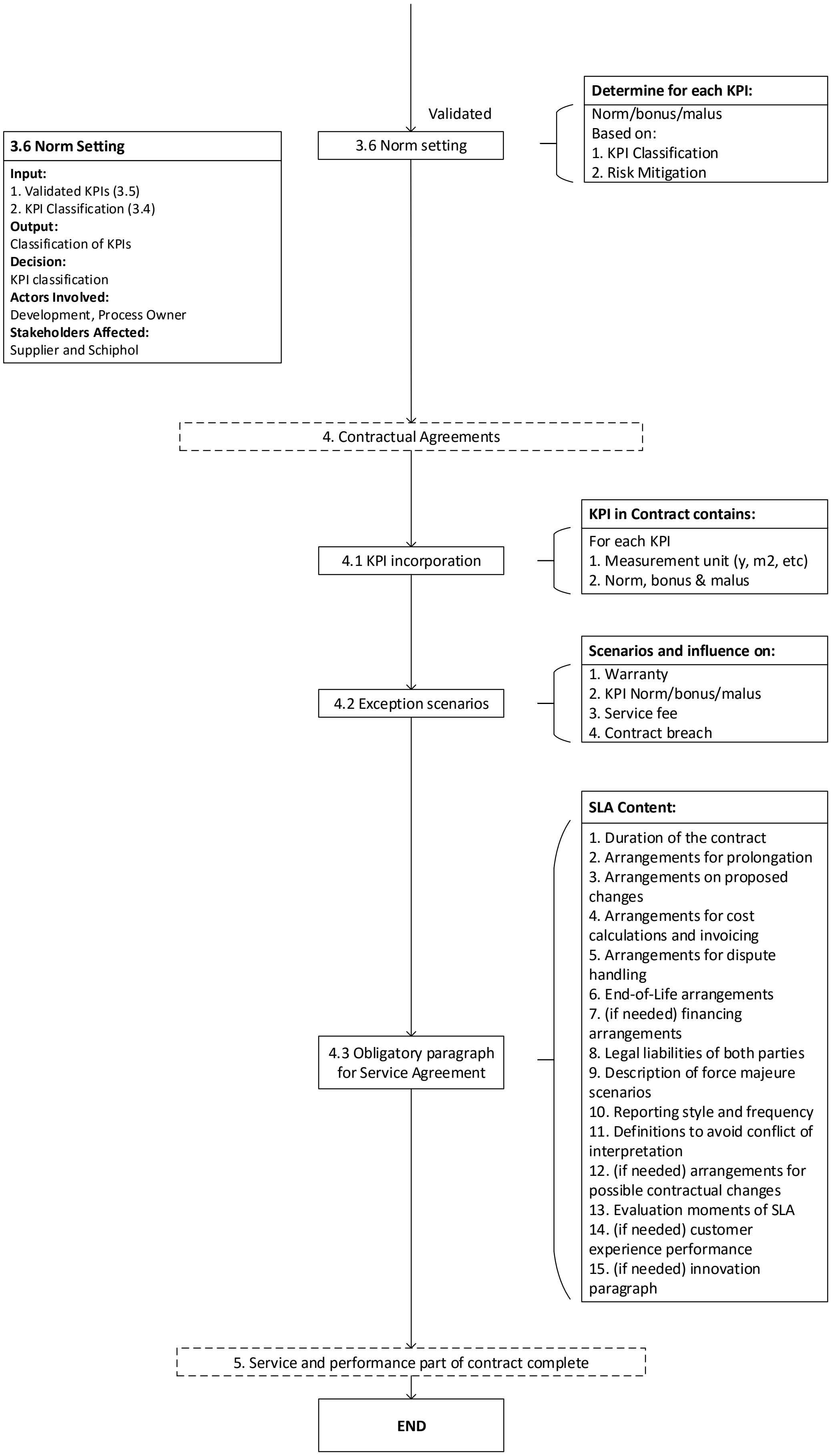
3.4 KPI Classification

Input:
SMART KPIs (3.3)
Output:
Classification of KPIs
Decision:
KPI classification
Actors Involved:
Development, Process Owner
Stakeholders Affected:
Supplier and Schiphol

3.5 Validation

Input:
1. SMART KPIs (3.3)
2. KPI Classification (3.4)
Output:
Validated KPIs
Reporting of KPI
Decision:
1. Are the valid 2. can the KPI be approved by internal and external stakeholders 3. What reporting frequency is wanted by teh process owner
Actors Involved:
Development, Process Owner, Supplier
Stakeholders Affected:
Supplier and Schiphol




Validated
3.6 Norm setting
Determine for each KPI:
Norm/bonus/malus
Based on:
1. KPI Classification
2. Risk Mitigation
3.6 Norm Setting
Input:
1. Validated KPIs (3.5)
2. KPI Classification (3.4)
Output:
Classification of KPIs
Decision:
KPI classification
Actors Involved:
Development, Process Owner
Stakeholders Affected:
Supplier and Schiphol
4. Contractual Agreements
4.1 KPI incorporation
KPI in Contract contains:
For each KPI
1. Measurement unit (y, m2, etc)
2. Norm, bonus & malus
4.2 Exception scenarios
Scenarios and influence on:
1. Warranty
2. KPI Norm/bonus/malus
3. Service fee
4. Contract breach
4.3 Obligatory paragraph for Service Agreement
SLA Content:
1. Duration of the contract
2. Arrangements for prolongation
3. Arrangements on proposed changes
4. Arrangements for cost calculations and invoicing
5. Arrangements for dispute handling
6. End-of-Life arrangements
7. (if needed) financing arrangements
8. Legal liabilities of both parties
9. Description of force majeure scenarios
10. Reporting style and frequency
11. Definitions to avoid conflict of interpretation
12. (if needed) arrangements for possible contractual changes
13. Evaluation moments of SLA
14. (if needed) customer experience performance
15. (if needed) innovation paragraph
5. Service and performance part of contract complete
END

1.11 Appendix K – List of Uncertainties

Commercial

Uncertainty Type	***Description***	***Source***
Customer equipment usage	Degree of misuse in equipment usage	Customer
Labour availability	Labour avaialbaility rate is considered; this also considers the uncertainty in skill loss over contract duration	OEM
Work share between partners	Driven by dependency on partners, uncerainties htat arise from conduction individual work shares	Customer -OEM - Supplier
KPI Specification	Selecting the appropriate KPIs at bidding and how these evolve throughout the contract	Customer -OEM
Interest Rates	Interest rates affecting expenditure for the project or influencing customers funding	Financial
Environmental impact	Environmental burden arising from pollution and disposal within the project duration	Financial
Relationship with suppliers	Over the contract duraciton the ucneratinty in the relationship with suppliers. This uncertainty has an ifluence over the flow materials/skills/cost along the supply network	OEM -supplier
Warranty Scope	Predicatability of the warranty scope for the given project	OEM
Relationship with customer	Driven by the progress (in terms of delivered quality and managing customer requirements) of a project resulting in unceratinty over the relationship with the customer	Customer -OEM
Stability of customer requirements	The uncertainty in customer requirement that influence the delivery of a project	Customer
Commodity and energy prices	The uncertainty level in ocmmodity and energy prices during the project duration	Financial
Exchanges Rates	Unceratintiy in exchange rates that influence expenditure and income over the project duration	Financial
Inflation/deflation	Uncertainty in the inflation/deflation rate	Financial
Material cost	Unceratinty in material costs: inlcudes spares, and consumables (influenced by scarcity)	Financial
Labour Rate	Uncertainty in the labour rate	OEM
Labour hours	Level of labour requirement which influences labour cost	OEM
Labour Efficiency	Uncertianty over how laobur is utilised in a project	OEM

Affordability

Uncertainty Type	***Description***	***Source***
Customer ability to spend	For the given project the ucneratinty in customer ability to spend	customer

Bid success rate	The bid success rate for an organisation inlcuences the setting of the prices. The variation is driven by the expeirnece of employees adn skill level. The link between bid success rate and affordability is price	OEM
Project life cycle cost	Driven by the rate of difficulty existing in predicting the whole life cycle costs (driven by complexity or technological newness)	OEM
Economy	Affordability influenced by the uncertainty in the eocnomy, which includes a combination of interest & exchange rates, and inflation	Financial
Equipment Availability	In availability contracts the affordability for customer is driven by the rate of equipment availability that is to be provided. Achievements with equipment availabilitiy are not static and vary driven by various factros such as labour quality adn efficiency, failiure rate and emergent work (requires definition of difference between at war and not)	Customer -OEM
Customer willingness to spend	The variation in the cusotmers' willingness to spend on a particular project	Customer

Performance

Uncertainty Type	***Description***	***Source***
IT	IT refers to its role in the infrasturcture and in project management tools. The unceratinty is associatated to the perofmrance of these spects driven by the IT capability	OEM
Performance against KPIs	Measures the performance in agreed levels (i.e. for OPDEFs), the question takes a high elvel view of the KPIs	OEM
Rate of surge	Rate of surge	OEM

Training

Uncertainty Type	***Description***	***Source***
Trainee skill level	Given the scenario that the customer does not specify or misspecifies the trainee skill level there is uncertainty that OEM needs to address. This influencdes the delivered course in terms of course spreed, depth of covered material.	Customer
Availability of trainers	The OEM is repsonsible to provide the trainers for the given training. However, the availability of trainers over project duration is not certain, cue to uncertainties in the labour quantity and customer requirements.	OEM

Number of students	It may be the case that the customer does not konw the number of trainess to be sent. It is also the case that rate of demand in the market is hard to predict	Customer
Facilities available	Theis includes the uncertainty the level of course material, computers or software tools, lecture rooms or buildings requirerd.	OEM
Courses to be offered	The number of courses that the customer reuqires is uncertain because of its evolving needs.	Customer
Availability of suitable candidates for training	The uncertainty is driven by the ability to find candidates for training	Customer
Ability to screen candidates for training	The uncertainty is driven by the ability to asess the candiddates that will be trained	Customer
Length of course	Related to the skill level of students and the uncertainty in the demanded length of the training course	Customer

Operations

Uncertainty Type	***Description***	***Source***
Complexity of equipement	The complexity of equipment effect the requirements for maintenance and spares	OEM -Supplier
Quality of component(s)	Typically certification for bought-in components, which may create uncertainty. This has a knock-on efffect on the service delivery	OEM -Supplier
Quality of manufacturing	Includes the unceratinty in the manufacturing quality of the equipment. The uncertainty is driven by the certification of the system assembly	OEM -Supplier
Maintainer performances	This covers the uncertainty in the service delivery due to the varying performance of maintainers	OEM
Equipment utilisation rate	The uncertainty is consdiered to be driven by equipment operaitong enviroment and the unceratinty in the rate of equipment utlitsation	Customer
Rate of emergent work	The uncertainty in the additional work needed to do prior to actual work (i.e. breaking down an engine to conduct repair)	OEM
Supply chain logistics	The uncertainty associated to the timeliness of spares/maintenance logistics from the supply chain	Supplier
OEM logistics	The uncertainty to the timeliness of spares/maintenance logistics from internal sources	OEM
Rate of repairability	The uncertainty is related to the number of times that equipment is reaprable. This affects the level of spares requirements	Customer

Mean time between failure data	This uncertainty is in the data that represents the MTBF. As a result interpretation of het MTBF becomes diffucult	Customer -OEM
No fault found rate	The uncertainty in the NFF rate of occrurence	Customer
Location fo maintenance	The uncertainty relates to visits to various places that are made to maintain equipment	Customer
Calibration of workscope	The rate of change in the required level of service requirement	OEM
Availability of maintenance support resources	Availability of resources in order to meet the agreed availabaility level. However, driven by the varioiation in the resource usage its availablity is unceratin	OEM
Rate of materials	The unceratinty in the rate of amterials (i.e. spares) is driven by the requirements taht arise in the maintenance process	OEM
Turnaround time	There are many factors such as skill level, tools and facilitites availability that influences the overall turnaround time. This is an uncertainty that affects the repair costs	OEM
Rate of beyond economical repair	The uncertainty in the rate of beyond economical repair (REB)	OEM
Rate of provision of consumables	The uncertainty that is associataed to the amount of required consumbles	OEM
Operating parameters	Uncertainty deriving from the temperature, sand, moisture in the equipments operating environment	Customer
Effectiveness maintence policy part level	Uncertainty deriving from the level of maintainability of the equipment	Customer -OEM
Failure rate of hardware	Uncertainty in the failure rate of hardware	OEM
Uncertainty level of spare parts storage	Involves the level of spare parts that will be needed to be stored	OEM
Customer equipment utilisation	The unceratinty assoicatiated to the degree of equipment usage, which eveolves based on customer preferences	Customer
Component stress and load	The uncertainty in the stress and laod that is applied at the component level	Customer

Engineering

Uncertainty Type	***Description***	***Source***
Rate of capabilities upgrades	The requirements of capability upgrades (i.e. enhancing the equipment availability level) is an uncertainty that influences service delivery performance and customer affordability	Customer

Rate of system integration issues	The uncertainty that arises from system integration relates to the awareness of the possible failures. These aspects also relate to the customer misuse and the scope of warranty	OEM
Maintaining design rights	Over an equipmetns life cycle, the desing righs can get transferred to other support providers. The uncertainty is embedded in who holds the design rights	Customer -OEM
Cost of licensing and certification	The uncertainty the cost of licensing and certification covers an numer of areas	Customer -OEM
Rate of rework	It involves nay kind of reqork inclucidng desing or service deliverd. The ucnertainty is assoicated with the level of certianty in predicting the rate of rewokr	OEM
failure rate for software	The level of uncertainty in the failure rate for software	OEM
Rate of severity of obsolescence	The certainty in costs that arise from obsolescence is assessed. This is aligned with the ability ot determine the severity of the likely obsolescence issues. The quiestion takes a broad view of obsolescence, without distringuishing across the many types of obsolescence	OEM -Supplier -OEM
Cost estimating data reliability or quality	Issues such as reliability and quality of data that creates uncertainty in the cost estimation process	OEM
Effectiveness of managment of risk and opportunities	Uncertainty concerning the lelemts that are coverd in the risk and opportunities management process	OEM