Towards reliability and predictability

Probabilistic Maintenance Cost Analysis at Schiphol AMS

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Luuk Duijndam | May 2012

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Preface

SCHIPHOL GROUP, operator of airports including Amsterdam Airport Schiphol, has invited me to do a research on improving cost estimates for their maintenance projects using a probabilistic approach. This appealed to me since I was looking for a subject in which technical and financial expertise is combined. Not only does this interest me very much, but it also fits well within my MSc curriculum of Construction Management and Engineering.

This thesis was written to conclude my study at the Delft University of Technology as part of the 3TU master program of Construction Management and Engineering.

First of all I would like to give my gratitude to the people at SCHIPHOL GROUP and especially the Airfield Maintenance Services division for making this study possible, giving their support and making me feel welcome within their organization. Especially Arnaud, my supervisor, is thanked for his ongoing support, his willingness for helping to formulate my thoughts whenever possible, challenging me and always making time for me to do all this.

Next to that my gratefulness goes out to my thesis committee. Thanks to Jos for thoroughly checking my report and giving his critical remarks; thanks to Jules for always being a sparring partner, also throughout the rest of my study, and for guiding me in designing a research; and thanks to Han for his unlimited expertise, his critical notions and for guarding the technical aspects of my work.

I also owe thanks to my interviewees at SCHIPHOL GROUP, RIJKSWATERSTAAT, PRORAIL and the Delft University of Technology.

Furthermore, I would like to thank my family and close friends for supporting me in all kinds of ways, their encouragements and making it seven fantastic years.

Most of all my appreciation goes out to Karen for her patience, pushing me forward and simply for always being there when it was most needed.

Luuk Duijndam
Schiphol, May 2012

Summary

The main research objective of this study is to gain more insight into the uncertainties that are occurring in maintenance projects. A lot of research has already been performed on the subject of budget overruns in large scale new development infrastructure projects, however, information on budget overruns in maintenance projects is lacking.

Uncertainties are an important contribution to the cost increase of (infrastructure) projects. During a project unforeseen events are always occurring. This is taken into account by adding an item 'unforeseen' to the cost estimate. The actual occurring unforeseen costs can be split up into three categories: unforeseen costs in the execution phase, contractors bid uncertainty and 'other unforeseen' due to, amongst others, further specification of the project. It appears that in new-to-build projects the unforeseen in the execution phase (quantified by additional works) can be as high as 25 to 30 percent of the total project costs. In maintenance projects this is a lot lower: a maximum of five percent. This has to do with the repetitive character of maintenance works, the often limited project size, the possibility for detailed inspections and the fact that the works often take place in already stirred ground. Though, maintenance projects are characterized by a relative large uncertainty between the initiation phase and the start of the execution. This is because in maintenance projects one never starts with a 'green-field' situation. In other words, the initial state is often unclear in the early phase of the project, and this is especially the case for unique, technical complex projects, such as control system projects.

Because this report was initiated by the Airfield Maintenance Services (AMS) division of Amsterdam Schiphol Airport, applying the information found on the basis of the main research objective is a second goal of this thesis. It is in the ambition of AMS to be reliable and predictable. Not only when it comes to the management of its assets, but also when the financial performances are concerned. Also within the rest of the organization accurate cost estimates are seen as an important means towards more efficient and effective cost control. This enables them to make better informed decisions. Therefore, the second research objective of this study is

to improve the early-phase cost estimation process of maintenance projects and to find out whether probabilistic cost analysis techniques could be of value in this process. The scope of this study is limited to the CAPEX projects; the large renovation projects.

The current practice in the cost estimation process at SCHIPHOL GROUP is that every year in the first quartile a business plan for the upcoming five years is made based on the company's strategic goals. The input for this business plan is the budget estimates that are provided by the maintenance managers of AMS. At this moment uniformity is lacking in these estimates. Moreover, when the estimates are made the scope of the project is often still very unclear.

Based on this business plan, after further specification, the project budgets are determined in the fourth quartile. The annual budget for the next year is the project budgets combined.

From a comparison between the business plan, the annual budget and the actual expenditures in the projects it appeared that the latter are significantly lower. This can be mainly explained by the fact that throughout the year projects have been removed from the business plan scope. However, a statistical analysis of the projects itself shows that on an average the expenditures were 7% higher (with a standard deviation of 34%) than estimated in the business plan. This can be further specified per project type. Because the project budget estimates were made in a later stage, they are more in line with the actual costs. What also showed from this analysis is that smaller projects show a larger variation in the nominal unforeseen than larger projects. This could indicate that in maintenance projects larger projects can be seen as a cluster of smaller projects with relatively little overlap between them, thus acting as a portfolio where overruns in one part of the project are compensated by underruns in another.

The cost estimation process can in first instance be improved by creating uniform estimates in combination with a clear definition of the scope. When, next to this, the costs are booked into the accounting software system in a corresponding manner, a database can be built with very usable information. At first this information can be used to gain insight into the size of the cost items. If needed, it will then be able to make decisions accordingly. Further this can be used as a starting point for new estimates, which will make them more reliable.

In the second place it is recommended to do the estimate in a probabilistic manner. This means that the total estimated amount is represented by a probability function with an average value and a standard deviation. With this a probability of exceeding the chosen project budget is introduced. In this way one recognizes the uncertainty of an estimate and this information can be used to determine the budget. There are different methods by which a probabilistic cost estimate can be made. In this thesis it is recommended to do this statistically (with the use of historical data) and not Bayesian. This is related to the issue that it appears to be difficult for cost estimators to estimate extreme values, uncertainties and risks. It should be noted that when historical data is not present, the Bayesian method can be used until enough statistical information is gathered.

For the determination of the project and the annual budgets the following is proposed. When the annual budget is applied for one can take the uncertainty of the estimates into consideration. This becomes relatively smaller when the projects are bundled in a portfolio and regarded as a whole. The annual budget can be set to a value equal to the sum of the project cost averages plus a value of *k* times the standard deviation. Subsequently the projects can be given a budget with a probability of exceedance of 0.5 or even higher. Next to this a contingency fund with a size of the earlier mentioned *k* times σ can be kept at the management level of AMS. If it seems that the projects will be more expensive than the set budget the project manager can request for extra budget from this contingency fund, but only on the basis of solid argumentation.

It should be noted that it is not in everyone's interest to make the estimates more accurate and transparent. Some stakeholders could benefit from a large budget and more freedom when it comes to the allocation of financial resources. This could lead to strategic behavior. Budget slack is an example of this. This means that one applies for a larger budget to make it easier to reach a target. Also there is the MAIMS (money allocated is money spent) principle, which means that one is inclined to fully spent a given budget, even though this is not always necessary for the originally set scope and quality of the project. By using the in this thesis proposed estimation method and budgeting process, these effects can be diminished, by increasing the transparency and starting off with tighter budgets for the projects. Besides, it is regarded in the best interest of the entire organization when transparency and reliability of the estimates is increased, such that more efficient and effective cost control is possible.

Finally, the estimation process of Schiphol AMS can be improved by starting the projects more early. When there is already a preliminary design of a project before the budget is set in the final business plan, a part of the uncertainty in the scope and in the further specification can be reduced. Information of the project organization within SCHIPHOL GROUP and the contractor can serve as valuable information here. This does not necessarily have to cost extra money and time, since a part of the engineering of the project that needs to be done anyway is only moved forward in time. On top of that there is added value in the fact that more reliable estimates can be delivered.

Samenvatting

De hoofddoelstelling van dit onderzoek is om meer inzicht te krijgen in de onzekerheden die zich voordoen bij onderhoudsprojecten. Er is tot op heden al veel onderzoek gedaan naar budgetoverschrijdingen bij grootschalige nieuwbouw infrastructuur projecten, maar informatie over budgetoverschrijdingen bij onderhoudsprojecten is er nauwelijks.

Onzekerheden vormen een belangrijke bijdrage in kostentoename van deze projecten. Tijdens een project treden er altijd onvoorziene gebeurtenissen op. Hier houdt men bij de raming al rekening mee door een post 'onvoorzien' op te nemen. De uiteindelijk opgetreden onvoorziene kosten kunnen opgesplitst worden in drie categorieën, te weten: onvoorziene kosten in de uitvoeringsfase, aanbestedingsonzekerheid en 'overig onvoorzien' door onder andere verdere detaillering van het project. Het blijkt dat bij nieuwbouw projecten het onvoorzien in de uitvoeringsfase (gekwantificeerd door meerwerk) vaak kan oplopen tot 25 a 30 procent van de totale project kosten. Bij onderhoudsprojecten ligt dit echter een stuk lager: maximaal vijf procent. Dit heeft te maken met het repetitieve karakter van onderhoudswerken, de vaak geringere omvang, de mogelijkheid tot gedetailleerde inspecties en het feit dat in geroerde grond gewerkt wordt. Onderhoudsprojecten kenmerken zich wel door een relatief grote onzekerheid in de fase tussen de initiatie en de start van de uitvoering van het project. Dit komt doordat bij onderhoudsprojecten nooit begonnen wordt met een 'green-field' situatie. Met andere woorden, de uitgangspositie in de vroege fase van een project is vaak onduidelijk, en dit is in meerdere mate het geval bij unieke, technisch complexe projecten, zoals stuur- en regelsysteem projecten.

Omdat dit rapport is geschreven in opdracht van de Airfield Maintenance Services (AMS) afdeling van Amsterdam Schiphol Airport, is het toepassen van de informatie gevonden op basis van de hoofddoelstelling een tweede doelstelling van deze thesis. Het is de ambitie van AMS om betrouwbaar en voorspelbaar te zijn. Niet alleen als het gaat om het beheer van de 'assets', maar zeker ook wanneer het de financiële prestaties betreft. Ook binnen de rest van de organisatie worden accurate kostenramingen gezien als belangrijk middel om het kostenbeheer efficiënter en effectiever te maken. Op deze manier is men beter in staat om goed afgewogen beslissingen te maken. De tweede doelstelling is dan ook om het vroegtijdige

ramingsproces voor onderhoudswerkzaamheden te verbeteren met als basis probabilistische technieken. Het onderzoek beperkt zich op slechts de CAPEX projecten, dat wil zeggen, de grotere renovatie projecten.

In het huidige kostenramingsproces wordt er vanuit de strategische doelstellingen ieder voorjaar een businessplan voor de komende vijf jaren opgesteld. De input voor dit businessplan zijn budget ramingen die worden geleverd door de technische beheerders van AMS. Op dit moment is er geen sprake van uniformiteit in deze ramingen. Bovendien, wanneer deze ramingen worden gemaakt is de scope van het project nog vaak zeer onduidelijk.

Aan de hand van het businessplan worden, na verdere specificatie, in het vierde kwartaal de projectbudgetten vastgesteld. De projectbudgetten samen vormen dan weer het jaarbudget voor het komende jaar.

Uit de vergelijking tussen het businessplan, het jaarbudget en de werkelijke uitgaven in de projecten blijkt dat deze laatste significant lager zijn. Dit is voornamelijk te verklaren uit het feit dat er gedurende het jaar projecten uit de businessplan-scope zijn gehaald. Echter, een statistische analyse van de projecten zelf laat zien dat deze gemiddeld 7% (met een standaardafwijking van 34%) duurder zijn geworden ten opzichte van de projectkostenramingen gemaakt voor het businessplan. Dit kan per project type nog verder worden gespecificeerd. Omdat de projectbudgetten nog een keer in een latere fase worden geraamd, liggen deze ramingen wel dichter bij de uiteindelijke kosten. Wat verder blijkt uit deze analyse is dat kleinere projecten een grotere variatie vertonen in het nominaal onvoorzien dan grotere projecten. Dit kan er op wijzen dat bij onderhoudsprojecten de grotere projecten gezien kunnen worden als een cluster van sub-projecten met onderling weinig overlap. Dus dat het zich gedraagt als een portfolio, waar de tekorten kunnen worden opgeven door overschotten.

Het kostenramingsproces kan in de eerste plaats verbeterd worden door de ramingen te uniformeren en daarbij een heldere scope voor de projecten te definiëren. Als hiernaast de uiteindelijke kosten op eenzelfde wijze worden ingeboekt in het accounting software systeem, kan een database worden aangelegd met zeer bruikbare informatie. In eerste instantie kan deze informatie worden gebruikt om een beeld te krijgen over de grootte van de kostenposten. Indien nodig, kan men aan de hand van deze informatie overgaan tot optimalisatieprocessen. Daarnaast kan deze informatie als uitgangspunt dienen voor nieuwe ramingen, waardoor deze steeds betrouwbaarder worden.

In de tweede plaats is het aan te raden de raming probabilistisch te maken. Dit houdt in dat het totale geraamde bedrag wordt gepresenteerd als een kansverdelingsfunctie met een gemiddelde waarde en een standaard deviatie. Hiermee wordt een overschrijdingskans van het gekozen budget geïntroduceerd. Men erkent op deze manier de onzekerheid van een raming en kan deze informatie gebruiken bij het vaststellen van het budget. Er zijn verschillende manieren waarop een probabilistische raming kan worden gemaakt. In deze thesis wordt aangeraden dit op een statistische wijze (met behulp van historische data) en niet Bayesiaans te doen. Dit heeft er mee te maken dat het lastig blijkt voor kostenramers om extreme waardes, onzekerheden en risico's in te schatten. Op het moment dat historische data (nog) niet aanwezig is, zal men toch moeten ramen met behulp van de Bayesiaanse methode totdat een relevante database is aangelegd.

Voor het bepalen van de project- en jaarbudgetten wordt het volgende voorgesteld. Bij het aanvragen van het jaarbudget kan rekening worden gehouden met de onzekerheid in de raming. Deze wordt relatief kleiner als men de projecten samenvoegt in een portfolio en het als geheel beschouwd. Het jaarbudget kan vastgesteld worden op de som van de projectkostengemiddelden plus een waarde k maal de standaardafwijking. Vervolgens kan aan de projecten een budget worden toegekend met een haalbaarheidskans van 0.5 of zelfs lager. Hiernaast wordt op het management niveau van AMS een risicopot van de gestelde k maal σ beheerd. Als projecten duurder dreigen uit te vallen kan de projectmanager, op basis van solide argumentatie, aanspraak maken op extra budget uit deze risicopot.

Het moet worden opgemerkt dat het niet in ieders belang is om de ramingen accurater en transparanter te maken. Sommige stakeholders zullen gebaat zijn bij een zo ruim mogelijk budget en bij meer vrijheid betreffende het aanwenden van financiële middelen. Hierdoor kan strategisch gedrag ontstaan. Zo is er het principe van budget speelruimte. Dit houdt in dat men te veel budget aanvraagt om de target gemakkelijker te kunnen halen. Daarnaast bestaat het 'Money Allocated Is Money Spent' (MAIMS) principe, wat inhoudt dat men geneigd is het budget volledig aan te wenden, ook al is dit voor de origineel gestelde scope en kwaliteit niet altijd nodig. Door de in deze thesis voorgestelde ramingsmethode en budgetteringsproces te gebruiken, kunnen deze effecten worden verminderd, doordat transparantie wordt vergroot en in eerste instantie minder ruime budgetten ter beschikking staan voor projecten. Bovendien wordt het in het algemene belang van de organisatie beschouwd wanneer de transparantie en betrouwbaarheid van de ramingen wordt vergroot, zodat een efficiënter en effectiever kostenbeheersing mogelijk is.

Tot slot zou het ramingsproces van Schiphol AMS nog verbeterd kunnen worden door de projecten eerder op te starten. Als men voordat het businessplan wordt vastgesteld al een voorontwerp heeft van een project kan een gedeelte van de scope- en detailleringsonzekerheid van de businessplanraming worden weggenomen. Informatie van de projectorganisatie binnen Schiphol en de aannemer kunnen hierbij al waardevolle informatie zijn. Dit hoeft op zichzelf niet veel meer geld en tijd in beslag te nemen omdat een deel van het project dat überhaupt gebeuren moet slechts naar voren wordt geschoven in de tijd. Daarnaast zit er meerwaarde in het feit dat betrouwbaardere ramingen kunnen worden afgegeven.

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1 Introduction

1.1 Introduction to the subject

Budget overruns or inadequate cost estimates are the rule rather than the exception in large scale infrastructure projects (Hall, 1980; Altshuler and Luberoff, 2003; Wachs, 1989; Wachs, 1990; Cantarelli et al., 2010; Flyvbjerg, 2005; Flyvbjerg et al., 2002). Recently a lot of research has been done on budget overruns on new large scale development projects, also in the Netherlands (Cantarelli et al., 2010; Prorail, 2011). However, similar studies on infrastructure maintenance projects seem lacking. Nonetheless, this type of projects forms a significant part of the annual expenditures of most organizations. When looking at the expenditures of RIJKSWATERSTAAT for example, it can be seen that 26% (1399 million euro) of the total expenditures in 2010 was spent on maintenance (Rijkswaterstaat, 2011). One of the aims of this study is to discover whether maintenance projects have similar budget overruns as a lot of new development projects.

In the above mentioned studies several causes of these inadequate cost estimates are posed. Among the technical explanations, changes in scope, changes in the market and the occurrence of unforeseen events are important contributors to budget overruns. To deal with these causes, in the Netherlands in 1992 the project "Project Ramingen Infrastructuur" (PRI) was initiated. The objective was to establish a methodology for estimating costs of projects that are characterized by (high) uncertainty. In this project the estimation uncertainty is quantified by a standard deviation with the help of probabilistic techniques. Because of the fact that in a probabilistic cost analysis a specific uncertainty margin is derived and (the major) risks can be identified, this method offers great advantages for controlling the budget estimates. The uncertainty in a project depends amongst others on the project phase in which the estimate is made. It is not certain whether and in what way the probabilistic cost estimate approach can also be of value for maintenance projects.

It is hypothesized that maintenance projects are surrounded with less uncertainty in the execution phase than new-to-build infrastructure. The risk profile of and 'typical' uncertainties in maintenance projects are examined in this research.

SCHIPHOL GROUP thinks the use of a probabilistic approach might be a solution to obtain more accurate and reliable estimates. Therefore they initiated this research.

This thesis looks into this problem and its surrounding topics. Not only is explored how Probabilistic Cost Analysis can be applied for maintenance projects, but also how the results of such an analysis can be used for allocating budgets. Estimating costs is one thing; setting budgets accordingly can be something completely different. Once an estimate has been made, this needs to be translated into an appropriate budget. Also psychological and (business-) political effects come in to play here, thus strategic behavior has an important influence on budget allocation. Recommendations on how to deal with this type of budget management issues are also given in this thesis.

1.2 Problem analysis

Since the initiative of this research subject originates from SCHIPHOL GROUP itself, first an introduction is given to the problem at the Schiphol Airfield Maintenance Services (AMS) division. After that a general problem definition for this research is presented.

1.2.1 Introduction to the problem; the Schiphol Case

The division Airfield Maintenance Services (AMS) controls and maintains all the infrastructure of Schiphol Airport[1]. It is its yearly task to make a cost estimate for the planned maintenance works in the upcoming year. The annual budget of AMS is around 40 million euro (OPEX 15 M, CAPEX, 25 M). The department wants to be reliable, not only in terms of the performance of the assets and the service provided, but also when the financial expectations are considered. The latter can be difficult, since the costs of most of the projects have to be estimated in an early phase, when scope and risks are scarcely known.

The budgeting process at SCHIPHOL GROUP can best be explained with the diagram below (Figure 1), however more detailed information on this process is given in Appendix B. In the business plan estimates are made for the yearly needed budgets. This is done every Q1/Q2 for the upcoming five years. Because this is a cyclic process, the next four years are reassessed and one new year is added. The second phase of the financial planning process is the so called annual budget plan. This is executed in Q3/Q4 of each year. The purpose of this process is to determine the budget for the

[1] *More information on Schiphol Airport and the company profile of Schiphol Group can be found in Appendix A.*

upcoming year based on the business plan and other frameworks and guidelines.

In theory every autumn the budgets are established for the following year, because at that point it is better known what is going to happen the following year. However, in practice it appears that because of the fact that the budgets have already been determined in the business plan, there is not much room for adjustments of the budgets.

Based on data of the last couple of years and interviews with the management team of AMS (Appendix C), it seems these business plan estimates have not been accurate enough, in the sense that adaptations in the scope were needed to make it possible to meet the estimated budgets. Firstly there is a general need to be more reliable and predictable when it comes to cost estimation. Furthermore, although it seems that the AMS department manages to stay within their annual budgets, there still is a problem. Unforeseen events happen, which can cause budget overruns (or underruns) on a project level, in CAPEX as well as in OPEX, as on the portfolio level.

AMS manages to stay within budget by 'playing with scope'. For instance when a certain project is in reality more expensive than estimated, another project is postponed to the next year to be able to stay within budget. By this a scope wave (also called: scope bump) is created, and new financial resources (larger budget) have to be found for the next year(s), or other projects must be postponed or even cancelled.

One of the main principles in economics is that resources are scarce. This is no different for the financial resources in a competing company like SCHIPHOL GROUP. Hence, just allocating a larger budget is not a solution. Moreover, budget reservations also cost money. Financial resources have to be obtained from the market, thus interest will be paid on this. Estimating too high budgets can therefore also be considered a problem.

Nonetheless, the key issue here is controllability. When budgets are estimated more accurately and it is done in a transparent manner, it will be easier for the organization to make good trade-offs and underpinned decisions. The ability for efficient and effective resource allocation is then created. Thus, accurate cost estimation is not a goal in itself; rather it is a means to have a better insight in the control of the costs.

For these reasons there exists a very strong need to give a more accurate and reliable budget estimate already in the business plan phase. However, because the business plan is made further in advance, more things are uncertain. These uncertainties can amongst others be contributed to price fluctuations, changes in legislation and scope changes.

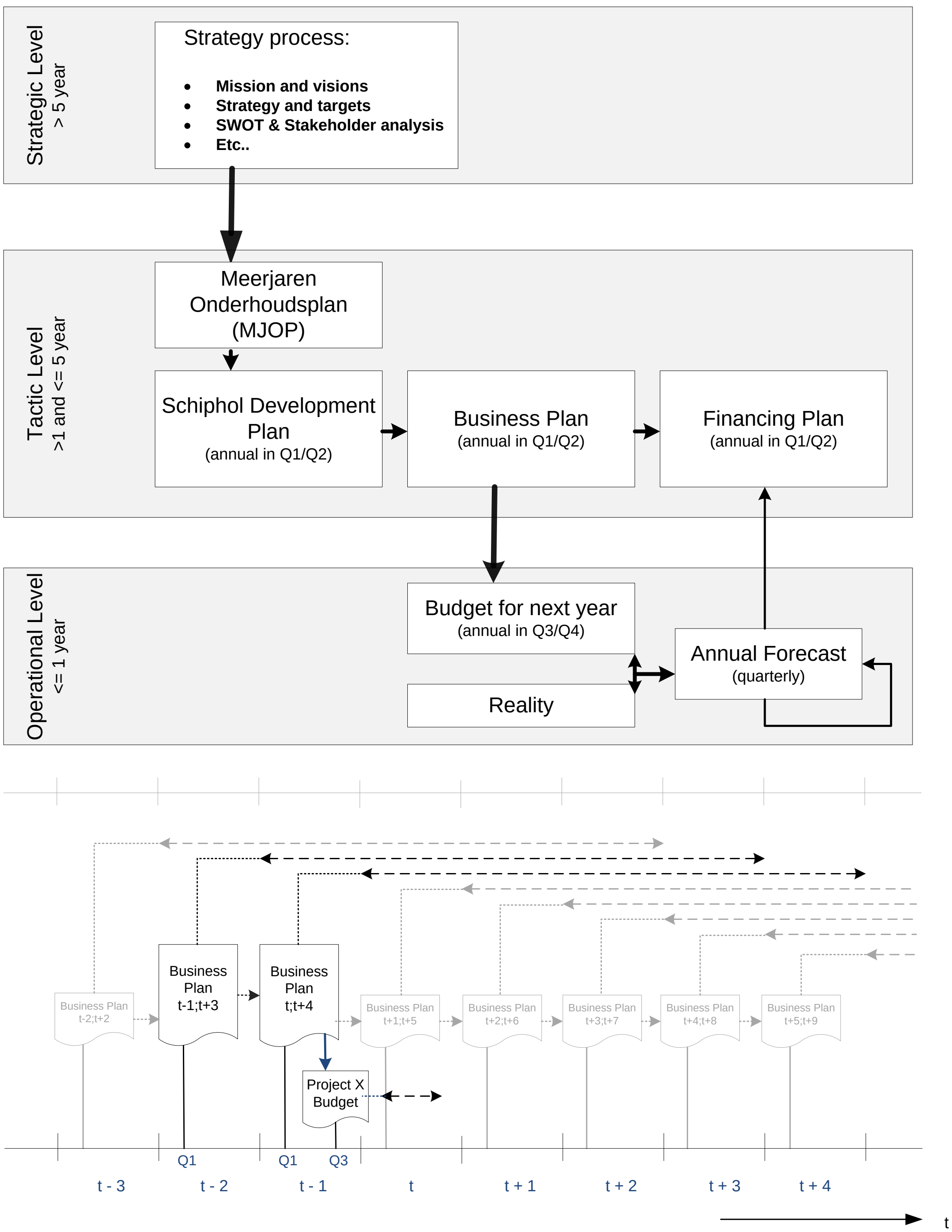

Figure 1: Budgeting cycle of Schiphol Group

In the current practice the maintenance managers ('beheerders') are asked to deliver their estimates using basic spreadsheets which differ from maintenance manager to maintenance manager. The input is based on standards and historical data only on pricing. According to the management team this is too coarse (interviews: Appendix C). Also risks are barely taken into account. Some uncertainties are taken into account by adding certain percentages, however these are hardly underpinned. On top of that every maintenance manager does the cost estimation in his own manner. Thus uniformity, and with that transparency, is lacking as well.

On a project level, one of the main causes of budget overruns in SCHIPHOL GROUP is that the cost item 'unforeseen' is insufficiently underpinned and allocated (Reinders and Geurtjens, 2011). Also scope changes are not handled appropriate. So, the need for more insight into uncertainties is useful here as well.

1.2.2 *Problem definition*

Not being able to meet the budget is always a problem. Cost underruns (because money was reserved at a certain interest rate) as well as budget overruns (more money needs to be collected somewhere) are undesirable situations. The latter is generally speaking considered more undesirable, though. It seems that in the construction industry (large) budget overruns are occurring often (Cantarelli et al., 2010).

The question is whether maintenance projects on infrastructure suffer the same problems. Because maintenance projects are of a less unique character than new development projects and are more repetitive, it could be that cost estimation is easier and cost overruns are occurring less and are smaller. In line with this it can be hypothesized that this is due to a lower uncertainty and risk profile. Still, the need for more reliable budget estimates exists also in maintenance projects.

1.2.3 *Research objective*

Following from the above, it becomes clear that there is a need for more reliable budget estimates. This is translated into the following objectives for this thesis. In the first place the main objective is to *gain more insight into the uncertainty in the cost estimates of maintenance projects*. Related to this the aim is be to discover what type of (systematic) uncertainties are occurring in these maintenance projects.

Once this is known, the second objective is to apply this information to the Schiphol AMS organization. In other words, the goal is to *optimize the early* *budget estimation process for maintenance works* (at Schiphol AMS)[2]. In relation to this it is explored in what way Probabilistic Cost Analysis methods are valuable for providing more insight into the uncertainty (expressed in a standard deviation), to be more reliable and predictable in terms of financial expectations. Also recommendations are given on what this implicates for the budget setting process.

1.2.4 Research questions

Consecutive to the objective stated above, research questions can be formulated to provide a structured approach to the study. They form a guideline for this thesis.

According to Verschuren and Doorewaard (2007), the requirements for the research question is that the answers to these questions are sufficient to accomplish the research objective. Thus, the primary research questions follows from the main objective stated above and are based on the formulated problem description.

1. *What types of 'systematic' uncertainties occur in maintenance projects?*
2. *How should these uncertainties be dealt with in the cost estimate, in order to come to a reliable budget estimate?*
3. *How can a Probabilistic Cost Analysis approach contribute to making early budget estimates for maintenance works more reliable (at Schiphol AMS)?*
4. *In what way should the budget setting process at Schiphol AMS be organized to better be able to stay within budget?*

1.3 Research method

Firstly, the problem context of this research is explored in a literature study. The topics, on which the literature study focuses, are:

- Budget overruns in projects
- Probabilistic Cost Analysis
- Risk Management
- Budget Management

The focus when looking at these subjects is on a maintenance and asset management context. This also means that maintenance theory and asset management are not addressed separately. The results of these are presented throughout this report.

[2] *The research is done at Schiphol AMS, and will therefore also look at the benefits and implementation practices for this organization.*

Next to this, 42 recently finished projects at Schiphol AMS are analyzed. Historical data is analyzed to review the budgeting adequacy and historic cost estimates are compared to the actual expenditures. Data of estimates and actual cost have been compared. On the basis of this information and interviews with project managers and others involved it is explored what the main causes of cost overruns (or underruns) are; an inventory of the systematic uncertainties is made. Also, based on the statistical analysis percentages are derived which can serve as a guideline for estimating the costs of uncertainty in maintenance projects.

After that, Probabilistic Cost Analysis theory and the current practice at SCHIPHOL GROUP are combined to design an improved process for cost estimation as well as budget setting suited for Schiphol AMS. Also, the information obtained from the above described analysis is used as input for this improved estimation technique. The results of these estimates, and more specifically the standard deviation, are compared to the historical data.

In line with this it is explored in what way the outcomes of such cost estimates can be used as management information, for allocating budgets, applying portfolio management, deal with risk and uncertainties and prioritizing expenditures.

1.4 Report overview

This report starts with the introduction. In this chapter the subject and the problem of this study are introduced. On top of this the research objective and questions are presented. In chapter 2 the problem context including surrounding topics such as asset management and maintenance theory is further explored.

In chapter 3 and 4 a statistical analysis on the projects assessed in this thesis is presented. In chapter 3 this is done on a rough scale for all the projects. After that, in chapter 4, eleven projects are studied in more detail. Here the first findings on the type of unforeseen events happening in maintenance projects are touched upon.

Chapter 5 addresses the subject of risk management. This is mainly a theoretical chapter. It ends with an identification of typical risks in maintenance projects.

In chapter 6 and 8 the model developed in this study is presented. First the cost estimation part is described in chapter 6. How this translates into a budget setting process, including some theory on budget management practices has been written down in chapter 8. In chapter 7 various cost estimation methods are by means of example used to calculate the costs for a future Schiphol AMS project.

The thesis ends with conclusions and recommendations, given in chapter 9.

2 Problem context

Inadequate cost estimation often causes budget overruns or leads to scope shifts. This can be considered a problem. For that reason this subject is first elaborated in general, since it forms the main driver behind this research. After that the study of PRI is briefly touched upon, since it formed the start for a new cost estimation procedure in the Netherlands. The final section of this chapter deals with the question why cost estimates need to be made for maintenance projects. This relates to maintenance and asset management theory, which is also explored.

2.1 Cost overruns in infrastructure projects

Simply put, a cost or budget overrun means that the estimated budget was insufficient. Bent Flyvbjerg (2005; 2007a; 2007b; Flyvbjerg et al., 2002; Flyvbjerg et al., 2003b; Flyvbjerg et al., 2004) has systematically investigated 258 transport infrastructure projects (mainly new development) on budget overruns. He concluded that 86% of the projects suffered from cost overruns, with an average overrun of 28% overrun (Table 1). Also in the course *Voorzien, onvoorzien of onzeker (PAO, 2009)* it is shown that in recent history in the Netherlands projects have suffered severe overruns of the budget. Bordat (2004) has found in her studies on federal highway projects in the state of Indiana, US, that maintenance projects have a 7.5% cost overrun on average, compared to a 8.1% on bridge projects and 5.6% on general road construction projects. More data on maintenance projects specifically was not found.

Several different explanations can be given for inadequate cost estimates (de Jong, 2010):

- Technical explanations
- Psychological explanations
- Political-economic explanations

TABLE 1: COST OVERRUNS DIVIDED PER REGION OF LARGE-SCALE INFRASTRUCTURE PROJECTS [SOURCE: (FLYVBJERG ET AL., 2002)]

	Type	
Europe	Number of projects	181
	Average cost overruns	25.7%
	Standard deviation	28.7
North America	Number of projects	61
	Average cost overruns	23.6%
	Standard deviation	54.2
Rest of the world	Number of projects	16
	Average cost overruns	64.6%
	Standard deviation	49.5
Total	Number of projects	258
	Average cost overruns	27.6%
	Standard deviation	38.7

The way in which the estimates are made, is the focus of *technical explanations*. These problems include imperfect forecasting techniques, inadequate data, incompleteness of estimates, honest mistakes, incomplete studies before approval, poor project design and implementation, poor project management and reporting, price rises and bids from contractors that were higher than expected and other inherent problems in predicting the future (Cantarelli et al., 2010; Flyvbjerg, 2005). Improperly taking uncertainties into account can also be seen as a technical explanation (Dillon et al., 2002). For instance, uncertainties are accounted for by adding contingencies (typically 20 percent), however these rarely cover extraordinary events, such as major technical or regulatory problems. Agencies defend this approach by noting that their projects are not different than others, and the owner and management structure remain the same from project to project (Touran, 2003). However, practice proves differently (Flyvbjerg, 2005).

Although methodologies for cost estimates have improved over the years, and next to that more experience is gained, cost overruns have not decreased as time passed (Flyvbjerg, 2007a; Flyvbjerg, 2007b; Flyvbjerg et al., 2003a). Thus, the problems cannot only be explained through the above mentioned causes.

Another explanation is of *psychological* character. This means that imperfect cost estimates are explained through imperfections of human reason (de Jong, 2010). Rather than rational weighting of gains, losses and probabilities, humans tend to overemphasize their own abilities and to be overly optimistic about the future (Lovallo and Kahneman, 2003; Wachs, 1986). This means that positive scenarios are given prominence, while scenario's involving mistakes, miscalculations and risks are overlooked upon (Flyvbjerg, 2005). Moreover, in some organizations people are encouraged to lean towards the optimistic, while pessimistic opinions are being discounted (Lovallo and Kahneman, 2003). Also attempts to incorporate uncertainties in cost estimates using probability distributions are often influenced by biases in human judgment (Alpert and Raiffa, 1982; Dillon et al., 2002; Kujawski et al., 2004; Tvesrky and Kahneman, 1974).

Political-economic explanations are the third cause of cost underestimates (de Jong, 2010). In this case estimated costs are deliberately said to be lower by either managers, politicians, planners or controllers in order to gain approval and funding (Altshuler and Luberoff, 2003; Flyvbjerg, 2005; Flyvbjerg et al., 2003a; Hall, 1980; Wachs, 1989; Wachs, 1990; Kain, 1990). In other words, cost underestimates are used to get approval for projects. It is not the case that politicians themselves underestimate the costs, but it is them who are responsible in the end. It can be seen that once a project has started, it is easier to gain extra budget to finish the project (point of no return), rather than start off with a higher budget. This is called strategic misrepresentation by Flyvberg and advocacy or plain lying by Wachs (1986; 1989; 1990).

Although these explanations are given mainly for new development projects, because of its general nature it is also assumed that it can be applied to maintenance projects. Further, these different explanations might help to explain cost overruns in a general way, but it is not said that all three play part in every project. As a starting point it is assumed that at Schiphol AMS all three explanations are valid.

2.2 Cost estimation using PRI

In the Netherlands research on the increase of costs of infrastructure projects has been done as well. In 1989 the budget for the main road network projects for the accessibility of the Randstad (in Dutch: "BBP") showed a large increase, which lead to an investigation of the Ministry of Transport. In line with this RIJKSWATERSTAAT initiated a group called "Werkgroep Ramingen Problematiek". The results of this study were bundled in the report "Een raamwerk voor Ramingen" (Merchant and Van der Stede, 2007).

This group has examined eleven infrastructure projects and also found similar explanations for the increase in the estimates as mentioned in section 2.1. These were divided in 'Causes due to the estimation technique' and 'Other causes', and are summed up below.

Causes due to the estimation technique
1. Not taking general price increases into account;
2. Incompleteness of estimates;
3. Scope changes;
4. Adjustments out of self-interest of people involved;
5. Uncertainty of the estimate;

Other causes
6. Means to control the estimate or budget are lacking;
7. Organizational aspects cause fragmentation of relevant project information;
8. Internal or external accountability is not (or barely) required;
9. Administrative instruments are not able to control the problem;

Except for the first cause, none of the causes mentioned here gave a general explanation for the increase in the cost estimates.

In 1992 the Project Ramingen Infrastructuur (PRI) was started in order to implement the recommendations of the aforementioned report. This implementation has led to a number of insights regarding the improvement of the quality of cost estimates, which were reported in "Werk in uitvoering" (Prorail, 2011). The following three items were the result of this research.

1. Cost estimation process
2. Uniform estimation format
3. Risk analysis (RISMAN)

The first item is explained here. The other two items are described in chapter 6 respectively chapter 5 of this thesis.

As part of the cost estimation process outcomes, one of the recommendations of PRI was to always phase a new project in a uniform manner and make cost estimates accordingly. The phases that can be distinguished are:

1. The initiative phase (feasibility)
2. The study phase (primary design)
    a. The primary study phase
    b. The route study phase
3. The realization phase
    a. The design phase
    b. The specification phase
    c. The implementation phase
4. The control phase (maintenance)

During the lifecycle of a project there are various moments in which an estimate needs to be made, each serving a different goal.

1. Initiative phase: In this phase a cost estimate is made in order to determine and prioritize new study projects.
2. Study phase: In this phase estimates are made for the "Traject Nota" and the "(Ontwerp) Tracé-Besluit". To be able to test the feasibility of the projects is also a purpose of the estimate here.
3. Specification phase: In this phase an estimate is made to determine the specification and to be able to compare the bid of the contractor (in Dutch: "Bestekraming").

2.3 Cost estimation purpose of maintenance projects

Maintenance projects are somewhat different from new-to-build infrastructure projects, and therefore its phasing does not totally correspond to the phasing as described in PRI (Prorail, 2011). On top of that, companies that are responsible for the maintenance of their own assets all have their own manner in which they specify the project phasing. Nonetheless a comparison can still be made. Moreover, cost estimates are required for maintenance projects, albeit sometimes with a different purpose.

In this section the purpose of cost estimation in the different phases of maintenance projects is described. First the initiative for a maintenance project is explored. It is derived from the asset management theory and maintenance concepts, so this theory is also elaborated. After that the project phasing of maintenance projects at Schiphol AMS is described including the reason for cost estimates at certain phases.

2.3.1 Asset management and maintenance strategies

The scientific theory of maintenance was developed to optimize structures taking into account investment, management, maintenance and risk (Bryson, 2004). However, in this approach only the technical lifetime is considered, and revenues are left out. It can be wiser to also look at the economic lifetime. In this section this is further explained. First, asset management and maintenance strategies are described in general. After that the current situation at Schiphol is explored including a comparison to the general theory.

Asset management in general

Maintenance can be defined as follows (CUR, 1997):

> All activities that restore or keep (a part of) an object to its desired quality level

The two main activities in maintenance are inspection and repair. In general two types of maintenance can be distinguished, namely corrective maintenance (after failure) and preventive maintenance (before failure) (van Noortwijk, 1997). Preventive maintenance is preferred if the costs of corrective maintenance are much higher due to the cost of consequences than the cost of preventive maintenance (CUR, 1997). It is not always easy to express the consequence in a financial cost. So one could also say that if the consequence of failure is in general too large, regular inspection and preventive maintenance is preferred. Preventive maintenance can be subdivided into time-, use-, load-, and condition dependent preventive maintenance. The first three are done after a predefined time or load, and are used when inspection and monitoring are hard. State dependent maintenance is to be done on the basis of inspections (CUR, 1997). In Figure 2 it is illustrated how the choice between maintenance strategies can be made.

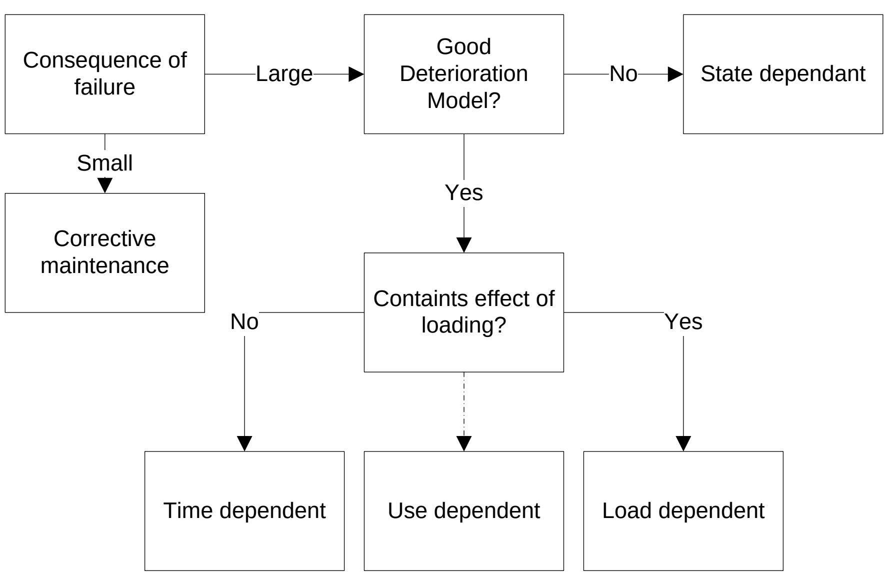

FIGURE 2: THE CHOICE BETWEEN MAINTENANCE STRATEGIES (VRIJLING, 2011A)

There seems to be a growing need to be able to predict and optimize the required maintenance (CUR, 1997). In literature much is written on maintenance optimization models (Ghosh and Roy, 2004; van Noortwijk, 1997). However, as Bryson (2004) points out, asset management strategies should be regarded at three different levels:

1. Maintenance optimization according to traditional maintenance theory
2. Economic viewpoint: renewal
3. Economic viewpoint: renewal including benefits

In traditional Maintenance Theory (1) the optimal cycle of inspection and repair is determined by minimization of the present value of the sum of the failure costs, inspection costs and repair costs; also called cost-effectiveness. Reliability theory and probabilistic methods are increasingly used to asses this. Moreover, maintenance theory is an aid to traditional Life Cycle Cost analysis. In Life Cycle Cost analysis future cost for maintenance and removal expenses at the end of the productive live are taken into account already in the design phase, and investment decisions are made accordingly. The 'theory of maintenance' aims to optimize the maintenance costs by choosing the right inspection and repair intervals. One can argue whether this is (economically speaking) an important cost item, since maintenance cost often form a small percentage (7-8%) of the total investment costs of a civil engineering structure (also due to discounting).

A downside to the above described theory of maintenance is that it addresses only the technical lifetime of structures. From the economic viewpoint (2) also the option for complete renewal should be assessed. In this analysis the total variable costs of the 'old' asset are compared to the full integral costs of the 'new' asset (new investment costs + new variable costs). If the new structure is more efficient, thus cheaper, in forms of for instance less consumable materials or less maintenance, this should be outweighed against the investment costs for renewal. This means that the economic lifetime has exceeded the technical lifetime.

A third viewpoint is to also take the revenues into account (3). It could be possible that the new asset also generates more income. For instance, when the quality of the asset is enhanced, it could be that the willingness to pay of clients rises as well.

Something that should be included in these analyses is *the missed revenues due to unavailability of the asset*. When an asset is constantly in use, it often needs to 'close' in order for maintenance to happen. This could lead to a loss of revenues. The same goes for renewal of the asset. Since, generally speaking, complete removal of the old asset and building a new one takes more time than only doing maintenance, the extra loss in revenues due to a longer unavailability of the asset should also be included in the economic analysis. It should be noted that these 'costs' (loss of revenues) should also be added to the costs of maintenance in the first asset management strategy. A calculation of the costs due to closure of certain assets at Schiphol Airport is given in Appendix D, where it is shown that these costs can add up to two million euro per week.

The above also points out the limitations of the described methods. Because one only looks to the economical side, other aspects such as sustainability or reputation towards clients are not taken into account.

What should also be regarded here is that optimization of a single component is most of the time not very useful. It is often part of a larger system, as is the case at Schiphol Airport. The limiting factor in terms of capacity is the component with the smallest capacity. The same goes for reliability, which is limited by the component with the largest probability of failure. The limiting factors should be treated, until other components become the limiting factor.

Asset management at Schiphol

In general Schiphol AMS only does preventive maintenance, because in case of serious damage or failure of assets it will result in (partial) closure of the airport. This means not only loss of revenue, but also damaged reputation.

At Schiphol the following asset management and maintenance strategies are used. Schiphol's asset management forms the bridge between maintenance and finance (Groen et al., 2006), where assets are defined as:

> *Assets are all physical (capital-intensive) industrial fixtures, managed by the company.*

The approach of SCHIPHOL GROUP to asset management is integral. Asset management is about the management of these assets throughout the whole lifecycle, at which all aspects such as sustainability, performance, risks and costs are balanced in order to realize the company's objectives. So, maintenance is only a small part of the whole asset management process.

Schiphol's asset management focuses on being as efficient as possible with the investments done. In order to do this, cost-efficiency is required, which is minimizing the cost of achieving an intended result through a certain strategy (Groen et al., 2006). For this understanding of the risks is needed. Only when the risks are known, something can be said about the reliability and availability of the system or components of that system.

The maintenance managers at Schiphol AMS use asset management control systems (software) such as XEIZ and MICROPAVER to determine whether maintenance activities will be planned on their assets. It is done on the basis of a deterioration model, which is constantly updated by input out of inspections. It means that there is a combination between state and time dependency. These models not only take the technical aspects into account, but also economical. Based on the software models it is decided whether regular maintenance will be done (OPEX) or that a renovation project (CAPEX) is initiated. What can also play a role here is whether a project on a related asset is being planned, such that activities can be bundled, which can increase cost-effectiveness.

When a CAPEX project is proposed based on the asset management models it does not automatically mean that it will be executed. An investment decision comparing the projects to other projects on the basis of drivers related to the strategic goals will be done first, as explained in Appendix B.

Comparing the practice at Schiphol to the theory described in the former section, it can be concluded that the technical as well as the economical viewpoint are being assessed. The considerations on the aspect of benefits (the third viewpoint) are not really taken into account when the project is initiated. However one could say that the benefits compared to other projects are weighed when the project has to pass the investment committee's judgment.

2.3.2 Cost estimation in different phases at Schiphol

The way in which a project at Schiphol follows the budgeting process is best explained through Figure 3.

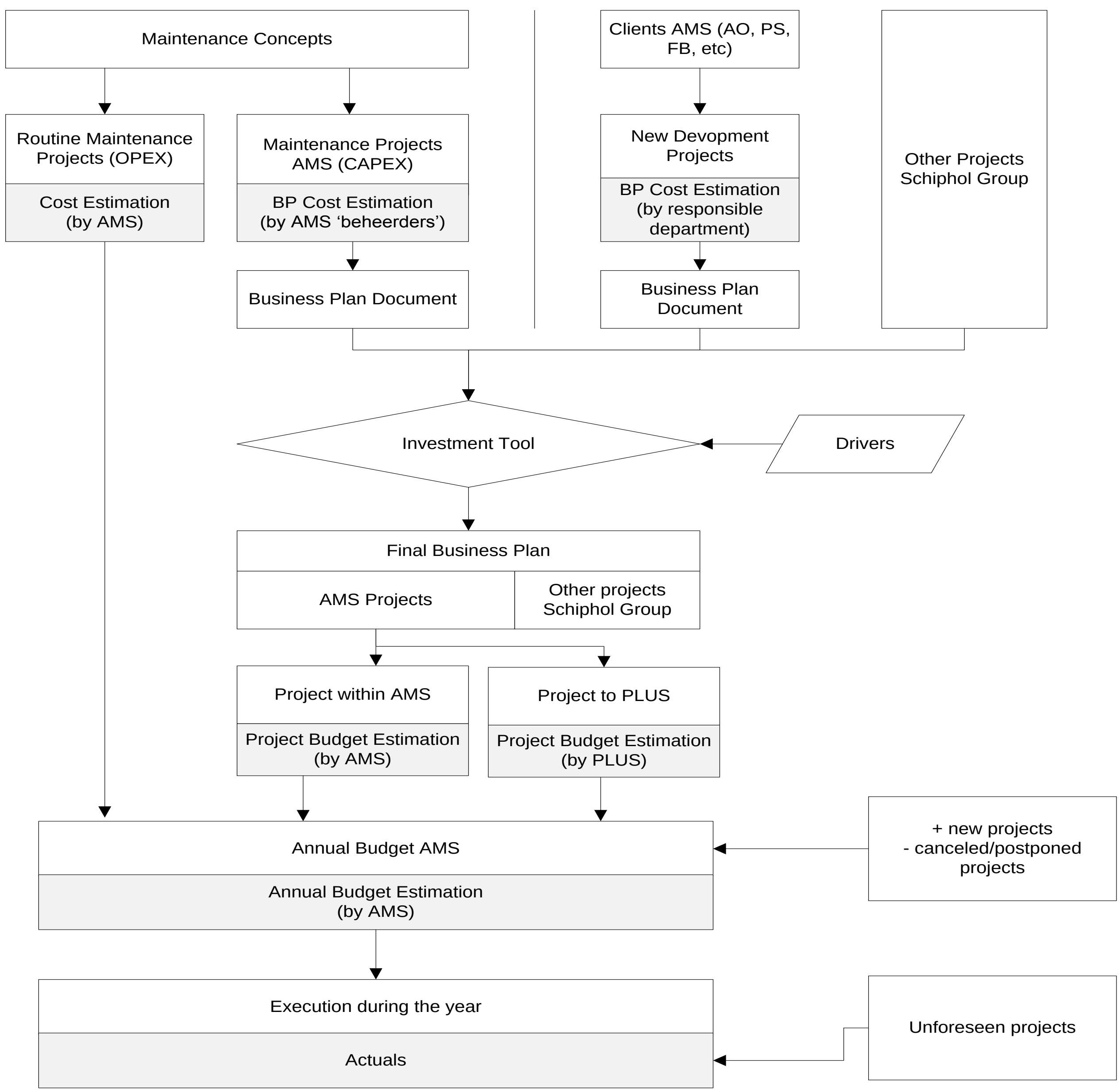

FIGURE 3: BUDGETING PROCESS OF A PROJECT AT SCHIPHOL AMS

Depending on the maintenance concept and the asset management strategy, as explained in the former section, it is considered whether a maintenance project is initiated. Depending on the project type (OPEX or CAPEX)[3], the project can either be 'kept' within the department, or it has to pass the business plan process. During this process all (large) projects within Schiphol are compared to each other via the so called Investment Tool. Based on drivers set by the various departments, the projects are tested against multiple criteria that relate to the intended strategy of SCHIPHOL GROUP. A maximum amount of funds is available beforehand, and the best projects can be executed, until the funds are exhausted. This acts as a kind of sieve.

Once the project has passed the Investment Tool it becomes part of the final business plan of SCHIPHOL GROUP. Then, depending on the project, AMS itself or, which is more often the case, the project organization within SCHIPHOL GROUP called PLUS works out the project in more detail and realizes the project with the cooperation of the contractor (see box).

Contractors at Schiphol: The framework agreement

The procurement for maintenance projects done at Schiphol differs from the tendering of new-to-build infrastructure projects by RWS for example. It is because SCHIPHOL GROUP has set up framework agreements with a couple of main contractors.

In a framework agreement or a Call Off Contract it is possible for the client to 'call off' goods, works or services provided by the supplier. It is held open for a guaranteed period of time under the terms and conditions established by both.

SCHIPHOL GROUP has a framework agreement with several contractors, such as KWS and Heijmans. With Heijmans there is an agreement for a period of five years, in which rates for materials and services have been agreed upon. This implies that for SCHIPHOL GROUP the 'normal' uncertainty of price fluctuations for a maintenance project does not exist. However, the productivity of the contractor is still an uncertain issue.

[3] See Appendix A.

During the lifecycle of a project various plans and cost estimates are made. Depending on the phase the project is in, different requirements are set for the cost estimates.

The need for cost estimates can be looked at in two different ways, namely for the project as a whole and for the annual expenditures on that project. Since almost all of the projects within Schiphol AMS are realized within one (calendar) year, the annual budget for a project and the project budget itself are more or less equal. The different estimates are summed up below and are visualized in Figure 3 in grey. In Appendix E it is described what requirements are given for the estimates and to which estimate in PRI it can be compared.

1. Business Plan Cost Estimate: The goal of this estimate is twofold. In the first place it is meant for means of prioritization. Next to that it is used to be able to determine the budget for the next five years. *(Initiative Phase Estimate)*
2. Project Budget Estimate: This estimate is used to determine the project budget, but also to assess the contractors bid. *(Specification Phase Estimate)*
3. End Of Project: This is the (prediction of) total of money spent at project completion.

As explained, next to these estimates an annual budget estimate is made. The annual budget estimate is used to determine the annual budget and is used as a steering instrument.

<u>Analysis of portfolio results</u>

In order to give more insight in the problem context, the total estimates for the phases described above are presented and analyzed in this section. Unfortunately the only years that have been assessed are 2010 and 2011, since the quality of earlier data was insufficient.

In Figure 4 and Figure 5 diagrams are given in which the total estimates are compared to each other. They also show how the differences are build up. In Appendix F a more detailed analysis is given, including the project names.

2010

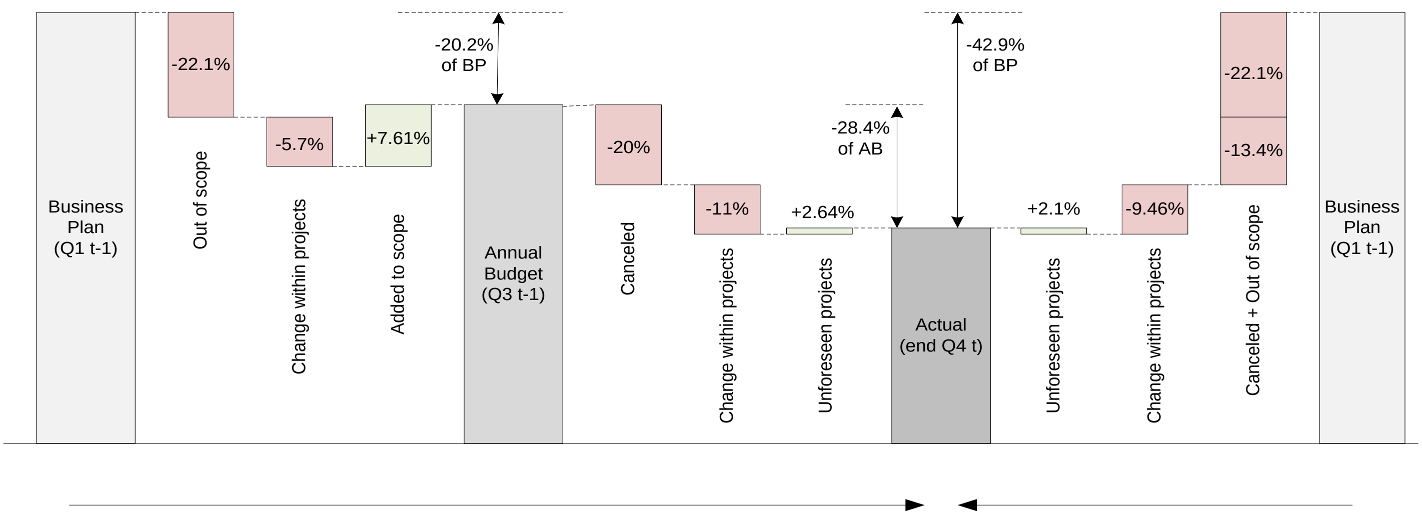

FIGURE 4: FINANCIAL PORTFOLIO ANALYSIS OF 2010

2011

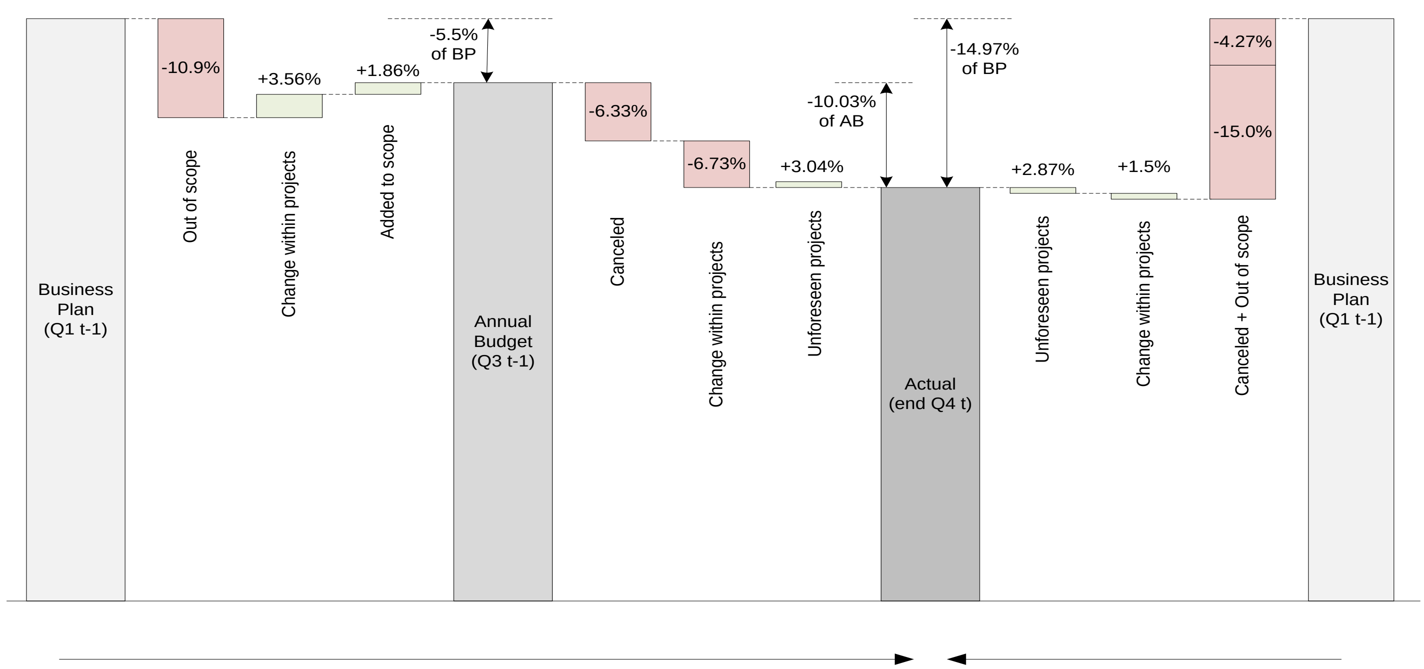

FIGURE 5: FINANCIAL PORTFOLIO ANALYSIS OF 2011

What should be noted here is that the above presented numbers are not the total annual budget of AMS. It is only the budget for the projects. The annual budget also consists of other items, such as staffing costs and depreciations.

What can be concluded from the graphs above is the following:

1. Apparently Schiphol AMS has managed to stay well within their project budget the last two years. It is caused by the fact that the projects that were canceled (for instance the deterioration was less than expected or the project was postponed) outweighed new and unforeseen projects. Moreover, the projects that were planned ánd executed appeared to be cheaper (2010) or just a little more expensive (2011) on average.
2. Based on the last two years, around 2.5% should be added to the Business Plan estimate to account for unforeseen projects. It can also be said that around 3.5% of the actual expenditures went to unforeseen projects.
3. A large amount of money is reserved in the Business Plan estimate (14% to 40%) and the Annual Budget estimate (10% to 30%) for projects that have not been executed in that year. Looking at this in more detail (Appendix F) it appears that actual 'scope bump' is relatively small, because only a few (large) projects were actually postponed and the rest was fully cancelled. Thus, large funds were reserved for projects that were in the end not (yet) necessary.
4. Based on these data one could conclude that there is definitely room for improvement of the accuracy of the budget estimates.

3 Statistical analysis of Schiphol maintenance projects

Various methods can be used for estimating the costs of (maintenance) projects. The Black-box method is one of these. On the basis of a statistical analysis based on historic data 1) a percentage for the unforeseen and 2) a corresponding standard deviation or margin can be given depending on the project phase[4]. This percentage for the unforeseen is the average difference between the actual cost and the estimates, also called *nominal unforeseen*. The second component is the *statistical fluctuation* (coefficient of variation or standard deviation as percentage of the base estimate) around the estimated base value plus the unforeseen (PAO, 2009). This is illustrated in Figure 6.

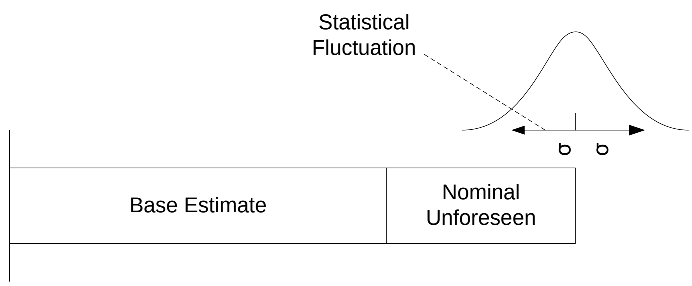

FIGURE 6: NOMINAL UNFORESEEN AND THE STATISTICAL FLUCTUATION

The values presented in earlier studies (given in section 6.2.2) do not necessarily have to be valid for (specific) maintenance projects. Therefore for this research an analysis is made of completed projects at Schiphol AMS. The values for nominal unforeseen and the standard deviation have been quantified and are discussed and analyzed in this chapter. These values can then be compared to the existing 'general' Black-box values.

[4] *More information on this and the different estimating techniques can be found in paragraph 6.2.*

3.1 Nominal unforeseen and the standard deviation

Based on data of 42 projects at Schiphol AMS the average difference between the various estimates and the actual costs has been calculated[5]. This is the aforementioned nominal unforeseen. When this percentage is added to the estimate, on average this value should be equal to the actual expenditures. Next to that the standard deviation of the total estimate (base estimate plus nominal unforeseen) is determined. This is an indication of the margin around the estimate.

3.1.1 All Schiphol AMS Projects

First, the dataset of Schiphol AMS maintenance projects have been assessed as a whole, to find a general nominal unforeseen and standard deviation for all maintenance projects. Further down, these have been divided into categories. The values are presented below in Table 2. In Appendix G more details are given on the determination of the probability function and the values.

The projects that were used for the statistical analysis are from 2010 and 2011. Finding reliable data on earlier projects proved to be very hard. Almost all projects from 2010 and 2011 were assessed. Projects of which data was lacking or that were not finished yet, were left out however.

TABLE 2: ESTIMATE DIFFERENCE AND -UNCERTAINTY CALCULATED FOR 42 PROJECTS

	Project viewpoint		
	Business Plan Estimate	Project Budget Estimate	End of Project
Nominal unforeseen	+17%*B	+10%*B	+0%*B
Standard deviation	34%*B	22%*B	-

B = base estimate

From the analysis it appears that the estimate for the evaluated projects shows a skewed probability distribution. In this thesis it was found that it approximates a *lognormal distribution* (see Appendix G).

What can be seen here is that the standard deviation is lower in the project budget estimate phase. This indicates that when the project is in a later stage the accuracy becomes better, as to be expected. Hence, the uncertainty is smaller when the project budget is estimated.

[5] *These estimates have first been corrected by subtracting the already included unforeseen (see Appendix G.1).*

3.1.2 Schipol AMS projects sorted by category

The forty-two projects that have been examined, which are mentioned in the former section can be subdivided into categories. This is based on the type of project. The following categories have been used.

- Runway & Taxiway project (11)
- Engineering project (4)
- Platforms (4)
- Systems (7)
- Roads (10)
- Others (6)

A further explanation of the categories used can be found in Appendix G. In order to make the datasets not too small, it was chosen to bundle some of the projects that have similarities, but can also be seen as different types. For instance "Runways and Taxiways" can also be subdivided into two separate categories. For now they have been put together in one category, but it is recommended to split these when a larger data set is at hand (maybe in the future). The reason for categorizing this is that the found nominal unforeseen can be used for setting the 'item unforeseen' in future projects. This can be set based on the project type. To be more accurate in the estimation for the unforeseen, it will be better when the project category is even more specified.

For the different categories the following values were found.

TABLE 3: ESTIMATE DIFFERENCE AND -UNCERTAINTY CALCULATED FOR 42 PROJECTS DIVIDED BY CATEGORIES

Category		Business Plan Estimate	Project Budget Estimate	End of Project
All	*Nominal unforeseen*	*17%*	*10%*	*0%*
	Standard deviation	*34%*	*22%*	*-*
Runways & taxiways	Nominal unforeseen	16%	14%	0%
	Standard deviation	23%	23%	-
Engineering	Nominal unforeseen	46%	46%	0%
	Standard deviation	29%	29%	-
Platforms	Nominal unforeseen	4%	7%	0%
	Standard deviation	22%	3%	-
Systems	Nominal unforeseen	33%	-1%	0%
	Standard deviation	45%	17%	-
Roads	Nominal unforeseen	6%	-2%	0%
	Standard deviation	30%	16%	-
Others	Nominal unforeseen	-12%	15%	0%
	Standard deviation	29%	26%	-

For these data also the lognormal distribution was found. This is validated in Appendix G. It should be noted here that due to the fact that the large dataset of 42 projects was split up in smaller datasets the found values have become more unreliable. However, the values given above still give a good indication on how the uncertainty is related to the different project types. To neutralize this shortcoming in the analysis, in the next chapter some projects are assessed in more detail. By doing this the above mentioned values are verified.

Looking at the above data, especially the categories "Runways & Taxiways", "Systems" and "Roads" are worth looking at. The datasets of the other categories were simply too small to say something about these findings.

Nonetheless, an indication is given that also the engineering projects should be assessed in more detail.

The *runway and taxiway projects* appear not to be very special. Based on the data an uncertainty of around 15% should suffice. Furthermore it seems that between the business plan estimate and the project budget estimate not much changes in terms of the uncertainty level. Apparently a more detailed estimate cannot be reached between these phases.

Looking at the *systems projects* it strikes that in the business plan estimate the nominal unforeseen and the standard deviation are relatively high. Apparently for this type of projects there is a lot uncertainty in the early phase of the project: uncertainty of initial state. Not much is known about the project when these estimates are made. On top of that, because a new system has to be installed in replacement of an old one, extra uncertainty is introduced; there is not a 'green-field' situation. However, when the project budget is calculated in more detail and more is known about the project the nominal unforeseen approaches zero and the standard deviation decreases to a similar level as the other maintenance projects.

The nominal unforeseen in *road projects* is low compared to the total average of all the projects, but the standard deviation is still relatively large. This could indicate that often the estimate is relatively accurate and a small percentage for the item unforeseen is sufficient. However, if something unforeseen happens in a project the costs can rapidly increase.

What can be noted here is that the estimates are made by different maintenance mangers, since each of them is responsible for a certain category. Since they estimate the costs in a different manner (see section 6.4), this could also play a role in the differences between categories. Although, looking at the data more closely it is not very likely that this is a main cause of the difference.

The above are mere first interpretations based on the statistical analysis. As said, in the next chapter the projects will be looked at in more detail. After that, in section 6.6.2 the values are compared to the existing 'general' Black-Box values and the differences are explored.

3.1.3 *Projects sorted by budget*

Similar to the categorization made in section 3.1.2, the dataset has also been examined grouping it by the height of the costs. The following distinction has been made.

- Projects larger than € 1 million (14)
- Projects smaller than € 1 million (28)

This can be seen as a representative measure for the size of the project. The results are presented in Table 4.

TABLE 4: ESTIMATE DIFFERENCE AND -UNCERTAINTY CALCULATED FOR 42 PROJECTS DIVIDED BY COSTS

Category		Business Plan Estimate	Project Budget Estimate	End of Project
All	*Nominal unforeseen*	*17%*	*10%*	*0%*
	Standard deviation	*34%*	*22%*	*-*
> 1 mln €	Nominal unforeseen	9%	3%	0%
	Standard deviation	14%	10%	-
< 1 mln €	Nominal unforeseen	31%	16%	0%
	Standard deviation	48%	28%	-

What can be seen from the table above is that apparently the large projects are estimated far more accurate than the smaller projects. This is illustrated by the smaller values for the nominal unforeseen as well as the standard deviation. The values for the normal unforeseen or the larger projects are even below 10%. It indicates that the used unforeseen percentage of 10% was even too high. Thus, on average these projects came out lower than their estimates.

Explanations for the found values could be the following. In the first place larger project can be seen as a portfolio of smaller projects. In this way costs overruns in one smaller subproject can be compensated by another subproject. This implies however that these subprojects have a small correlation. Otherwise the rise of costs in one of the subprojects would also mean higher costs for other projects. This could in its turn be a sign that maintenance projects (at Schiphol) can be fairly easily split up in smaller subprojects, which have relatively little overlap. It is in fact the case that the larger projects of AMS can be seen as a cluster of smaller projects. These subprojects are sometimes even estimated separately.

Another explanation could be found in the fact that the estimates compared to the actual expenditures are measured relatively. In chapter 4 it is shown that in maintenance works the unforeseen events that are actually occurring are relatively small. However, these events weigh relatively heavy on smaller projects. This could therefore be an indication that in the larger projects no significantly larger unforeseen events occur.

Finally, a third explanation could be that the budget estimated for indirect costs and additional costs is partly allocated to direct costs overruns as explained in chapter 4. In line with the former explanation, these items are in absolute terms larger for large projects. It could be that additional costs for small project are in fact relatively larger than for large projects. Thus, in small projects not much buffer from the additional and indirect costs items is left to allocate to unforeseen events or scope additions.

It has to be noted that the dataset was, as said before, too small to properly test these possible explanations. But, based on interviews (Appendix C), it is very well possible that all three explanations are valid.

3.1.4 Projects sorted by year

The projects have also been sorted per year, as shown in Table 5. Since two years were examined only 2010 (22 projects) and 2011 (20 projects) could be differentiated.

TABLE 5: ESTIMATE DIFFERENCE AND -UNCERTAINTY CALCULATED FOR 42 PROJECTS DIVIDED BY YEAR

Category		Business Plan Estimate	Project Budget Estimate	End of Project
All	*Nominal unforeseen*	*17%*	*10%*	*0%*
	Standard deviation	*34%*	*22%*	*-*
2010	Nominal unforeseen	14%	13%	0%
	Standard deviation	35%	23%	-
	Total[6]	-1%	-7%	-
2011	Nominal unforeseen	20%	10%	0%
	Standard deviation	32%	28%	-
	Total	-1%	-3%	-

[6] *In the row 'Total' the total sum of the portfolio of certain representative projects (around 20 per year) are compared.*

Looking at Table 5 it can be seen that no large differences can be found between the 2010 and 2011 values. The standard deviations are more or less equal as well. Still the nominal unforeseen of the business plan estimate in 2011 is somewhat higher than in 2010. The only explanation for this could be that in 2011 some price rises with a new contract occurred, which were not yet taken into account when the business plan was made.

Based on the total sum of the portfolio of only two years one could say that this is rather constant (small standard deviation). Apparently on a portfolio level, the plusses were able to cancel out the minuses. The issue that the total portfolio of the projects is estimated higher than the actual expenditures, but at the same time that the projects on average are estimated too low, is hard to explain. In line with the findings in the former section, the reason for this could be that the large projects were done below budget, which in absolute terms created a large buffer. This could have compensated the smaller projects that exceeded the estimate.

3.2 Validation of the values found

In the previous section the percentages for the nominal unforeseen, the standard deviation and the probability density function have been determined. However, these values can show some uncertainty. This can be caused by:

1. Uncertainty caused by the limited dataset;
2. Uncertainty in the acquired data.

A detailed analysis is presented in Appendix G and the results are presented below.

3.2.1 Limited dataset

Of course there are limitations due to the limited data set that has been used. When all projects are placed together a dataset of 42 is assessed. This is not extremely large, but still reasonable. However, when the projects are divided into categories, the datasets become much smaller, which also increases the uncertainty of the found values extremely.

Probability density function

As explained the data was found to best fit a lognormal function. This is done on the bases of known principles from literature, such as the skewedness of the dataset and the fact that the values of the dataset cannot be smaller than zero. In Appendix G also some statistical tests have been done in order to verify this assumption. On the basis of these tests the assumption of a lognormal distribution cannot be rejected. Moreover, it is found that a lognormal distribution is more likely than a normal distribution.

Parameters

When a certain probability function has been assumed, uncertainty can also exist in the found corresponding parameters. In Appendix G this is also assessed. It appears that especially the standard deviation found has a relatively high uncertainty (based on high variance coefficient). Although this is the case, the found values are still a good indicator for the average uncertainty surrounding the estimations.

3.2.2 Uncertainty in acquired project data

The data extracted from the Schiphol AMS database does not necessarily have to be 100% reliable. The highest uncertainty here comes from the fact that every maintenance manager makes the estimation in his own manner. Uniformity and transparency is somewhat lacking. In the process of correcting the estimates by subtracting the already included unforeseen, this can play an important role. However, the uncertainty in the acquired project data is almost impossible to quantify and is for that reason neglected. This uncertainty was reduced by talking to project controllers, project managers and cost specialists within Schiphol and investigating the data thoroughly.

3.3 Findings of the statistical analysis

On the basis of the statistical analysis the following can be concluded:

The nature of the data:

1. Looking at the financial project data it is very probable that both the business plan and the project budget estimations show a skewed density function. Congruent with literature (Boschloo, 1999; CUR, 1997; Kujawski et al., 2004) and earlier findings it is likely that the dataset resembles a lognormal distribution. Testing the original data against this distribution function, this assumption is acceptable.
2. Based on the statistical tests the lognormal distribution is a better approximation than the normal distribution.
3. It is valid to also assume a lognormal distribution for the individual categories.
4. Due to the large variance in all the standard deviations that have been calculated, these values should be handled with care, both for the business plan and for the project budget estimations. This is especially the case for the individual categories, since the datasets were even smaller here. The nominal unforeseen also has a relatively large variance, but compared to the standard deviation the predictive value is far better.

5. Although some values show a large variance, the standard deviation and especially the nominal unforeseen are still a good indicator for the average estimation uncertainty.

The results:

6. The generally applied 10% unforeseen for the business plan estimates seems not sufficient. It is better to use a percentage between 15-20%. For the project budget it does seem appropriate to use a 10% unforeseen percentage.
7. Currently a spread around the estimate (standard deviation) is not taken into account. The statistical analysis shows however that this cannot be neglected.
8. When setting a percentage for the item unforeseen it is recommended to look at the type of project, since based on this the average unforeseen and standard deviation strongly differs. When for instance a system project is estimated it advised to use a larger uncertainty margin for the business plan estimate, than if it were a simple road renovation project.

In the next chapter a couple of the projects are assessed in more detail. This is done in order to discover the nature of the nominal unforeseen. Next to that it is also a verification mechanism to check whether the general/average values found in this chapter are corresponding to the values found at the project level.

4 Detailed analysis of Schiphol maintenance projects

In this chapter some of the projects analyzed in chapter 3 are examined in more detail. Eleven CAPEX projects (see appendix H for more information) are assessed. The general findings are presented in the main report. In Appendix H the detailed project description including the cost estimates and the unforeseen events are given. After the general findings some information is given on an earlier study on OPEX projects. In the last section an overview of the occurred unforeseen events in these projects is given as well as the costs belonging to these events.

The following projects have been examined:

- Large maintenance on runway 06-24 (Runways + Taxiways)
- Large maintenance on runway 04-22 (Runways + Taxiways)
- Taxiway Bravo (Runways + Taxiways)
- Taxiway Delta (Runways + Taxiways)
- DE-bay (Runways + Taxiways)
- Cluster control systems runway stations (Systems)
- Taxiway stations N/M (Systems)
- Roads on airside 2011 (Roads)
- Roads on airside 2010 (Roads)
- Cateringweg (Roads)
- Handelskade (Roads)

In Appendix H first a general description is given for these projects. After that the different cost items are summarized. Further, for each project it has been assessed how much was spent on unforeseen in the execution phase ('meerwerk') and what this contained.

4.1 General findings by detailed project analysis

For means of overview, in the table below the comparison between the Business Plan estimate and the End of Project as well as between the Project Budget estimate and the End of Project are given (Table 6). This is not only done for the total project costs, but also for just direct costs combined with the indirect costs. The reason why this has not been split up any further is that in the accounting of Schiphol the direct cost and the indirect cost could not be retrieved. This is because these costs were often not booked separate. Mere the total contracting sum was written down.

TABLE 6: OVERVIEW OF MORE IN DEPTH PROJECT ANALYSIS

		Direct + Indirect costs		Total (incl. additional and unforeseen costs)	
		BP vs EOP	PB vs EOP	BP vs EOP	PB vs EOP
Ruway + Taxiway	06-24 runway	1,43	1,35	1,12	1,06
	04-22 ruway	1,01	1,15	0,76	1,06
	B Taxiway	1,21	1,21	1,09	1,09
	D Taxiway	1,08	1,08	0,96	0,96
	DE-bay	0,81	0,81	0,75	0,75
Ruway station	Cluster runway station			0,94	0,96
	N/M runway station	1,06		0,97	0,75
Roads	Road airside 2011	0,60	0,60	0,57	0,57
	Road airside 2010	1,13	1,13	0,86	0,86
	Cateringweg	2,16	1,00	1,66	1,00
	Handelskade	1,18	0,96	0,82	0,85
TOTAL	**Mu** (lognormal)	**1,17**	**1,03**	**0,96**	**0,90**
	Sigma (lognormal)	**0,34**	**0,21**	**0,29**	**0,18**

What can be seen in this overview is that for these projects the total of direct costs and indirect costs are estimated too low. In other words these budgets are overrun. However, when looking at the total project costs (including additional costs and unforeseen), the actual costs come out lower than the estimate, which means the project is delivered within budget. This could indicate two things: either the unforeseen is booked on the direct costs (within contractor sum) or the surplus in the additional cost item is used to cover higher direct or indirect costs. The first is definitely the case, since the booking is done on a high level and the separate cost items cannot be easily retrieved. That the second is probably also the case is explained in the next section (Additional Costs).

Moreover, what can be seen in the above table is that the average cost overrun (μ) and its standard deviation (σ) for the direct and indirect costs are similar to the values derived in chapter 3. This indicates that the values found earlier are a relative good indication for the unforeseen of the project itself. Only the average for the project budget seems somewhat lower. This could again have to do with the accounting on a rough scale.

Another thing that can be mentioned here is that due to this accounting it was unfortunately not possible to retrieve data for the various subprojects. This means that for instance for the storm water drainage estimates it could not be checked whether these were done correct or what the unforeseen for this type of projects is. The projects could be only regarded as whole, since the total contract sum has been written down, instead of the separate costs for the various subprojects.

<u>Additional Costs</u>

When looking at the actual additional costs of the projects examined in this chapter also some things can be noted. Firstly the average values of the actual booked additional costs are presented below sorted per type.

- Runway = ~ 5% of Primary Costs
- Taxiway = 15% - 20% of Primary Costs
- Runway stations = ~ 20% of Primary Costs
- Roads = ~ 10% of Primary Costs

For all the projects it appeared that the actual additional costs were less than the estimated additional costs. A similar thing could be seen with the OPEX projects research (next section).

These numbers should be treated with care though. Since at Schiphol AMS the (additional) cost items are not always booked separately it was not easy to discover the actual expenditures on these items. It could be that some of these costs, were booked as part of the whole contractor sum, and thus clouding the data. However, it still gives a good indication for the order of magnitude of the additional costs. Therefore these numbers also served as input for section 7.1. Moreover it indicates that attention needs to be given as to how the additional costs are estimated and if the percentages used are correct. Thus, it is recommended that further research – similar to the OPEX research – should be done on the additional (as well as indirect) costs. A prerequisite for this is that these costs are then booked on specific cost items (according to estimation), by AMS as well as the contractor, such that these numbers can be easily compared.

4.2 Operational expenditures at Schiphol AMS

As explained earlier OPEX stands for Operational Expenditures. In Schiphol AMS lingo with OPEX projects is referred to inspections and (small) regular (also preventive) maintenance projects, such as filling of holes, small repairs, etc. In 2009 a research has been done within Schiphol AMS to the operational costs of OPEX projects (Schiphol Group, 2009).

With operational costs the following cost items were meant:

- Temporary measures (gates, etc.)
- Waiting time
- Costs due to phasing
- Extra costs due to evening or night work
- Unproductivity due to operational conditions

From the conclusions of this research it appeared that in total only between *1.5 and 5 percent* – depending on the work area – was spent on these operational costs. On an average throughout all the work areas this was 3.0%. Within this 3% the costs were distributed as seen in Figure 7.

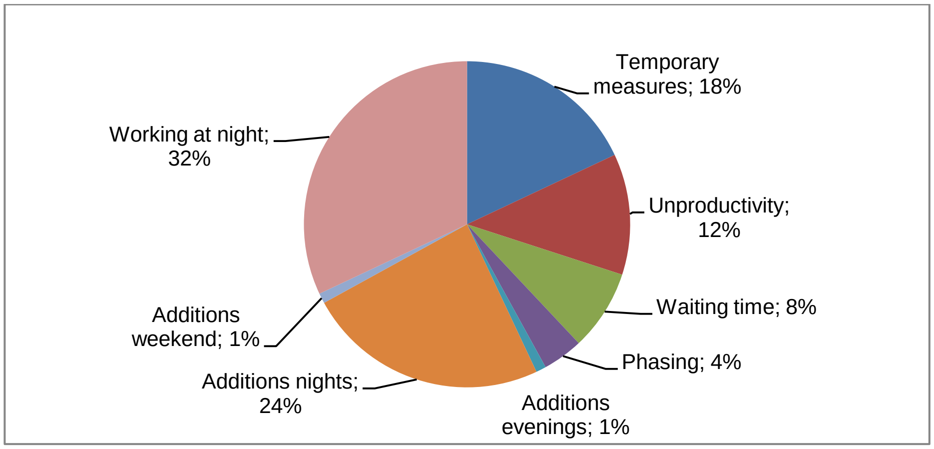

FIGURE 7: OPERATIONAL COSTS OF OPEX PROJECTS

The interesting thing to notice here is that for the OPEX projects in general 20% was estimated (or reserved) for these operational costs. This money was spent most of the times. But, since 3% was only spent on the actual operation costs, 17% was apparently allocated to something else. This could be on unforeseen events, but this did not become clear out of the research.

As seen in this chapter apparently a similar thing is happening in the CAPEX projects. Money reserved for additional costs – similar to the operational costs – is used for something else, since these are in general overestimated.

4.3 The unforeseen in Schiphol maintenance projects

The percentage for the nominal unforeseen can be split up into three different categories, as pictured in Figure 8 and explained below.

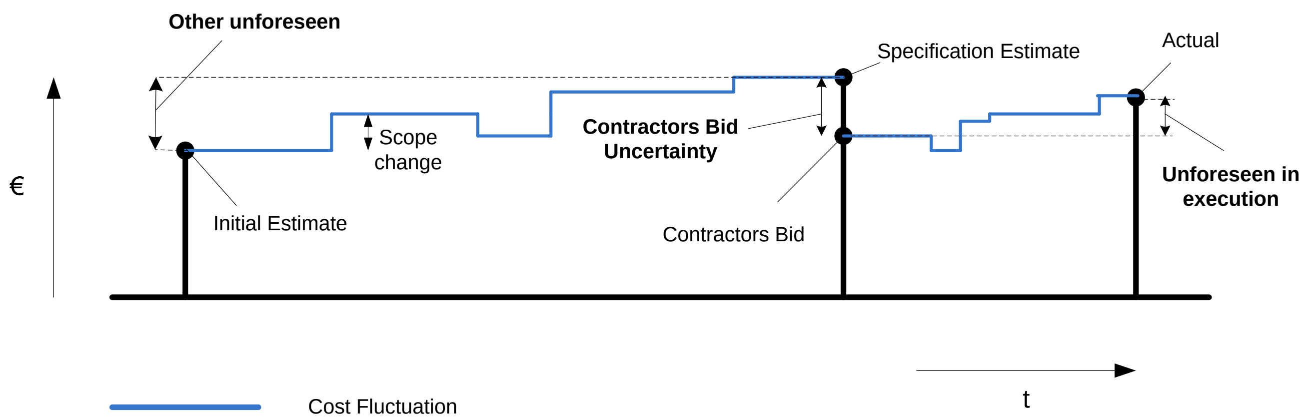

FIGURE 8: DIFFERENT TYPES OF UNCERTAINTY

1. Unforeseen in the execution
   This is the unforeseen due to special events that happen during the execution. This is calculated by comparing the contracting bid to the eventual contracting sum; the additional work (in Dutch: 'meerwerk'). A part of the unforeseen in execution has to be paid by the contractor itself. Since only the costs for the client (Schiphol) were taken into account, the extra costs for the contractor were not calculated.
2. Other unforeseen
   These costs form an addition on the estimate for further specifying and completing the design and work method. Also scope and design changes are part of this. On top of that a part of this percentage is caused by imperfect estimation methods or sometimes deliberate underestimation. This type of unforeseen is thus caused by normal uncertainties as well as scope uncertainties.
3. Contractors bid uncertainty
   As Boschloo (1999) showed in his analysis on seven large infrastructure projects a part of the unforeseen is also caused by a difference between the specification estimate and the actual contractors bid. This can for instance be caused by market forces (i.e. discounts given by the contractor), price changes or optimization of execution methods. In this thesis this type of uncertainty was not taken into account. The first reason for this is the fact that framework contracts (see page 17) have been made

between Schiphol and main contractors, which reduces this uncertainty significantly. The second reason is that no specification estimates are made by Schiphol so a comparison could not be made. The contractor bids are however checked by experts.

In Appendix H detailed information on the unforeseen is given per project, which is summarized in Table 7. In this table the total unforeseen has been split up into the unforeseen due to special events (unforeseen in execution) and due to further specification (normal unforeseen).

TABLE 7: UNFORESEEN SORTED

		Business Plan			Project Budget		
		Unforeseen in execution	Other unforeseen	Total	Unforeseen in execution	Other unforeseen	Total
Ruway + Taxiway	06-24 runway	2,90%	18,07%	20,97%	2,75%	12,06%	14,81%
	04-22 ruway	3,90%	-22,32%	-18,42%	5,52%	9,98%	15,50%
	B Taxiway			18,19%			18,19%
	D Taxiway			4,02%			4,02%
	DE-bay			-17,83%			-17,83%
Ruway station	Cluster runway station	4.69%	-10.65%	-5.96%	4.79%	-8.65%	-3,86%
	N/M runway station	0,96%	0,33%	1,29%	0,72%	-25,23%	-24,52%
Roads	Road airside 2011			-42,93%			-42,93%
	Road airside 2010			-0,78%			-0,78%
	Cateringweg			90,46%			0,00%
	Handelskade	-16,18%	-5,35%	-21,54%	-14,60%	-14,60%	-29,20%

What can be seen from this is the following. Firstly only a *small part* of the total unforeseen happening in these maintenance projects *is caused by special events.* Compared to for instance the findings of Boschloo (1999) where these percentages for new-to-build projects range between 20 and 30% of the total contracting sum, the values here are very low (maximum 5%). What can be concluded from this is that apparently in maintenance projects relatively little special events happen during the execution phase.

The uncertainty percentages in the road projects are all caused by uncertainty in the initial state. For instance more traffic light loops were found than initially thought. In the case of the Cateringweg this was already adjusted in the project budget.

On the other hand, a large contribution to the difference between the estimate and the actual expenditures is caused by the uncertainty related to further specification. In the initiative and early design phases of maintenance projects it seems that a lot is still uncertain and scope changes occur. However, when more engineering and inspections are being done and the design is further completed, these uncertainties disappear. The contractor can then give an accurate bid, without too many risks occurring during execution.

Another thing to notice here and which is also verified by talking to the project managers, in the (relatively simple) road maintenance projects no special events happen during execution. Everything is rather straightforward. Differences between estimates and actuals can only be explained by scope shifts and design errors, but not by 'unknown-unknows'.

Interviews held at RIJKSWATERSTAAT and PRORAIL gave similar insights. Also at those organizations it was found that in new-to-build projects the additional work could go up to 25-30% whereas for maintenance works this is much lower. Moreover, they also experienced that the normal and scope uncertainty due to further specification was relatively high in maintenance projects. For more information on the estimation practice at RWS and PRORAIL see section 6.5.

4.3.1 Analysis of the unforeseen during execution

The unforeseen during execution can be further classified into several types of deviations. For maintenance works this can be done as follows:

1. Deviation of environmental conditions
    a) Deviation of work field conditions initial state
    b) Extraordinary operational disturbances
2. Changes in program of requirements
    a) Extra requirements of client (Schiphol)
    b) Change in law and regulations
3. Deviation of design
    a) Specification deviation (procedural)
    b) Dimension deviation (construction)
4. Execution errors

In appendix I a more detailed explanation for the above mentioned types of unforeseen during execution is given.

When looking closer at the special events occurring during the execution of the maintenance works on Schiphol, the following distribution relative to the total execution unforeseen can be derived (Figure 9).

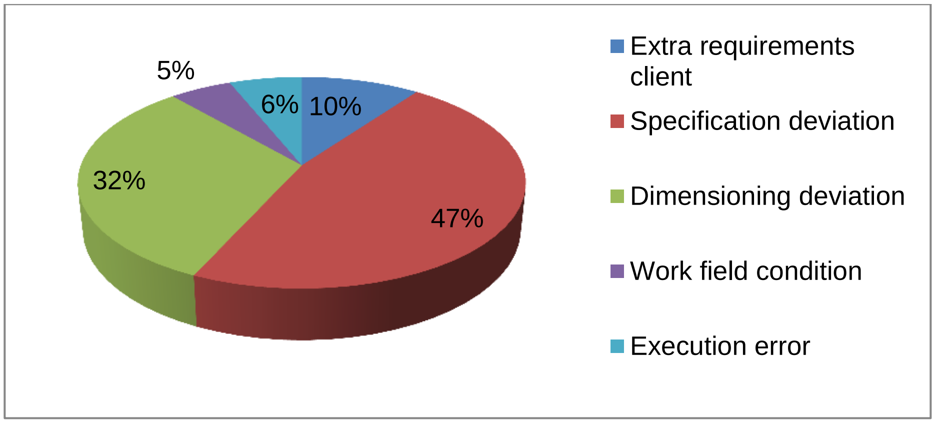

FIGURE 9: CLASSIFICATION OF UNFORESEEN EVENTS IN EXECUTION PHASE

What shows from Figure 9 is that a large part (almost 80%) of the special events happening during execution is related to errors in the design. These are deviations from either the specification or the dimensioning. The other types of unforeseen tend not to happen that often. However what becomes clear from Appendix H is that when they do occur the extra costs are relatively large. Some of the events that are typically occurring in the Schiphol environment and were found in the examined projects are:

- Bombs found (work field condition)
- Unforeseen storm water drainage damage (work field condition)
- Measures for cables and pipelines (work field condition)
- Asphalt containing tar (execution error)

What can also be seen from Figure 9 is that during execution scope changes (extra requirements) are still happening and on average make up around 10% of the unforeseen. This can actually not be regarded as a real special event though.

5 Risk management in maintenance

In this chapter first an introduction is given into risks, uncertainty and risk management. After that the findings of the previous chapter are combined to see what types of risks typically occur in maintenance projects. This can be later used as input for making a cost estimation for a new maintenance project.

5.1 Risk in general

The most broad definition which is commonly accepted is that a measure of risk is a *function of probability of occurrence times consequence* (CUR, 1997; CROW, 2010; Well-Stam et al., 2003; PMI, 2000). Some sources take into account that the consequence can only have a negative effect (Well-Stam et al., 2003), while some define it as a combination of threats and opportunities (PMI, 2000). In this research both positive and negative consequences will be dealt with, although it is expected that mainly the downside risks will predominate.

In this thesis risks will first be assessed at the project level, since costs will be estimated of individual projects and are then added up to determine the total needed annual budget. In the chapter on budget management, risk is also assessed on a portfolio basis. Cost of a process or object in conjunction with risk plays an important role in an economical optimization process. A condition is then that it must be possible to express the risk monetarily.

Risk and uncertainty are closely related. According to Hillson and Simon (2007) "everyone agrees that risk arises from uncertainty". The three different types of uncertainties in probabilistic cost analysis are described in section 5.4.

Considering the above the following (smaller) definition of a risk will be used in this thesis.

> *Risk = an uncertain event or set of circumstances that, should it occur (probability), will have a financial effect[7] (consequence) on the costs or benefits of the project.*

Two types of these risks can be distinguished.

- Known unknowns
  With the help of a risk analysis these risks have been identified and are taken into consideration in the Probabilistic Cost Analysis.

- Unknown unknowns
  As the term indicates, nothing is known about these risks beforehand, so they cannot be foreseen.

5.2 Risk Management

Risks can have a large influence on the project result. The policy on how to deal with risks is called "risk management". There are many different theories and definitions of risk management. It is commonly accepted that in risk management not only risks are identified, but it also encompasses taking action (or deliberately not) with the purpose of securing the project objectives.

Looking at the different theories, the risk management process can generally be seen as an iterative process of recognizing and analyzing risks (both are part of the risk analysis), taking action (the actual risk management) and monitor and evaluate this, before doing the analysis again (RISMAN, 2011; Hillson and Simon, 2007; PMI, 2000). The terms given for the various steps in this process differ from theory to theory, but here the following terms are used, which will be briefly explained in this section: identify, analyze, respond and monitor.

[7] *It can also have an effect on the planning of the project, but this can be calculated into costs by expressing the unavailability of a runway for instance into a monetary unit. (see also paragraph 2.3.1)*

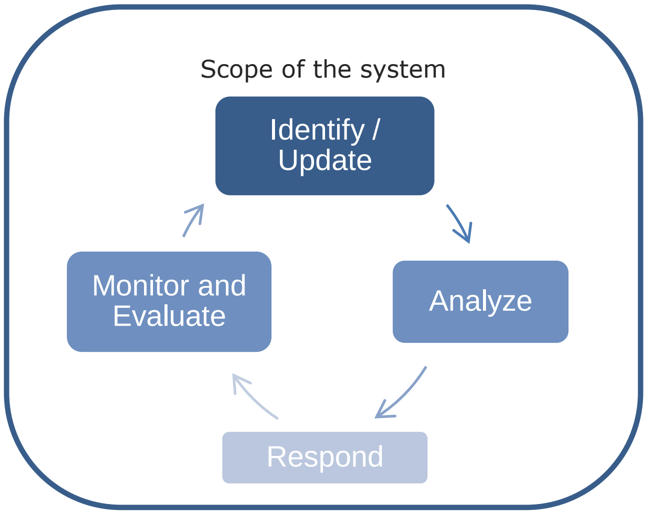

FIGURE 10: GENERAL RISK MANAGEMENT PROCESS

Identify

Risk management always starts with identifying the risk that influences the project objectives[8] and setting the scope of the system. This results in a risk register which contains a long list of risks. This list is obtained in various ways. Consulting experts or brainstorm sessions are examples of this. What should be noted is, that these found risks are only the *known-unknowns,* and thus the category *unknown-unknowns* is only reduced (see section 5.1).

The RISMAN-method (Well-Stam et al., 2003; RISMAN, 2011) is an often used tool in Dutch infrastructure projects. It uses a risk matrix to support this process. On the horizontal axis different points of view are given (such as technical, organizational, political, etc.) and on the vertical axis the project process is shown.

Analyze

When the risks are identified, the next step is to prioritize them. This can be done either qualitatively or quantitatively. This is often done by looking at the probability of occurrence and (cost of) consequence. To visualize the prioritized risks a probability-impact-matrix is often used (see Figure 11). Fault- or event-trees can also be used for this (Vrijling, 2011b).

[8] *Project objectives are often defined as: costs, time, scope and quality: WINCH (2002b). Managing Construction Projects, Blackwell Publishing.*

Qualitative Risk Analysis Matrix

Likelihood	Consequences				
	Insignificant	Minor	Moderate	Major	Severe
Almost certain	M	H	H	E	E
Likely	M	M	H	H	E
Possible	L	M	M	H	E
Unlikely	L	M	M	M	H
Rare	L	L	M	M	H

FIGURE 11: EXAMPLE OF A PROBABILITY-IMPACT-MATRIX

Respond: the actual risk management

This step in the risk management process can be seen as the actual risk management. The actual risk management roughly exists of the following two steps:

1. Think of measures to reduce the uncertainties or consequences.
2. Carefully weigh the costs of these measures against the benefits and reduce when opportune the list of uncertainties. If necessary also adjust the item unforeseen and margin (section 6.2.2).

Depending on the nature of the risk one has to decide how to respond. In literature often several strategies for dealing with risk are described, for instance the 4T's (Verbraeck, 2009). However, one can reduce this to only two: bear the risk yourself or transfer it to another party. The other strategies can be placed beneath these two main strategies as indicated below.

- Bear the risk yourself. When doing this one can of course decide to reduce or avoid the risk (or not).
    - Take (or Accept): nothing is done on the actual risk at the moment, except making a contingency plan. This can also mean that extra budget/time is reserved.
    - Treat (or Reduce): changing something in the scope or taking mitigation measures which will reduce the probability of occurrence and/or the impact of the event.
    - Terminate (or Avoid): changing the scope in such a way that the risk will be eliminated.
- Transfer: transfer the risk to another party, for instance the contractor or an insurance company.

If there is still a risk left after treating or avoiding a part of it (which is often the case), this is called a *residual risk*. This residual risk is often accepted. A *secondary risk* is a new risk that is caused by treating another risk.

Monitor and Evaluate

When an action is taken in the previous step, things have changed. This can be the probabilities, consequences or even a secondary risk can come up. So the risks and control measures have to be evaluated and monitored. More information is available in this step, so lessons can be learned. From this point the risk management cycle can start over. After project completion a subsequent calculation is needed for the normal uncertainties and special events (foreseen and unforeseen).

When the risk management cycle has been executed several times, there are always some residual risks that need to be accepted. This is done by adding a margin to the cost estimation. These residual risks play a crucial role in cost estimation and planning including uncertainties.

5.3 Risk Analysis

An important aspect of a probabilistic cost analysis is the risk analysis. A general goal of a risk analysis is to provide a base on which rational decisions can be made (CUR, 1997). As stated in the previous section, a risk analysis is part of the whole risk management process.

So, in a risk analysis not only an inventory of the possible risks is made, but also the risk are prioritized by looking at how large the risks are. Also the evaluation of the control measures can be seen as part of the risk analysis. It should be noted that to use the information generated by the risk analysis in a probability cost analysis, the risks have to be quantified in probability (%) and consequence (€).

5.4 Types of uncertainties in risk analysis

In probabilistic cost estimates three types of uncertainties can be distinguished (PAO, 2009):

- Normal uncertainties
  The values of the normal uncertainties (prices and quantities) are given by a probability density function (p.d.f.) with a certain average (μ) and the standard deviation (σ). This is often simplified by a triangular distribution with so called LTU (lower limit, top and upper limit) values.

- Special events
  With the help of a risk analysis a list of 'special events' is composed. These unforeseen events are then being quantified by multiplying the probability of occurrence (%) with the cost of the consequence (euro). This last item can either be given by one explicit amount or if the consequence is uncertain by a probability density function.

- Plan uncertainties: alternatives
  This last uncertainty is somewhat different. Sometimes various alternatives are proposed. In that case the cost engineer can estimate the probabilities of the various alternatives being chosen and determining the total p.d.f. by weighing the probabilities. In this research this type of uncertainty will not be treated. This is due to two reasons. In the first place, it is assumed that in maintenance works the choice on various alternatives will not be such as in creating 'new' infrastructure. And secondly, if for some reason there can be opted for more alternatives, these will be estimated separately.

In the light of this research the second type of uncertainty (*special events*) will be considered as risks.

5.5 Risk in maintenance

As mentioned in chapter 4, risks, defined in this thesis as special events happening during execution, are not often occurring in maintenance projects. This is because after the detailed engineering is done, the situation is examined rather well and there is a clear view of what has to be done. Moreover the work often takes place in already stirred ground, which reduces the risks tremendously. This is because, considering new-to-build projects, a large amount of risk is involved when building underground (Boschloo, 1999). On top of that maintenance projects are often relatively small and are therefore well controllable.

In maintenance projects a relatively large part of the uncertainty lies in the phase between the initiation of the project and the actual execution. The scope is often very uncertain and thus not well defined. This has to do with two things. In the first place this is due to uncertainty of the initial state, which can make the scope definition unclear. If one compares it to new-to-build projects one could say that in maintenance type of projects there is less a 'green-field' situation. The other thing is that when the initial budgets estimates are made the design and scope are still on a very course level, which means there is not a good picture of what the project entails. Only after inspections are done and more detailed engineering is performed, this uncertainty reduces.

Three types of risks can be distinguished that relatively often do occur. The first one is the situation where inspections cannot give a complete view of the starting situations. This is most of the times the case where works have to be done underground. It could than occur that for instance a bomb is found or hidden cables and pipelines are discovered. However it should be noted that the probability of this happening is far less than in new-to-build projects.

The other risk involves the operational conditions. Maintenance projects are often done on assets that are still being used at that moment and will be used after the renovation works. It can even happen that a part of the asset will be in use during the maintenance works. This is not only the case for runways at Schiphol for example, but also the roads of RWS and the railways of PRORAIL. This complicates the execution of the work. Normally this type of relative normal uncertainties is taken into account by the spread in the direct or indirect costs. In the Schiphol case percentages for extra operational expenses in the form of night work or phasing are used. Nonetheless, an extra ordinary operational disturbance (think of an airplane crash, long periods of bad weather or security issues) can occur, which will push the project further into time, with of course financial consequences. This can be seen as a typical special event in maintenance projects. But, the probability of this type of extreme events will not be that high.

The third one has the largest contribution to the additional work as shown in section 4.3.1: design errors. These are not unique for maintenance projects as they also occur regularly in new-to-build projects (Boschloo, 1999). It was found that in the maintenance works at Schiphol almost 80% of the additional work was spent on design flaws, which had to be corrected during execution. As said the total sum of the unforeseen happing during execution is not that large, thus this is not a very big problem. Nonetheless, it is something that could be given attention to since it takes up a relatively large part of the additional works.

6 Cost estimation including risks

In this chapter the various cost estimation techniques are explained and how this can be done including uncertainty. In the first sections the theory is elaborated. After that the current practice at Schiphol, RWS and PRORAIL is explained when it comes to maintenance projects. This chapter ends with the section in which a 'new' process for the cost estimation at Schiphol AMS is introduced. This last section is an important part of this thesis.

6.1 Uniform budget estimation structure

There are many advantages to a uniform cost estimation structure. It gives transparency, different costs estimations can be easily and fairly compared, the danger for incompleteness is reduced and information from third parties can be easily included and so on.

PRI and the RISMAN method prescribe the following structure (Table 8). An explanation of these main items is given in Appendix J. In the SSK-2010 a similar budget structure is proposed (CROW, 2010).

TABLE 8: UNIFORM COST ESTIMATION STRUCTURE ACORDING TO PRI AND RISMAN

Cost Estimate							
Direct Costs							
Indirect Costs	+						
Primary Costs							
	Additional Costs						
	Miscellaneous	+					
	Base Estimate						
		Unforeseen	+				
		Subtotal					
			Taxes	+			
			Total				

Such an estimate is always a prognosis of future expenditures, thus it has uncertainties. In Figure 12 these uncertainties are pictured next to the uniform cost structure.

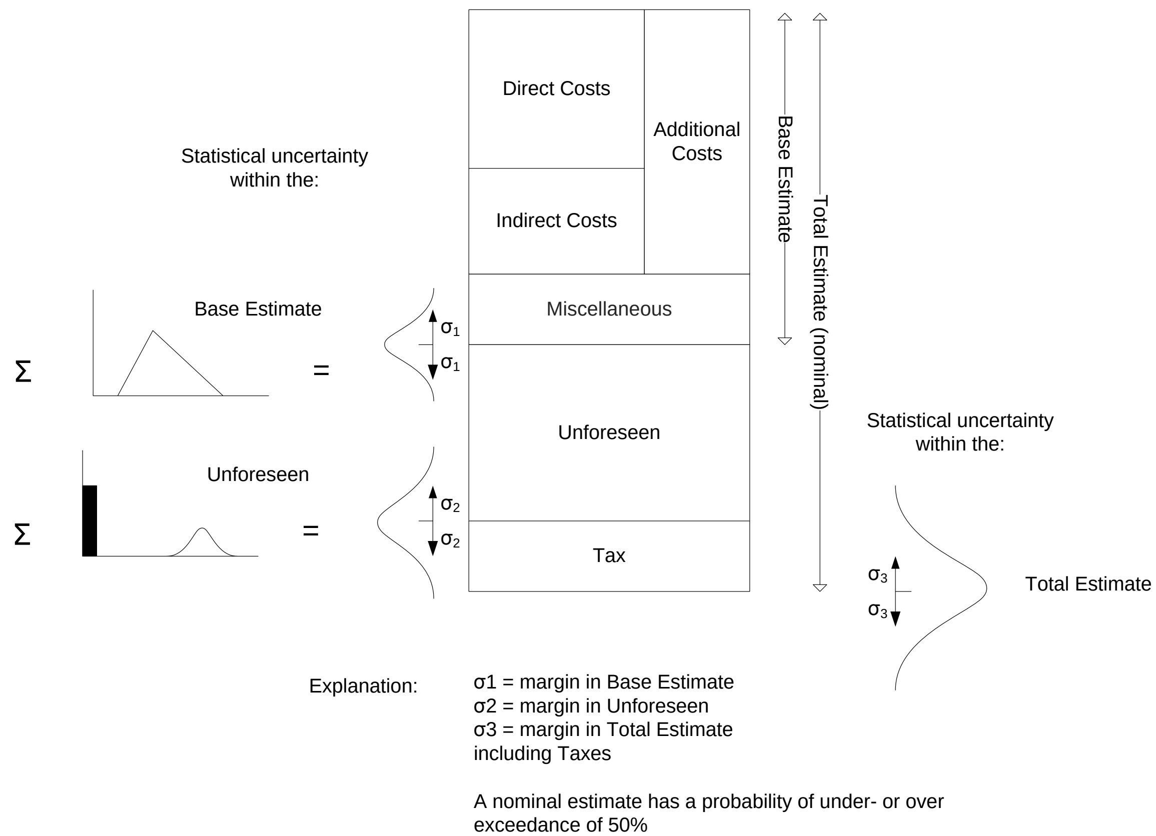

FIGURE 12: COST ESTIMATION STRUCTURE INCLUDING UNCERTAINTIES [SOURCE: (PRORAIL, 2011)][9]

6.2 Cost estimation methods

In different phases of a project the information that is available differs. That is why the composition of the cost estimate is different depending on the phase. The difference in composition is called the cost estimation technique. This also has to do with the costs (and time) of making an estimation. This is illustrated by Table 9.

[9] *At Schiphol Group no VAT-taxes are taken into account*

TABLE 9: COST ESTIMATION TECHNIQUES IN DIFFERENT PHASES

Phase	Cost estimation technique	Level of detail
Initiative	Estimate per object (tunnel/bridge)	Less
↓	Estimation on cost indicators	↓
	Estimation on quantities and unit prices	
Execution	Estimation on work methods and quantities	More

The actual amounts that form the input of the different cost items of a cost estimate can be determined with different methods. These methods are the following and are described in the next sections.

- Deterministic approach
- Black-box approach (or semi-probabilistic approach)
- Probabilistic approach

6.2.1 *Deterministic approach*

In traditional cost estimates, *deterministic approach,* one uses an average or most probable (mode) value for all of the items of the base estimate. Actually, uncertainties are not properly taken into account here (PAO, 2009; DACE, 2007; Dillon et al., 2002; Kujawski, 2002). Only a margin or an extra item 'unforeseen' is added to make the estimate more realistic. The values of these items are dependent on the available information, the type of project and the phase the project is in. It is based on the experience and the estimates of experts and is often expressed as a percentage of the base estimate.

Characteristic of the deterministic approach is that the margin is not expressed as the spread of an estimate, rather as a safety factor (percentage) that is added to the base estimate.

A deterministic value should only be used when detailed or specific cost estimates are available from a reliable sources (Chou et al., 2009). This is because each cost element is a random variable representing an unknown future cost.

6.2.2 *Black-box approach*

Similar to the deterministic approach, in the black-box approach also average values are used for the cost items of the base estimate. The margin and the item 'unforeseen' are purely dependent on the project phase and are again expressed as a percentage of the base estimate.

The difference however lies in the fact that compared to the deterministic approach this method determines the margin with a standard deviation (σ).

Thus the margin is not a fixed amount, but rather a statistical spread around the expectation value. This difference is illustrated in Figure 13. In the box below more information is given on the difference and also the item 'unforeseen' is explained.

Margin and item 'unforeseen'

Margin

Margins are used in the deterministic and the (semi) probabilistic approach, but the meaning is different.

In the *deterministic approach* the needed budget is calculated by adding a margin to the cost estimation. This margin is calculated by using a predetermined percentage which is dependent on the project phase. In reality there always exists a spread around the cost estimate, but this is not regarded in this method.

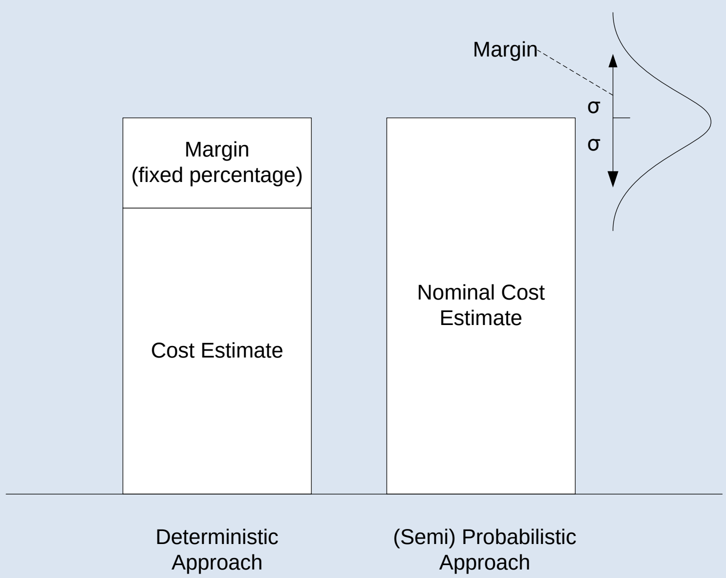

FIGURE 13: MARGIN IN DIFFERENT COST ESTIMATION APPROACHES

In the *(semi) probabilistic approach* the margin is dependent on the spread (or standard deviation) of the cost estimate. A large margin represents a large standard deviation and thus the estimate is probably not very accurate. In the black-box approach the margin is dependent on the project phase only. In the probabilistic approach the margin is calculated based on the normal uncertainties and special events.

<u>Item unforeseen</u>
In the item unforeseen costs are covered that will be made in the future. The expenditures can occur due to uncertainties. These can be scope changes within the program of requirements or complexities during the execution phase. According to PRI external scope changes (outside of program of requirements) are not a part of the item unforeseen.

In the deterministic and black-box approach the item unforeseen is calculated by adding a percentage to the base estimate depending on the project phase in which the estimation is made. In the probabilistic approach the item unforeseen is determined by assessing the probability and the consequence of special events. On this bases an expectation value and standard deviation for the item unforeseen is determined and this is included in the total estimate. An example of black box values for the item unforeseen is presented in Table 10.

TABLE 10: DELPHI STUDY RESULTS LARGE 'DRY' ROUTINE PROJECTS

Project phase	Expectation value item unforeseen	Standard deviation item unforeseen
Initiative	32%*B	22%*B
Pre-design	34%*B	13%*B
Design	13%*B	10%*B
Specification	8%*B	7%*B

By using a standard deviation to express the margin, the term ‘probability of exceedance’ is introduced. This is based on the chosen value for the total cost estimate. For instance, when the nominal estimate (P_{50} estimate) is chosen, this means that there is a 50% probability that amount will not be exceeded. A risk aversive manager would choose a higher percentage, for instance P_{85}. This is based on the budget management strategy and this subject is further described in chapter 8.

The percentages used in the black-box approach can be determined by assessing historical data. How this can be done using the *nominal unforeseen* and *statistical fluctuation* has already been explained in chapter 3.

In 1989 DACE (DACE, 1989) made such an analysis for 25 construction project of factories and installations. The Dutch Railways (PAO, 2009) made a similar analysis for twenty of their projects. Finally the results from the study on 7 tunnel projects of Boschloo (1999) are also presented. The results of these are presented in Table 11.

TABLE 11: BLACK-BOX VALUES ACCORDING TO VARIOUS STUDIES

DACE	Initiative	Pre-design		Specification	Execution phase
Nominal unforeseen	30%*B	20%*B		10%*B	5%*B
Standard deviation	50%*B	30%*B		10%*B	5%*B
Dutch Railways	Cost indication		Price	Credit request	Construction budget
Nominal unforeseen	20%*B		15%*B	10%*B	-
Standard deviation	20 – 30%*B		15%*B	10%*B	-
Boschloo	Initiative	Pre-design	Design	Specification	Contractor Bid
Nominal unforeseen	58%*B	24%*B	18%*B	16%*B	23%*B
Standard deviation	33%*B	21%*B	8%*B	7%*B	13%*B

B = Base Estimate

Because it cannot be said that the values are also applicable to maintenance projects, in this thesis an analysis has been made for the projects at Schiphol AMS. These are again presented below (Table 12).

TABLE 12: ESTIMATE DIFFERENCE AND -UNCERTAINTY CALCULATED FOR 20 PROJECTS AT SCHIPHOL AMS

	Business Plan Estimate	Project Budget Estimate	End of Project
Nominal unforeseen	+17%*B	+10%*B	+0%*B
Standard deviation	34%*B	22%*B	-

B = base estimate

Comparing values found in this study to the black-box values of earlier research the following can be seen. As described in Appendix E the business plan estimate of Schiphol AMS can be compared to the initiative estimate in other projects. It appears that the percentage for the nominal unforeseen for maintenance projects is lower than for new-to-build projects. The explanation for this could be that in maintenance projects the unforeseen during execution is very small, which reduces the total uncertainty significantly.

At the same time the value for the nominal unforeseen found in the project budget estimate – comparable to the specification phase – are more or less equal. The reason for this is that in maintenance works also scope uncertainty exists and design errors are made and that it is not so much different than new-to-build projects. The higher standard deviation is more difficult to explain. This could be due to imperfections in the statistical analysis, but another explanation is that because maintenance works are smaller an unforeseen event has a larger impact on the total budget.

6.2.3 *Probabilistic approach*

In the probabilistic method the uncertainty of the cost estimate is also expressed as a standard deviation σ. The difference with the black-box approach is that here the standard deviation is not determined as a function of the project phase. This is determined by taking normal uncertainties and special events into account (see section 5.4). The normal uncertainties can be found in the spread of the base estimate. The 'unforeseen' item can be determined by 'foreseeing' special events. Together they form the input of a probabilistic model that calculates the expectation value and the standard deviation of the total cost estimate (see also Figure 12).

There are two ways to calculate the uncertainties: statistical and Bayesian. In the statistical manner one uses historical data to estimate a probability function. If the historical data is not sufficient to determine the statistical parameters, input from experts can be used to give an estimate for the uncertainty. This is called the Bayesian approach. In the Bayesian approach the normal uncertainties are often determined by estimating a minimum, an average and a maximum price and quantity per item and then a triangular distribution or a PERT distribution is used for calculating the standard deviation. This can be done by one or more experts.

When looking at special events, Boschloo (1999) showed in an analysis of eight tunnel projects that in every project at least one undesired special event of considerable size occurred. Also mistakes in the engineering, both in the design as in the execution phase, appeared to be a typical type of 'special events'. Moreover, other events can occur that were not predicted beforehand, the so called 'unforeseen unforeseen'. Kuiper and Vrijling (2005) suggest to also take unexpected (thus unappointed) special events into account.

A large advantage of Probabilistic Cost Estimation is that it enables one to make an order in the events that have the largest influence on the margin, and from a financial perspective, have priority when dealing with uncertainties. Because risks are identified, a system can be designed for controlling this. Also it can be tested whether the controlling measures actually lead to a reduction of the total costs. One could also say that the Probabilistic Cost Analysis helps to explain and gives insight into the uncertainty margin of the deterministic estimate.

There are different ways to calculate the probabilistic cost estimate (PAO, 2009).

- Approximation probabilistic computation (Level II)
- Detailed approximation probabilistic computation (Level II)
- Exact probabilistic computation (Level III)

Simply put one can distinguish the Level II and Level III method. In the Level II method the cost estimate is considered a mathematical function of the quantities, prices, additions, etc. In the Level III method the estimate is calculated using a Monte Carlo simulation. For more information on these techniques is referred to (PAO, 2009; CUR, 1997). Both computational models are used in this thesis as explained in chapter 7.

Other aspects of the probabilistic method

Next to the risk analysis there are also other aspects that play a part in the Probabilistic Cost Analysis that should be considered for enhanced credibility and realism: The assessment of the cost elements, correlation effects, budget allocation, human behavior, and organizational considerations all influence each other and have a significant impact on the (estimated) project cost and/or probability of success (Kujawski et al., 2004). All of these elements will be dealt with in this research and will be briefly explained here.

In a cost estimate the input of experts is used to *assess the different cost elements* as well as for the risk analysis for the special events. Since experts are people, they are prone to human behavior and psychological effects. As explained earlier cost overruns can also have psychological explanations (see section 2.1). For instance, Alpert and Raiffa (1982) came up with the following findings:

1. People have a systematic bias toward overconfidence. The subjective probability distributions tend to be too tight. Typically 33% rather than 50% of the actual values fell within the 0.25 to 0.75 fractiles.
2. The judgment of extreme values is significantly worse. Typically, 20% rather than 2% of the actual values fell outside the 0.01 to 0.99 fractiles.
3. Minimum and maximum values are vague terms.

These type of confounding effects should be taken into account when performing a Probabilistic Cost Analysis. In the assessment of the uncertain cost elements also the right or most realistic probability distribution function should be used (Kujawski et al., 2004).

A realistic and practical treatment of *correlation* among cost elements and risks is very important as well (PAO, 2009; Kujawski et al., 2004). The dependence between cost items can have large influence on the standard deviation of the estimate (DACE, 2007). Therefore it is important to take these effects into consideration, however this can be a complex analysis. To make sure it is also practicable a good way to implement this in the cost estimate process, a practical solution has to be found. Often this is done by doing one calculation with full dependency between the cost items, and one calculation were the cost items are fully independent. This is also done in chapter 7.

Finally, incorporation of budget management practices has to be taken into account too. This will further described in chapter 8.

6.3 Reference Class Forecasting

Flyvbjerg and Cowi (2004) claim that they developed the first instance of practical reference class forecasting. It can be doubted whether this is true. First the method will be explained to be able to give arguments for this doubt. This method was originally developed by Kahneman (Kahneman and Tvesrky, 1979; Kahneman, 1994). In his Nobel prize-winning work he saw this as a method to compensate for the type of cognitive bias in human forecasting. Here the outline of this method is presented, based mainly on Lovallo and Kahneman (2003) and Flyvbjerg et al. (2003b).

The main idea behind reference class forecasting is that one takes an 'outside view' of the project being estimated. With an inside view one tries to identify the particular uncertain events that will affect the project. Instead of this, when an outside view is used, one tries to find similar projects, a certain class of projects, and uses historical information of these projects to make an estimate for the new projects. The historical information is composed by making a statistical distribution based on these data.

Reference class forecasting aims at using the following three steps for individual projects (Flyvbjerg, 2007b):

1. Find a relevant reference class for a project. The class of past projects must be broad enough to be statistically meaningful, but narrow enough to be truly comparable with the specific project.
2. Establish a probability distribution based on the historical data from this reference class.
3. Comparing the specific project with the reference class distribution, in order to establish the most likely outcome for the specific project.

Research of Gilovich et al. (2002) shows that when people are asked simple questions requiring them to take an outside view, their forecasts become significantly more accurate. The reason of this is that the outside view "bypasses cognitive and political biases such as optimism bias and strategic misrepresentation and cuts directly to outcomes". When using this method planners and estimators are not required to make scenarios, foresee uncertain events or risks, so they cannot get these things wrong. On the other hand it has to be noticed that historical data cannot always predict extreme events that lie outside all historical precedents. However, in most cases it will give an accurate result.

Although it seems that most large infrastructure projects are of a unique character, Flyvbjerg argues that they are only non-routine on a locally basis and most of the times well-known technologies are used. For that reason reference class forecasting can definitely be of value to large (local) one-off projects. Adding to this, in the light of this thesis it can be stated that this method is even more of value to projects that are routine like and have many similar precedents: maintenance projects.

Comparing the method of reference class forecasting to the Black-box approach explained in section 6.2.2, one has to conclude that there are strong similarities. The Black-Box method was already introduced in the PRI research in 1993 (Prorail, 2011) and studies developing a reference class like database were executed by for instance DACE (1989) already in 1989. Also Boschloo (1999) presented in his thesis a similar method. Nonetheless, projects for which the black box or reference class forecasting method was actually used for estimating the cost were not found. This was also stated by Flyvbjerg (2007b): "… not a single genuine reference class forecast of costs and benefits has been identified". As will be explained in section 6.6, the estimation method proposed for maintenance projects (at Schiphol) in this thesis is based on the black-box or reference class forecasting method, but it is taken one detail level higher, towards a statistical probabilistic method.

6.4 Current practice at Schiphol AMS

At Schiphol the costs for large maintenance projects are estimated fully deterministically. The way costs are estimated for the business plan differs per maintenance manager, however in general they first estimate the so called 'bare' costs (only the direct costs for the materials and the execution of the works) and then, depending on the maintenance manager, percentages are added for amongst others 'the unforeseen', temporary measures, addition for working at night, etc.

In order to compare the different percentages a reordering has been done in this thesis. It has been categorized according to the different cost items as mentioned in PRI (Appendix J). These percentages and items vary enormously per maintenance manager, as can be seen in the table below (Table 13), while their jobs are very much comparable. Some just add one percentage including everything; others split it up in various smaller items and corresponding percentages. Even the percentage for the unforeseen differs per manager. It has to be noted however that this was the practice until 2011. Already some (small) changes are implemented, but still uniformity is lacking completely.

As has already been shown in chapter 4, the estimates for the additional and indirect costs are off when they are compared to the actual expenditures on these costs items. It seems that the percentages used here do not represent reality. It is advised to use historical project data to reassess these percentages and create uniformity amongst the maintenance managers. This is worked out further in section 6.6.

For the estimation of direct costs, ratio's (in Dutch: "kentallen") are used. These are either obtained on the basis of historic data, on the basis on some research or simply given by the main contractor. In some cases a software program was used (i.e. XEIZ), which calculates the 'bare' costs with price input from the main contractor.

Within Schiphol some of these issues are acknowledged. Therefore in 2011 it has been instructed to use three different percentages for the unforeseen depending on the project phase (see also Appendix E). It goes from 20, to 10, to 5 percent, when more is known about the project. Also it has been decided to use a part of the unforeseen for scope changes (change budget) and a part for special events (risk budget). Often this is divided as 5% and 5% in the project budget phase. Also in this phase the estimations are deterministic.

TABLE 13: ADDITIONAL PERCENTAGES FOR SCHIPHOL AMS

	Civil Engineering runways 2010	CT & ET runways 2013	Electrical Engineering	Drainage	Roads	Runway Station
Direct costs (I)	x	x	x	x	x	x
Execution costs (Ia)			x			
Material costs (Ib)			x			
Indirect costs contractor (II)	15.90%	> 40%	22%	5.90%		
Management fee (for contractor) (IIa)	5,9% of I	11.2% of I + IIe + IIb + IIc + IId		5,9% of I		
Execution costs contractor			6% of (Ia)			
General Costs			4% of (Ia)			
Profit and Risk			4% of (Ia)			
One-off Costs			8% of (Ia)			
Phasing Costs (IIb)		6% of I				
Additional Costs main contractor (IIc)		5% of I				
Project bureau (IId)		9% of I + IIe + IIb + IIc				
Addition evening/night work (IIe)	10% of I + IIa + IV	6% of I	0% of (Ia)			
Additional Costs (III)	29.50%	27%	25%	21%		20%
Project Management	7,5% of I + IIa + IV	8% of I + II	5% of I			6% of total
Specification						
Engineering	2% of I + IIa + IV	3% of I	8% of I			Fixed (10%)
Preparation	2% of I + IIa + IV	3% of I				
Control					25% of I	
External quality control	5% of I + IIa + IV			16% of I + IIa + IV (VAT)		
Revision			3% of I			
Execution guidance			5% of I			Fixed (1%)
Guide	2,5% of I + IIa + IV	2,5% of I + II				
Lookout	2,5% of I + IIa + IV	2,5% of I + II				
Management			2% of I			
Environmental costs	3% of I + IIa + IV	3% of I	2% of I			
Temporary measures (fences)	5% of I + IIa + IV	5% of I + II	Fixed	5% of I + IIa + IV		Fixed (3%)
Unforeseen (IV)	10% of I	10% of total	~20%	25% of I + IIa		5% of total
Change budget		5% on total				
Risk Budget		5% on total				
Unforeseen on execution			10% of Ia			
Unforeseen on material			5% of Ib			
Unforeseen on project costs			5% of II			

6.5 Current practice at RWS and PRORAIL

In this thesis also the current practice on cost estimation at two other large principal parties in the Netherlands has been examined. These are RIJKSWATERSTAAT (RWS) and PRORAIL. These parties also put their maintenance work out under contract and use cost estimates in early phases in order to set the budget. First the practice at RWS will be assessed, after that PRORAIL. The information presented in this section is mainly based on interviews (Appendix C).

6.5.1 Rijkswaterstaat

Within RWS the current practice is that in all projects (also maintenance projects) the costs are estimated using the SSK (CROW, 2010) framework. This also includes a probabilistic estimate. In order to do this all the quantities, prices, but also additional percentages are given by LTU (lower, top and upper) values. Next to this uncertain events, or risks, are taken into account by filling in a probability of occurrence and the consequence in the form of an amount in euro. By using the software program called 'Risico Raming' the estimate is calculated using a Monte Carlo analysis. The reason for the use of this program is that default values can be set, which individual users cannot change. By using the standard SSK framework in combination with this program uniformity is created for all cost calculating employees.

The outcome of the above described calculation is a probability density function with a corresponding μ and σ. At RWS the budgets are always set on the μ value. The σ is used to be able to explain the context of the estimate. This means that an estimate is never only given by just a number, but also an explaining note is added. This includes amongst others, a description of the scope, the assumptions and the risks. The σ value can help to explain the uncertainty of the estimate and it can be used to compare estimates in different project phases in terms of improved certainty. At this point RWS is steering towards presenting estimates with the help of margins, however the funders (ministry of infrastructure) are still holding this off, due to lack of knowledge on this part on their side.

The amount that is reserved for unforeseen events is split up in an underpinned part and a part based on expertise. The first is based on a risk assessment and is the responsibility of the risk manager. Based on experience and historical data an amount is added to this, which determines the total amount for the item unforeseen.

This historical data is up till now not very complete and specified. However initiatives have started to assign certain people ('the analysts') the task to do subsequent calculations to fill this database. In order for them to do this, RWS is working certain control mechanisms. In the first place contractors are required to not only write down their final contracting sum, but also specify this using 10 to 15 cost items set by RWS. In the second place RWS will book the actual costs in their accounting software (SAP) according to earlier mentioned SSK framework. This has not yet been implemented however.

RWS also faces the problem that between the initial estimate and the start of execution a lot changes in terms of scope (see also section 4.3.1 on uncertainty due to unclear scope definition). This makes the initial estimate less accurate or, in other words, more uncertain. Nevertheless the budget is still based on this initial estimate. Keeping more firmly to this initial estimate, is seen as a possible solution. A condition for this is that the scope is clearly defined. Moreover they have to make sure that (large) scope expansion cannot be easily added to the project anymore. Project management has to gain approval of higher management for this by clear argumentation and then extra budget has to be created. Small scope additions can still be taken out of the item unforeseen. On top of this RWS also believes that when there is cost windfall ('meevaller') in a project, this has to be given back to the organization. Finally it is in the opinion of RWS that an important part of the aspect is the attitude of the project team. It should be motivated to act responsible if it comes to budgeting and scope.

6.5.2 Prorail

As RWS and Schiphol also PRORAIL has faced similar issues when it comes to cost estimation. They used to set an undefined margin of around 20% for unforeseen events and scope changes. However, over the recent years they have taken steps towards improvement.

Central in PRORAIL's cost estimation methodology is the RailCaseBase (Vrouwenvelder and Vrijling, 2006). This is a database in which a vast number of up to date ratios ('kentallen') are collected. These values are based on historical data as well as on calculations and vary in level of detail (from object to detail) and type of cost item (e.g. material costs, cost of engineering or additional costs).

In principle, PRORAIL makes full probabilistic cost estimates using a Monte Carlo simulation, especially for new to build projects. For maintenance projects (by PRORAIL referred to as 'vernieuwingsprojecten') this is not always done in the early project phase. These estimates are used for setting a budget and are made by the asset managers. Since most maintenance projects are more clearly defined, PRORAIL believes in this phase often a deterministic estimate using the RailCaseBase can suffice. The maintenance managers can still use their own estimate format, but with the RailCaseBase uniformity is created, because the individual maintenance managers are not allowed to change values of this database.

Clearly and strictly defining scope is something PRORAIL has stressed upon in the recent years. Scope uncertainty is for that reason not taken into account in their estimates. It is the responsibility of the financier, and when a scope change occurs it should not be resolved inside the project, rather extra budget needs to be requested. It has to be noted here that when for instance it is estimated to perform maintenance on 1 kilometer of railway, but it appears to be that 1,1 km has to be replaced, this is often regarded as an internal scope change or knowledge uncertainty.

Next to this knowledge uncertainty (normal uncertainty), PRORAIL also defines execution uncertainties and future uncertainties. For this last item standard a percentage of 5% is reserved and is used for small changes in law and regulations. Together with an extra amount to lower the probability of exceedance, the above mentioned items form the reservation for uncertainty. PRORAIL does not take contracting uncertainty, thus market forces, into account in its estimates.

Looking at the executions uncertainties, PRORAIL defines the following eight categories:

- Change in program of requirements
- Additions to program of requirements
- Imperfections in the contract
- Not able to fulfill contract by PRORAIL
- Deviant requirements by contractor
- Unforeseen unforeseen
- Deductible amounts (‘verrekenbare hoeveelheden’)
- Priced items to a value of… (‘stelposten’)

At this moment PRORAIL is working on booking costs such that they can be assigned to the above items. Although no actual research on this has been done yet, PRORAIL sees that the costs due to additional work in maintenance works are much less than in new-to-build projects. They estimate this to be a maximum of 10% of the total contracting sum.

6.6 The probabilistic cost estimation model for Schiphol AMS

In this section the developed probabilistic cost estimation methodology and model for Schiphol AMS will be described. This can be summarized by the following diagram (Figure 14). In the upcoming sections this will be further elaborated. The budget setting part will be discussed in chapter 8: Budget Management.

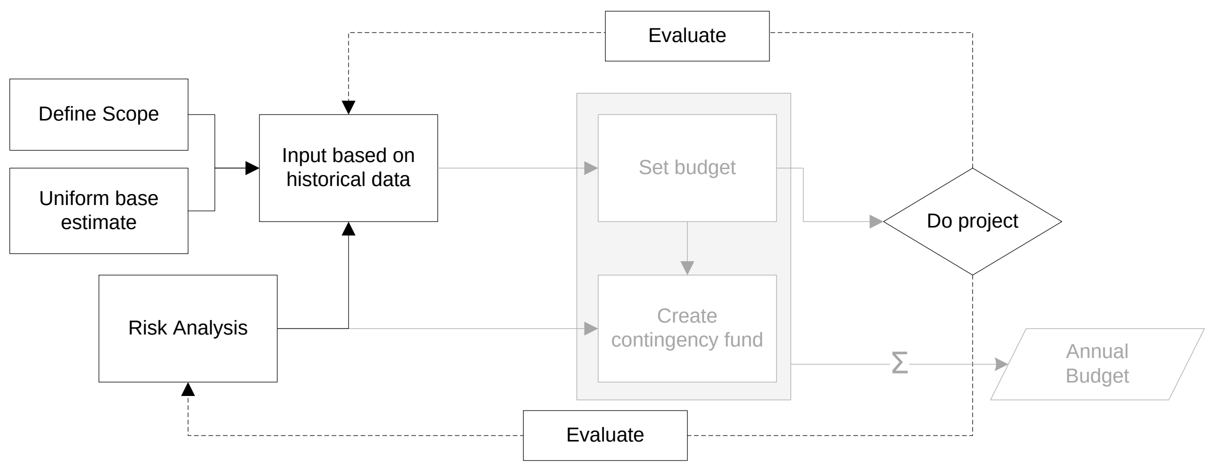

FIGURE 14: COST ESTIMATION METHODOLOGY FOR SCHIPHOL AMS.

6.6.1 *Define scope*

The start of every estimate has to be a clear definition of the project scope. It is not much use making a cost estimate when the scope is not clearly defined. This does not mean that in a later stage of the project the scope cannot be adjusted, but one has to have a clear starting point. Then it will be easier to trace what impact future scope changes will have on the costs and thus considerations can be made accordingly.

In section 6.7 an advice is given for optimization of the current cost estimation process in order to have a better understanding of the scope when the business plan estimates are made.

6.6.2 *Uniform base estimate*

Looking at the findings mentioned in chapter 4 and section 6.3, it becomes clear that uniformity is missing in the cost estimates. As said the advantages for a uniform cost estimate are obvious, such as transparency and comparability. For that reason as a first step it is advised to create a uniform base estimate format. It will only have to be created once, however it can still be updated when needed. A suggestion for such a uniform estimation model is made in chapter 7. This format is based on PRI and SSK as described in section 6.1.

On a rough scale it comes down to the main items as shown in Table 14. When the format has been created, it should be used in every project cost estimate made. Only the input will change.

TABLE 14: UNIFORM BASE COST ESTIMATE SCHIPHOL AMS

Cost Estimate		
Direct Costs	Fixed Amount	
Indirect Costs +	+ % of Direct cost	μ & σ
Primary Costs		
Additional Costs	+ % of Primary Costs	μ & σ
Base Estimate		
Other Unforeseen	+ 10% of base estimate	μ & σ
Execution Unforeseen +	+ 5% of base estimate	μ & σ
Total		**μ & σ**

6.6.3 *Input based on historical data: statistical probabilistic approach*

When the scope has been determined the actual estimate can be made using the uniform estimation structure. How the different items can be estimated is described below.

<u>Direct costs</u>

First the direct costs have to be estimated. These include materials and execution of the actual maintenance works. This can also be called the bare estimate (in Dutch: 'kale raming'). The way these costs are estimated can be done by simply giving the mean value. Sometimes it is advised to give the LTU (lower, top and upper) values of a triangular or PERT distribution to introduce normal uncertainty already in these items. As explained in the box on page 20 at Schiphol AMS normal uncertainty mainly exists in terms of productivity rather than prices. Moreover, as will become clear in chapter 7, LTU values are often hard to estimate and do not represent a well enough uncertainty. That is why for Schiphol AMS it is advised to only use a mean value and add (normal) uncertainty later on in a separate item, based on historical data.

<u>Indirect costs</u>

Secondly the indirect cost (for the contractor) can be estimated. This can either be given by a fixed amount or as a percentage of the direct costs. For Schiphol AMS it is most easy to use a percentage. Since data on this was scarce, it is advisable to first set up a proper data set and set a percentage accordingly. Uncertainty has to be incorporated here as well. This is done by not only giving a mean percentage, but also a spread around this number, based on a historical dataset. For now, based on the examined projects, it is advised to use a mean percentage of 15% for this, with a standard deviation of 30%. This includes the (new) management fee of 11.2% and extra payments due to working at night.

Additional costs

Thirdly, similar to the indirect costs, the additional costs have to be estimated. Also a percentage (μ & σ) can be used here. It is advised not to split this up into further detail, since, especially in the business plan phase this does not add extra value. Based on the historical data (chapter 4), for Schiphol AMS a percentage of 15% will suffice. A distinction per project type can also be applied. For instance for simple road projects this could be somewhat lower, and for more complicated system renewals it could go towards 20%, as shown in chapter 4. Again, it would be better to base this on a proper evaluation based on a more complete dataset.

It should be noted here that in comparison to PRI the Miscellaneous item has been left out. The reason for this is that this has already been incorporated in the other items. In the additional costs a percentage has been used, rather than a fixed amount, which also gives room for some extra costs when working out the project into more detail. Moreover, because unforeseen is added in the next step, room for (scope) uncertainty is created.

The reason why the items Indirect Costs, Additional Costs and Unforeseen are split up is because now these items can be later evaluated. The consequence of this is that costs made that belong to these items should also be correctly booked on the related item. In this way the percentages can in the future be set more accurate, and evaluation is made much easier. In the project phase for instance these items can even be split up in more detail. However, this should only be done when the costs are also booked into more detail. Otherwise there is no purpose for doing this. More on the evaluation will be given in section 6.6.5.

Unforeseen

The last item that has to be added is the item unforeseen. This will be a percentage on top of the base estimate, again defined by a mean and a standard deviation. The percentages have to be deduced from historical data. When this dataset is more complete, the percentages can be set depending on for instance the type of project, the scale, etc. As explained in section 4.3 two types of unforeseen can be distinguished: other unforeseen and execution unforeseen. The first one can be seen as an addition for skewedness caused by normal and scope uncertainties, the latter as a reservation for special unforeseen events. For now, based on the statistical analysis done in this thesis, the other unforeseen is estimated to be 10% and execution unforeseen 5% of the base estimate.

It is advised to estimate the uncertainties (μ & σ) on the basis on historical data. However, what is important to mention here that when this data is not available, a Bayesian approach will be necessary. In other words, then the parameters have to be estimated by experts. When more historical data will be available in the future, the statistical approach can be used in larger extent.

6.6.4 *Risk Analysis*

A risk analysis has its up- and downsides. It can increase the understanding of and give insight into the possible project risks. However not all the in reality occurring risks can be foreseen in such an analysis. For that reason it is suggested not to base the budget on the risk analysis, but rather on historical data (statistical probabilistic approach). Nonetheless the risk analysis can still be used as a mechanism for helping to explain where the item unforeseen and corresponding uncertainty margin comes from.

The more important purpose of the risk analysis is to appoint project risks in order to be able to design and valuate risk mitigation measures. Especially in larger projects this can be of added value. With the help of probabilistic estimation software (@Risk or Risicoraming) or Level II methods the summed μ and σ of all the identified risks can be calculated. The software also provide methods to show which events are most heavily contributing to the total mean and standard deviation. Based on this one can decide to take actions (or not) on these events. Moreover, the calculated outcomes can be compared to the percentages derived from historical data. In this way a part of the percentage can be underpinned. Also, for instance one can use this comparison to check whether important risks have not been forgotten.

6.6.5 *Evaluate*

This might be the most important step of the process. Without this step the historical data which is needed for the estimate cannot be obtained. During the project it is the task of the project controller to correctly book the cost items into the accounting system. As mentioned before it is of utmost importance that it happens consistent to the uniform estimation model. This makes the process of building a historic database congruent with this model much easier.

When the project is finished (or already during the project) the actual expenditures have to be compared to estimates. This is not only the task of the project board, but also a responsibility of the AMS division, since it is them who are responsible for the estimates. Conclusions can be drawn from this information. Moreover, the cost estimation database and percentages used in the estimates can be complemented or adjusted. Next to this this information can also be used to evaluate on certain project cost items and design action if needed.

Another part of the evaluation will be to identify the risks that have occurred during the execution. These risks have to be communicated towards the AMS maintenance managers and it would be wise to also capture them in a risk database. This will give useful insights for future risk analyses and one can learn from these events when executing future projects.

6.7 Optimized cost estimation process

The current cost estimation process at Schiphol AMS has already been described in section 1.2. In this section an optimization for that process is suggested. This is summarized in Figure 15.

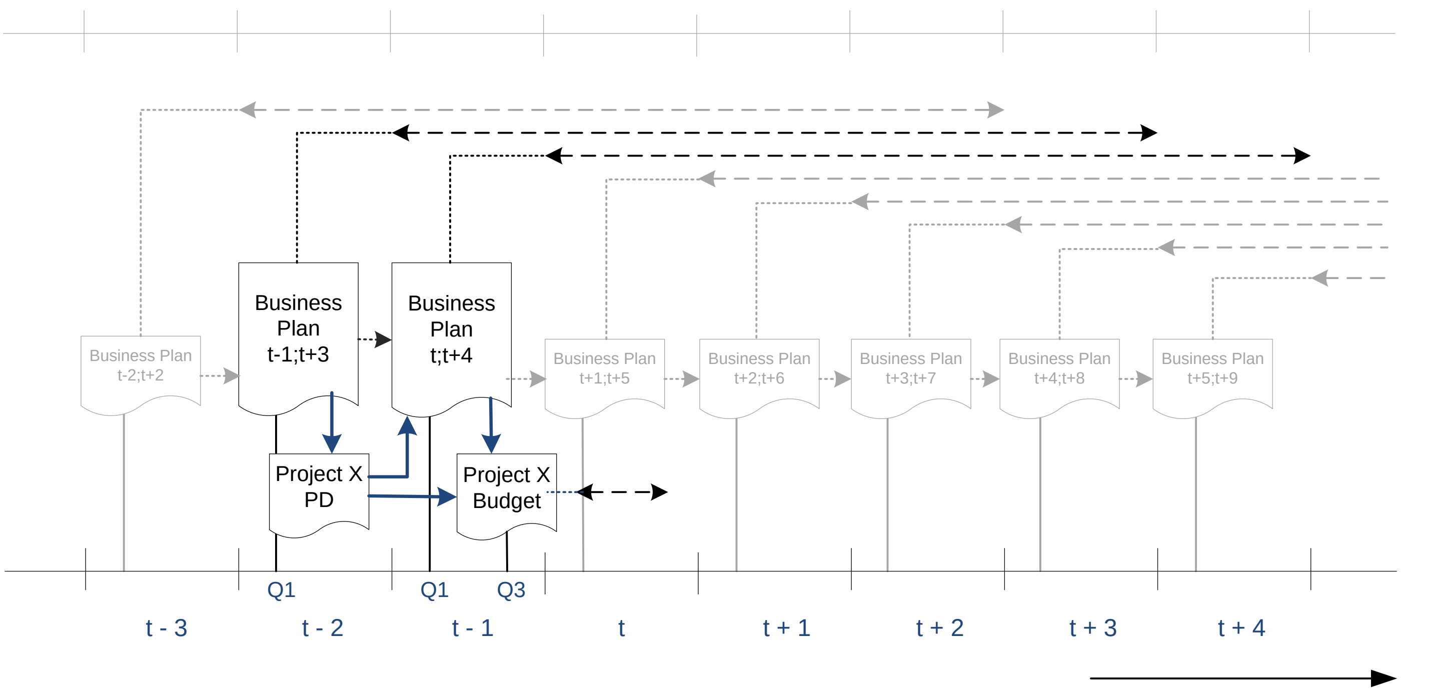

FIGURE 15: OPTIMIZED COST ESTIMATION PROCESS SCHIPHOL AMS

It is advised to start up a project earlier, thus before the business plan *t;t+4*. A preliminary design (PD) for the project can already be made before the final business plan is accepted. In this way the business plan budget estimates that have to be made can be based on a more clearly defined project, and thus scope. So it can reduce the "Other unforeseen" caused by design and scope uncertainty significantly. Since the project budget is decided upon in this business plan, it would be wise to do so, to be able to give a more accurate estimate.

One could argue that it would be better to only start the project when it is actually definite in the business plan *t;t+4*, because only then it is certain that the project will go on. Against this stands the fact that the business plans are always made five years in advance, thus the project was already part of an earlier business plan. Hence, one knows already about the need for that project and it has already been planned. Moreover, the above argumentation would suggest that it would not be possible for the organization to plan more than one year ahead, which is not very likely.

What should be stressed here is that a preliminary design is suggested. This means the project is not set in stone yet and changes are still possible of course when time progresses. Nevertheless, when making such a preliminary design some things can become clearer. Especially when the project organization PLUS and the contractor are involved into the project already.

7 Fully probabilistic cost estimation at Schiphol

By means of example in this chapter five different estimation methods are used to estimate the costs for a future project of Schiphol AMS. Not only the different estimation techniques are illustrated by doing this, it is also possible to compare the outcomes and validate the proposed estimation method in chapter 6.

The project that has been examined in this chapter is the GH-bay of taxiway A19 (see Appendix K). This project is to be executed in 2013 and it was chosen, because it is a relatively standard project of Schiphol AMS. Furthermore, for this project an estimate was already made for the Business Plan 2013-2017. This estimate formed the basis for the estimates presented in this thesis.

First the differences between the estimation methods are briefly described and the outcomes are given. After that the outcomes are compared and conclusions are drawn from this.

7.1 Five different estimates of the same project

In this section the different estimation methods are explained and the outcomes are presented in Table 15. For detailed information on these estimates is referred to Appendix K. The following estimation methods have been used.

1. Deterministic estimate (as done by AMS)
2. Black-box estimate 1
3. Black-box estimate 2
4. Statistical Probabilistic Estimate
    a. Level II (proposed method)
    b. Level III
5. Bayesian Probabilistic Estimate
    a. Level II
    b. Level III

Deterministic Method

This estimate is the same as the original estimate done by AMS. The difference lies in the way the estimate is structured. The items as estimated by AMS have been placed into the uniform estimation model as described earlier.

Black Box Method 1

This estimate is more or less similar to the deterministic estimate. The difference is that the percentages for the unforeseen have been adjusted to match the findings in chapter 3 of this thesis. Moreover a standard deviation has been added to the total estimate. This is also based on the statistical analysis.

Black Box Method 2

The difference between this estimate and the former is that now the uncertainty margin (read: standard deviation) is not calculated over the total estimate sum, but over the different subparts of the estimate. To be able to do this a statistical analysis needs to be made for the various subparts. Since this has only been done for a small number of projects, these values are not very reliable. When in the future this data is gathered, the advantage of this way of estimating is that it becomes less a black-box, because one can more clearly see where the actual uncertainties lie.

Statistical Probabilistic Method (proposed method)

In this method the various cost items that are estimated by a percentage (such as night work addition, engineering, but also unforeseen) are estimated using a mean value and a corresponding standard deviation. The difference with the second Black Box method described in the former section is that in that method a percentage is added to the subtotal of certain cost categories. In this method not a percentage is added, and the uncertainty is considered on a level lower; on the cost items itself. For that reason this method can be seen as a full probabilistic method.

The calculations have been done using the Level II and Level III (Monte Carlo, 10000 runs) calculation method. For both methods the calculations have been done once considering the individual items fully independent and once fully dependent.

Bayesian Probabilistic Method

This estimation method is also done fully probabilistic. Here the normal uncertainties are estimated by using a triangular distribution with the so called LTU-values. Input from the maintenance managers was used for this. Next to this special events were added using a binominal distribution, specified by a probability and the costs of consequence. These costs were also presented as uncertain values by a triangular distribution.

TABLE 15: COMPARISON OF OUTCOMES OF DIFFERENT ESTIMATION METHODS ON THE A19 PROJECT

	Deterministic	Black Box 1	Black Box 2	Probabilistic statistical	Probabilistic Bayesian
Item i	$Q_i * P_i$	$Q_i * P_i$	$Q_i * P_i$	$Q_i * P_i$	$Q(LTU)_i * P(LTU)_i$
…					
Direct Costs	$\Sigma Q_i * P_i$	$\Sigma Q_i * P_i$	$\Sigma Q_i * P_i$	$\Sigma Q_i * P_i$	$\Sigma Q_i * P_i$
Indirect Item j	% of DC	% of DC	% of DC	% of DC (μ_J & σ_J)	% of DC (LTU)
…					
Indirect Costs	% of DC	% of DC	% of DC	% of DC	% of DC
Black Box over PC			+ 15%*(DC+IC) σ = 35%*PC		
Primary Costs (μ)	**€ 2.159.720**	**€ 2.159.720**	**€ 2.483.678**	**€ 2.159.720**	**€ 2.159.720**
Additional item k	% of PC	% of PC	% of PC	% of PC (μ_k & σ_k)	% of PC (LTU)
…					
Black Box over Additional			-5% * Σ(AC) σ = 35%*Σ(AC)		
Additional Costs	% of PC	% of PC	% of PC	% of PC	% of PC
Base Estimate (μ)	**€ 2.718.033**	**€ 2.718.033**	**€ 3.014.076**	**€ 2.718.033**	**€ 2.718.033**
Change Budget	5% of BE				
Risk Budget	5% of BE				
Other Unforeseen		10% of BE	10% of BE	10% of BE (μ & σ)	Risk assessment: % * €(LTU)
Execution Unforeseen		5% of BE	5% of BE	5% of BE (μ & σ)	
Black Box over Unforeseen			+0% * TU σ = 25%*TU		
Total Unforeseen	10% of BE	15% of BE	15% of BE	15% of BE	PDF (μ & σ)
Total Estimate (μ) level II	**€ 2.969.309**	**€ 3.125.739**	**€ 3.466.188**	**€ 3.125.739**	**€ 2.838.034**
Total Estimate (μ) level III				**€ 3.125.580**	**€ 2.832.142**
σ (level II; independent)		25% of μ (set)	22.8% of μ	21.8% of μ	10.1% of μ
σ (level II; dependent)				26.5% of μ	16.7% of μ
σ (level III; independent)				21.3% of μ	12.7% of μ
σ (level III; dependent)				28.3% of μ	18.3% of μ
P_{50} (level II; independent)	(μ)	μ - 3.0%	μ - 2.5%	μ - 2.3%	μ - 0.5%
P_{50} (level II; dependent)				μ - 3.3%	μ - 1.4%
P_{50} (level III; independent)				μ - 4.9%	μ - 2.6%
P_{50} (level III; dependent)				μ - 6.8%	μ - 1.9%

7.2 Comparison of estimate results

Looking at the outcomes of the various estimates, the first thing that can be noticed is the difference between the total estimates. The difference between the (original) deterministic estimate and the others is that a higher percentage for the item unforeseen is used, which is in correspondence with the findings of the statistical analysis (chapter 3). The second probabilistic estimate is an exception of this however. This is explained below. The second black box total estimate is higher because the primary costs are already higher. Since other sub items are calculated using a percentage of the primary costs, this has a double effect: percentage over percentage.

Secondly, looking at the standard deviations it can be seen that the values found in the second black box method and first probabilistic method, are close to the statistical found standard deviation which has been used in the first black box method. This is not very strange, since in these methods statistical historical data has been used for determining the different μ's and σ's.

As said in section 7.1, the calculations have been done with full independency and with full dependency between the cost items. It is very likely that the most realistic outcome will be somewhere in between of these two extremes. As shown in Table 15 when all the items are considered correlated the standard deviation of the total estimate increases. This is normal and consistent with literature (PAO, 2009). More on dependencies and how it was taken into account in this estimate is described in Appendix K.

Comparing the outcomes of the Level II estimates with the Level III estimate it appears that in the latter the standard deviations are always somewhat higher. The error is rather consistent (around 2%). Although a precise explanation could not be found, it is assumed that it lies in the way the software (@Risk) calculates the estimate. Further research is needed for this.

The outcomes of the second probabilistic method are a complete different story. Not only the total estimate is lower than the other estimates, also the standard deviation is much smaller. Explanations for this have been separately addressed in the next section.

<u>Difference between Black-Box and full probabilistic estimate</u>

That there is almost always a difference between the black box and the full probabilistic estimate was also shown by Boschloo (1999). He formulated the following six hypotheses which will also be checked in this thesis.

Inaccuracy Black Box values

1. Historical data is not representative
2. Dataset is too small
3. Historical data incorporates scope changes, which are not taken into account in a probabilistic estimate

Inaccuracy Probabilistic values

4. In a probabilistic estimate the items are considered independent
5. The item unforeseen calculated by the probabilistic estimate is incomplete
6. The spread of the items are estimated too small

Answers to all six of the hypotheses are formulated here. That the historical *data used is not representative* is not very likely. Because the data has been categorized, this has been offset. Most maintenance projects at Schiphol AMS can be placed in a certain category of similar projects and this is definitely the case for the A19 project considered here. The statistical dataset used was therefore very representative.

What is more likely is that the *dataset was too small*. This deficiency has already been addressed in chapters 3 and 4. It can definitely be the case that when a larger set is formed in the future the value for the standard deviation will change.

It is true that in the historical data *scope changes are incorporated*. Although it could not be verified it is assumed that a large part of the 'other unforeseen item' is due to scope changes. However, what should be noted here is that in the type of project that is considered here not many large scope changes occur. In the probabilistic estimate the sort of scope changes that are occurring in these types of projects were partly incorporated by taking uncertainty into account when estimating the quantities. So the scope changes can only partly explain the differences.

Making the items dependent between each other will increase the standard deviation. But as is shown in this chapter, even when *dependency* is taken into account the standard deviation is still smaller than the black box value.

In a probabilistic estimate the *item unforeseen* is often regarded as *incomplete*. It is very probable that this is also the case here. Only a small number of special events were appointed. This has to do with the fact that the maintenance managers are not very accustomed to making a risk assessment and moreover the projects are often not fully evaluated, which does not give insight into the actual occurring special events. Also Boschloo (1999) showed that almost in every large infrastructure project an unforeseen unforeseen event of significant size occurs. These events are thus not taken into account in a probabilistic estimate. However, in this thesis (chapter 4) it is shown that in maintenance projects the type of events are not occurring that often, due to the repetitive character of the work and because one works in already stirred ground. This means that the difference here cannot really be explained by unforeseen unforeseen events.

What is also a highly likely explanation is the possibility that the *LTU values are estimated to small*. As explained on page 84 this is also backed by literature. To overcome this, the L and U values given by the maintenance manager were not set at the 0% and 100% value, rather the 10% and 90% values were used.

Summarizing, the difference between the probabilistic outcome and the black box value can be explained by a combination of causes. It is most probable that the too small dataset, the fact that scope changes are part of the statistical obtained data and the inaccuracy in estimating risks and margins together explain the differences.

7.3 Validation of proposed method

After comparing the five estimates, it appears that the proposed method is a good and effective way to estimate the cost for maintenance projects. The advantage is in the first place that insight into the separate cost items is created. One can see which cost items have the largest uncertainty. Next to that with this method the total estimate is presented as a distribution with a μ and σ, which tells more than merely a deterministic amount. Also the standard deviation found is in the range of the statistical value found in this thesis. The disadvantage of the full probabilistic method is that this standard deviation is much lower than the black box value as explained in the former section (section 7.2).

A requisite for this method however is that statistical data is obtained. One has to know the means and spreads of the individual items in order to estimate them. On the plus side, having this data is not only good for giving more accurate estimates, but also insight into these items is created. This insight can for instance lead to optimization processes and be of help for active control. Nonetheless, when statistical data is not yet available, the uncertainty parameters have to be estimated by experts (Bayesian method).

8 Budget Management

The viewpoint in this chapter in contradiction to the other chapters is switched somewhat. It is one thing to estimate the costs for a certain project, the way how this is translated into budgets has to be regarded as well. Therefore this will also be handled in this thesis. The goal of this chapter will be to present how the budget management practice can best be combined with probabilistic cost estimates.

8.1 Budget management theory

As explained, in order to account for uncertainties and risks in the project cost estimate, a (semi-)probabilistic approach can be used.

8.1.1 Budget setting

The probability or confidence level that the total project cost estimate will not be exceeded can be chosen by management. From the resulting cumulative probability function this estimate can be derived. For instance, the outcome of a probabilistic cost analysis could be: "there is a probability of 85% (P_{85}) that the project will not cost more than x million Euro's".

A standard rule for budget setting is given by the following formula (PAO, 2009):

$$Budget = \mu + k \cdot \sigma$$

μ = estimate mean value
σ = standard deviation of estimate
k = variable factor

The factor k can be chosen by management and is dependent on the probability of exceedance of the budget. A risk aversive manager will choose a larger k, in order to make the probability of exceedance smaller. When the probability function of the total cost estimate is known, the budget can be derived from this (see Figure 16).

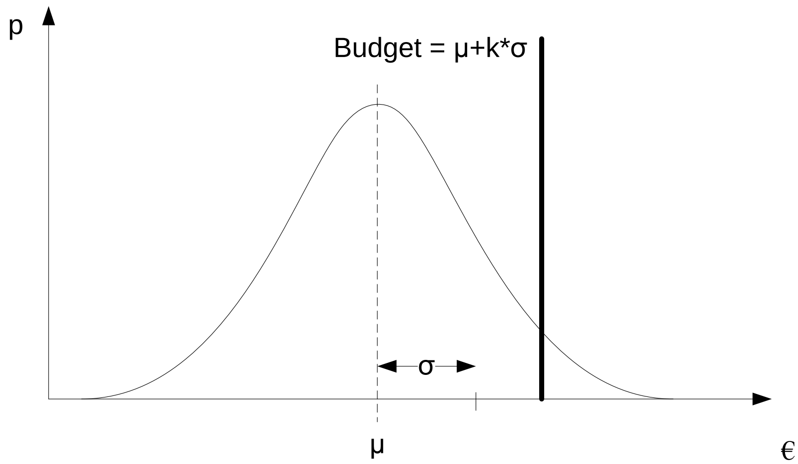

FIGURE 16: BUDGET SETTING

8.1.2 *Portfolio management*

A solution for more efficient budget reservations can be to look at it on a portfolio level. According to PAO (2009) there are two ways in which this portfolio management can be organized:

- Controlled approach
- Target approach

In both cases the way in which the budgets are allocated on a project level contributes to the desired effect on a portfolio level. The effect becomes more severe when more projects are part of the portfolio. Both methods will be explained below.

Controlled approach

Budget is given to the individual projects on the basis of the nominal (thus expected) cost estimate. On the portfolio level a contingency fund is created on the basis of the uncertainty margins (or standard deviations) of the projects. When the nominal budget is overrun, project managers can, on the basis of solid argumentation, request extra budget from this fund. When less expenditure is made than expected, this difference has to be deposited into the contingency fund. Why it is better to have a contingency fund at a portfolio level is explained in the box below.

Contingency at a portfolio level

The following shows why it is better to keep a contingency fund on a portfolio level, rather than subdividing it to the individual projects.

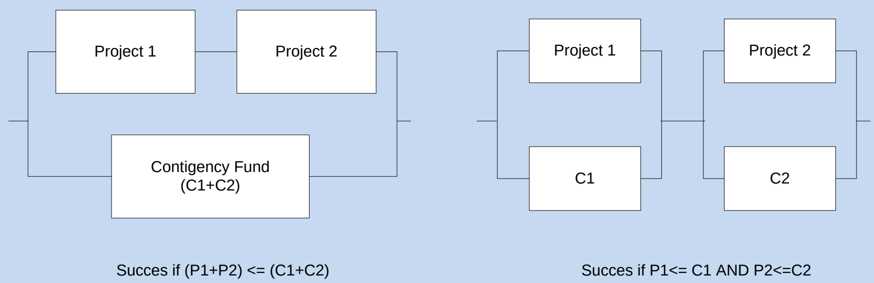

FIGURE 17: RELIABILITY BLOCK OF CONTIGENCY AT A PORTFOLIO LEVEL

The contingency allocation options can be graphically represented using the concept of reliability block diagrams as shown in Figure 17 (Kujawski, 2002). It is assumed that in both projects, only one independent risk can occur. On the left side of Figure 17 the situation is modeled that the full contingency fund is available to both projects. On the right side the contingency is allocated to the individual project, and is for that reason no longer available to the other project (also because of MAIMS, see next section). Moreover, when a risks strikes in one of the projects, the impact (€) is often larger than the reserved contingency (often probability % * €) for that risk. Using reliability theory it can be shown that the left side is more reliable.

Target approach

This approach is somewhat similar to the former. Still a contingency fund is created. However the difference lies in the fact that the individual project managers are given a large budget (for instance with a probability of exceedance of only 2,5%, thus k=2), instead of the nominal budget. All the surpluses of the individual projects will be deposited in the contingency fund.

The controlled approach is preferred over the target approach. This has to do with the MAIMS principle, that will be elaborated in the next section.

8.2 Behavioral displacement in budget management

Behavioral displacement occurs whenever a management control system, such as a target budget, produces and actually encourages, behaviors that are not consistent with the organization's objectives, or at least with the strategy that has been selected (Dekking et al., 2005). Hans de Bruijn (Werkgroep Ramingen Infrastructuur, 1991), states that performance measurement can have positive, but also 'perverse' effects, another term for behavioral displacement. Examples of perverse effects of performance measurement are strategic behavior, a larger internal bureaucracy and the impediment of innovation.

Gamesmanship is also a form of behavioral displacement. This term is generally used to refer to actions that employees take to improve their performance indicators without producing any positive economic side effects for the organization. Creation of slack resources can be seen as a form of gamesmanship. The MAIMS principle is not gamesmanship per se, but can still be seen as behavioral displacement. The two phenomena will be discussed here. Because strategic behavior has a link to the roles that reside within the organization, the interests within the Schiphol AMS organization have been addressed first.

8.2.1 Stakeholders involved with the budget process within Schiphol

Here only the roles and interests of the employees involved in the cost estimation process within Schiphol for the AMS projects will be described. In the following part the stakeholders are assessed by conducting a stakeholder analysis with the article of Bryson (2004) as point of departure.

A summary of this stakeholder analysis is given in Table 16. This has been further elaborated in Appendix L. In Table 16 the stakeholders are ranked on the basis of hierarchy in the organization, bottom-up.

TABLE 16: STAKEHOLDER IDENTIFICATION OF BUDGETING PROCESS

Actor	Tasks/Responsibilities	Interest
PLUS	- Project management of the larger (CAPEX) projects - Spending of financial resources	Deliver project within time, budget and quality
Maintenance Managers	- Asset maintenance - Make budget estimates	Good state of assets
AMS Plot Managers	- Monitor and control plot budget - Supervision on all of assets belonging to plot - Resource allocation	- Good state of assets - Cost efficiency
Senior Manager AMS	- Monitor and control AMS budget - Asset owner - Supervision on all of AMS assets	- Good state of assets - Cost efficiency - Reach budget target
Investment Committee	- Approve proposed budgets - Selection of proposed projects	Control financial resources Make a well informed decision for project selection
Upper management	- Set budgets - Set company strategy	Revenue Well performing Schiphol Airport
Treasury	- obtain financial resources from the market - cost control	Control financial resources

What can be seen from the table above as well as in Appendix L is that the interests among the stakeholders differ. This raises the question whether accurate cost estimates are in the interest of every stakeholder. In the introduction of this thesis it was stated that accurate cost estimates are in the interest of the organization in general. This is because when the appropriate amount of resources can be obtained from the market, no extra costs are made for lending too much money or for later collecting more financial resources. On top of that, when costs are underestimated it could be that scope and/or quality of the project (or other projects) are compromised. Moreover, when the costs are estimated accurately the organization will be able to make better considerations and well informed decisions. The choices are made on the basis of more reliable information.

To put it in other words, when it comes to controlling costs, it is a critical first step to make appropriate estimates at the outset of a project. Being able to control costs is largely a matter of complying with established guidelines, often by learning from previous projects and reacting to current circumstances efficiently and effectively. It is argued that this efficient and effective control on the costs is in the best interest of the organization. This is because amongst others better insight in the costs gives room for cost reduction on the basis of optimization processes, rather than cutting in scope or quality. And even when the latter is the case, this can be done on the basis of better information.

Thus, accurate cost estimation is not a goal in itself; rather it is a means to be able to control the costs more efficient and effective.

Nonetheless, when returning to the stakeholder analysis, it could be in the interest of some stakeholders not to make the budget estimates very accurate or transparent. Meaning, when this accuracy or transparency is lacking more 'room for play' is given to actors within the organization to spend their budgets as they see fit. Or, when the budgets are not too tight more resources will at the disposal of the asset managers, which makes it easier to keep the assets in a good condition, or at the disposal of the project managers, which makes it easier to execute the project within budget.

What can be concluded from this is that the difference in interests of the actors inside the organization can lead to strategic behavior. Two forms of this will be further elaborated in the next two paragraphs.

8.2.2 Budgetary slack

Slack is the use of resources of the organization that do not directly contribute to the objectives of the organization (Vrijling, 2011a; Project Ramingen Infrastructuur (PRI), 1991). It is often created when employees, mostly at management levels, are evaluated primarily on whether or not they achieve their budget targets (DACE, 1989). An example of this is that a manager will receive bonus when he meets his budget target. In this type of circumstances the situation can occur that a manager will give a higher cost estimate than what is most probable, in order to meet the target more easily. This is called *budget slack*. It can also be created when employees know that in future challenges it is expected of them to reduce the budget no matter what.

Some studies have shown that significant amounts of slack exist in most business organizations and that managers (80% of managers interviewed) have admitted that they engaged in slack creation (Winch, 2002a; Verbraeck, 2009). Numbers in these studies indicate that slack can be as high as 20 to 25% of the operating. A survey done at Schiphol AMS indicates that, although it is not being done on a large scale, budget slack is sometimes created when estimating the cost (see Appendix M).

The question is whether slack creation is a bad thing. It has it positives as well as negatives. On the positive side, slack can reduce manager tension and the extra not needed budget can be used for innovation for instance, what not given otherwise (Vrijling, 2011b). On the negative side, budget slack makes the true performance less transparent, and thus decisions on performance optimization are distorted.

It seems slack is almost impossible to prevent. Theoretically, when *information asymmetry* exists slack will be inevitable (Dekking et al., 2005).

This means a situation where subordinates have more information on for example the cost structures, than their managers who have to set the target. This implies however, that when performance can be accurately forecasted, by use of objective data for example, it should be possible to prevent or at least mitigate budget slack.

8.2.3 The MAIMS principle

If project management decides to establish a budget as large as the probabilistic estimate, a contingency is also included for dealing with unforeseen in-scope events. Some project managers even allocate the total project cost contingency to the individual subsystems (Kindinger, 1999), as explained above. This seems like a valid policy, however even with a high cost-contingency there are still numerous project that have (severe) cost overruns (Kujawski, 2002). This is because of the so called MAIMS (money allocated is money spent) principle (Gordon, 1997).

The MAIMS principle is the money-analog of Parkinson's Law, which states that the amount of time scheduled for a certain task is always fully used. MAIMS has been identified as a major cause of significant cost overruns (Kujawski, 2002). This is comparable to the year-end peak that is also described in literature (PAO, 2009). Gordon (1997) states that there are "hidden incentives" in present management styles that stimulate this type of behavior.

1. The inability and reluctance to off-load competent personnel from the program.
   Often people are kept in the project team although they are no longer needed. The reason why they are not off-loaded from the team can be that managers are afraid of later needing such an employee. Still having budget can then be a reason for keeping this person.
2. The need to spend the budget provided or "it will not be available next year."
   Often people are afraid that when a budget is not fully spent, a smaller budget will be available the next year based on this.
3. The need by the program personnel such as design engineers to provide the most reliable product for the money provided.
   For example, design engineers will continue to develop their design as long as they are funded, because they are evaluated on how their design works during testing and after delivery. This is a much larger incentive to them than underrunning or overrunning the budget. If the engineers were to underrun the budget and have a failure during development tests, they would be considered a failure. If, however, they overran the budget but had a successful test, they would usually be considered a success.

The MAIMS principle captures the fact that cost underruns are rarely available to protect against cost overruns. Each cost item in a probabilistic cost analysis has uncertainties, which can be potential overruns or underruns. Because of MAIMS the underruns are not occurring, while overruns are still possible.

Solutions offered by literature (Gordon, 1997; Kujawski, 2002; Kujawski et al., 2004; PAO, 2009) state that it is best to provide only that budget which will give the "expected" result. This is usually the P_{50} point. Next to that management should dynamically manage contingency funds as a risk portfolio at the project level. Thus, contingencies should not be allocated at the task-level and held by individual subsystem managers. An additional suggestion is to incorporate the MAIMS principle in the Probabilistic Cost Analysis by setting "all sampled values less than their associated cost baseline budgets equal to the latter". What is meant by this is that the probabilistic cost estimate has to be designed such that no values can be obtained lower than the chosen budget. Figure 18 is an example of this. The red line shows the 'normal' cumulative density function (cdf), the other lines show what the cdf would look like taking MAIMS into account, and thus setting the lowest possible cost to be equal to the chosen budget (P_{50}, P_{75} and P_{mean}).

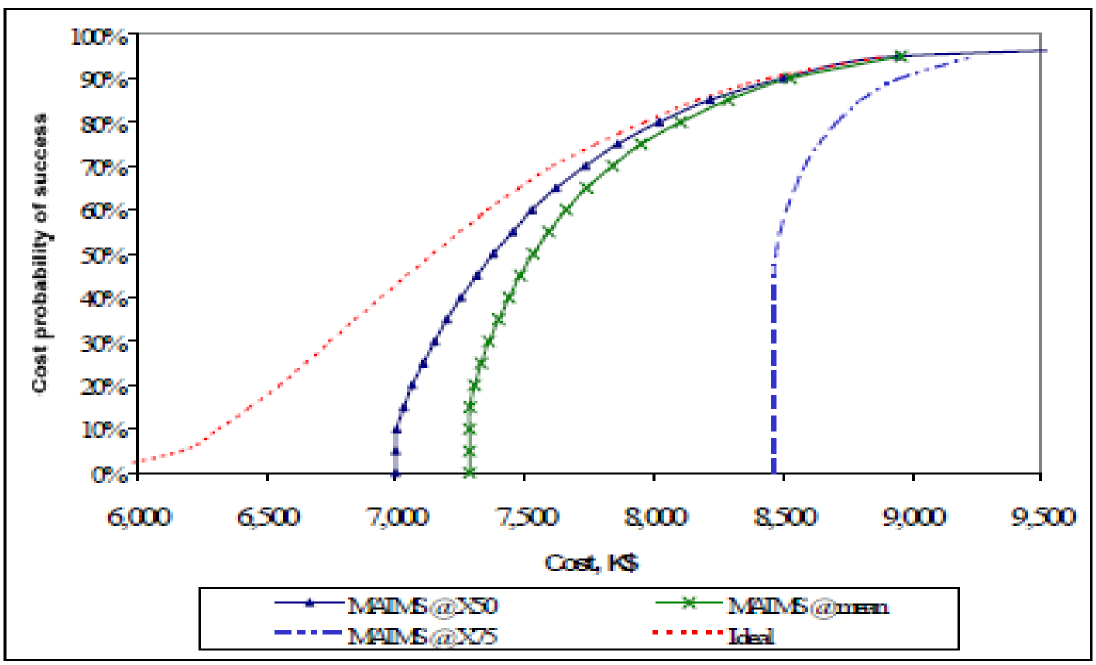

FIGURE 18: EXAMPLE OF CDF INCLUDING MAIMS

8.3 Budget management model for Schiphol AMS

This section is the follow up from section 6.6. It continues to explain the total budget setting model which is designed in this thesis for Schiphol AMS.

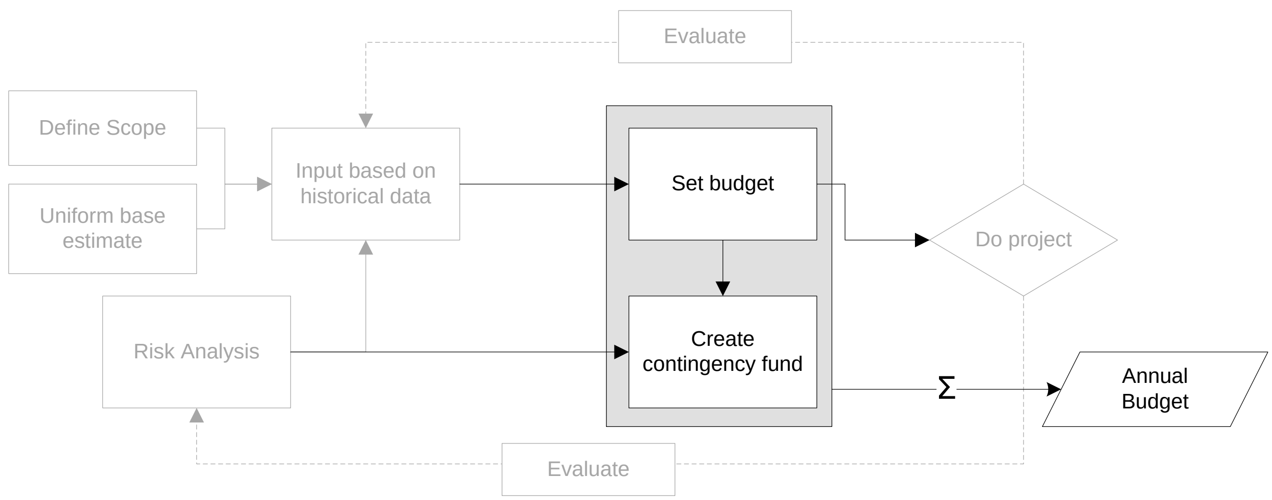

FIGURE 19: BUDGET SETTING MODEL SCHIPHOL AMS

8.3.1 Set budget

Because of the MAIMS principle explained in the former section, it has been chosen to set the budget according to the nominal value of the total estimation (base estimate + nominal unforeseen from historical data) or lower, thus $k_{project} \leq 0$. The opportunity for MAIMS is made smaller this way.

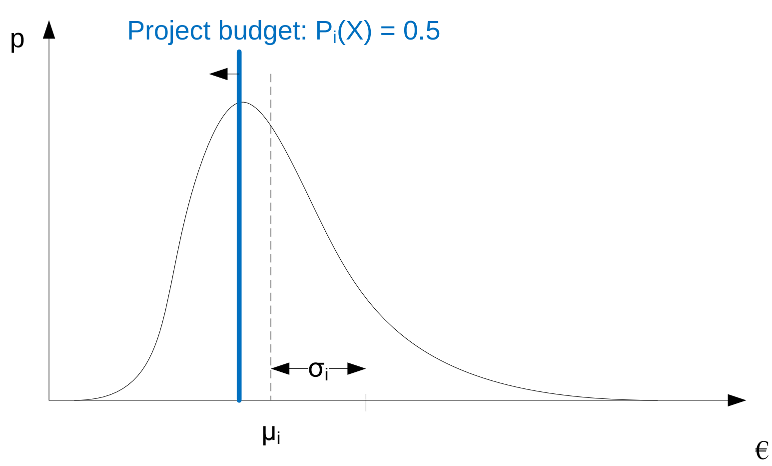

FIGURE 20: PROJECT BUDGET SETTING

When doing this, there is still a minimum probability of 50% that the budget will be overrun. When this occurs, the project manager will have to ask for extra budget. It has to be the choice of the management of AMS if this extra budget is made available. Thus, the project manager should always provide solid argumentation why the extra budget is needed. It is proposed to have a contingency fund at the management level of AMS out of which this extra money can be extracted. In this way the level of bureaucracy can be reduced. The creation and size of this contingency fund has to be regarded on a portfolio level. How this is done will be described in the next section.

On the other hand, the probability that the budget will not be reached still exists. It is therefore also the project manager's responsibly to give not needed budget back to the contingency fund. This has to become part of the organization's culture and awareness for this has to be created. To make it an also an interest for the project organization to finish the project under budget, it could be an idea to give them an incentive for underrunning the budget in the form of a bonus.

8.3.2 Add to contingency fund

The annual project budget is the sum of the predicted costs of the projects that will be executed that year. When the annual budget is established the following is suggested.

When the costs for the projects have been estimated probabilistically, a mean and a standard deviation are derived for each project. The individual projects are assumed independent, thus in order to calculate what this means on a portfolio level, the μ's can be summed and the σ_{tot} is the square sum of the individual σ_i.

$$\mu_{tot} = \sum_{i}^{n} \mu_i \qquad ; \qquad \sigma_{tot} = \sqrt{\sum_{i}^{n} \sigma_i^2}$$

For setting the annual budget it is advised to choose a k_{tot}-factor that is larger than 0 and larger than $k_{project}$. In this way the probability of exceeding the budget is decreased. Furthermore, a contingency buffer is created with which setbacks on the project level can be funded.

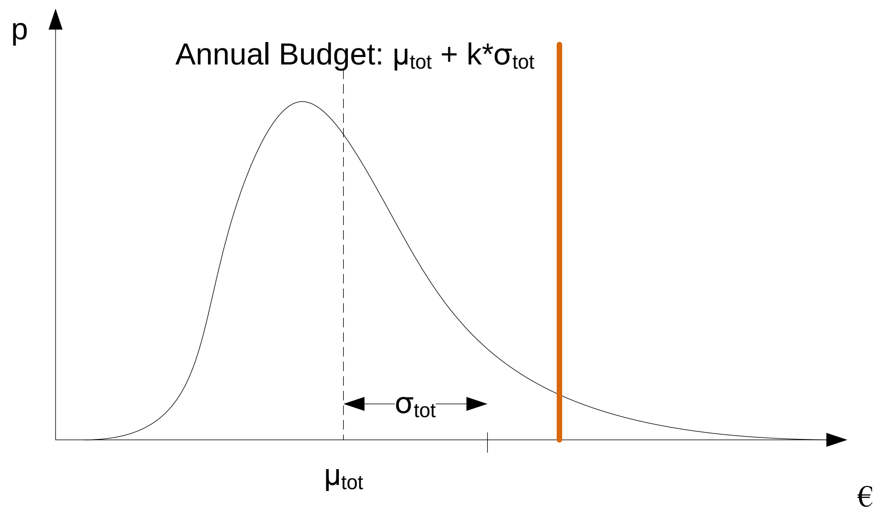

FIGURE 21: ANNUAL BUDGET SETTING

9 Conclusions and Recommendations

In this thesis maintenance projects of SCHIPHOL GROUP are examined. The motivation to do this study stems from the aim of the Schiphol Airfield Maintenance Service (AMS) department to be more predictable and reliable, not only in terms of the performance of the assets and the service provided, but also regarding the financial expectations. Next to this relatively little is known on the uncertainties surrounding maintenance projects and whether they differ from uncertainties in new-to-build projects.

In chapter 1 goals are formulated for this thesis. In the first place the main objective is to *gain more insight into the uncertainty of cost estimates of maintenance projects*. Once this is known, the second objective was to apply this at Schiphol AMS, thus to *optimize the early budget estimation process for maintenance works* (at Schiphol AMS)[10]. Also it is explored whether using Probabilistic Cost Analysis methods can be valuable for providing more insight into the uncertainty (expressed in a standard deviation).

Based on these objectives the following research questions are formulated.

1. *What types of 'systematic' uncertainties occur in maintenance projects?*
2. *How should these uncertainties be dealt with in the cost estimate, in order to come to a reliable budget estimate?*
3. *How can a Probabilistic Cost Analysis approach contribute to making early budget estimates for maintenance works more reliable (at Schiphol AMS)?*
4. *In what way should the budget setting process at Schiphol AMS be organized to better be able to stay within budget?*

[10] *The research is done at Schiphol AMS, and will therefore also look at the benefits and implementation practices for this organization.*

In this chapter conclusions and recommendations are formulated in order to provide answers to the research questions posed above. First, conclusions are given per research question. After that, general recommendations have been written down.

9.1 Conclusions

As stated the conclusions of this study are given sorted by the above mentioned research questions posed in this thesis. The second and third question are bundled and addressed in conjunction.

9.1.1 Uncertainties in maintenance projects

When looking at the unforeseen costs of the maintenance projects examined in this thesis, it can be split up in two. On one hand there is uncertainty due to further specification of the project: in this thesis defined as 'other unforeseen'. It can include scope changes, design errors, or simply estimation errors because relatively little is known about a project in the early project phase (especially the case in systems projects). The latter can also be named initial state uncertainty. On the other hand, unforeseen events can occur during execution of the works, the so called 'special events'.

In maintenance works it appears that the contribution of these special events to the total unforeseen is relatively small. In complicated new-to-build works this can go up to even 25 to 30 percent of the total contracting sum, while in the maintenance works examined in this thesis the highest value found was 4,5 percent of the total contracting sum, and the average value found was 3 percent. Apparently because of (I) the repetitive character of maintenance projects, (II) the situation that these type of works often take place in already stirred ground, (III) the relatively small scale and (IV) the possibility to do detailed inspections, the final design can be made rather accurate and the projects are very controllable and straightforward during execution.

However, this study points out that a large difference between the (early phase) estimates and the eventual costs can still occur. The explanation for this can be found in the 'other' uncertainties. Especially in early project phase, when relatively little is known about the eventual (scope of) the project, estimates can be far off. An average of 7 percent higher actual costs than estimated, with a standard deviation of 32 percent, was found in this thesis. Subtracting the unforeseen caused by special events during execution, around 10 to 15 percent on average of the total project budget should be reserved for the item 'other unforeseen'.

When differentiating in project types, the amount should be even higher for control system maintenance projects such as runway stations. It can be even higher than one would use for a new development projects. An explanation for this can be found in the fact that for these type of projects the uncertainty of the initial state is relatively high. Uncertainty is increased because one does not start with a so called 'green field'. Often an old system is in place of which the current state is relatively unknown. The system has to be renewed by a new system, which can bring all kinds of extra challenges. In early project phase these challenges are hard to predict and estimates made in this phase are therefore often far off, as one does not have a good idea of the scope of the project (see cartoon cover page). Only once detailed engineering and good inspections are done in a later stage of the project, estimates become much more accurate.

In road renovation works the money spent on additional work is even negligible. The differences between estimates and actuals can be fully explained through design errors and scope extension.

What the statistical analysis also showed is that larger projects (larger than one million euro) were less likely to end up over budget and with a smaller variation than smaller projects. An explanation for this could be that the larger maintenance projects can be regarded as a portfolio of subprojects and acting like such as well. Meaning, overruns in one part of the project could be compensated by underruns in another part. This would then indicate that the subparts in maintenance projects are not very correlated and can be easily controlled separately.

Types of special events

There are three types of unforeseen events during execution that can be identified as typical for maintenance projects based on this study.

The first one has to do with the uncertainty of the state of the asset or the work field conditions. Inspections cannot always give a complete picture of the current conditions and some uncertainty still remains. Especially when the works have to be executed below ground, these events can occur, even though the ground has already been stirred. Examples of this are old bombs that are being found, hidden cables and pipelines, unforeseen extra traffic light loops, etc.

The other type of typical unforeseen events has to do with the operational conditions surrounding maintenance works. The assets are either still in use themselves or are situated in an operational active environment, which can bring extra complexities and risks. Needless to say, if the maintenance work is postponed due to operational causes, it can give unforeseen extra costs.

Design errors that are to be corrected during execution are the third category of unforeseen events during the construction phase. It turned out that almost 80 percent of the unforeseen costs occurring during execution could be related to this category. Also in new-to-build projects design flaws occur, so it is not typical for maintenance works only. It probably takes up such a relative significant part because other types of unforeseen events are occurring significantly less in maintenance works.

9.1.2 *Cost estimation method*

For a good estimation of costs of projects where uncertainties occur two estimation methods are available:

- Semi-probabilistic Black-Box approach
- Probabilistic approach

With both of these methods it is possible to take the uncertainty (quantified by the standard deviation) of a cost estimate into account when setting the budget. For the (early) budget estimates of the maintenance projects at Schiphol AMS it is recommended to use the statistical probabilistic approach. It is a more detailed method compared to the black box or reference class forecasting method. The reasons for using the statistical probabilistic method are given below. It should be noted here that a statistical approach is only possible when historical data is available. Until then the input of experts will be necessary to estimate the uncertainty of the cost items.

In the first place during a year a reasonably large amount of maintenance projects are estimated and these projects are relatively small. On top of that the projects often exist out of even smaller subprojects that are estimated separately. A Bayesian probabilistic approach for each of these projects would be simply too time consuming without much added value in comparison to a statistical probabilistic estimate.

In the second place, as explained above, relatively little special events occur during execution. To do a full risk analysis, which is necessary for a probabilistic approach, would be not worth the while. A relatively small percentage added to the estimate can suffice for maintenance projects. What should be taken into account here as well is that a risk analysis has its up- and downsides. It can increase the understanding of and give insight in the possible project risks. However not all the in reality occurring risks can be foreseen in such an analysis. This notion is also proven by the example estimates in chapter 7. For that reason it is suggested not to base the budget on the risk analysis, but rather on historical data (statistical probabilistic approach). Nonetheless the risk analysis can still be used as a mechanism for helping to explain where the item unforeseen and corresponding uncertainty margin come from.

Another conclusion that can be drawn on the cost estimation method is that a uniform base estimate is essential. Not only transparency is created in this way, but also the estimates can be easily compared. It is even more important for evaluation purposes.

Evaluation and subsequent calculation are crucial for this methodology. A dataset of historical data is namely not only used to predict a percentage for the unforeseen and corresponding standard deviation, but for other items of the estimate as well. If the dataset on which the historical determined percentage for unforeseen is extended, the uncertainty of the actual estimation decreases. Moreover, the insight into the risks and uncertainties surrounding the maintenance projects also grows. What is of utmost importance for being able to do such an evaluation, is that the project costs are booked on items in correspondence with the uniform estimation structure. In other words, the estimation and final administration should be in line.

The added value for creating such a database is that insight into certain cost items can be obtained. For instance, when it is discovered that a certain cost item is relatively large, one can act on this information and can decide on subsequent actions.

What should be added here is that when those datasets are related to specific types of projects, one will be able to make the estimates even more accurate. This is also suggested in the reference class forecasting method explained in chapter 6.

<u>Percentages</u>

Looking at the percentages used for the unforeseen, the following can be concluded based on the statistical analysis done in this thesis. The general used 10% unforeseen for the business plan estimates at Schiphol AMS seems not sufficient. It is better to use a percentage between 15 to 20 percent. This percentage can in its turn be split up in 10 to 15 percent for normal uncertainties including some minor scope changes and a maximum of 5% for special events (risk budget). For the project budget it does seem appropriate to use a 10% unforeseen percentage (5% normal uncertainty, 5% for special events during execution). Currently a spread around the estimate (standard deviation) is not taken into account. The statistical analysis shows however that this cannot be neglected. When setting a percentage for the item unforeseen, it is recommended to look at the type of project, since on this basis the average unforeseen and standard deviation strongly differs.

9.1.3 Budget setting method

Accurate and transparent cost estimates are necessary, not only to be able to obtain the right amount of resources from the market, but even more to be efficient and effective in terms of (cost) control. Better considerations and decisions can then be made. However, it is not in every actor's interest to have accurate and transparent budget estimates and thus in budget management practices behavioral displacement can occur. Behavioral displacement is unintended, or 'perverse', effects caused by the 'rules' set in the budgetary practice, such as bonus regulations. One of these effects is the creation of budgetary slack. Extra budget is requested by for instance estimating the costs too high or the scope too large, to be able to meet the budget target, and sometimes associated bonus, more easily. Signs of this happening were also found at SCHIPHOL GROUP.

Another form of behavioral displacement occurring in budget management practices is the so called MAIMS (money allocated is money spent) principle. This means that a given budget is often fully used although this is not always actually necessary. For instance extra, unneeded scope is added to the project under the title that there was 'still room in the budget'. A reason for this happening is amongst others the fear that the same budget will not be available next time. A consequence of the MAIMS principle is that there are no budget underruns which can compensate for overruns.

When setting a budget it is suggested to take the uncertainty of the estimate into account by using the estimated mean value and standard deviation. Based on the risk attitude of the responsible manager the budget can be determined using these values.

To make the summed standard deviations of the individual projects smaller one could assess the budget management on a portfolio level. A controlled approach where a contingency fund is held on a portfolio level is preferred here. This not only reduces the possibility of MAIMS happening, but also arguments following from reliability theory support this. When contingency is held on a portfolio level, 'minuses' in one project can compensate for 'plusses' in another. Moreover a larger amount of money is at the disposal to compensate for the damage caused by a risk firing in an individual project. In the last place this contingency fund on a portfolio level can also be used to finance complete unforeseen projects.

To minimize the possibility for budgetary slack, MAIMS and possibly also out of efficiency promotion reasons, it is advised to set the budgets of individual projects to the P_{50} value (probability of exceedance of 50%) or even less. To compensate for these tight projects budgets a contingency fund should be established at one management level higher. The size of this contingency budget has to be determined by using the probability function of the summed means and standard deviations of the individual projects. When a project manager is in need for extra budget he can request this out of the contingency fund with solid argumentation. Since the funds are held only one management level higher, the bureaucracy surrounding the process should be limited. Furthermore, not only the management team will be more in control of the projects, but accountability is also increased.

9.1.4 *Other conclusions*

Other conclusions that are found in this study are mentioned here.

Asset management and maintenance strategies

When maintenance on assets is initiated, it is often done out of the viewpoint of only the technical lifetime. This is also known as the traditional maintenance theory. What is often forgotten is the option for complete renewal, also the economical viewpoint. When maintenance on an asset needs to be performed, one has to make the consideration whether complete renewal might be economically better. One of the aspects that should be taking into account in this consideration is the costs for unavailability of the asset during the maintenance or renewal activities. These costs, especially in an operational active environment as Schiphol, can be rather large. Another thing that can be taken into account is that the new asset can provide larger benefits, which is a third viewpoint on asset management.

It appears that in the models used at Schiphol to determine the need for maintenance, the second viewpoint is incorporated. Maintenance versus complete renewal is being assessed. The possibility of extra revenues due to a new, improved asset is taken into account at the level of the investment committee.

Cost estimation process at Schiphol AMS

When looking at the cost estimation process at Schiphol AMS it has to be concluded that more detailed engineering has to be done earlier in time. Since at present budgets are requested on the basis of estimates which are often based on rough drafts. Especially for the larger projects it is advised to start the project earlier and thus to involve the project organization and contractors earlier. The budget estimate can then be based on a more detailed preliminary design. Since business plans are made already five years in advance, the projects itself are already decided upon. The earlier start can reduce the scope and design uncertainty significantly.

9.2 Recommendations

The recommendations of this study are split up into three categories: general recommendations, recommendations for SCHIPHOL GROUP (AMS division) and suggestions for further research.

9.2.1 General recommendations

The model for cost estimation described in thesis can be applied for general means. It is especially useful for estimates in the early phase of a project. It is less time consuming than a Bayesian probabilistic estimate and it appears that it is also more accurate. Hence, it is recommended that this method should be applied more often. The same goes for the budget allocation model described. Nonetheless, when historical data is not yet available, the Bayesian method still has to be used if one choses to do a fully probabilistic estimate, which is recommended over a deterministic approach.

It is advised that when a Bayesian probabilistic estimate is being made, to also do a statistical probabilistic estimate, or even a black-box or reference class forecasting type of estimate, next to that. The outcomes can then be compared and adjusted if needed. The added value of the Bayesian probabilistic estimate is that it can give more insight into the uncertainties surrounding a project and by doing a risk assessment the project team gets familiar with the project.

Considering asset management it would be wise to not only look to the technical lifetime if a maintenance project is initiated. The viewpoint should be broader and also include economic considerations. One should always keep in mind whether it would be economically better to perform maintenance on a certain asset or replace the total asset. Whether extra revenues can be obtained with the new assets should also be part of the equation.

9.2.2 Recommendations for Schiphol (AMS)

In the first place it is recommended for SCHIPHOL GROUP that when a cost estimate is made that the *scope is clearly defined* and also to *implement a uniform estimation method*. The method proposed in this thesis can be a good starting point. Also the framework provided by the SSK can be adjusted such that it can serve the goals for SCHIPHOL GROUP.

Next to this the actual costs should be *booked consistent to this uniform estimation method*. If the items accounted for in the accounting system are the same as those being used in the uniform estimate, the comparison can be made easily. Not only will this be vital information for making future estimates more accurate, it can also serve as a controlling instrument by knowing what is spent on what cost items more precise.

Thirdly it is advised to *use the proposed estimation (statistical probabilistic) method* when estimating project costs. Based on historical data, several cost items, including the unforeseen items, can be estimated using a μ and σ. This means that the outcome of the estimate will also be presented with a mean value with a corresponding standard deviation.

Furthermore, it is suggested to *determine the budgets based on the probabilistically obtained project estimates*. Using the uncertainty margins it is then recommended to determine the projects budgets on the P_{50} value or even less. On the management level of AMS a contingency fund should be created to be able to compensate for projects overruns and extra unforeseen projects. The size of this contingency fund can be derived from the probability function depending on the risk attitude of the management. If needed, project managers have to request extra budget by solid argumentation at this management level.

Another recommendation is to *start a project more early* in time, before the final business plan at least. In this way the business plan budget estimate can be based on a more detailed design, which will enhance accuracy by reduction of scope and design uncertainty. Risk management sessions can be done in the preliminary design phase. The project organization and the contractors should also be involved in this early stage.

9.2.3 Suggestions for further research

One of the things that is suggested here, is to create a larger database of financial performance of maintenance projects. In this study only projects are examined at SCHIPHOL GROUP. It will be valuable when the dataset is extended. Maintenance projects from other organizations within and outside of the Netherlands can then be added. As pointed out in this thesis not a lot of research has yet been performed on maintenance projects compared to new-to-build projects. This thesis provides a good starting point and gives an indication for this specific category of projects. However, it is not a full picture. When the dataset is enlarged by not only looking at more infrastructure type of maintenance works, but also at other categories, such as software projects for instance, a more complete view can be established.

It seems that the statistical probabilistic method, as well as the black-box method and the reference class forecasting method, have not been applied very often. It would be interesting to see the results when one of these methods, or the method described in this thesis, are actually executed. The use of these methods can be evaluated and adjusted if needed.

The same goes for the budget allocation process described in this study. Checking whether budget slack creation or MAIMS still occurs when applying the method, or if other types of behavioral displacement arise, can be something for further research.

Also a difference is found in applying the Level II and Level III computational models. A solid argument for the difference could not be found. It is assumed that it has to do with the way that the @Risk software calculates the estimate. Further investigation on this matter could be done.

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APPENDICES

A Company Profile

Schiphol Group

This chapter will give a short introduction to the company that initiated this research. Also a description of the department at which the research is done will be given: Airfield Maintenance Services

General

SCHIPHOL GROUP is an operator of airports. It currently has 2200 employees (Wikipedia, 2011). The company is full owner and operator of Amsterdam Airport Schiphol, Rotterdam The Hague Airport and Lelystad Airport and it has 51% of the shares of Eindhoven Airport. Outside of the Netherlands the SCHIPHOL GROUP also takes part in a couple of airports.

The most important activity of SCHIPHOL GROUP is the operation of Amsterdam Airport Schiphol. Looking at passengers AAS is the fourth largest airport in Europe and the ninth worldwide.

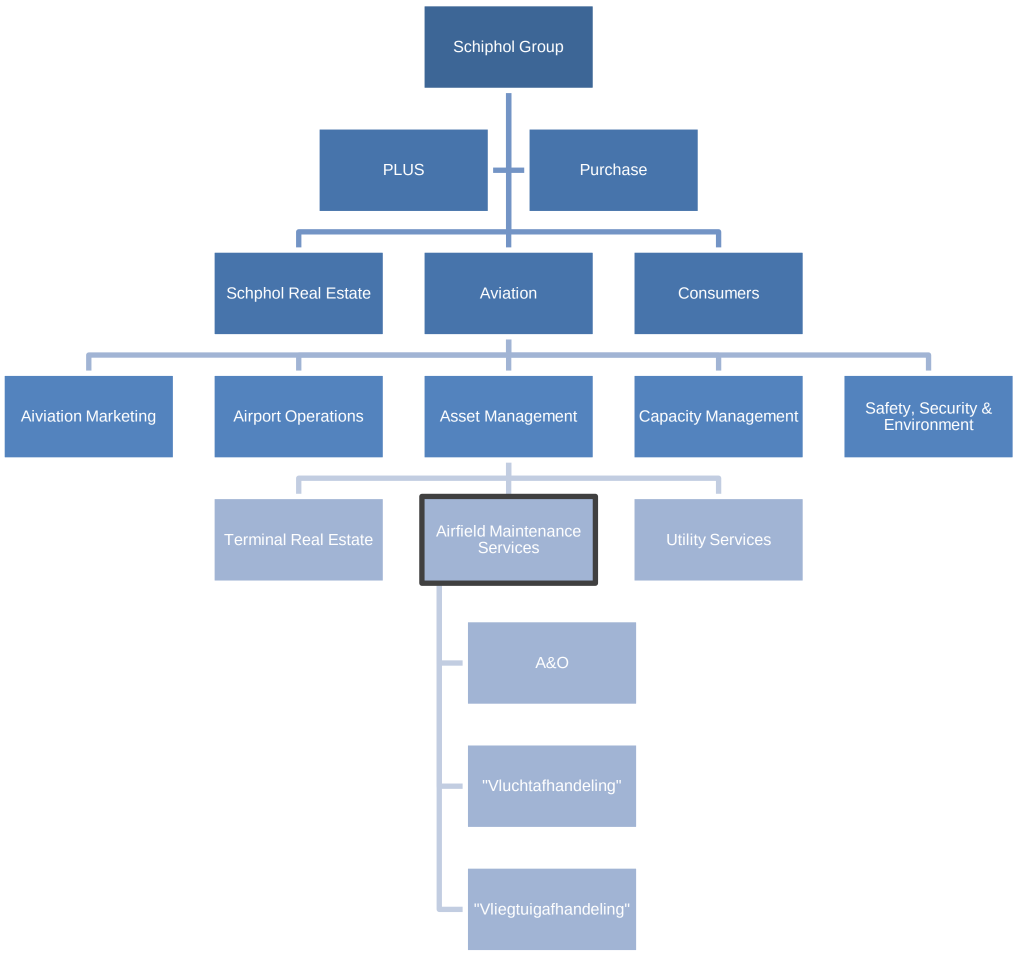
The Dutch state (Ministry of Finance) has a 69.77% ownership of SCHIPHOL GROUP. 20.03% is owned by the municipality of Amsterdam and 2.2% by the municipality of Rotterdam. The other 8 percent is property of Aeroports de Paris (Schiphol Group, 2011).

Organisation

The organizational chart can be found on the next page. Within SCHIPHOL GROUP Aviation is one of the business areas. It has Amsterdam Airport Schiphol as working field. Aviation offers services and facilities to airlines, passengers and handling companies. The Asset Management department within Aviation deals with the development, realization, management and conservations of its assets. These assets include amongst others:

- Terminal (and related buildings)
- Platforms, lanes and runways
- Gas, electricity, waste and water facilities

Airfield Maintenance Services (AMS) is in its turn a part of Asset Management and, simply put, takes care of the management and maintenance of all the physical assets outside of the terminal, the utilities excluded.



APX FIGURE 1: ORGANIZATION CHART SCHIPHOL GROUP

It should be noted that this is a simplification, where AMS has been highlighted.

<u>Projects</u>

Within financial management a distinction is made between two different types of expenditures: Operational Expenditures (OPEX) and Capital Expenditures (CAPEX). This is also done at Airfield Maintenance Services. OPEX stands for returning costs of a product or system, while CAPEX stands for the costs of investment of renewal projects. CAPEX are generally spread over multiple years. As an example renovation of an asphalt layer can be seen as CAPEX, where the replacement of lamps is typically OPEX. The real differentiation comes from the rules for depreciation. The fact whether the investment can be depreciated determines whether the project is OPEX or CAPEX. One can only depreciate the Capital Expenditures.

Most of the time, Schiphol AMS takes care of the OPEX projects itself. For CAPEX projects the project organization PLUS is used. This is a staff department within SCHIPHOL GROUP, which takes care of the project management within Schiphol. They are given a budget to complete the project, and AMS is of course still used for advice and feedback. The current project management approach that SCHIPHOL GROUP now uses is STAP (Schiphol Group, 2010), which is an applied translation of the PRINCE2 approach (van den Akker, 2010). The main idea behind this approach is that a project board is installed to control the project on a higher level.

A last thing that can be noted here that management in SCHIPHOL GROUP steers and controls by means of a target (Dutch: "taakstellend") budget. This means that during the year the cost are controlled by looking at the given budget and steer accordingly.

B Budgeting Process

In this appendix the budgeting process at SCHIPHOL GROUP is explained from the viewpoint of AMS.

Based on the maintenance concepts at AMS projects are initiated. These can either be OPEX or CAPEX projects. The OPEX projects are funded from the OPEX budget. For the CAPEX projects individual budgets have to be requested from the investment committee.

First within AMS a selection of projects is made for the five upcoming years and a global planning is made for which project has to be executed when. This is a yearly process. Also cost estimates are made for these projects, the so called business plan estimates. Since the projects have not been engineered in too much detail, these cost estimates are more indicative. The cost estimates for all the projects are combined in the business plan document.

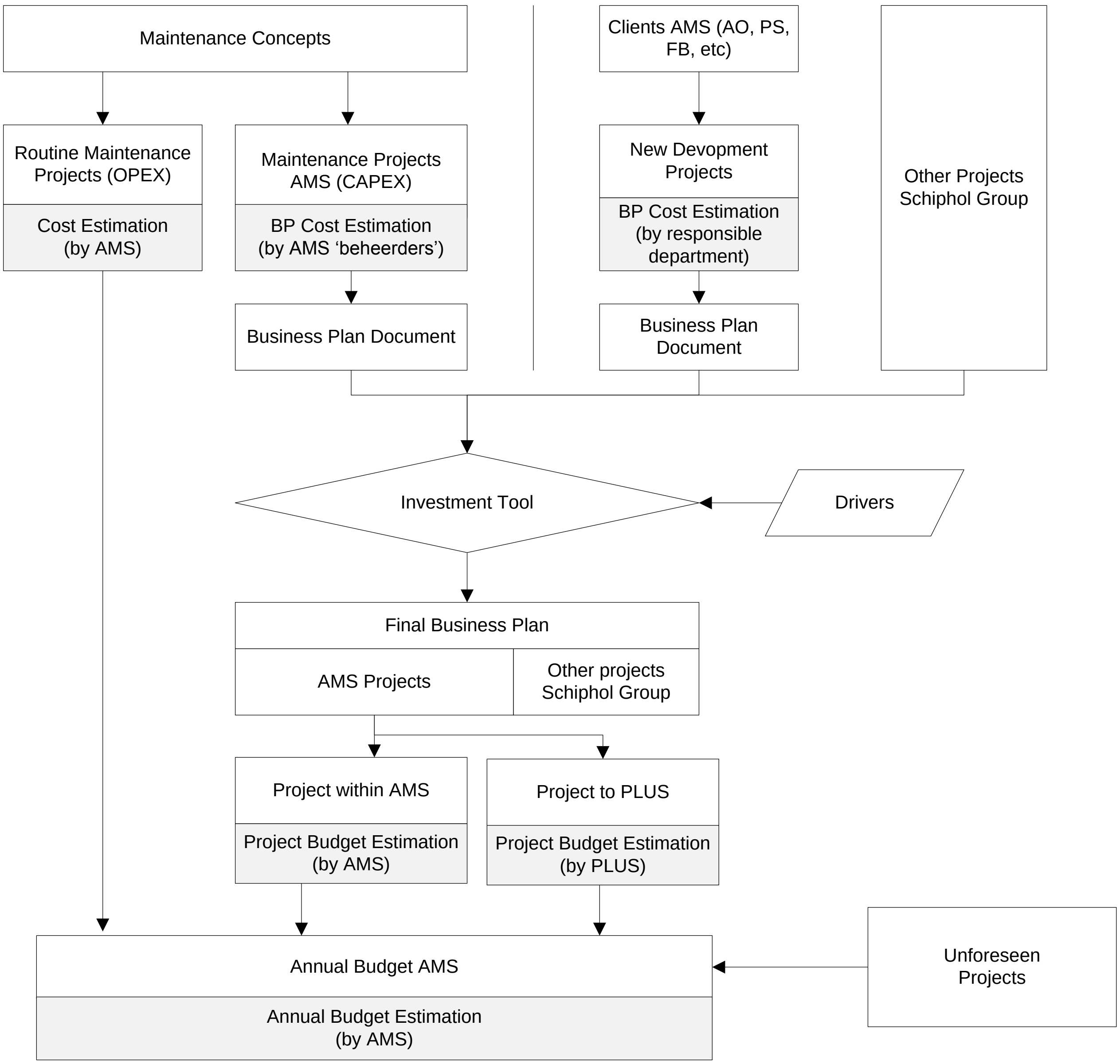
Together with the projects in the business plans of the other divisions the projects are submitted to the investment committee. They use a certain investment tool which ranks the projects according to certain predefined drivers that are based on the long term strategy of Schiphol.

The selected projects make part of the final business plan. Based on this business plan the projects that will be executed the year after will be started, either by AMS itself or by the project organization PLUS. More detailed engineering will be done and also a more detailed project budget estimate will be made.

The project budget estimates will via a decision document again be presented to the investment committee. They will give their final approval.

The project budgets of the next year together with the OPEX budget (and other things such as depreciation) will form the annual budget for AMS.

During a year unforeseen, but very necessary projects can come up. These projects will also have to be signed off by the investment committee and are most of the times financed out of the annual budget.



Apx Figure 2: Budgeting process of a project at Schiphol AMS

C Interviews

Date	Organization	Name	
19 October 2011 19 January 2012	Schiphol Group	Dhr. Danny Woud	Controller AMS
24 October 2011 30 January 2012	Schiphol Group	Dhr. Paul Zeeuw	Manager AMS: Vliegtuigafhandeling
26 October 2011 1 December 2011	Schiphol Group	Dhr. Jelle Nijdam	Manager AMS: Vluchtafhandeling
26 October 2011	Schiphol Group	Dhr. Gijs Emsbroek	Manager AMS: Advies en Ontwikkeling
30 October 2011	Schiphol Group	Mevr. Joyce Groot	Airport Development and Innovation
31 October 2011	Schiphol Group	Dhr. Govert Ho	Senior Manager AMS
1 November 2011 29 February 2012	Schiphol Group	Dhr. Wim Grit	Controller PLUS
17 November 2011	TU Delft / Witteveen&Bos	Dhr. Mig de Jong	PhD. Cost Overruns / Risk Manager
23 January 2011	Schiphol Group	Dhr. Melvin Bakker	Beheerder Baan en Rijbanen
25 January 2012	Schiphol Group	Dhr. Ruud van Rijssel	Beheerder (rand)wegen
25 January 2012	Schiphol Group	Dhr. Marco Ponsen	Beheerder ET
30 January 2012	Schiphol Group	Dhr. Remco Duiveman	Beheerder HWA
27 February 2012	Schiphol Group	Mevr. Carmen Chueng	Controller PLUS
29 February 2012	Schiphol Group	Dhr. Herman Stol	Service Manager AMS
15 March 2012	Schiphol Group	Dhr. Frans Schenk	Project manager PLUS
21 March 2012	Schiphol Group	Dhr. Adri Groeneveld	Project manager PLUS
28 March 2012	Schiphol Group	Dhr. Rob Kooper	Project manager PLUS
29 March 2012	RijksWaterStaat	Dhr. Ton de Vries	Senior Kostenadviseur
2 April 2012	Prorail	Dhr. Harold van der Werve	Teamleider Cost Engineering Baan- en spoorbouw

Next to these formal interviews a lot of information was gathered talking to different of people within and outside SCHIPHOL GROUP. Especially the advisors within Schiphol AMS were of good help.

D Costs due to closure of a runway

Not available due to sensitive information. Please consult author at lrduijndam@gmail.com for more details if needed.

E Cost estimation requirements

Not available due to sensitive information. Please consult author at lrduijndam@gmail.com for more details if needed.

F Analysis of annual estimates and expenditures

Not available due to sensitive information. Please consult author at lrduijndam@gmail.com for more details if needed.

G Statistical analysis in detail

In chapter 3 a statistical analysis is executed of several projects at Schiphol AMS in order to compare the various estimates to the actual expenditures. To be able to fairly compare the values to each other, the numbers have to be made similar. This can be done by correcting and normalizing the amounts to a percentage. There are various methods by which this can be done. First the method used in this report will be described. After that it will be explained how the statistical analysis has been performed on the basis of this method.

Corrected Estimates

To be able to calculate the nominal unforeseen, the data of the estimates of the examined projects first have to be corrected. What is meant by this is that the total estimate has to be adjusted in such a way that the base estimate is left. In this research this is done by subtracting the included unforeseen from the estimates given. The table below (Apx Table 1) shows this process.

APX TABLE 1: CORRECTED BUSINESS PLAN ESTIMATES

Not available due to sensitive information. Please consult author at lrduijndam@gmail.com for more details if needed.

APX TABLE 2: CORRECTED PROJECT BUDGET ESTIMATES

Not available due to sensitive information. Please consult author at lrduijndam@gmail.com for more details if needed.

Categorization

The forty-two projects that have been examined, which are mentioned in the former section can be subdivided into categories. This is based on the type of project. The following categories have been used.

- Runway & Taxiway project
- Engineering project
- Platforms
- Systems
- Roads
- Others

Runway & Taxiway projects

Runway and Taxiway projects are maintenance projects on the actual asphalt on airside. This often also includes electro technical works, such as replacement of lighting systems. Most of the times also storm water drainage projects are combined with these type of projects.

Engineering projects

With an engineering project, only the engineering or design of a certain project is meant. Sometimes these types of projects are accounted separate, while most of the times the engineering is included in the 'whole' project itself. When it is a separate project, it has been given the 'engineering project' category.

Platforms

When work on the platforms is being done, it is brought into this category. This is often more than a mere asphalt replacement project. It could be that also the complete platform is redesigned.

Systems

This category holds a combination of projects and is therefore hard to define. It mostly always includes some sort of electro technical system, such as the lighting system of a runway or a communication system.

Roads

When work on the surrounding roads (only accessible for cars, not airplanes) is being done, this is included in this category. It most of the time only includes asphalt renewal projects.

Others

Some projects could not really be fitted into one of the other categories and where therefore bundled together in the 'others' category.

Normalization methods

As explained by Boschloo (1999) there are three ways to express the estimate as a percentage.

1. The estimates are a percentage of the actual costs (R/U);
2. The actual cost are a percentage of the estimate (U/R);
3. Scale the estimates to a certain phase (Rn/Rm);

First normalization method

(R/U): The idea behind this method is that the certainty of the actual costs is relatively large. This is the amount Schiphol has paid and most of the times this is very accurately documented. A disadvantage of this method is that the found standard deviations are expressed as a percentage of the eventual costs. Because these costs are never certain during the project, this does not give the right information.

Second normalization method

(U/R): In this method the standard deviation of the estimate itself can be calculated, which is an advantage above the first method.

Third normalization method

(Rn/Rm): One can also scale the project to one specific phase. One looks at which value the expectation of the estimate will be in a different phase.

By the above and as Boschloo explained, one can conclude that the second normalization method is the best. This is also because when the probability distribution function is regarded, it appears that the values of the normalized estimate follow the same p.d.f.. For that reason this method has been used in this analysis.

Overview of normalized values

Based on the evaluated projects for this research the following values have been derived. They can be found in Apx Table 3.

APX TABLE 3: PROJECT OVERVIEW OF NORMALIZED VALUES

Not available due to sensitive information. Please consult author at lrduijndam@gmail.com for more details if needed.

Probability density functions

Graphically an estimate can be represented by a probability density function when the expected value and project uncertainty are known. The cumulative density function F(x) is the integral of the p.d.f.. It represents the possibility that a variable crosses the value x. This function will always lie between 0 and 1, since a probability cannot be smaller than 0 or larger than 1.

In literature as well as coming from interviews, it seems that experts do not agree on the type of probability function that accurately fits cost estimates. It is argued by some that a probability of exceeding the estimate is larger than ending up below it. On the other hand some experts argue that because of the fact that a cost estimate is a summation of different cost items, the Central Limit Theorem should be applied, and therefore it is normal distributed. Nonetheless, this is only valid when the random variables are independent with the same probability function.

Even when a cost estimate is normal distributed, due to the occurrence of special events a skewedness will occur. This could be modeled by a logarithmic distribution. An advantage of this is that in the case of this type of distribution no negative values can be obtained, which is generally speaking the case in cost estimates. Other skewed probability functions are also available; the Gumbel, Fréchet and Weibull distributions for instance. For more information about probability functions is referred to (Vrouwenvelder and Vrijling, 2006; Dekking et al., 2005; CUR, 1997)

As explained above, in general a normal distribution is assumed for cost data. In this research however it is assumed that the data of the projects at AMS is lognormal distributed. This assumption is not only backed by literature (Boschloo, 1999; CUR, 1997; Kujawski et al., 2004) and by talking to experts, but also on the basis of the skewedness of the data, the fact that no negative values can be obtained and is validated by performing statistical tests. In the last section of this appendix more information is given on this. Here it is also shown that the lognormal distribution fits the data better than the normal distribution.

Another advantage of using this distribution is that it can also be easily described by a mean value and a standard deviation. When the distribution type is known also the corresponding parameters have to be estimated. This can be done in several ways, as will be explained in the next section.

Parameter estimate

The parameters (μ, σ, skewedness, etc) of a probability density function determine the position and the slope. There are several ways to estimate these parameters. Three of them are given below:

1. Method of moments
2. Least square method
3. Method of maximum likelihood

These methods will be explained here. For all methods also an example calculation is given with the AMS data. In these calculations the lognormal distribution is assumed. The dataset that is being used is the BP vs EOP normalized data.

$$X_1 = 1.28; X_2 = 0.99; \ldots; X_{33} = 0,66$$
$$n = 33$$

For more information it is referred to (CUR, 1997).

<u>Method of moments</u>

In the method of moments the parameters are estimated by setting the moments of the dataset equal to the moments of the distribution.

The moments of the data set are given by:

$$\mu = E(X) = \frac{1}{n}\sum_{i=1}^{n} x_i = 1,17$$
$$\sigma^2 = E(X^2) = \frac{1}{n}\sum_{i=1}^{n} {x_i}^2 = 1,53$$

The moments of the distribution are given by:

$$E(X) = e^{\mu+\frac{\sigma^2}{2}}$$
$$E(X^2) = e^{2\mu+\frac{4\sigma^2}{2}}$$

Thus,

$$\ln 1,17 = 0,16 = \mu + \frac{\sigma^2}{2}$$
$$\ln 1,53 = 0,42 = 2\mu + \frac{4\sigma^2}{2}$$

Gives,

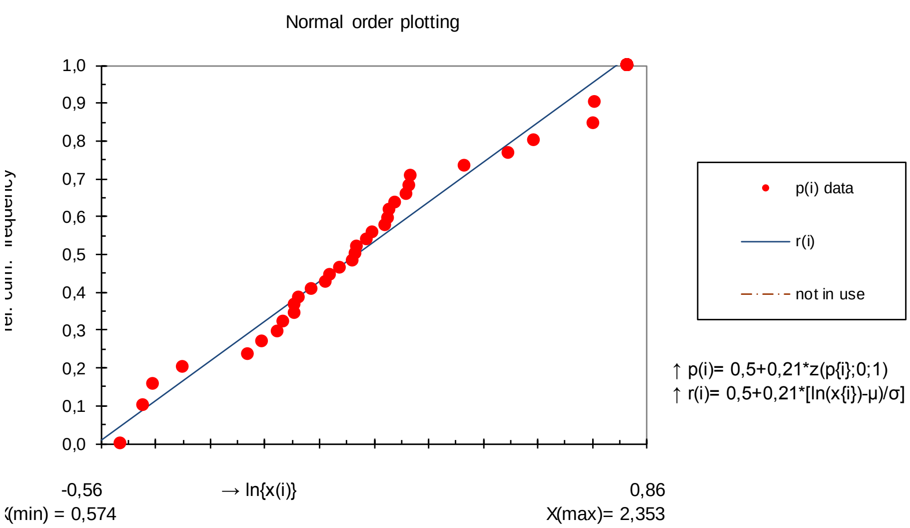
$$\mu = 0{,}11;\ \ \sigma = 0{,}33;$$

$$mean: E\ X\ = 1{,}17$$

$$standard\ deviation:\ \ \sqrt{E\ X^2}\ = 0{,}39$$

<u>Least square method</u>

This method to estimate the parameters of a dataset has a graphical basis. One has to draw the data as points on lognormal paper. Then one tries to draw a straight line through those points. The parameters are estimated by minimizing the sum of the squared differences. This has been done with the help of excel and the graph has been printed below.



APX FIGURE 3: NORMAL ORDER PLOTTING GRAPH

Using the graph the following values were obtained:

$$\mu = 0{,}11;\ \ \sigma = 0{,}34;$$

$$mean: E\ X\ = 1{,}17$$

$$standard\ deviation:\ \ \sqrt{E\ X^2}\ = 0{,}40$$

<u>Method of maximum likelihood</u>

In the method of maximum likelihood parameters are estimated for which the observed data will have the largest probability. This means that the likelihood function is maximized. The definition of likelihood is: the *likelihood* of a set of parameter values given some observed outcomes is equal to the probability of those observed outcomes given those parameter values.

The likelihood estimators for the lognormal function are defined as follows:

$$\mu = \frac{1}{n} \sum_{i=1}^{n} \ln x_i$$

$$\sigma = \frac{1}{n} \sum_{i=1}^{n} (\ln x_i - \mu)^2$$

This gives,

$$\mu = 0{,}11; \ \ \sigma = 0{,}31;$$

$$mean: E[X] = 1{,}17$$

$$standard\ deviation: \sqrt{E[X^2]} = 0{,}38$$

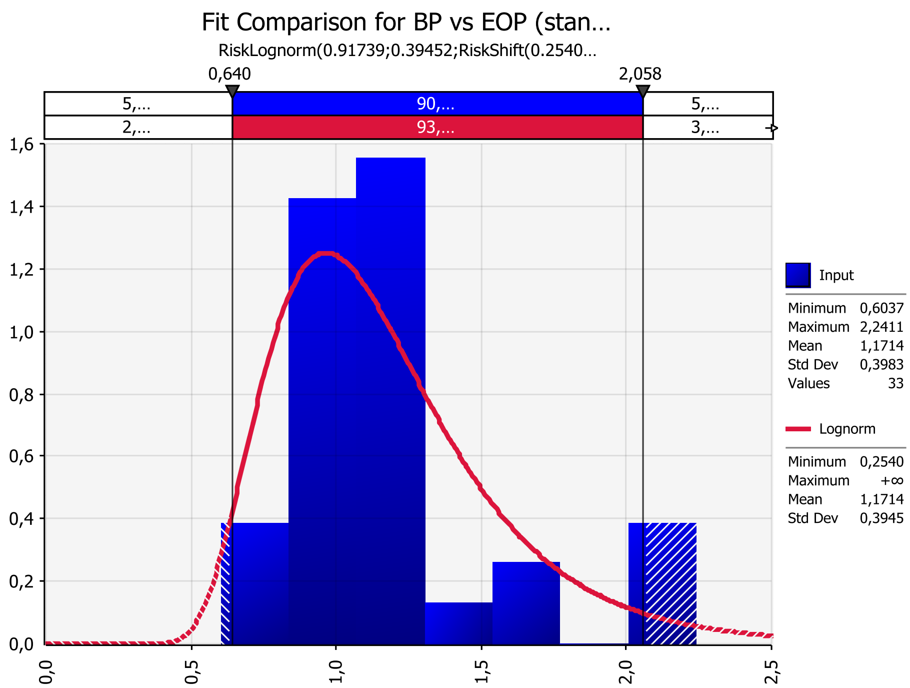
Statistical Analysis

The statistical analysis is not performed by hand, but by using computer software Bestfit in @Risk. This software uses all parameter estimation techniques and decides on the bases of the chosen distribution function which method best suites the fitting process. Below the results are given of the parameter estimate. Based on the results the average nominal unforeseen has been determined. This was added to the original estimate and then the parameters were estimated again, which can be found in the last two columns of Apx Table 4.

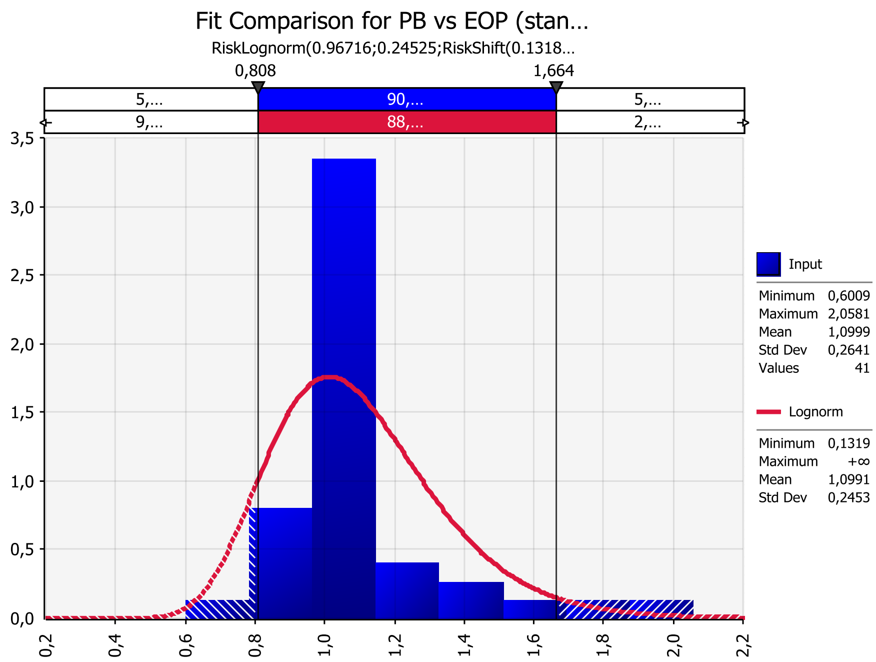
This analysis has first been done for all forty-two projects together. After that the same is done for the separate categories. It should be noted that, because for the different categories the number of projects on which the μ and σ are based are small, these numbers are far less accurate. Nonetheless it gives insight in what type of projects are more likely to go over budget.

APX TABLE 4: RESULTS PARAMETER ESTIMATION

Business Plan Estimate					
Probability Distribution	μ	σ	Applied nominal unforeseen	μ	σ
Lognormal	1.17	40%	17%	1.0	34%
Project Budget Estimate					
Probability Distribution	μ	σ	Applied nominal unforeseen	μ	σ
Lognormal	1.10	25%	10%	1.0	22%



APX FIGURE 4: BP VS EOP



APX FIGURE 5: PROJECT BUDGET VS EOP

For the different categories the following values were found.

APX TABLE 5: DIFFERENCE BETWEEN ESTIMATE AND ACTUAL PER CATEGORY

Business Plan Estimate			
Category	μ	Applied nominal unforeseen	σ
All	*1.17*	*17%*	*34%*
Runways & taxiways	1.16	16%	23%
Engineering	1.46	46%	29%
Platforms	1.04	4%	22%
Systems	1.33	33%	45%
Roads	1.06	6%	30%
Others	0.88	-12%	29%
Project Budget Estimate			
Category	μ	Applied nominal unforeseen	σ
All	*1.10*	*10%*	*22%*
Runways & taxiways	1.14	14%	23%
Engineering	1.46	46%	29%
Platforms	1.07	7%	3%
Systems	0.99	-1%	17%
Roads	0.98	-2%	16%
Others	1.15	15%	26%

Verification of found values

The first thing that should be noted here is the limitations of the limited data set that has been used. When all projects are placed together a dataset of 42 is assessed. This is not extremely large, but still reasonable. However, when the projects are divided into categories, the datasets become much smaller, which also increases the uncertainty of the found values extremely.

On the basis of the results of this thesis a skewed distribution, such as the lognormal distribution, is very probable. This is also backed by literature as described earlier. It was first tested for the total dataset of 42 projects. This is described below. It is assumed that if the hypothesis for the whole dataset holds, the same distribution can also be assumed when the projects are divided into categories. This assumption is also tested for some of the categories.

The complete dataset

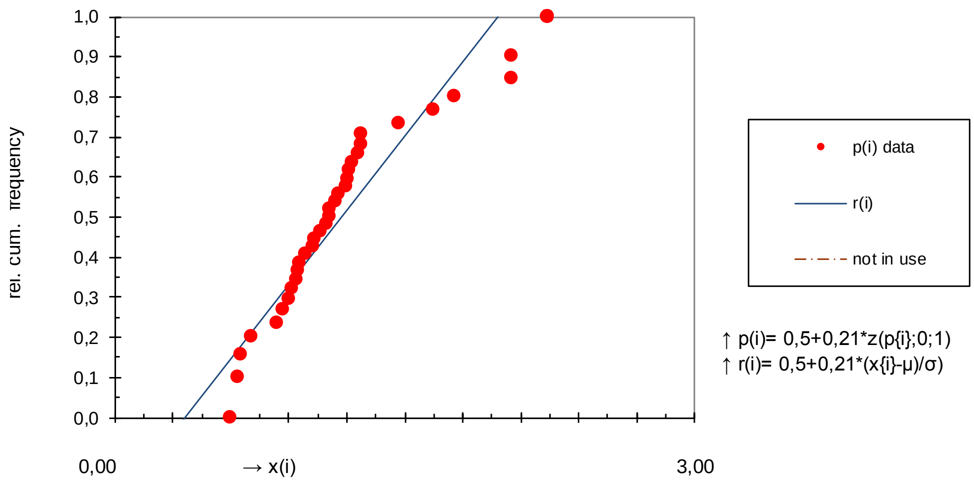
Probability density function

As explained a lognormal distribution was assumed to approximate the financial project data of Schiphol AMS. In this section some tests are done in order to check whether this assumption can be accepted, or at least not rejected.

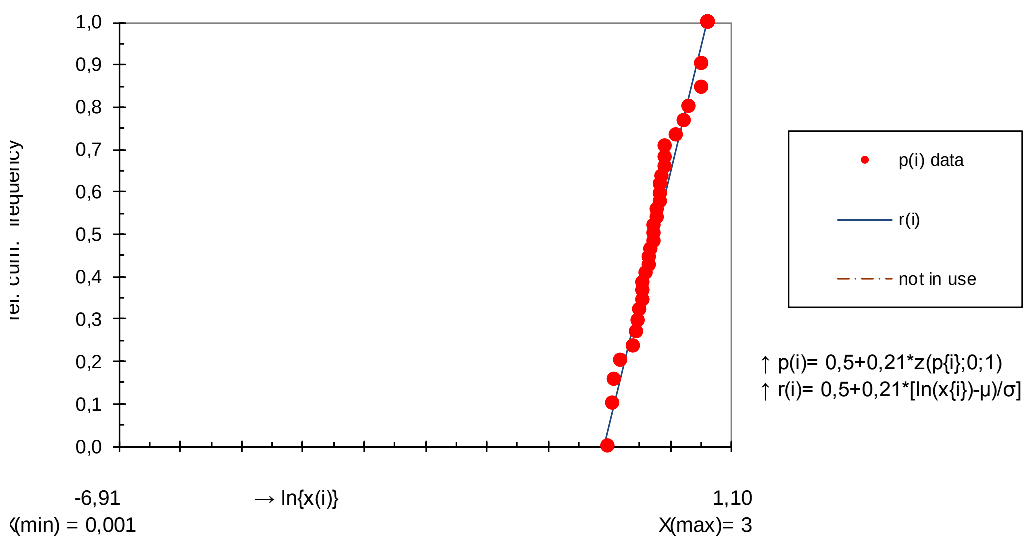
The tests that are performed are graphically plotting the data and the so called Chi-square test, the Kolmogorov-Smirnov test and the Anderson-Darling test.

Graphically Plotting

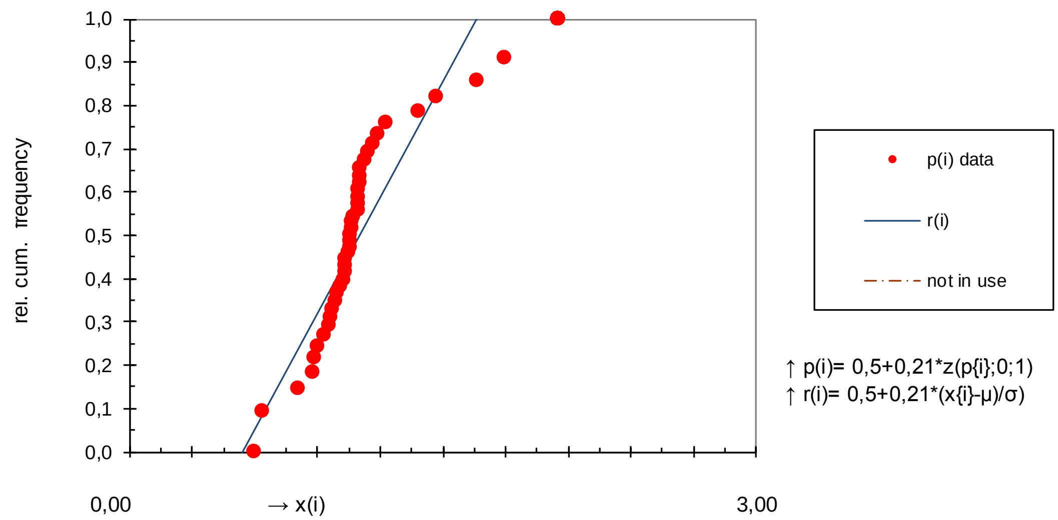
The most simple test to perform is to graphically plot the data on the correct paper (correct scale) and to see whether it follows a reasonably straight line. The graphs for the normal as the lognormal plots are given below.



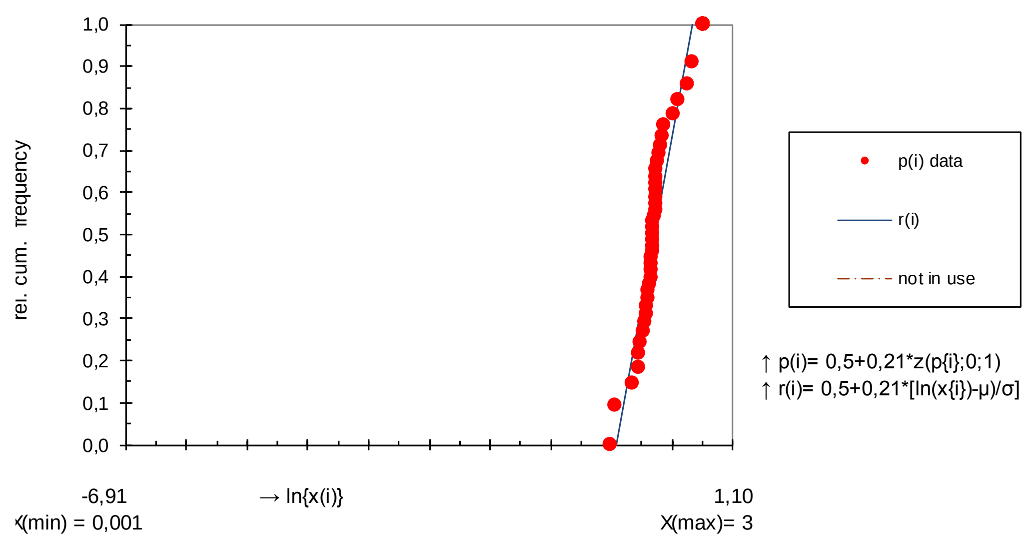
APX FIGURE 6: VERIFICATION PLOT NORMAL PDF, BP VS EOP



APX FIGURE 7: VERIFICATION PLOT LOGNORMAL PDF, BP VS EOP



Apx Figure 8: Verification plot Normal PDF, PB vs EOP



Apx Figure 9: Verification plot Lognormal PDF, PB vs EOP

Looking at the plots the assumption of a lognormal distribution over a normal distribution seems valid.

Chi-square test

In the Chi-square test, the maximum difference between the assumed probability density function and the histogram of the actual data is assessed. The test compares the amount of observations in a certain class of the histogram of the data to the expected amount of observations relating to the pdf. With a reliability of 95% (α = 5%) it is tested whether the hypothesis (the data is lognormal distributed) can be accepted. The following results were obtained.

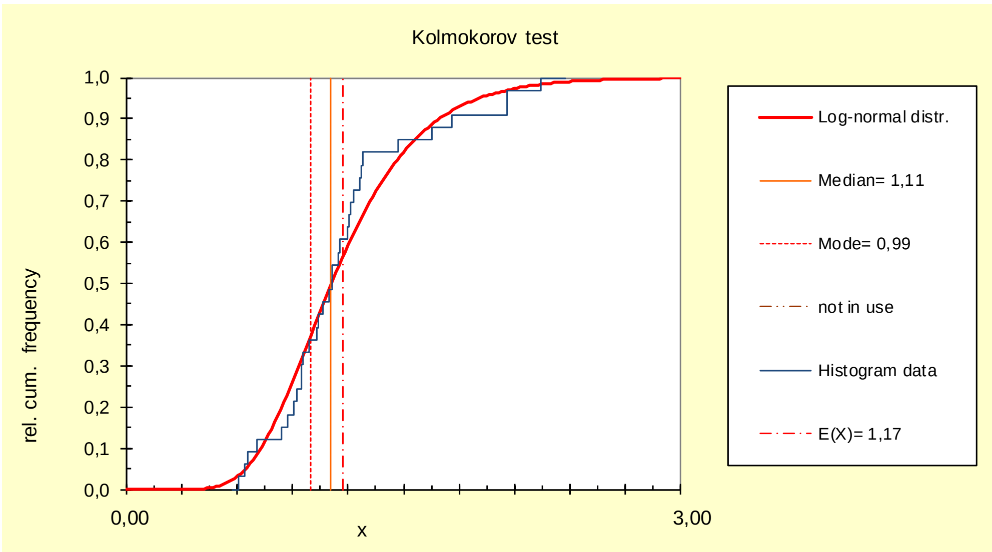
APX TABLE 6: CHI SQUARE TEST

	Businessplan	**Projectbudget**
A	5%	5%
Classes	20	20
Degrees of freedom	9	7
χ^2 data	26,81	28,52
χ^2 test	16,92	14,07
Hypothesis accepted	no	No

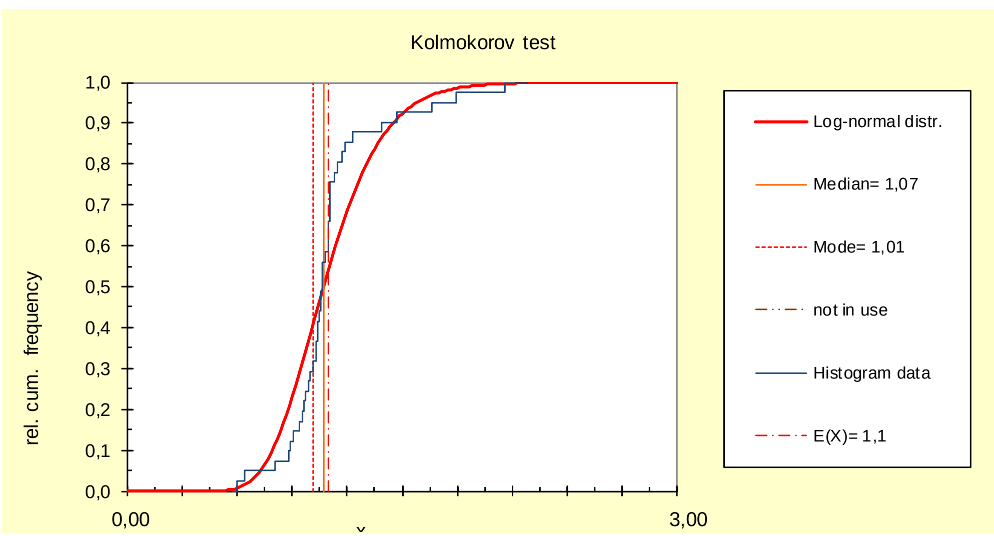
So according to the chi-square test the data is not approximated by a log-normal distribution. It should be noted that also for other distributions, such as normal, Gumbel, Weibul or frechet the hypothesis was rejected.

Kolmogorov-Smirnov test

In contradiction to the Chi-square test, in the Kolmorov-Smirnov test no classes are used. This means that the maximum difference between the data and the cumulative density function is assessed. This is illustrated in the graphs given below.



APX FIGURE 10: KOLOMOKOROV SMIRNOF TEST BP VS EOP



APX FIGURE 11: KOLOMOKOROV SMIRNOF TEST PB VS EOP

APX TABLE 7: KOLMOKOROV SMIRNOV TEST

	Businessplan	**Projectbudget**
A	5%	5%
Degrees of freedom	33	41
Dn	0,15	0,20
Hypothesis accepted	Yes	Yes

Based on the Kolomogorov-Smirnov test a lognormal distribution is accepted as an approximation for the dataset. The normal distribution was rejected.

<u>Anderson-Darling test</u>

Also the Anderson-Darling test calculates the difference between the hypothesized distribution and the data set. The following values were found.

APX TABLE 8: ANDERSON DARLING TEST

	Businessplan	**Projectbudget**
α	5%	5%
A*	0,535	2,248
$A_{critical}$	0,733	0,736
Hypothesis accepted	Yes	No

So, on the basis of the Anderson-Darling test the lognormal distribution is also accepted for the BP estimation data. Here it can be noted that the normal distribution hypothesis was rejected.

Parameters

Not only uncertainty exists in the chosen probability function, but also in the found parameters (μ and σ) corresponding to this pdf. By using a numerical method, bootstrapping, insight can be given into this uncertainty. In this process new datasets are created by generating random values out of the original dataset. By estimating the parameters of the new datasets, the function of the different estimators can be obtained.

The found variation coefficients (σ / μ) are a measure for the uncertainty of the parameters. The following variation coefficients have been found when using the bootstrapping method.

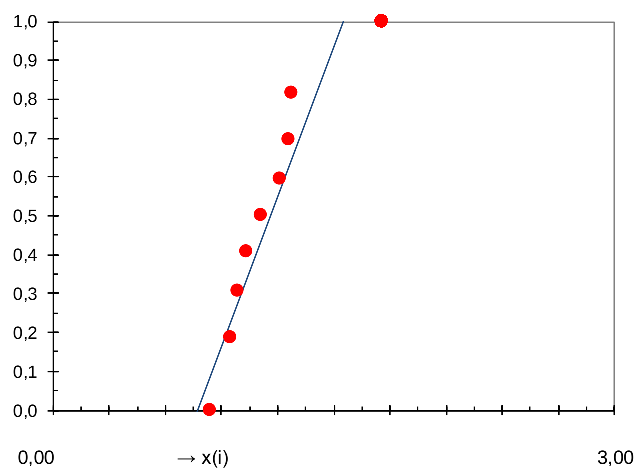
APX TABLE 9: PARAMETER VERIFICATION

	Businessplan		**Projectbudget**	
	μ	σ	μ	σ
Normal	c_U = 0,17	c_U = 0,37	c_U = 0,12	c_U = 0,32
Lognormal	c_U = 0,14	c_U = 0,35	c_U = 0,16	c_U = 0,31

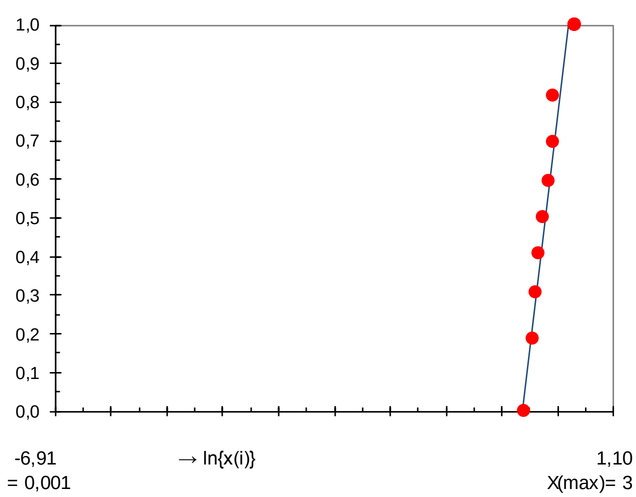
For both estimates it can be seen that the variation coefficient is larger than 0.1. This implies that there is a relatively large uncertainty in the found values of the parameters. The nominal unforeseen however, has a smaller variance than the standard deviation. This implies that the values found for the nominal unforeseen have a better predictive value.

Separate Categories

To check whether the datasets of the separate categories can also be approximated by a lognormal distribution, similar tests as above are executed. However it can already be said that the parameter estimation is very uncertain due to the even smaller size of the datasets. The graphical plot test is only shown for the category of "Runways & Taxiways", since the other categories show similar results. After that an overview is given of the statistical test results of all categories.



APX FIGURE 12: NORMAL ORDER PLOTTING SEPERATE CATEGORIES



APX FIGURE 13: LOGNORMAL ORDER PLOTTING SEPARATE CATEGORIES

APX TABLE 10: OVERVIEW VALIDATION TESTING

	Businessplan			Project budget		
	χ^2	K-S	A-D	χ^2	K-S	A-D
Runways & taxiways	n/a	yes	yes	yes	yes	Yes
Engineering	n/a	yes	yes	n/a	yes	Yes
Platforms	n/a	yes	no	n/a	yes	yes
Systems	n/a	yes	yes	n/a	Yes	No
Roads	n/a	yes	yes	No	Yes	No (normal: yes)
Others	n/a	yes	yes	n/a	yes	yes

Conclusions validation of found values

The following can be concluded from this section:

1. Looking at the financial project data (Apx Table 10) it is very probable that both the business plan as the project budget estimations show a skewed density function. Based on literature and earlier findings the lognormal distribution is likely. Testing the original data against this distribution function, this assumption is acceptable.
2. Based on the statistical tests the lognormal distribution is a better approximation than the normal distribution.
3. It is valid to also assume a lognormal distribution for the individual categories.
4. Due to the large variance in the standard deviation the found values should be handled with care, both for the business plan as for the project budget estimations. This is especially the case for the individual categories, since the datasets were even smaller here. The nominal unforeseen also has a relatively large variance, but compared to the standard deviation the predictive value is far better.
5. Although some values show a large variance, the standard deviation and especially the nominal unforeseen are still a good indicator for the average estimation uncertainty.

H Examined projects

Not available due to sensitive information. Please consult author at lrduijndam@gmail.com for more details if needed.

I Classification of unforeseen events during execution

In the analysis of chapter 4 unforeseen events that happen during execution were differentiated. The following classification is used in this thesis.

1. Deviation of environmental conditions
    a) Deviation of work field conditions
    b) Extraordinary operational disturbances
2. Changes in program of requirements
    a) Extra requirements of client (Schiphol)
    b) Change in law and regulations
3. Deviation of design
    a) Specification deviation (procedural)
    b) Dimension deviation (construction)
4. Execution errors

In this appendix these types are further specified.

Extraordinary operational disturbances

The special event mentioned here is very typical to the type of maintenance work done by organizations such as SCHIPHOL GROUP, PRORAIL and RWS. Often either the assets that are being renovated are in use themselves or the nearby surrounding is still in operation. One can thing of a traffic lane for instance that is being renovated, while the adjacent lanes are still in use. This often complicates the execution of the works. If for some reason the maintenance works have to be postponed due to security issues or other operational hindrance, this can cause serious financial consequences. Some of the disturbances of the work due to operational restraints are taken into account as a normal uncertainty. However extreme events can still occur which will have a more profound effect on the planning and the costs. One could think of a crash or bad weather for a long period of time.

Deviation of work field conditions

This type comprises events caused by deviations between the assumptions on the conditions of the physical working area and the conditions as they appear to be in reality during execution. This can be assumptions about the composition of the soil, the groundwater level or the state of the foundation for instance. An example of this is that asbestos is being found in a location where it was not expected and that it has to be removed still.

Extra requirements of client

This includes extra requirements of the client that come up during execution. For instance the renovation of the structure in which the runway system resides, if that was not part of the original scope.

Change in law and regulations

During the execution of the works the law or certain regulations (external) can change which has consequences for the project. An example is a new environmental law that has consequences on the disposal of old material.

Specification deviation

In the specification of the works it is written down what the contractor is supposed to do. It could be possible that the contract is not complete and things have to be added during execution.

Dimensioning deviation

This comprises deviations that occur because during execution it appears that the original design or plan cannot be executed as thought. This can include calculation mistakes, small changes or forgotten load cases.

Execution errors

Execution errors encompass the events that happen due to wrong execution of the works. An example is that a too thick layer of asphalt is removed with the consequence that the waste material has tar in it. To dispose this material will have larger costs than would be the case otherwise.

J Uniform budget estimation

In chapter J the uniform budget estimation is introduced. In this appendix the parts of this will be further explained based on Project Ramingen Infrastructuur (PRI) (1991).

Direct Cost

These are the cost of items in the estimate that are directly dependent on the quantities. The prices of these are obtained through the market based on the specification (in Dutch: "bestek")

Indirect Cost

These are the cost items in the estimate that are not directly dependent on the quantities. These are often the costs that are made for the specification as a whole. The indirect cost exist of time dependent costs, unique costs and final costs, such as general costs, profit and risk margin and priced items to a value of a certain amount.

Additional Cost

These costs are not obtained through the market. These entail amongst others engineering costs and ground acquisition. Also temporary measures fall into this category.

Miscellaneous

These costs are an addition to the budget estimate by means of further working out the estimate. It is expected that more costs will be made when the design and working method are further specified. These can be covered with this item.

Unforeseen

This item has already been explained on page 54. It can concern either the direct, indirect or additional costs.

Taxes

This is the VAT (in Dutch: BTW). The percentages for this are set by the government.

K Cost estimate of the A19 GH bay project

Not available due to sensitive information. Please consult author at lrduijndam@gmail.com for more details if needed.

L Stakeholder identification

In this appendix the internal stakeholders that are involved in the budgeting process are described.

Plus

The project organization PLUS is the division that is responsible for the project management of the large (CAPEX) projects. By managing a subcontractor they execute the maintenance works. It is their target to deliver the project within the set timeframe, budget, scope and quality. PLUS makes use of the budget requested by the maintenance mangers. It can be seen that PLUS is employed by AMS.

Maintenance Managers

The maintenance managers have the responsibility to keep their assets in good condition. They are the asset maintainers so to speak. It is their task to do inspections on the assets and control the state.

Next to this they are responsible for the cost estimates that serve as input for the business plan. These are costs estimates for maintenance projects on the assets. The CAPEX budget is eventually used by the project organization PLUS to perform the projects. In this way they have an indirect interest in the budget height. Next to this OPEX budget is requested as well and this comes more or less directly at the disposal of the maintenance managers.

AMS Plot managers

The AMS Plot (in Dutch: "perceel") managers are the line managers of the maintenance managers. Where each maintenance manager is responsible for a certain type of assets, the plot managers supervise the asset management of their (physical) plot. Within Schiphol this is known as VLU ('vluchtafhandeling') en VLI ('vliegtuigafhandeling').

It is the task of these managers to control the budgets of the work that has to be done in their plot. They are in control and have the power to steer and adjust when needed. They will be also looking for cost efficiency when managing their assets.

Senior Manager AMS

This is the leading manager of AMS and therefore also head of the AMS management team. This means he is head responsible for the assets AMS owns: the asset owner. Next to that it is his responsibility to control the entire AMS budget. Just like the plot managers, he will be looking for efficient allocation of the resources. He is also rewarded with a bonus when reaching his budget target.

Investment committee

The investment committee is at the top of the hierarchical chain, budget wise. Every CAPEX expenditure first has to have approval by this committee. They approve the proposed budgets and also select the projects that will end up in the final business plans.

Upper Management

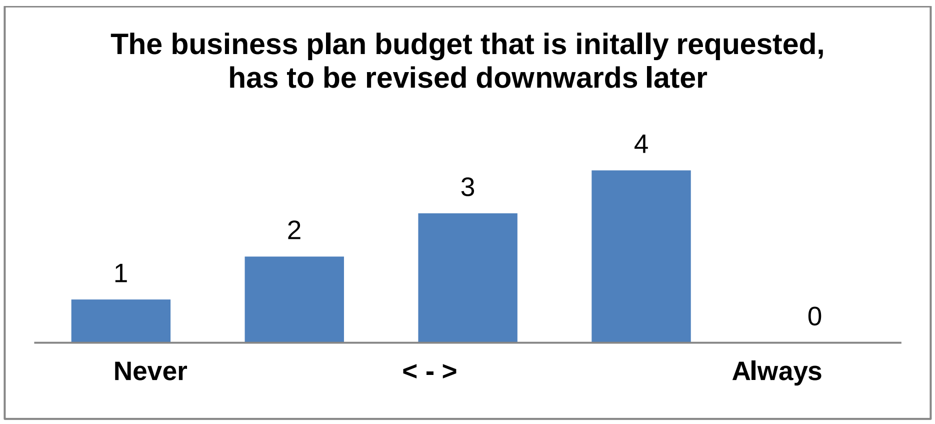
Finally there is the upper management within the Schiphol organization. It is their task to decide on the company's strategy. In the end it will be their target to make sure Schiphol is a well performing Airport, or in other words maximize the revenue. They will make sure that there is so called cost efficiency, which more or less means that resources are well allocated.

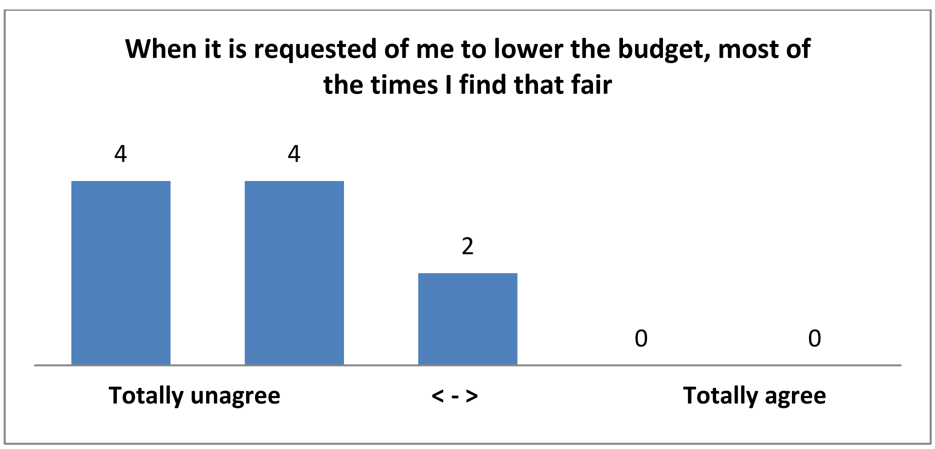
The treasury department

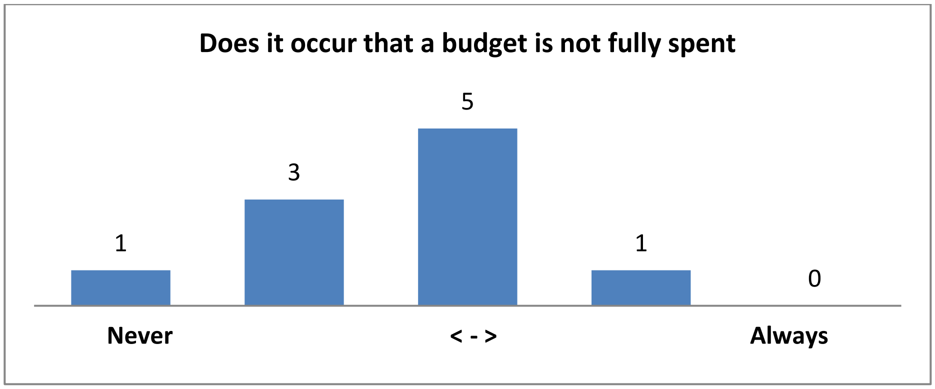
This department is responsible to attract financial resources from the market in order to be able to finance the projects.

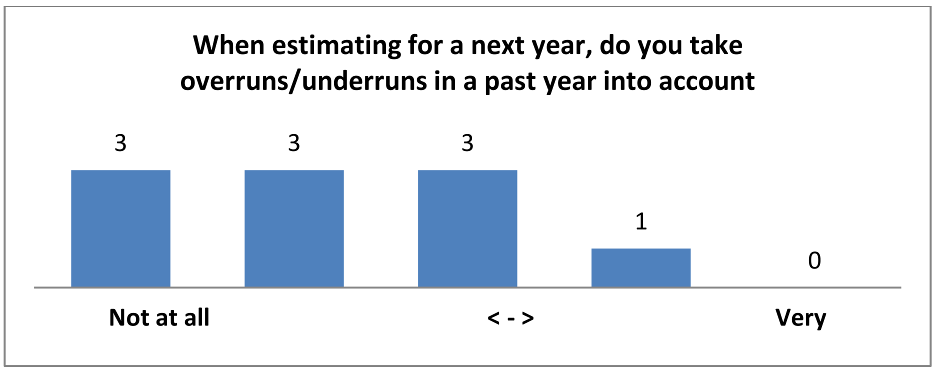
M Survey on budgetary slack

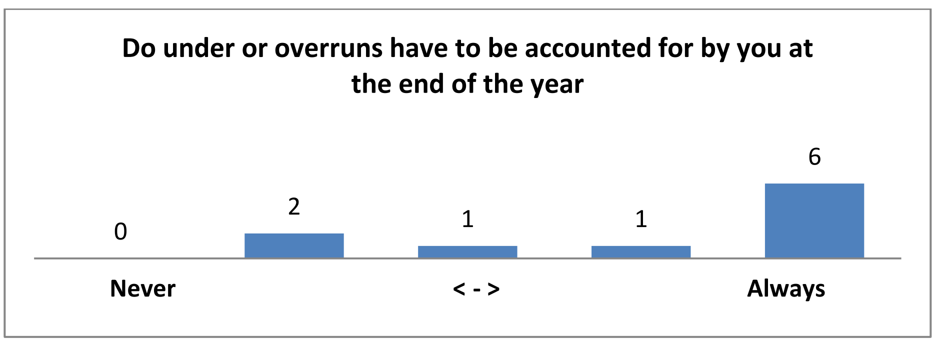
For this thesis a survey was held among the maintenance mangers and managers at Schiphol AMS, to find out whether budgetary slack also exists in this organization. The questions and outcomes are presented here.

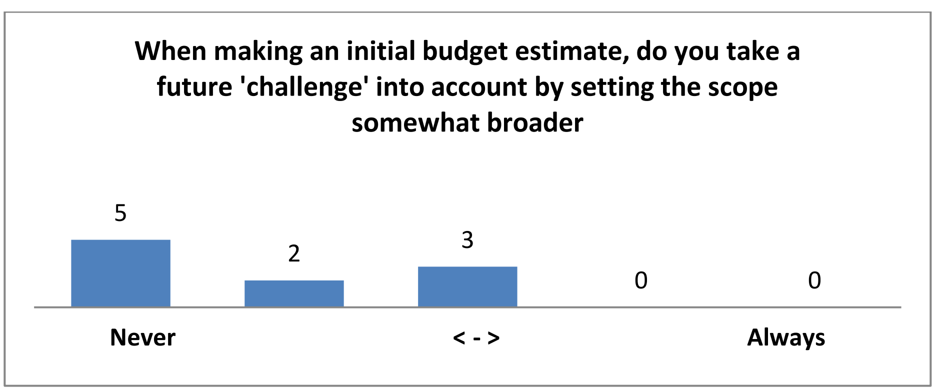





Does it occur that a budget is not fully spent
5
3
1
1
0
Never
< - >
Always


When estimating for a next year, do you take overruns/underruns in a past year into account
3
3
3
1
0
Not at all
< - >
Very


Do under or overruns have to be accounted for by you at the end of the year
6
2
0
1
1
Never
< - >
Always


When making an initial budget estimate, do you take a future 'challenge' into account by setting the scope somewhat broader
5
3
2
0
0
Never
< - >
Always

On the question how the maintenance managers are able to lower the budget all of the respondents answered that they did this by making the scope smaller. Three also stated that they did this by optimizing. Also 'challenging the contract party' was one of the answers given here.

On the open question how it could be that the budget was not fully spent, the following answers were given:

- "The item unforeseen is taken into account in an estimate. Whether there are unforeseen events or not determines if there will be budget left after project completion."
- "When there is budget left, most of the times adjacent maintenance works will be executed to fill the budget."
- "Activities under certain percentages are not as high as estimated."
- "Wrong quantities could be estimated."
- "Wrong estimate because scope was unclear at the time"