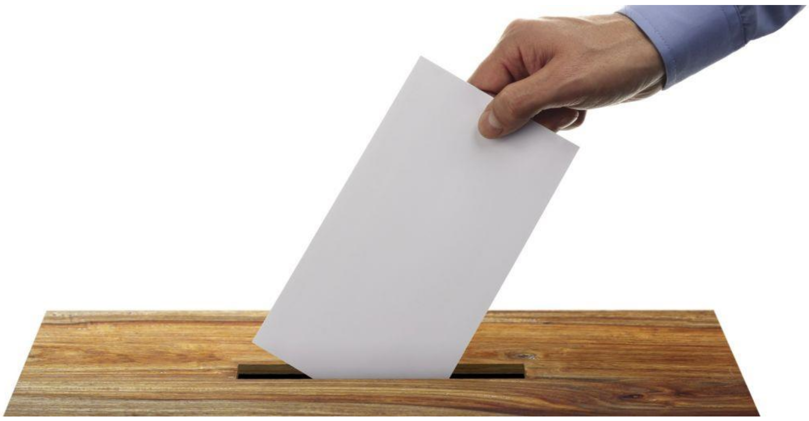
A more effective way of tendering

Insights into the principles of probabilistic cost estimation, to optimize tender phases of large complex infrastructural projects in a well-considered way



Master thesis project by:
C.J.T. Michielsen

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The most important questions of life are, for the most part, really only problems of probability.

—PIERRE SIMON DE LAPLACE, 1812

Colophon

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Personal information

Name:	C.J.T. (Thijs) Michielsen
Student number:	4190378
Telephone number:	+31 (0)6 13 68 50 31
Email:	thijs_michielsen@hotmail.com

Study program

University:	Delft University of Technology
Master:	Construction Management and Engineering (CME)
	Faculty of Civil Engineering and Geosciences
Address:	Stevinweg 1
	2628 CN Delft
Website:	http://www.citg.tudelft.nl

Graduation Committee

<u>TU Delft</u>

Chairman:	Prof. dr. ir. A. (Alexander) Verbraeck	
Supervisor:	Ir. L.P.I.M. (Leon) Hombergen	
Supervisor:	Dr. J.L.M. (Jos) Vrancken	(until mid-2016)
Supervisor	Dr. J.A. (Jan Anne) Annema	(since end-2016)

<u>Heijmans</u>

Supervisor:	Ir. H.W.N. (Harm) Heijmans	(until mid-2016)

Graduation organization	**(until mid-2016)**
Organization:	Heijmans N.V.
Department:	Heijmans Infra B.V.
Address:	Graafsebaan 67
	5248 JT Rosmalen
Telephone number:	+31 (0)73 543 5111
Website:	www.heijmans.nl

Preface

This document is the final product of the master thesis course. The master thesis is the final part of the master program Construction Management and Engineering at the Delft University of Technology. This thesis is the result of my graduation internship at construction company Heijmans and it concludes my study in the city of Delft. After finishing my bachelor study Civil Engineering in ‘s-Hertogenbosch I ended up here for a deepening in the legal, financial and management aspects of the construction industry.

Tender processes have always been a particular interest to me. To a large extent, it is in this phase of the construction process where the successfulness of new projects is determined. In this context, successful means: bringing in enough work for the contractor, and scoping projects which have sufficient profit margin and are competitive at the same time. Key work streams are ensuring the risks are properly identified and treated in a good way. Just a handful of important things that are determined in this phase of the construction process, will have major consequences if anything has been overlooked or managed in the wrong way. It can safely be said that the continued existence of companies depends of these tenders. A crucial phase for the entire business. Also through the development of new types of contracts and other types of projects, a tender will be created in a new and different way. Hereby, new and other work methods need to be developed in order to make the tendering process as optimal as possible.

I had the pleasure to carry out this research in the area of probabilistic cost estimating at Heijmans. This has been a great experience, where I had the possibility to meet experts in the field of cost estimating in the tender phases. At Heijmans I had the flexibility, the opportunities and support to bring this research to a success. I would like to thank Harm Heijmans for making this research possible and for the advice provided throughout the research process. Also, I would like to thank all colleagues and experts from Heijmans for making me feel welcome and for contributing to this research.

In addition to that I would like to thank my supervisors at the Delft University of Technology. Alexander Verbraeck; for sharing your expert knowledge in the field of probabilistic estimating, Jos Vrancken and Leon Hombergen for your input, enthusiasm and encouragements in all meetings. Also for giving the last push in the right direction. Thereby I want to thank Jan Anne Annema by joining the graduation committee.

Last but not least, I would like to thank my family, friends and Louise for all their support, their encouragements and all the great moments in the past years.

‘s-Hertogenbosch, January 2017.

Thijs Michielsen

Abbreviations

ARW	Aanbestedingsreglement Werken
BIM	Bouw Informatie Model
CROW	Dutch knowledge center for traffic, transport and infrastructure
D&C	Design and Construct
DACE	Dutch Association of Cost Engineers
DBFM	Design, Build, Finance, Maintain
MEAT	Most Economically Advantageous Tender
MIRT	Meerjarenprogramma Infrastructuur, Ruimte en Transport
PCE	Probabilistic cost estimating
PD	Probabilistic design
PRI	Project risico inventarisatie
RAW	Rationalisatie en Automatisering Grond-, Water- en Wegenbouw
RISMAN	RISicoMANagement; method for the quantification of risks
SSK	Standaardsystematiek voor kostenramingen
TNR	The New Rules
UAC	Uniform Administrative Conditions for the Execution of Works (traditional contracts)
UAC-IC	Uniform Administrative Conditions for the Execution of Works (integrated contacts)

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Summary

In the days when traditional RAW[1] contracts were still popular for large infrastructural projects, the entire engineering of a new project was made by the clients themselves. After the realization of the design, this design was put on the market and was contracted. Contractors who wish to enroll for this work made a cost calculation on the basis of this design and the given quantities, required to carry out this work. The contract costs of the several tenderers were handed over to the client, after which the work was awarded to the lowest bidder.

About a decade ago, integrated contracts were introduced after which this type of contract has increasingly gained popularity. Now, these types of contracts are fully integrated in the procurement phase of large complex infrastructural projects. The main difference between the traditional contracts is the design responsibility. By integrated projects, this is for the contractor. In the past, this responsibility was for the client. Nowadays the client only set up the functional requirements. Due to this shift, the contractor has obtained an additional design task besides providing costs. On the basis of functional requirements no factual cost calculation can be made. First, a design should be made out of which the design quantities can be extracted. With this data the cost experts can begin to calculate.

In a tender phase is it far from certain that the work can be acquired and realized. It is more likely that a tender will be lost because of the number of candidates competing. If this is the case, the destination of all the hard work – drawing up a tender bid- is the bin.

Until last year, the level of detail in the entire design of the work was high in order to calculate an accurate cost price. Because the design component is added into an integrated contract, the tender costs are rising. That is why Heijmans has identified the need to prepare their tenders in a more abstract way with the aim to reduce these tender costs, which are a direct load for the overhead of the company. So, the first win to reduce tender costs are costs that aren't spent in advance. At this time the market in the construction industry is saturated. It's a must to make a competitive bid.

The tender preparing should be approached in a more abstract way. This can be achieved through the method of probabilistic cost estimation and design. A method where the cost- and design parameters are imported by means of the allocation of bandwidths. With these parameters Monte Carlo simulations can be executed. After this the estimated project costs are shown in a probability distribution. For several reasons, Heijmans is in the process to work out tenders in this way. This change in the procurement process can't be implemented successfully without any difficulties. What this conceals is that this process of change management can't happen suddenly. In addition, there are multiple ways to implement the technical aspects in the probabilistic cost estimation and design process. At this moment, there is still room for improvement in the use of these technical aspects. This opportunity has led to the following research question in this research:

[1] Rationalization and Automation Grond-, Water- en Wegenbouw

> *How can the current method of probabilistic cost estimating and designing be complemented in such a way, that in a more effective way, within the entire width of the tender organization, the tender bid can be realized in a clear, systematic and objective way?*

The research question above is quite extended. By means of a literature review the process of probabilistic cost estimation and design was studied. Also, the method of probabilistic cost estimation and design within Heijmans was mapped. Research has been done into the gap between these two approaches, from the point of view from the available literature and the current practice. Interviews with cost experts and designers were conducted to learn more about this topic and possible problems within the organization.

First, the conclusion can be drawn that probabilistic cost estimation and design serves as a way to get the tender design and tender costs- required for draw up the tender bid- with less effort of personnel and in a shorter timeframe. That has been taken up in a recent accomplished tender. This also means less tender costs. The staff involved in working with this new approach, unanimously agreed that they should continue with this method of procurement. However, there are still pitfalls that hamper an optimal procurement process.

Secondly, two main reasons have come to light which provides resistance to the current application. The first cause is the change[2] of an ingrained process. This goes hand in hand with resistance. The other cause is about the technical part of this way of procurement. Here it is about the way to deal with the importation of probabilistic cost parameters for the execution of Monte Carlo analysis. The accuracy of the parameters are of great importance.

It has been found that the aforementioned gap between theory and practice mainly consists of the subjectivity[3] about the input of the parameters. At this time the bandwidths are primarily estimated on the basis of expert judgement. This is one of the reasons why the input has a certain degree of subjectivity. This is not the intention when the costs and the design will be estimated based on the probabilistic way. There are more reasons to be found. To illustrate one of them: the assessment of risks. With this new approach, risks are assessed explicitly instead of implicit. More about this in the research.

The main conclusion is that data should be collected to achieve more accurate results in the cost estimations in the future. A first attempt will be given. Subsequently, the correlations between the risks identified upfront should be mapped more thoroughly to get a better, more accurate approximation of the reality. There is a saying “garbage in is garbage out”. Therefore “garbage in” must be avoided as much as possible. When working with the wrong details in the program, the outcome is not usable.

The first recommendation that is given concerns the involvement of an expert in the field of statistics. This person needs to look, together with a number of cost experts, to the further objectification of the margins in the bandwidths in a responsible manner. These margins are related to the quantities and unit prices. Also, this statistician should look to the dependencies of

[2] The change of the deterministic approach to the probabilistic approach
[3] Expert judgement is also a type of objectivity, but it isn’t when it’s associated with statistics

the line items including the risks, whereby Monte Carlo simulations are carried out. Next – and a statistician will agree with that- a database should be set up to collect data. This need has been demonstrated, because without data no tender can be executed in a pure objective, probabilistic way. Databases are not only necessary to support the probabilistic based tenders, but also useful for information about the life span of components in maintenance contracts. Question that comes to mind are about the validity and viability of the collected data in the future, focusing on the data about unit prices. From a database, well-founded and objective conclusions can be drawn with respect to acceptable likelihoods.

To validate this new working method, comparisons of the elaboration of this probabilistic method are necessary. Lessons can be drawn from the discrepancies that occur. Too little is done on this at this moment. After a project is completed, the focus is mainly on the new work that is waiting. There is little attention and time for proper analysis. Perhaps it's a good idea to appoint a new employee in part- or full time employment for these analysis tasks. Because without meaningful comparisons and the absence of feedback, no good lessons can be drawn. Finally, more awareness of the concept of probabilistic cost estimation and design should be raised within the organization. Their usefulness must be transmitted explicitly in order to promote this way of working throughout the whole organization. By doing this, other staff members will be thinking about this relatively new method of procurement.

Samenvatting

In de tijd dat traditionele RAW contracten nog populair waren bij grote projecten, werd het gehele civieltechnische ontwerp van een nieuw te realiseren werk door de opdrachtgevers zelf geconstrueerd en uitgewerkt. Daarna werd dit ontwerp op de markt gezet. Opdrachtnemers die zich voor dit werk wilden inschrijven maakte aan de hand van een bestek een kostencalculatie door middel van het afprijzen van deze werkzaamheden. Vervolgens werd deze prijs overhandigd aan de opdrachtgever. Het werk werd gegund op basis van de laagste prijs.

Sinds een tiental jaar zijn geïntegreerde contracten ontstaan waarna deze contractvorm steeds meer aan populariteit heeft gewonnen. Bij de grote complexe infrastructurele werken kennen we niet meer anders. Het verschil met traditionele contracten is dat opdrachtgevers nu niet meer het ontwerp zelf op zich nemen; zij stellen alleen nog maar de functionele uitvraag op. Dat heeft betekent dat de ontwerpverantwoordelijkheid van de opdrachtgever is verschoven naar de opdrachtnemer. De opdrachtnemer heeft hierdoor naast het afprijzen en het realiseren van het werk een extra taak gekregen, namelijk ontwerpen.

Aan de hand van een functionele uitvraag kan een aannemer tijdens een tender geen prijs maken. Eerst moet er een ontwerp komen, waarna een prijs kan worden gecalculeerd. Maar in een tenderfase is het allesbehalve zeker dat het werk ook kan worden gerealiseerd. Het komt vaker voor dat een werk niet wordt verworven dan wel. Als er een werk niet wordt aangenomen kan de gedane arbeid –het maken van een compleet aanbiedingsontwerp- in de prullenmand. Tot op heden werd er tijdens een tender het ontwerp tot in hoog detailniveau uitgewerkt om een nauwkeurige kostprijs te kunnen calculeren. Tenderkosten lopen op in vergelijking met vroeger; toen hoefde er “alleen maar” worden afgeprijsd. Door die reden heeft Heijmans de noodzaak gezien om een tender op een abstractere manier in te vliegen met als doel het verlagen van deze kosten, die een directe last zijn voor de overhead van het bedrijf. En, wat er op voorhand niet is uitgegeven, hoeft er achteraf niet bij worden gerekend. Op dit moment is de markt in de bouwwereld verzadigd, dus het maken van een concurrerende prijs is een must.

Een oplossing voor het op een abstracte manier benaderen van een tender is probabilistisch ramen en ontwerpen. Een methode waarbij de ontwerp- en kostenparameters, door middel van het toekennen van bandbreedtes aan de meest verwachte waarde, worden ingevoerd. Monte Carlo simulaties worden uitgevoerd, waarna de geschatte projectkosten in een kansverdeling worden weergegeven. Heijmans is sinds enkele jaren stapsgewijs bezig met het benaderen van tenders op deze manier. Deze verandering van het aanbestedingsproces kan niet zomaar succesvol worden ingevoerd. Dit heeft tijd nodig. Daarbij is dit proces nog erg gevoelig voor verbeteringen. Dit heeft geleid tot de volgende onderzoeksvraag in dit onderzoek:

> *Hoe kan de huidige werkwijze van probabilistisch ramen en ontwerpen worden aangevuld op een zodanige wijze, dat er op een effectievere manier, binnen de gehele breedte van een tenderteam, het aanbiedingsontwerp op een duidelijke, systematische en objectieve manier kan worden gerealiseerd.*

De onderzoeksvraag is vrij breed gesteld. Door middel van een literatuuronderzoek is de algemene werkwijze van probabilistisch ramen en ontwerpen bekeken. Ook de werkwijze van probabilistisch ramen en ontwerpen binnen de organisatie is in kaart gebracht. Onderzoek is

gedaan naar de kloof tussen beide benaderingen en aan de hand van deze verschillen heeft het onderzoek zich verder gefocust op deze benaderingen. Naast beschikbare literatuur zijn er interviews gehouden met ontwerpers en kostendeskundigen om meer te weten te komen over dit onderwerp en mogelijke problemen.

Allereerst kan de conclusie worden getrokken dat op dit moment probabilistisch ramen en ontwerpen fungeert als middel om in een korter tijdsbestek en met minder inzet van personeel tot een aanbiedingsontwerp te komen. Dat is gebleken bij een recent gedane aanbesteding. Het personeel wat tot nu toe gewerkt heeft met deze nieuwe benadering is het er unaniem mee eens dat moet worden doorgegaan met deze manier van aanbesteden. Maar, er zijn nog genoeg valkuilen die een optimaal aanbestedingsproces in de weg staan.

Er zijn twee hoofdoorzaken aan het licht gekomen die de huidige toepassing weerstand bieden. Een oorzaak is de verandering van een ingebakken proces – deterministisch ramen wordt probabilistisch ramen- wat niet zonder slag of stoot gaat. Andere oorzaak gaat over het technische gedeelte. Hoe moet worden omgegaan met de invoer van probabilistische parameters voor het uitvoeren van Monte Carlo analyses. Het gaat hier dan over de nauwkeurigheid.

Gebleken is dat bovengenoemde kloof voornamelijk bestaat uit de subjectiviteit van invoerparameters. Op dit moment worden bandbreedtes voornamelijk ingeschat op basis van expert judgement waardoor de input een bepaalde mate van subjectiviteit heeft. Dit is vooral niet de bedoeling als er op een probabilistische manier -letterlijk vertaald: vanuit de waarschijnlijkheidsleer- kosten worden geraamd en het ontwerp wordt uitgedacht.

Er bestaat nog een gat tussen de theorie en de praktijk. Risico's worden met de nieuwe benadering expliciet gemaakt en er bestaat een mogelijkheid om risico's, die met elkaar verbonden zijn, met elkaar te koppelen. Dit is erg van belang om de actuele kosten van een bouwproject zo goed mogelijk te benaderen. Alleen hier wordt nog niet secuur mee omgegaan.

Hoofdconclusie is dat er data verzameld moet worden, zodat in de toekomst op een meer statistische wijze gekomen kan worden tot nauwkeurigere uitkomst van de kostenraming. Een aanzet voor het verzamelen van gegevens is gegeven. Vervolgens moeten de correlaties van risico's beter in kaart worden gebracht voor een betere benadering van de werkelijkheid. Er wordt ook wel eens gezegd: "garbage in, is garbage out". Die "garbage in" moet dus zo veel mogelijk worden beperkt of worden voorkomen. Want anders is het de ideale manier om jezelf, en ook het bedrijf, voor de gek te houden.

Aanbevelingen die worden gegeven zijn allereerst dat er een expert op het gebied van statistiek tezamen met de kostendeskundigen gaan kijken naar het verder objectiveren van de bandbreedtes van invoerparameters van hoeveelheden en eenheidsprijzen. Vervolgens moet een database worden opgericht voor het verzamelen van data. De noodzaak hiervan is aangetoond want zonder data kan een tender niet probabilistisch worden ingestoken. Vraag die hierbij komt kijken gaat over de geldigheid en houdbaarheid van de verzamelde (kosten)data. En wanneer is er genoeg data verzameld om voor het eerst statistiek los te laten op deze data om vervolgens betrouwbare uitspraken te kunnen doen op basis van deze data. Ook moeten de gemaakte modellen die op voorhand worden gemaakt vergeleken worden met de uiteindelijk gemaakte kosten om lering te trekken uit verschillen die optreden. Zonder vergelijking kan er namelijk geen lering worden getrokken uit gedane projecten. Tenslotte moet er binnen de organisatie meer bekendheid worden gegeven aan het begrip probabilistisch ramen en ontwerpen en het nut hiervan moet nadrukkelijk worden overgedragen, zodat deze manier van werken binnen de gehele breedte van de organisatie bekend wordt en overige personeelsleden gaan na- en meedenken over deze relatief nieuwe manier van aanbesteden.

1. Introduction

The conducted research is introduced by a brief explanation of the graduation company, the subject, the motivation of this research which are required for the preparation of the problem definition with the accompanying research questions. The research methodology is explained and the thesis outline is given. It serves as guideline for the entire research.

1.1.Heijmans Infra B.V.

Heijmans is a leading Dutch full-service construction and property development company which was established in 1923. Heijmans develops, designs, realizes, manages and maintains residential and business, recreational, traffic and transport projects. With approximately 7.000 employees and an annual turnover of EURO 2.0 billion in 2015, it's one of the major players in the Dutch construction industry. The company has been listed on the stock exchange since 1993 and has a country-oriented company structure. In addition to having outlets on its home market in The Netherlands, it also operates in Belgium, Germany and the United Kingdom (Heijmans 2005) (Heijmans 2013).

Heijmans is divided into four sectors as shown in the organizational chart below: Vastgoed, Woningbouw, Utiliteit and Infra. The latter sector comprises the former sectors Wegen, Civiel and Integrale Projecten and is joined together to one sector Infra since June 2015.

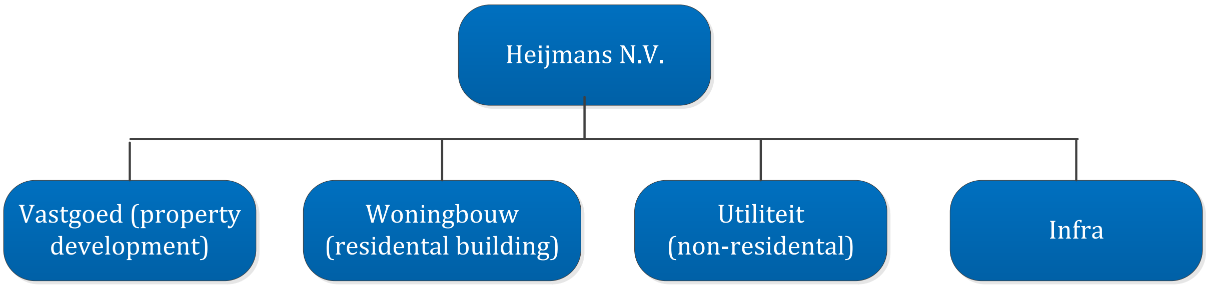

Figure 1: organization chart Heijmans (own figure)

Heijmans Infra focuses on providing, designing, constructing and maintaining complex integrated projects. As a result of combining several disciplines, Heijmans can realize projects from concept and design to maintenance and control. It comprises the following four departments, see Figure 2 on next page.

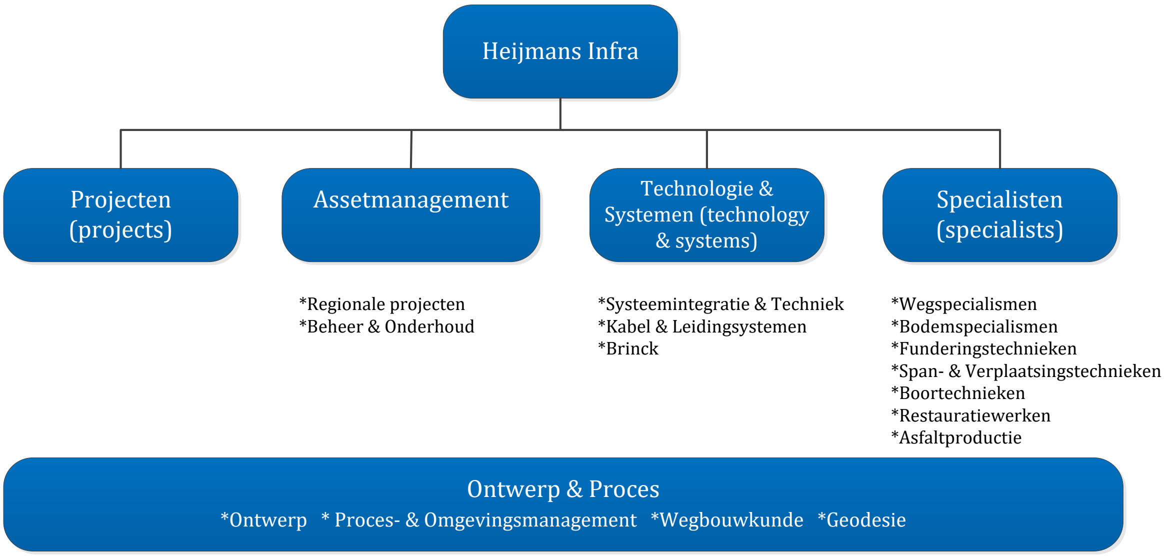

Figure 2: organizational chart Heijmans Infra (own figure)

The research is conducted for the department *Ontwerp & Proces*. This department develops and realizes among others the design of large integrated projects. Their central point is the delivering of tailor-made and innovative solutions. Hence the question to review the current procurement process to try to make this activity more effective and innovative. In the following paragraph the need for this is explained.

1.2. Introduction about the subject

The research is about the new process of a more abstract tender procedure for realizing tender bids of complex infrastructure projects in The Netherlands. In a tender bid a coarse plan is drawn up which is the basis of a cost estimation for a work. All critical aspects (financial, legal and technical) should be recognized and coordinated. First there will be a brief introduction of tender procedures. The relationship is explained between the involved parties and the major changes in the Dutch construction industry as well.

Since time immemorial, the civil engineering industry is a conservative industry with practically the same tendering procedures for many years. Until a couple of years ago, experiences and practices developed over time, have hardly changed after publication of the RAW-systematics in the seventies.

Major clients in this industry are authorities such as Rijkswaterstaat[4], provinces and water boards. The RAW specifications give a highly detailed description of the what and how had to be built by executive contractors. This traditional type of contact is characterized mainly by the fact that the executive contactors are approached after elaboration of the entire design. Because of the design responsibility of the client, they prescribed the design in all its detail in order to eliminate problems during the execution process. Amongst others, UAC[5] are used for this purpose. It's a document which governs the contractual relationship between the client and the executive party. In this way there is a strict separation between design and execution. This was

[4] Department of Waterways and Public Works
[5] Uniform Administrative Conditions for the Execution of Works

the standard procurement procedure for governmental authorities for many years. Because the project is specified by the client in advance, projects were awarded based on the lowest contract price.

Nevertheless, a new wind of change was blowing. A new way of procurement was necessary last decade. Fundamental causes were the conclusions of the "Parlementaire Enquête Bouwnijverheid", the new policy "andere overheid" and the target of cabinets Balkenende I and II in reducing the number of officials (Rijkswaterstaat 2007). Because the competition was only about the lowest price -and there are always contractors yearning for work- projects were accepted even below cost price. Moreover, the construction process becomes more complicated by stricter Dutch and European legislations and more and more parties become involved in increasingly complex, integrated works. Because of the retreating Dutch government and the need for a clear separation of risks by the executing party (BouwWeb 2004), integrated contracts have been developed.

These forms of contract only describe a desired end result, usually in the form of functional requirements produced by the client. Eventually, the functional requirements could be complemented by means of a reference design. It's up to the market to convert these requirements into an execution design after which the work can be executed.

There are several types of integrated contracts. With the Design & Build-like types of contracts, the executive parties take responsibility for the execution and the design. There are possibilities to expand that kind of contracts including maintenance, financing and operation. Now, all these tasks are often housed in one contract to ensure an integrated approach. This change requires different skills and competencies of the executive parties. They are no longer responsible for the execution, but also for the design and possibly other phases after the construction. This means there should be handled in a different way, from the tender phase to the execution. An integrated contract also leads to an overall accountability. For that reason a suitable name for an executive party is contractor.

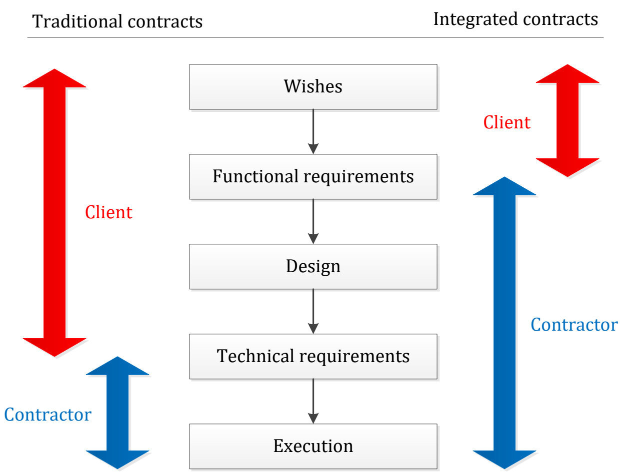

Figure 3: shift in tasks/responsibilities (own figure)

Nowadays, new constructed large complex infrastructural projects would be granted with this new forms of contracting. By trial and error, clients and contractors already have quite some experience of working with this new tender procedure.

One of the major changes for the contractor is the higher degree of complexity in tender phases. In addition to estimate the total price of a project, an entire tender design should be drawn up for the purpose of cost estimating. This requires more effort and, hence, more money of the contractor. As a result, tender costs of this non profitable process have increased considerably. These tender costs are costs incurred in activities which give no guarantee for the return of this investments by winning these tenders.

There are possibilities that can increase its efficiency in the area of tender preparation by means of more standardizing of the process and make them more uniform, introducing new tools and/or redesigning its processes. This research is about the objectification and the further optimization of a relatively new, more abstract method for Heijmans Infra, known as probabilistic cost estimating and designing.

1.3. Motivation of the research

Contractors working in the Dutch Civil Engineering sector are faced with increasingly higher tender costs for making well-thought-out tender bids of large complex infrastructural projects. It's of all times to make costs for the acquisition of new projects. But with the current abovementioned changes in the construction industry more effort is required than before. This applies to contracts where the design responsibility rests with the contractor, but especially if the financing and maintenance part have been added. This is something completely different than only make a price. Moreover, there should be built in a more sustainable and safer way with less financial resources. In addition, the newly acquired projects are becoming more complex and with the introduction of integrated contracts, the contractors are taking on ever more responsibility. Also the profit margins are in question; tender procedures become even more difficult.

At this time, tender bids of large complex infrastructural projects are mainly estimated and designed with the traditional, deterministic method. What exactly is meant by the deterministic method: the project is designed in the highest level of detail after which a price can be estimated on the basis of this design. That happens by multiplying single quantities and single unit prices belonging to a line item of, for example, materials or man hours. The sum of the costs of all line items is the total cost estimation. The question could be asked whether this familiar, outdated and time-consuming method of customization is working effectively enough nowadays.

This question also arises for Heijmans Infra. Every year they spent millions of euros on tender costs. This is money that has been spent on activities of which it's not certain whether this investment returns by winning these tenders. Depending on the number of competitors, the average hit rate of tenders of large complex infrastructural projects (>€15 million) is somewhere between 20-30%, depending on the size of the works and the tender procedures. Hence, Heijmans Infra have seen the necessity to organize their tender process in a more effective way. The tender costs in comparison with the total value of the integrated contracts are often no longer in proportion. Depending on the type of an integrated contract and project type, the tender costs are about 1-2% of the total contract price. And if contact prices are hundreds of millions... This was significantly lower when the RAW contracts were common. The first profits are costs that can be saved at the front side.

To reduce tender costs there can be chosen to work out a tender in a more abstract way in comparison with the deterministic method. This more abstract way could be the probabilistic approach. Probabilistic cost estimating relates to how to deal with unit prices of the design quantities, which are determined during the probabilistic design process. Different goals can be achieved with this approach. This can be: saving time and therefore money, so that costs can be saved when there will be participated in the same number of tenders. Of course there can be chosen to participate in more tenders with the same tender budget, in order to acquire more projects. Other goal can be, and perhaps it can automatically combine with the abovementioned goal: improve the reliability of the cost estimates whereby the success rate can be increased.

This can be achieved by working out the unit prices and the design quantities in a lower level of detail. Within the organization, it was agreed that they will apply this methodology by large projects from January, 2014. The aim is to participate in more tenders with the same budget. Or, to participate in the same numbers of tenders with less budget.

Heijmans is an innovative and dynamic company. They anticipate in the changing circumstances in the market to be a distinctive contractor and especially to continue that in the future. Tendering, based on the probabilistic method, both inside and outside the company, is still a relatively new approach. Because of that, a research about the process and the application of the probabilistic approach within the organization will be conducted.

Problem definition

- The application of probabilistic cost estimation and design within the whole width of a tender organization is not functioning as intended. Because the little experience with that approach, it's likely that more effort is requested in the realization of tender bids. These efforts shall ensure that unnecessary costs are incurred in making tender bids. To optimize the tender process, six problem statements are formulated. These are shown in the box below.

- Lack of a clear concept of "probabilistic estimation and design" within the organizational context.
- At this moment, the current probabilistic tendering method does not work as a tool to determine quickly where a project's focus should be, when starting a tender.
- Subjectivity in determining bandwidths in quantities and prices.
- A static process in the determination of levels of detail for the design quantities, because of the lack of communication between designers- cost estimators.
- Partial lack of a standard method within Heijmans Infra
- Lack of clarity about the interaction between designer and cost estimator.

1.4. Scope of the research

The problem definition as defined above can lead to different types of investigations. The subject is very complex and has an enormous scope, so it offers the possibility for decades of research which is not the purpose. It's therefore important to limit the scope. By doing so, the direction of this research becomes clear and feasible. Below there are five key terms given to clarify the scope.

Probabilistic design
"Probabilistic design" has multiple meanings. With probabilistic design, as studied in this research, design quantities are linked to the project information in the early stages of a project. In all quantities bandwidths are included with the consequence that designers are able to give dimensions of objects or components with minimal design effort (Heijmans 2014).

Another commonly used meaning of probabilistic design is the approach of the technical dimensions of structures. This is a method to design structures using the principles of probability, with the result that constructions going to meet a certain safety standard, taking explicitly into account the risks and uncertainties. For example, if a dike will be engineered, a safety standard should be met. The dike will be dimensioned on the basis of that standard, a certain probability of failure. That is not the case here.

Probabilistic cost estimation
Probabilistic cost estimation implies that calculators, based on knowledge, key figures and unit prices, determine the cost price of objects or components (Heijmans 2014). This happens by means of simulating the most probable value with corresponding bandwidths per line item.

Probabilistic cost estimation and design
Probabilistic cost estimating is closely connected with probabilistic design. There is an interaction between the design- and cost estimation departments during a tender.

Type of contract and minimum contract price
This research is based on tenders of complex infrastructural projects, performed with D&C or DBFM contracts. Hereby, the contractor is responsible for the design and execution on the new to build infrastructure. The client draws up a functionally specified program of requirements and so the contractor gets a solution space to apply innovations in the design and execution. Heijmans Infra works almost exclusively with this two type of contracts in projects with a minimum contract price of 15 million euros. This research mainly concerns the Design & Construction parts (also called Design and Build) of the contracts. Obviously the approach of the DB parts of the two abovementioned forms of contract are different, because of the increased responsibilities for the contractor in DBFM contracts. In a D&C contract, the project will be completed after completion of the construction. After that, the contractor finishes his work after handover. This is not the case in a DBFM contract. For the contractor the finance and maintenance part is defined for sometimes 30 years or longer, but usually between 15 and 30 years. By having investors, the financing part is more complex than a D&C contract. Suddenly, the interest rates are very important and responsibilities become larger. Also the design will be optimized for the maintenance period, which also requires a different approach. In this research the FM part is not included. Thus conclusions are entirely valid for D&C contracts and for a large part for DBFM contracts.

Optimization
Optimization, as intended in the subtitle and in a moment in the research question, is the term that will be used in this research to improve the tender process. A number of issues will be solved which makes this process more streamlined. Additions to the current method of probabilistic estimating and designing will be given which are assessed within the organization. The main issues here will be described in the research objective, as shown in next paragraph.

The focus is on the content side of the tender process. However, it does not mention the conditions within the organization to promote the further application of probabilistic cost estimation and design. But, if an addition to the current method is described, it is useful to consider briefly the factors which are necessary for a successful application of this new way of working.

1.5. Research objective

The above-mentioned problem has led to the following research objective:

> Reduce subjectivity within the current method of probabilistic cost estimation and design in tenders of large complex infrastructural projects as used by Heijmans. By reducing the subjectivity, the tender process will be improved. This provides a more conscious and more objective tender bid within a shorter time period.

with the aim:

- to determine at what level of detail the (sub)components will be elaborated in the early stage of a project. Also to reach the core more quickly by an early detection of items with large uncertainties
- to create a better understanding of the definition probabilistic cost estimating and design
- to look at factors that resist the implementation in the organization
- to achieve a more objective cost price determination and contingency reserve in the tender design
- how to deal with the different bandwidths per object

1.6.Research questions

To answer the main research question, sub-questions are drawn up. The path towards the answer of the main research question is based on the answers of these sub-questions. Each question covers a chapter in this research.

1.6.1. Main research question

The descriptive research question that has been drawn up is:

> *How can the current method of probabilistic cost estimating and designing be complemented in such a way, that in a more effective way, within the entire width of the tender organization, the tender bid can be realized in a clear, systematic and objective way?*

1.6.2. Research sub-questions

Abovementioned research question is supported by the next research sub-questions:

SQ 1: What is the current practice of clients regarding probabilistic cost estimation and design?
SQ 2: What is the exact meaning of the definitions probabilistic estimation and design and what does it mean?
SQ 3: What are the factors that obstruct a successful implementation of probabilistic cost estimation and design?
SQ 4: What is the current practice regarding probabilistic tendering within Heijmans Infra, and what is the final desired situation?
SQ 5: Which issues in the probabilistic procurement process can be further optimized?

1.7. Research methodology

In this section the research procedure will be described, to specify how to carry out this research. To answer the research question and sub-questions, it is important that the research is divided into different steps in the different phases of the research. The figure below provides a global impression of the research plan, after which the steps will be described in more detail. The results of every phase of the report serve as input for a new phase, whereby the literature survey and analysis phase are conducted in parallel.

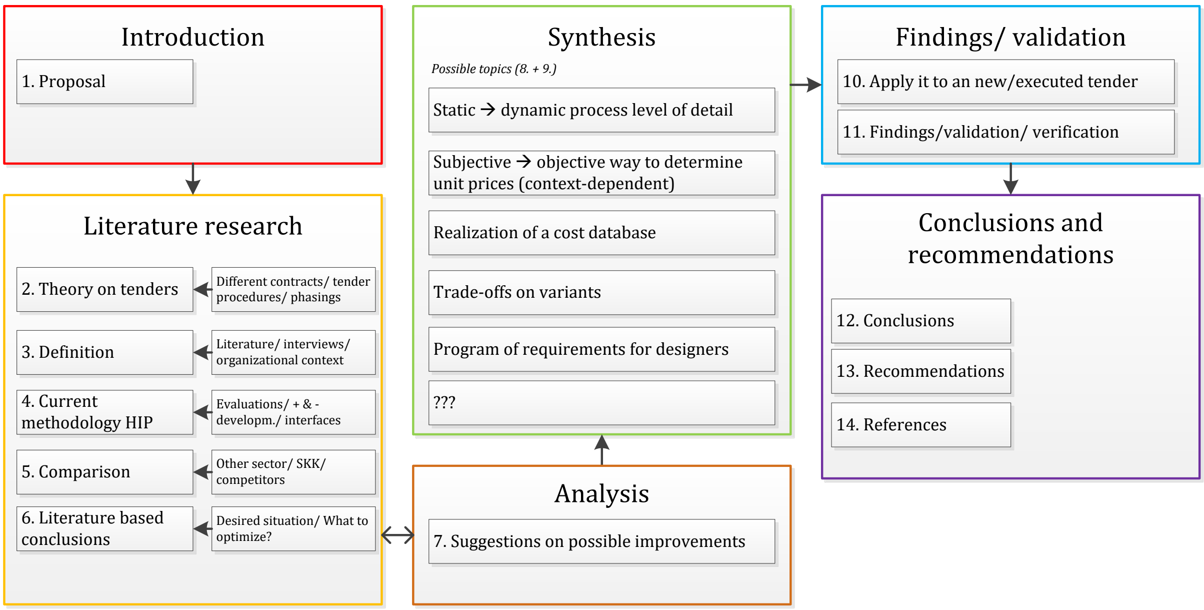

Figure 4: research methodology (own figure)

Step 0: finalizing thesis proposal

The research proposal should be approved after consultation with the entire graduation committee. Of course, the final proposal is sensitive to small changes such as the research question or an item in the synthesis phase. But the path that is being taken should be clear to everyone, and should be such that this master thesis may contain enough content, depth and scientific character.

Step 1: introduction
The proposal is part of the introduction. The subject, motivation, problem statement and research objective is explained and also provides an overview of the report.

Step 2: literature research
Subsequently a start is made with the literature research. First of all, the general tender procedure belonging to integrated contracts is explained. In literature is searched for general tender procedures after which the current tender procedure of Heijmans Infra is described. Aspects such as go/no go decisions and the identifying of risks are explained.

After that, it should be clear what the terms probabilistic cost estimating and designing exactly mean. By conducting some exploratory interviews with division managers and experts from different disciplines within Heijmans, it has become apparent that everyone has their own understanding and thoughts about this tender method. It is also questionable whether the word probabilistic is the right word for this way of working.

One of the outcomes of the interviews indicates that sometimes a probabilistic approach is considered as a deterministic approach. Also, there are various practices for the use of the probabilistic approach. This can create confusion. For that reason it is necessary to draw up an unequivocal definition of probabilistic estimation and design within the organizational context.

Alongside clarifying these two definitions, the current method of procurement within Heijmans Infra is investigated as a baseline measurement. The question is to what extent the probabilistic tendering method is used at this moment. Because it is impossible to improve a process if the current state of affairs is unknown. Bottlenecks should come to light by, among other, the evaluation of two tenders that have been carried out recently with help from the probabilistic approach. These are the tenders -won by Heijmans- for the projects: Ontsluiting Bio Science Park (OBSP) Leiden and the Highway A4 Delft- Schiedam. The basic principles of the probabilistic approach are used here for the first time. Available data will be analyzed and interviews will be conducted. Topics are:

- **Tender package**. What's already presented in this tender package? What are important decisions and at what times are these important decisions taken? How to determine a suitable level of detail for a certain (sub)component? In what way are the bandwidths underpinned? How to start?
- **Gant Chart**. What approach is being taken with activities on critical and non-critical path? Related to risks and the bandwidths.
- **Distinctive character**. What are the methods to determine the distinctive character of a tender in an early stage of a tender?
- **Risky line items**. How to detect these risky line items in the tender stage, and what finally happens with these items in the execution phase.
- **Other parameters**. These will be drawn up during the literature research.

Subsequently, this method will be compared with the SSK[6]. It is a document, drawn up by the CROW[7], that comprises the framework for project division, the standard investment model for

[6] Standard systematics for cost estimations in the construction industry

estimating costs and the theory dealing with risks and uncertainties in the estimate. In other words, a standard system for cost estimators. It also focuses on the subject probabilistic estimating. The SSK is primarily used by clients like Rijkswaterstaat for making their initial estimate, but it can also be used by contractors as stated in the systematics. Within the organization, this system is not used, or only a part. So the question is: why is this system not fully or partly applied? Why are certain principles of the SSK applied or not? The real reasons behind this will come to light and will be described in more detail. It will be investigated whether the cost estimation method of Heijmans and the SSK can reinforce each other.

After that, the current estimation method and the estimation method in the SSK theory are considered and the literature research can be continued on the next subject. The next subject is about how other construction companies within Bouwend Nederland[8] or other comparable industries deal with probabilistic cost estimation and design. There will be briefly looked in the width in order to look at similarities and differences. For example, the ICT sector is a progressive sector that uses different levels of abstraction in tender procedures. They use a specific ranking system, called "function points analysis", to determine the level of abstraction. How do they work with this ranking system? Can Heijmans get inspired by other sectors or fellow competitors?

During the literature research, information will be acquired by means of articles in professional journals, internal documents, tenders that have already been conducted, graduation committee members, interviews with experts and scientific articles.

This literature research pave the way to determine the most effective way to optimize the tender process. That will be examined in the analysis phase.

Step 3: analysis
The main conclusions of the literature research are the starting point for the analysis chapter. Here the best way to optimize the tender process will be treated. Suggestions and recommendations on possible improvements in the tender process will be given. At the same time, a careful consideration of the most effective adjustment will be further elaborated and developed. Including by arranging a workshop with experienced employees. And from there the decision is made, together with the midterm meeting with the entire graduation committee, which topic will be selected for the synthesis phase. Is it about a method to make a tender design with fewer employees of is it about making a competitive, reliable offer.

With the words "most effective" is meant a practicable improvement that fits within the given timeframe. Of course the goal is to make the tender process of Heijmans more unequivocal and effective. It serves as the run up for the synthesis phase.

[7] Dutch knowledge center for traffic, transport and infrastructure
[8] Dutch trade association for companies in the construction- and infrastructure sector

Step 4: synthesis
In this phase of the thesis report, this "most effective" addition will be further elaborated. At this moment the start is made with the literature research, therefore, it's not entirely clear how this chapter will be organized. However, there are already some ideas how to fill in this chapter.

Possible ideas are:

- Realization of a chart/ guide/ method to determine unit prices in a more objective way. When is a cost estimation of a certain component based on the skills and know-how of a cost estimator (how will they get their data?), and when the decision is made to approach the market? What are the differences in the bandwidths with and without the involvement of the market.
- Create a more dynamic design process. In the current design process of Heijmans, the levels of detail of (sub)components are fixed at the beginning of a tender. During the tender, no changes are applied to these levels of detail. These levels are determined in advance and are evaluated afterwards, but in the interim period, no moments of evaluation are inserted. When applying this intermediate evaluation steps, the tender process can be further refined by up- of downscaling the level of detail. In that way several evaluation moments will arise with the entire tender organization to fine tune and optimize this process.
- A better underpinning of the bandwidths with design quantities and/or unit prices. At this moment, this is probably done in a too subjective way. Of course it is not said that this is a wrong method, but to increase the uniformity it is necessary to make this estimations more objective. For example with the help of reference projects or a cost database (is a cost database already there?). There should be taken into account external factors like environmental factors. For example the steel prices on the world market. How is this world market price fluctuating at this moment, what is the trend for the coming years? How does this trend affect the bandwidths?
- Tender costs will be estimated on the basis of the design. Calculators are largely dependent on the designers to make their estimations. But, is there some kind of Program of Requirements from the calculation perspective?

Step 5: findings/ validation
The results of the synthesis phase will be verified with the aid of the two tenders OBSP Leiden and A4 Schiedam- Delft (or a fictive tender, or with a tender that runs during the graduation period). These projects will be analyzed again and the tool(s), designed in the synthesis phase, are used. Or, when possible, a new tender can be used for this purpose. The end result will be also verified also by means of a workshop. From this point an advice is produced. Findings from the analysis phase that are not covered in the synthesis phase because of the research time, will be put in the recommendations.

Step 6: conclusions and recommendations
This is a concluding chapter, it provides the most important achievements and findings of the research. In addition, recommendations are given for further research.

1.8. Thesis outline

Structure of the report consists of the following main chapters: introduction, literature research, analysis, synthesis and conclusions.

Introduction	Literature research			Analysis				Synthesis	Findings/ conclusion		
Chapter 1	Chapter 2	Chapter 3	Chapter 4	Chapter 5	Chapter 6	Chapter 7	Chapter 8	Chapter 9	Chapter 10	Chapter 11	Chapter 12
Introduction	The procurement phase in the construction process	What is probabilistic design and cost estimation exactly?	Literature based conclusions	Clients and the probabilistic approach	Definition of probabilistic cost estimation and design	Implementation factors	Methodology of the organization	Possible improvements	Conclusions and recommendations	References	Appendices

Figure 5: report overview (own figure)

2. The procurement phase in the construction process

In this chapter the construction process of large complex infrastructural projects will be explored, primarily in the procurement phase. That is because the design of the tender and the estimation of costs take place in this phase with the aim of realizing a tender bid.

Initially a number of definitions are explained, after which an overview of the different phases of the traditional and integral construction process will be given. The effects of the developments of last decades, as briefly described in the introduction, are further explored. All this to determine what a tender phase includes and how probabilistic cost estimation and design is interwoven in this phase.

2.1. Definitions

Procurement

There is often confusion about the terms tendering and procurement. They are sometimes used interchangeably while it does not mean the same. Hence, it is of interest to understand these definitions properly.

Procurement is the name of the entire set of activities, resulting in the acquisition of works, goods and/or services. It's a strategy to satisfy client's development and/or operational needs (Masrom 2012). A procedure whereby the client draw up the contract with the determination of, among other, the type of contract, conditions and terms with the objective to find a contractor.

Tender

When the clients have specified their requirements, the bidding in the tender process will be started. Tendering is the name of the formal procedure whereby interested companies -the potential contractors- are preparing their bids to meet these requirements for a possible business relationship. The company that has been successful in the tender process will sign the contract and will execute the work. A tender phase is also called the acquisition phase, whereby the tender phase is part of the procurement process.

Tender bid

A coarse plan which is the basis of a cost estimation for a large project. All critical aspects (financial, legal and technical) should be recognized and coordinated. Here the level of elaboration should be agreed in advance, which can vary by each project. Common ground between different disciplines must be assessed and possible alternatives will be elaborated on a sketch level. Further, optimizations are recognized whereby cost efficient variants will be elaborated, dependent on the financial impact. During the preparation of a tender bid, building details are not included, unless these costs are decisive. For instance, the rebar detailing in a long tunnel. Multiple disciplines are working on the design, which make it a multidisciplinary process. Key words that describe this plan: price determination, scope definition, coarse geometric design, explore and elaborate prince determination optimizations, coordinate interfaces in broad terms and manage them, multidisciplinary and conditioning activities (Heijmans and Simons 2012).

Large complex infrastructural projects
This research will focus on the procurement of large complex infrastructural projects. First the definition of *"large complex infrastructural projects"* will be explained in more detail.

Large
The word large is about the size of projects. In this research, large means a project with a minimum contract price of EUR 15 million. Infrastructural projects with a contract price around that minimum budget are covered by the department Integrale Projecten. For that kind of projects, Integrale Projecten steers the necessary interplay between the different specialisms, departments and project teams.

In literature, several ranges are given of the word large with regard to (complex) infrastructural projects. Some definitions of the word large are given. But in this case, the word large it is not about "billion dollars".

- "By large infrastructure projects I here mean the most expensive infrastructure projects that are built in the world today, typically at costs per project from around a hundred million to several billion dollars". (Flyvbjerg 2005)

- "The definition of large tends to be settled as a project for which the original budget exceeds US$1bn". (Holmes 2014)

Complex
The definition of the word complex is not univocal in literature. A certain meaning is not given and cannot be described by a single rule. But it is common ground that complex is more than just a "large project". However, characteristics of complex projects can be provided to clarify this notion.

Table 1: characteristics of complex projects (Hertogh 1995)

Major impact on the environment	Many actors
Static provision in a dynamic environment	Unequal distribution of joys and burdens
The project does not stand on its own	No linear or reversible process
Multiple targets	Long lead time
Complementary perspectives	Politically sensitive

Infrastructural
Infrastructure is the framework of society. Ports, roads, airports, railways, water supplies, energy generation, telecoms networks, hospitals and schools are not optional. They are essential in the daily functioning of society. Infrastructure comes in two flavors:

- Social: facilities that are dependent on population size and distribution, including hospitals, schools, intracity roads, sporting arenas, water supplies, prisons, food distribution, waste disposal and sewerage systems.
- Economic: the projects that facilitate our economic activity, including intercity roads, bridges, railways, airports, ports, energy generation and distribution, and telecoms (Holmes 2014).

There is sometimes no strict separation possible between the aforementioned subdivision. For example, roads are social and economic. Heijmans Infra focuses on the economic part of the infrastructural works.

<u>*Project*</u>
There are several definitions of projects available in literature. One of the definitions which is frequently seen:

"A project is an organization of people dedicated to a specific purpose or objective. Projects generally involve large, expensive, unique, or high risk undertakings which have to be completed by a certain date, for a certain amount of money, with some expected level of performance. At a minimum, all projects need to have well defined objectives and sufficient resources to carry out all the required tasks" (Steiner 1969).

2.2. Traditional construction process

During the tender process, probabilistic design and cost estimation will be applied on different moments. In first instance to get an idea of the order of magnitude until a final cost estimate is obtained.

Firstly, a generally accepted phasing of the construction process is given belonging to the traditional Building Contract (UAC 2012 conditions), after which the phasing of tender phases in integrated contracts (UAC-IC 2005[9] conditions) is looked at.

The term traditional construction process in this case means projects granted according the UAC 2012 with the help of the RAW systematics and the TNR 2011[10]. Until recently, most of the large works were contracted with this traditional form of contract. As described in the introduction, the characteristic is the strict separation of responsibilities in the design- and execution phase. It's known as the classic triangular relationship between client, advisor(s) and contractor(s) for the execution of the design. Hereby, the contracting authority may choose to execute the project management by a third consulting party. However, it can also be done by the organization itself. A schematic view is shown in Figure 6.

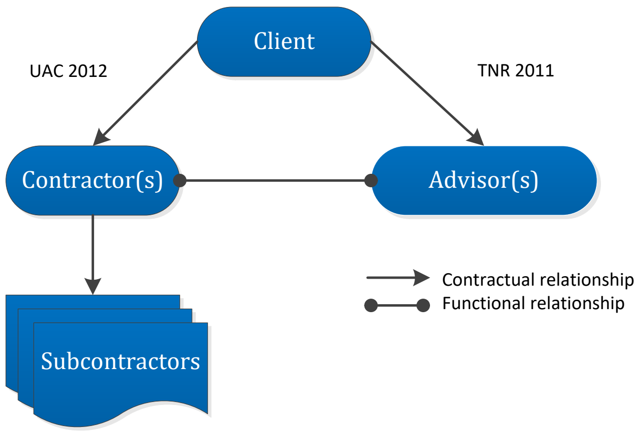

Figure 6: traditional construction model (Bruggeman, Chao-Duivis et al. 2010)

[9] Uniform Administrative Conditions- Integrated Contracts for the Execution of Works
[10] The New Rules 2011

There are also other types of traditional contracts. For example: cost plus contracts, framework contracts or job descriptions. Due to several reasons they are better suitable for smaller, reoccurring projects. Also, the UAC 2012/RAW follows the national and European legislation and for that reason it was the standard practice for large projects. There is still a form of a traditional contract that looks like a form of integrated contact: the building team. In this collaborative arrangement the building team consists of three parties: employers, designers and construction supervisors. All these parties are responsible for the development and realization of the project.

Several different sources describe more or less the same phases in the construction process (NEN-2634 2002, Bosch-Rekveldt and Hertogh 2014). All of them use the same subdivision, sometimes in a different wording. The phasing can be divided into five main roles, namely the program-, preparation-, realization-, operation- and demolition role. The first three roles can be further subdivided as seen in Figure 7[11].

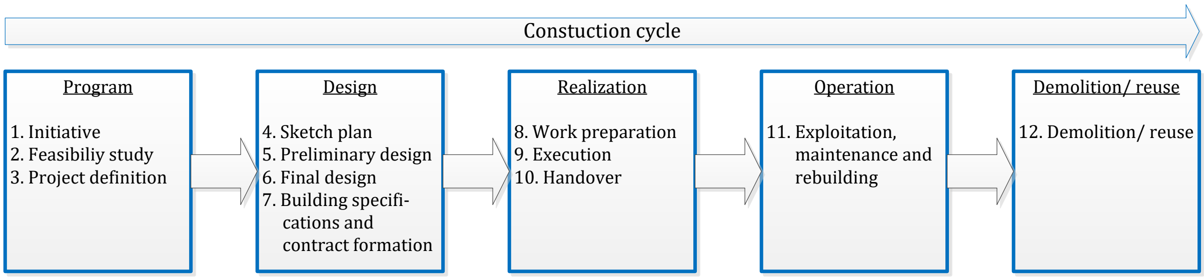

Figure 7: building process (own figure)

The five main roles will be further explored below:

1. Program: in this step there is a need for change in the existing situation. A feasibility study will be conducted to the purpose and necessity. If it is proved there is functional, spatial, organizational, technical and financial framework, the project will be defined in a list of requirements.
2. Design: during this step, the wishes and requirements of the client will be converted into a design. Often it starts with some sketches during a variant study, after which the design will be further detailed into a final design. After granting of authorizations and setting up the building specifications, the project can be tendered with the aid of RAW-specifications. The executive party with the lowest bid get the work.
3. Realization: the realization starts with the preparation of the project after which the construction of the project takes place. This phase ends with the transfer to the client.
4. Operation: after commissioning the exploitation phase takes place. This phase covers the longest period of the construction cycle.
5. Demolition/ reuse: if the construction no longer meets the technical or functional requirements, it will be demolished or reused.

It must be underlined that this construction process is undergoing changes because of the introduction of integrated contracts. For example, conversations should be held between the

[11] Heijmans generally distinguish four phases in the elaboration of the design: *aanbiedingsontwerp* (AO) and/or Preliminary Design (VO), Final Design (DO), Execution Design (UO), As-Built (AB).

contractor and client about the entire design of the project and the risks. Also the contract formation takes place in an earlier phase of the building process. This is done, depending on the demand of the client, in the phase around the preliminary design. Also the interweaving of the phasing –spatial procedures parallel to the design- plays a role (Bosch-Rekveldt and Hertogh 2014). For contracts with a including maintain part, the handover takes place after a certain period of time. These kind of integrated forms of contacts, which are the issue here, are extensively explained in next paragraph.

2.3. Integrated construction process

The term integrated contract refers to the fact that design and execution are in hands of a single party in relation to the employer (Bruggeman, Chao-Duivis et al. 2013). Due to various reasons as mentioned earlier, integrated contracts have made its mark last decade. Aforementioned factors in traditional contracts resulted in: high failure costs, not an optimal use of possibilities and opportunities, unsustainable solutions and underserved users because of the delivered price/quality ratio. For that reason the construction sector has been looking for other ways of cooperation over the past years, which can reduce these problems. An array of new forms of collaboration is originated. As an example: alliance agreements, Public Private Partnerships and integrated contracts (Hermans 2012).

The scope of this research is limited to integrated D&C contracts. This is, together with DBFM contracts, the most common way of contracting large complex infrastructural projects by Rijkswaterstaat. There are also some variations within these two forms of contracting, resulting in a slightly different approach in making the design and the cost estimation. Below, the differences will be explained briefly.

2.3.1. Differences in D&C and DBFM contracts

In The Netherlands, D&C is the common name for a Design & Build (DB) contract. It's the same DB just like the DB in the DBFM contracts. Tender phases are carried out in the Design phase of these contracts. For that reason, the financial and maintenance aspects are not included in this research -but of course they will affect the tender approach. This does not mean that the DB parts in these two forms of contract are similar.

Main difference is the orientation on costs and performance. In D&C contracts, there will be built with the lowest possible realization costs as opposed to the DBFM contracts. It may be worth it to invest more money in the realization costs. This is weighed up by means of a business case with the involvement of the net present value. A method of calculating the return of investment. For example, it may be attractive to apply a thicker cover layer of asphalt to postpone the routine maintenance, so that in a certain maintenance period the cover layer has to be replaced once instead of two times. Those kinds of considerations are made through trade-off matrices (van Hunen 2015). There is much more to it in comparison with a D&C contract. For that reason more effort is required in order to draw up a tender bid. And for that reason there is carefully considered to participate in a DBFM contract in advance.

Further, the market is often involved in the public service delivery which makes it also called a public-private partnership. Lenders such as banks make payments in advance and through availability fees and completion certificates, the investment returns after 20, 25 or 30 years.

With this, both the client and contractor start thinking about the life cycle of the construction, and that's beneficial for the client. With these long- term contracts, the price components evolve in accordance with a general or specific inflation rate. That is why a price reference date will be agreed after which an annual price revision with the aid of indexing is necessary. If specific prices are rising exponentially and this is not commensurate with the indexation, this reasonably and fairly solved between client and contractor. (van Hunen 2015)

In order to demarcate the research, the additional risks for the contractor belonging to DBFM are not included. As co-owner of the project, it means that a part of the risk is yours in the operational phase. Also the responsibility for the investors plays a role whereby a different approach in the tender phase is required. This is not included in this research and therefore the Design part of the D&C contract is taken into consideration. The most part of the tender approach can also be used for DBFM, but (design-)tradeoffs will be made in a slightly different way. In the rest of the report, the application of probabilistic design and estimation in D&C contracts can also be used for DBFM contracts, with due consideration of the foregoing differences.

2.3.2. D&C contracts

The UAC-IC 2005 conditions shall apply to D&C contracts and it governs the legal relationship between the client and the contractor. Below the model that shows the relationship between client and contractor.

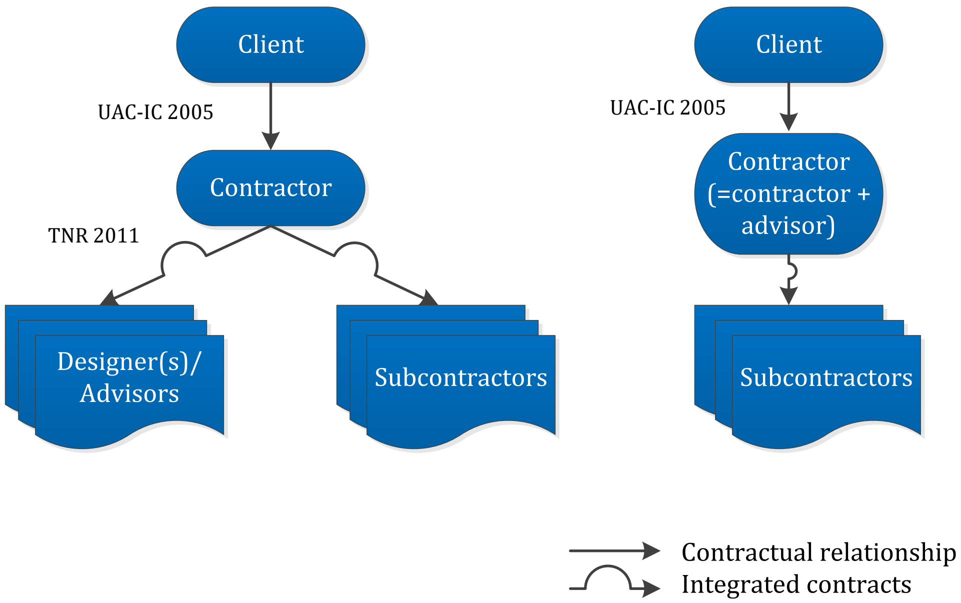

Figure 8: integrated construction models (Bruggeman, Chao-Duivis et al. 2013)

The client acts as the initiator on the building process and should coordinate the project; from the first initiative to the handover. The design and the execution is carried out by the contractor, but the client is free to interpret the distribution of tasks within these roles of design and execution.

Several terms are used for the same phases in the construction process. However, client and contractor organize these phases in a different way. See next paragraph, where the focus is on the tender phase.

2.3.3. Phasing in and around the tender phase

The phasing of the traditional building process is already mentioned. This does not deviate much from the building process with integrated contracts. Basically the difference with integrated contracts is the earlier contract formation. In the figure below, a distinction is made between the phasing of the client and the contractor. The focus is on the phasing of the contractor in the tender phase. From now, with the construction process is meant the phases in and around the tender phase.

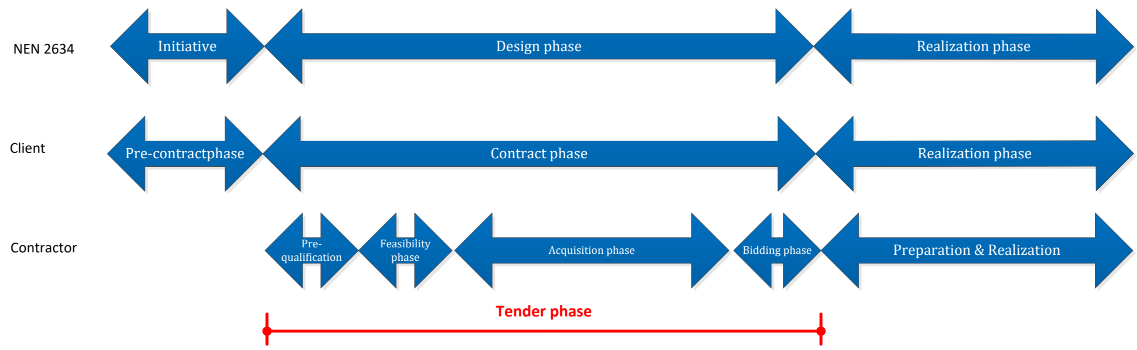

Figure 9: phasing of client and contractor roles in and around the tender phase[12] (own figure)

2.3.4. Duties of the client

For the client, the construction process can be distinguished in the following phases:

- Pre-contract phase
- Contract phase
- Realization phase

Pre-contract phase

The client is responsible for the pre-contract phase. The pre-contract phase includes all necessary processes and activities from the initiative to the request for tender (RFT). It includes choices about the project organization, distribution of tasks and the interpretation of the integrated contract. This includes the project organization, the level of support, knowledge and experiences, desired scope, risk inventory, laws and regulations, etc.

Substantive data are the basis for the program of requirements (sometimes for the preliminary or final design), from where the design process can start. The relation between the parties is determined in main contract components by the Basic Agreement, the Employer's requirements, Appendices and UAC-IC 2005.

[12] The design phase of the NEN2634 is part of the tender until the tender bid is submitted

Contract phase
In this phase tasks will be outsourced by the client. For that kind of organizations, a formal tendering obligation has arisen. Hereby, use is made of certain documents like the Directive 2004/17/EC, Directive 2004/18/EC and the ARW 2012[13]. Directive 2004/17/EC is about the coordination of the procurement procedures of entities operating in the water, energy, transport and postal services sectors. Directive 2004/18/EC is about the coordination of procedures for the award of public works contracts, public supply contracts and public service contracts. And the ARW 2012 contains a set of practical rules to streamline the abovementioned directives. With the objective to ensure the legal principles like equal treatment, transparency, proportionality and non-discrimination for the outsourcing of works (Ministerie van EZ 2013).

Public authorities are bound to European, national and their own legislations. The first distinction in the procurement phase are the European limits. When public procurement contracts will exceed a certain threshold for purchase work, goods or services, the contracts should be put out to European tender. In 2014-2015, the threshold for public work contracts is €5.186.000 (European Union 2013). This research is about works with a contract price well above this threshold; the European tender procedure is obliged.

After that, a distinction is made between an open or restricted procurement procedure. The open procedure will be applied for simple procurements with straightforward requirements, where low transaction costs are expected. There is no pre-qualification of bidders and anyone can submit for the work.

In almost all other cases the restricted procedure will apply. This procedure consists of two rounds. In the first round, candidates who are interested can apply for the tender. In the second round five candidates will be selected in line with the award criteria, published in advance. Often based on their professional capability and/or financial standing. The contracting authority should be able to draw up the entire requirement, such that interested parties can deliver a fully priced bid without the need for negotiations.

In all circumstances, an open of restricted procedure must be used according to the ARW 2012 “Policy Rules”. But there are exceptions of this rule in limited circumstances. There are other procedures of accessing the market for that limited circumstances. In addition to the open and restricted procedure there are other procedures available, like the:

- Competitive dialogue procedure
- Negotiated procedure with prior publication of a contract notice
- Negotiated procedure without prior publication of a contract notice
- Direct agreement procedure
- Concession procedure
- Framework agreement
- Design contest

For large complex infrastructural projects, the competitive dialogue is most widely used by Rijkswaterstaat. Only when the contracting authority is not able to determine specifications like the technical, financial and/or legal aspects for the entire work, without discussion with possible

[13] Tendering Regulations for Works 2012

candidates. Rijkswaterstaat uses this procedure in all DBFM contracts and regularly in D&C contracts (Rijkswaterstaat 2014). With a minimum of three interested parties a dialogue will be conducted. With drafted award criteria, the number of candidates will be reduced during several sessions. Until there left over some suitable candidates or solutions. Finally, the final contractor is selected by means of a reasoned award decision.

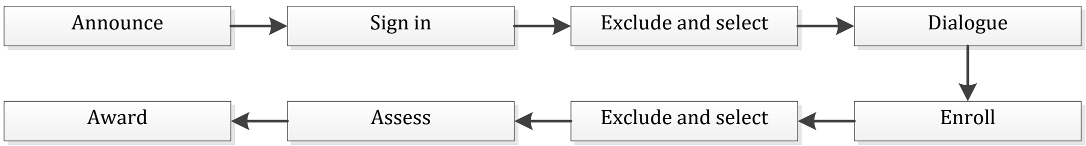

Figure 10: procurement procedure with competitive dialogue (Combined Business Power 2013)

Realization phase
The project will be further defined by executing design activities, conditional and preparatory activities after which the project will be realized. In this phase of the project, activities will be carried out both by the client and the contractor. The division of roles activities are defined in one or several contract documents, wherein the entire project scope and the risks of the preferred situation are described.

The contractor is usually responsible for design activities, the execution methods and realization, until the completion/hand-over. The multiyear maintenance is optional, dependent on the type of contract.

2.3.5. Duties of the contractor

For contractors like Heijmans Infra, the construction process can be distinguished in the following phases:

- Orientation phase
- Pre-qualification phase
- Feasibility phase
- Acquisition phase
- Bidding phase

A complete picture of the integral tender process of Heijmans is shown in Appendix A. In the Appendix, the phases are called in a somewhat different way, but the content of the phases is the same.

Orientation phase
Prior to the tender phase there is a screening in which the MIRT[14] is consulted. For the organization a number of factors and risks are important to see if it is an attractive work for a bid. Moreover, information about the content of the project is relevant for the search of possible collaborative partners. After the screening a go/ no go decision point takes place. At such a moment, there is looked at criteria by the organization as can be seen in Appendix B. If there is a go, there can be continued with the pre-qualification phase in order to be selected by the client.

[14] Multiannual program Infrastructure and Transport

Pre-qualification
In this phase questions are asked by the client about the financial situation, the reliability and the annual turnover of the organization, and whether all legal- and tax liabilities have met.

Furthermore, contractual terms are thoroughly analyzed. The selection requirements, opportunities, distinctiveness and risks of such conditions are globally examined. Through pre-qualification potential candidates will be selected to continue the tender process on the basis of a concept plan.

Feasibility phase
In case of a positive result, by means of a quick scan the feasibility of the project will be determined. After the acceptance of the tender documents of the client a quick scan is made. Within a time period of two weeks there will be drawn up a:

- Scope description, divided to the disciplines soil & roads, constructions, dynamic traffic management, traffic facilities, and 'other'
- Composition of candidate (combination) and consultants
- Tender organization and staffing
- Time planning of the tender and execution
- Tender budget (indicative)
- Environmental analysis, important stakeholders
- Parties involved at the client side
- Image of the competitors
- Award criteria
- Contractual risks and opportunities
- Contractual freedom of design
- Tender strategy (see Appendix C)

Within four weeks after acceptance of the tender documents, the findings of this quick scan will be discussed in the steering group of the tender team (Figee 2013). There is again a go/ no-go moment with criteria as shown in Appendix D. If it is decided to proceed, the tender strategy will be determined. After which the quick scan serves as the basis of the tender plan after the adoption by the tender organization manager of Heijmans Infra.

A plan of approach will be drawn up in which issues about planning, budget, organization, added value, opportunities and risks are discussed.

After the determination of the strategy, there is a third go/no-go moment by the enterprise with criteria as shown in Appendix E. With a go-decision, the design phase will be started.

Acquisition phase
At the commencement of a tender, a program of requirements is received from the client. Usually, at the same time, a reference design will be delivered which is the process input. Often the reference design is on sketch level, but it depends on the client. For example, reference designs made by Rijkswaterstaat are often made on a lower level of detail than municipalities. The latter are more afraid that something will be designed which is undesired, partly because there will be built in the immediate vicinity. So they often want more influence on the design.

Then it becomes clear to what degree of freedom the design can be continued and to what extent the organization can distinguish itself.

Because the market becomes more flexible and responsible, System Engineering (Daskin, Snyder et al. 2005) has been introduced during the introduction of the new types of contracts. SE is a method, an interdisciplinary approach for the systematic design and realization of complex systems. The methodology of SE is comprehensive with the emphasis on client requirements, the verification of requirements, design tradeoffs, configuration-, interface- and risk management with the goal of providing a quality product that meets the user needs. By working out this information in a fixed structure and to archive it properly, miscommunication will be prevented.

According to Leidraad Systems Engineering (Rijkswaterstaat, ProRail et al. 2007), the aim of the first part of the design phase is to analyze and to translate the function requirements and wishes of the client into measurable system requirements and functions of the system. Also these functions are converted into requirements and if necessary, dependent of the design choices, these are further translated into more detailed requirements.

These functional requirements should be "SMART" and expressed in, for example, terms of quantities, availability and performance. Distinction is made between main- and secondary requirements. At the same time limitations are considered. These limitations such as environmental factors and regulations define the boundary conditions of the design space.

Further requirements are the mutual internal and external interfaces of objects within a system, which are described in interface requirements. Besides that, there are aspects like safety and aesthetics which is separate from the primary function of the project and the objects within a project, the aspect requirements.

Second part of this phase consists of a functional analyzes and allocation, where the following steps are taken (Rijkswaterstaat, ProRail et al. 2007):

- Elaboration of functions within a system
- Deducing objects from these functions
- Applying structure and consistency to these objects
- Linking requirements to these objects

This creates a specification per object which serves as the basis of the design of the solution free objects.

Subsequently, the solution free objects are converted into a specific final solutions. After the selection of some variants during the variant study, this preferred solution is chosen which meet the clients phrasing of a question and objective the best, and it's chosen on the basis of the accepted cost estimations in the program phase. This is also the moment when the scope is explicitly enough to describe the preferred solution. Figure 11 clarifies abovementioned engineering process.

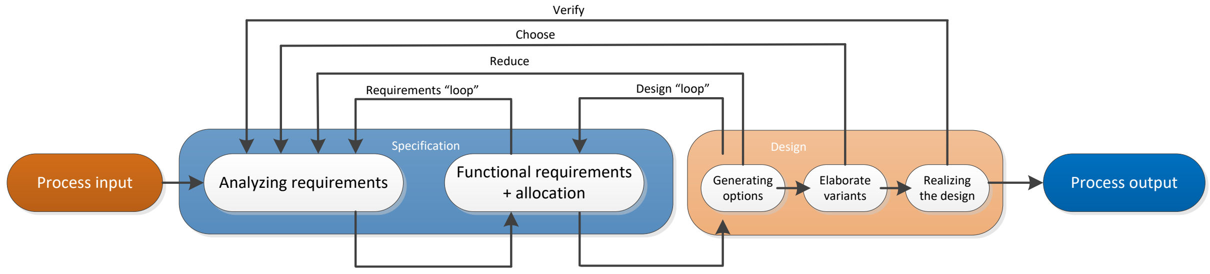

Figure 11: engineering process in the Civil Engineering industry (Rijkswaterstaat, ProRail et al. 2007)

During this acquisition process, the quality is monitored constantly through viewing the relationship between the requirements and the design. This iterative process is illustrated during the variant study in loops and in the during the further design process taking into account the initial requirements. Both during and after the acquisition phase. All details should eventually be associated with the functional requirements, which makes it necessary to organize this process systematically. To accomplish this, the method should have the following properties:

- Top down: from coarse to fine
- Systematically: makes the relationship between the design a functional requirement visible
- Integral: in order to take all aspects into account

Abovementioned is the rationale behind System Engineering, an effective way to capture all of this information out of the construction process. This method is often contractually required by the client in case of complex projects (Bouwend Nederland 2007). During the design the fourth go/no-go decision takes place, based on criteria as seen in Appendix F. More details of the design process within Heijmans, see Chapter 8.

Bidding phase
The activities of previous phases will ultimately lead to a tender proposal. Subsequently, the necessary activities for the realization of a project will be awarded with one or several contracts to the market parties. The work will be not fully awarded based on the lowest price anymore, but also on the basis of criteria that reflect qualitative, technical and sustainable aspects. The so-called most economically advantageous tender (MEAT) criteria.

Per contract the relevant part of the scope, including related risks, should be described clearly. All contracts together constitute the entire project scope including all the risks of the preferred solution. After awarding the design will be further elaborated, until this design will be realizable.

2.3.6. Tender organization

To get an impression of a tender organization for large projects, a brief explanation of the different functions within a tender organization is given below. A tender organization covers all persons who participate in a tender.

Koepel
Overarching management team of the tender or project which directs all activities in the "common domain" with the goal to ensure the integrated approach. This implies:

- Contact with the client
- Overall project management
- Contract management
- Process organization and monitoring
- Overall planning
- Design (preliminary design to the execution design)
- Environmental management
- Risk management (opportunities and treats, including bonuses and penalties)
- Conditioning

Tender manager
The tender manager controls the tender process on the basis on the demand of the client, with the aim of acquiring integrated projects. This person is responsible for managing the interfaces between the various objects in the tender and the coordination between the different object managers and other team members. This person engages in market research and tenders will be selected on the basis of distinctive elements. If required there will be sought for possible alliance partners.

Core team
Consists of a tender manager with discipline leaders

- Project manager (small projects) or –director (major projects); chairman core team
- Execution manager
- Design Manager
- Process Manager
- Environmental manager
- Project leaders or project managers

Steering group
Consists of the directors complemented by the tender manager. The steering group is decisive. The steering group "steers" the whole tender team, with the project manager as the person ultimately responsible for all the work (Heijmans 2013).

Others
In addition to the above mentioned positions, cost experts and designers also take part in a tender team.

2.4. Derailing of efforts and costs

The benefits of integrated contracts have been proven past decade. If the preparations of projects have gone well, main advantages can be (CROW 2004):

- Reducing phasing risks
- Better price/quality ratio
- Shorter lead times
- More innovation in construction projects

But, the application of integrated contracts can be further improved on the sides of both the client and the contractor. In this research it's about, in particular, the tender phase for contractors. That there is still room for improvement is not surprising despite the fact that this form of contract is no longer new anymore. That has multiple reasons. For example: in long-term projects, any lessons can be learned after handover. Such an evaluation moment is usually several years later after the start of a project. Usually, new projects will be announced that makes it difficult to evaluate the completed project. Furthermore, a lot of effort was required by introducing new mandatory methods such as System Engineering and BIM[15]. Now these methods are implemented and operate within Heijmans Infra, attention can be paid to the further improvement of the tender process regarding the design and cost estimation process.

Pitfalls

In the research about the application of D&C contracts in the Dutch Civil Engineering sector (PSIBouw Projectbureau 2007), a list of the top 10 best practices is formulated how to make the process, to drawn up the tender proposal, more successful. To get a picture of some of these best practices: put the focus during the preparation of a proposal on the MEAT award criteria and ensure that a (part of) the tender team remains involved in the project after awarding.

One of the best practices- number four in this ranking- is about the level of elaboration of tender proposals. Sometimes tender teams are elaborating parts of the design in more detail than is requested by the client, in order to get more accurate cost estimations. This can be reduced by working more with key figures based on recalculations, average grades and experiences. The risky components may be still further elaborated.

As described on page 61, sometimes it is necessary to elaborate large parts of the proposal on a high detailed level, depending on client and the type of projects/objects. When certain bandwidths are not acceptable, the contractor is obliged to look for a deepening in order to get a more accurate determination of the cost price.

If the client don't ask for a detailed proposal and objects aren't risky, little use is made of key figures. A less detailed elaboration level will be only achieved by working out of the riskiest parts (i.e. cost drivers or specials) of the tender design. This only applies to those parts of the design that is suitable. Choices must be made with the question: when are bandwidths acceptable and when are they not acceptable. Regarding that last point, a deepening is necessary.

[15] Building Information Model

To mark down on key figures there must be started with the establishing of indicators based on past experience and subsequent calculations. To facilitate this, a list of identified risks is required to provide insight into the interfaces for example. But this is easier said than done. The bandwidth seems to be too large in the current market, due to the competition by a saturated market (PSIBouw Projectbureau 2007).

2.5. Chapter evaluation

This chapter explained what a tender phase entails for both the client and the contractor. How a tender phase is embedded in the construction cycle, common types of contract are pointed out and the responsibilities are discussed. There is also been told about possible improvements in the tender phase, what is the basis for next chapter.
Figure 12 and Figure 13 summarize the differences of the various types of contract.

There is much more to tell about tenders. In the Dutch construction industry the market is currently saturated. Margins are under pressure. Even though MEAT criteria are introduced, the company with the lowest price -mostly a unrealistic price- often wins the tender. Interesting question is: in which way money is earned by contractors in the last few years? Is this compensated through change orders, a bad scope or is the quality of work at a minimum level? Here it is important to look at the differences in the subscription amount, the final costs and the cash flow of the project. Only this is not important for this research, because it's about cost estimates and not about considerations of the final bid price.

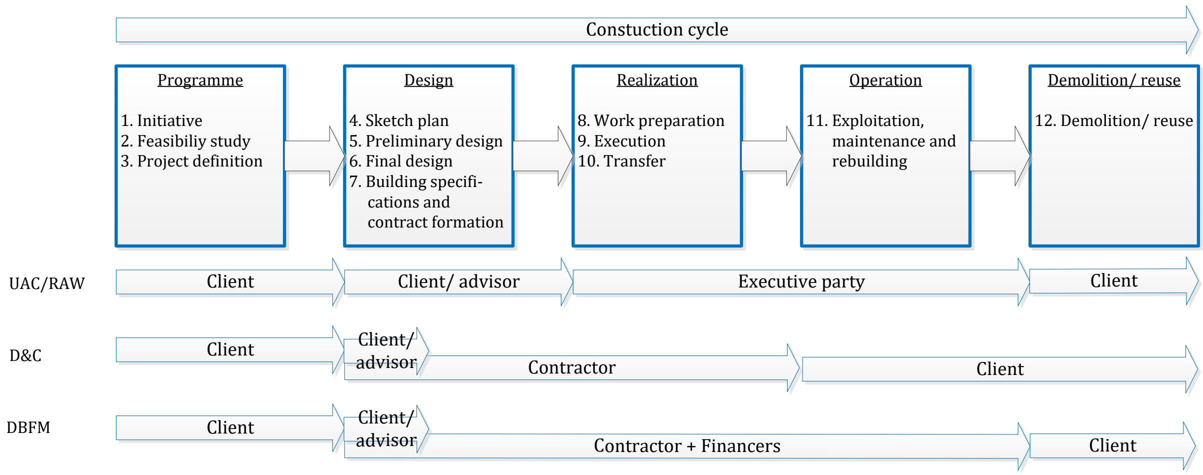

Figure 12: responsibilities for different parties (own figure)

	Traditional	DB	DBFM
Specifications	Input: design-led	Output: product-led	Outcome: service-led
Scope	Construct	Design and Construct	Design, Construct, Finance, Maintain
Decision freedom for contractor	None: has to follow the specifications	Little: can have some influence on the design	Much: can make decisions as long as remaining within the scope
Selection criterion	Price	Design creativity, constructability and price	Overall quality and price
Natural incentive	Low bid, with compensation through extra work	Low bid by design efficiencies	Low bidding and cost reduction by design and process efficiencies
Effect on the contractor's behaviour after contract closure	Opportunistic, mistake-hiding, quality-shirking, extra work-claiming	Opportunistic, mistake-hiding, quality-shirking	Opportunistic, mistake-hiding
Monitoring	Ongoing, by the principal	Ongoing, by engineering firms	Ongoing, by contractor and by his financers. Occasional, by the principal

Figure 13: characteristics of three contract types (Hoezen 2012)

3. What is probabilistic design and cost estimation exactly?

To answer this question as described in the title above, first the most common ways for drawing up tender designs and determining tender costs will be described in this chapter. The method of probabilistic cost estimation and design have become increasingly widespread since the last years. For that reason it is still in development. The basic principles of probabilistic cost estimation and design are clear. But at this time there is still room for improvement and optimization. There's still little experience gained with this way of tendering, both inside and outside the organization.

A distinction is made between the two components cost estimation and design, where different methods will be explained. First there is explained what the cost estimation process entails in literature, after which the applied method is explained.

3.1. Cost estimates

The estimated costs of a project is the expectation of what the actual costs of a project (to be executed) should be. "Cost estimating can be described as the technical process or function undertaken to assess and predict the total cost of executing an item(s) of work in a given time using all available project information and resources" (Kwakye 1994). Multiple sources describe a definition of the word cost estimation in a somewhat different description. There has been written about "the key factor in the construction process. It can influence issues ranging from project feasibility to profitability depend on the preparation of an accurate estimate" (Portas and AbouRizk 1997). Furthermore, "the success of failure of a project is dependent on the accuracy of several estimates throughout the course of the project. That is, from conceptual and feasibility estimates through to the detailed or bid estimates" (Ahuja, Dozzi et al. 1994). The importance of cost estimations is further emphasized by the small marches that are acceptable. According to Akintoye and Skitmore, underestimated costs could lead to a situation where the contractor incurs losses on the contracts awarded by the clients, in an industry where the profitability is low in comparison with other industries. On the other hand, overestimated costs could lead to an unacceptable tender for the client (Akintoye and Skitmore 1991). Also the opportunity to acquire a work is nihil, in a market that is saturated. At last, Oberlender considered the preparation of a cost estimate of a project as one of the most difficult tasks in project management because it must be done before the work is accomplished (Oberlender 1993).

The abovementioned definitions indicate that the process of cost estimation is the process to give an approximation of the actual costs and is one of the important and difficult parts of the construction process. It's an activity where many issues depend on. Decisive for the viability of a project and on larger scale for an organization. For example, the workload and the profitability of a work and organization depends to a large extent from these cost estimates.

The purpose of a cost estimation is providing cost information for the purpose of making policy choices, making decisions about next project phases, the inclusion in annual budgets, monitoring the project and for assessing tenders.

Task of cost experts is to approximate the actual cost as well as possible. Their goal is looking for the little area between under- and overestimation. The accuracy of these approaches depends on various components. Firstly it depends on the intention of the cost estimation. Is it a feasibility cost estimate in the pre-tender phase or should it be a sharp, detailed cost estimate intended for the bid. It's worth noting that these cost estimates are important at any stage, even though the range of the bandwidth is larger in a baseline estimation at the beginning. Further, the accuracy depends among others on the elaboration level of the design, financial issues like tender budgets, bidding situations like the type of contract, time pressure and which cost estimating method is used.

3.2. Cost estimation systematics

3.2.1. Scope, budget and cost estimates

To realize a cost estimation of a project, the basic objectives and scope must be clearly defined in the estimation dossier. Such are the initial conditions for a cost estimation. With this, a good overview of all activities of the work is obtained. "The scope includes both the specifications, established at a certain moment during the tender, and also the accepted technical solution (the design) based on these specifications" (CROW 2010). The designer will have to translate the scope into objects, which is the basis in order to draw up a cost estimation.

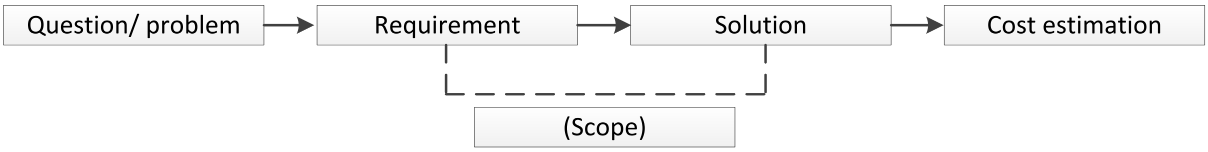

Figure 14: basis of a cost estimate (CROW 2010)

According to the SSK 2010, the first cost estimates are prepared during the initiative phase. If it is decided to continue with the tender, a variant study is prepared. Partly on the basis of accepted estimates of the several variants, the preferred solution is co-selected. After which the scope is explicitly enough to describe this preferred solution. The baseline, the description of construction works at a certain stage of development, is based on this. It consists of foreseen costs and quantified risks. The quantified risks are included in the risk reserve. At this moment, the references of the control of costs are the: scope, cost estimates and the budget (CROW 2010).

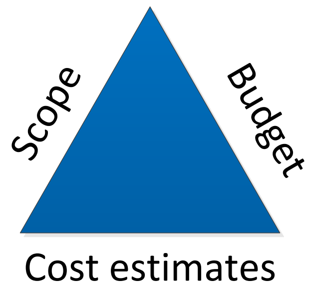

Figure 15: references of the control of costs (CROW 2010)

3.2.2. Continuation of the cost estimation process

In the further development of the scope, deviations of the scope and risk changes can arise with respect of the baseline. Scope changes will affect the budget and for that reason, changes must be approved by the client. During the tender, when the design is elaborated in more detail, scope changes take place constantly. So is it necessary to monitor the scope-, cost estimates and budget continuously during this process, among others by the calculators.

The further specification of the costs is an iterative process, which is shown in the figure below.

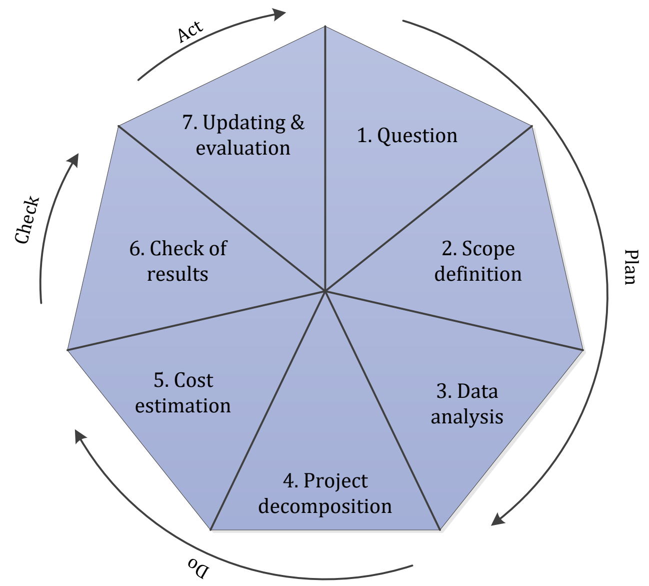

Figure 16: iterative cost estimation process (CROW 2010)

Each step is explained below.

1. Question: there is a demand for a cost estimate by a company manager or supervisor. The challenge is to determine the boundaries of the solution space and the influence of the components/ objects with regard to the other components/ objects of the entire project.
2. Scope definition: precondition for a cost estimate is a clear and representative scope.
3. Data analysis: the calculator indicates what is necessary to achieve a cost estimation, so that is meets the predetermined requirements.
4. Project decomposition: for an effective control of a project, the work will be divided into objects. Mainly, objects are defined as an item, consisting of materials and components which can be assembled into a whole. A “real thing” with three dimensions that can be recognized separately. Sometimes, objects are classified in a different way on the basis of an activity, geography, processes, types of work, functionality, type of contract or financing. This is done by means of a Work Breakdown Structure or a System Breakdown Structure.
5. Cost estimation: there can be started with the estimation of costs after the determination of objects. Per object, a distinction is made between the cost groups below:

- Foreseen costs
    - Direct costs, appointed
    - Direct costs, to be determined
    - Indirect costs

- Contingency reserves[16]
    - Object unforeseen
    - Project unforeseen

These cost categories are divided into the following categories:

- Investment costs
    - Construction costs
    - Property costs
    - Engineering costs
    - Other additional costs
- Life cycle costs (for example by DBFM contracts)

These terms will be explained in chapter 3.2.3. The total sum of the estimated costs per object should cover the entire project scope.

6. Check of results: the estimates will be assessed on the stated requirements. There will be considered if measures are necessary in order to reduce uncertainty. After acceptance, a decision is made whether an offer is being done and whether it is necessary to change the design.
7. Updating and evaluation: the current cost estimate will be regularly compared with the previous estimates of the baseline. Scope changes are explicitly indicated and uncertainties are determined again. Depending on the course of the budget, the project can be adjusted, the cost estimate can be changed or a budgetary adjustment can be made.

3.2.3. Cost categories

In this paragraph a brief explanation is given for some definitions of costs.

Cost groups

<u>Foreseen costs</u>: costs that can be calculated based on the scope and divided into:

- *Direct costs, appointed*: foreseen costs, directly associated with the production or supply of a product or service. Usually direct costs will be calculated with "quantities x unit prices" (Q x UP).
- *Direct costs, to be determined*: a surcharge on the "direct costs, appointed". These costs are foreseen and associated, but not explicitly elaborated. This because the disproportionate design effort in relation with the increased accuracy.
- *Indirect costs*: costs which are not directly accountable to an object. For example: general construction site costs, execution costs and contractor profit & risk. To these cost categories separate surcharge percentages are given for the determination of these costs. They are usually assigned by using a certain ratio of the direct costs.

[16] SSK 2002 describes the cost categories in a different, more extensive way than the SSK 2010. This cost group is described in the SSK 2010 way.

Contingency reserves: unforeseen costs to compensate potential negative influences on the cost estimation. For example: risks caused by uncertain situations or undesired events. This cost item is not intended for scope changes. There are several ways to calculate contingency reserves. Here, the reserves are divided into object unforeseen and unforeseen project. These costs are expressed as surcharge rate or calculated by the probability x consequence (P x C) formula.

Below is a schematic representation in order to clarify the abovementioned text.

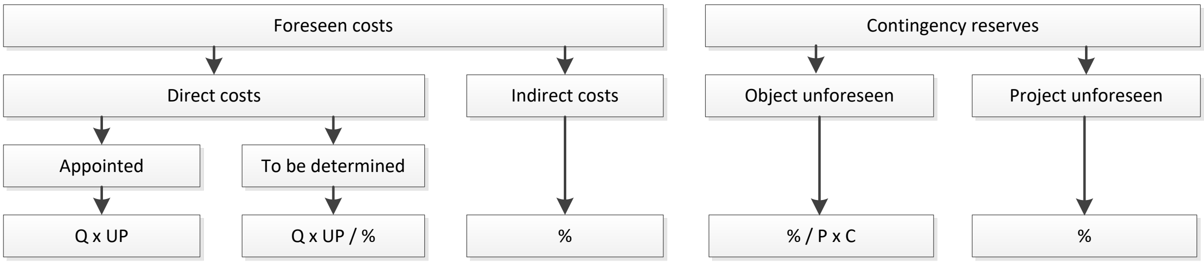

Figure 17: cost groups with their own calculation methods (own figure)

Cost categories

- Investment costs: overall cost of the project. It's about the investment, according to the cost estimate, to realize a project. It's the sum of the following four bullets.
    - Construction costs: costs associated with the psychical realization of a project
    - Property costs: costs for property acquisition (land and buildings)
    - Engineering costs: costs of, among other, designers, engineers, consultants and project management.
    - Other additional costs: the other costs which not belong to abovementioned three categories. Costs such as administrative expenses, permits, levies, line closures, soil surveys and for the preparation of land use plans. If no use is made of a fixed price level, wage and price increases are included here.
- Life cycle costs: costs that are incurred after hand-over, in order to keep the object intact. Like the management and maintenance.

There are two types of how a cost estimate can be presented. On the basis of cost categories and on the basis of objects. An example on the basis of cost categories is shown in Appendix G. With the mentioned object-oriented method, information of the object can be linked with other object information. For example with BIM. A cost estimation per object is presenting according to the uniform project estimation, as shown in Appendix H. How the entire object estimation of the investment costs is underpinned is shown in Appendix I.

3.2.4. Uncertainties and risks

There is an important distinction between the terms uncertainty and risk. According to most of the literature, uncertainty can be defined as a lack of certainty involving variability and/or ambiguity (Brauers 1986). In uncertainty situations, parameters are uncertain, and furthermore, no information about probabilities is known (Snyder 2006).

There is uncertainty if the future can't be predicted. Nobody knows in advance whether the event leads to success or failure. There is insufficient information available, the odds are unknown. It's clear that under uncertainty conditions, for example, because the lack of statistics, the calculation of the probability of loss or failure is not possible.

In the abovementioned definition, it is stated that nothing can be said about probabilities. This is in contrast to the definition of the NASA, which have a slightly different approach, with the use of historical data.

Uncertainty is the indefiniteness about a projects baseline plan. It represents our fundamental inability to perfectly predict the outcome of a future event. Uncertainty is characterized by a probability distribution, which is based on a combination of the prior experience of the assessor and historical data (NASA 2015).

The definition of uncertainty is different from the definition of risk. The word risk derives from the early Italian "risicare" and means "to dare". It's a choice rather than a fate (Bernstein and Boggs 1997). Here uncertain parameters are controlled by probability distributions that are known by the decision maker (Snyder 2006). Risk is a situation where all possible outcomes of a decision are known. But not which outcome occurs. For example when rolling a dice. So, it's about the actions that dare to be taken, depending on the freedom of action.

Because of the abovementioned difference in understanding of NASA, there is probably also a difference in the conceptualization of risk.

Risk is an event, not mentioned in the projects baseline plan, that is an undesirable outcome. This definition is similar to one that one would see in a risk matrix. The event is characterized by a probability of occurring and an expected impact if the event did occur (NASA 2015).

For cost estimation purposes, a risk can be defined as the chance of loss in unfavorable circumstances and these could be weather conditions, environmental or political factors, price increases due to inflation, etc. On the other hand, uncertainty is the intangible value that cannot be exactly defined (Elkjaer 2000).

3.2.5. Methods of assessing risks

There are several methods to identify and assess risks. Hubbard describes these methods and they are summarized below. He's skeptical about some methods, which look nice and convenient to use, but with a minimal attention to the quality of the results. Some are totally not founded on scientific research.

Some of the following methods can be combined with each other.

- Expert intuition; a kind of baseline of risk management methods. Pure on the basis of gut feel, without structured classifications or evaluation systems whatsoever. No use is made of scales, points, probabilities or even standardized categories.
- An expert audit; an extension of the expert intuition. Builds on gut feel, but more systematic. By means of newly developed comprehensive checklists and discussions with experts -usually independent and not come from the organization- optionally with the use of formal scoring methods discussed below.
- Simple stratification methods; these use rating scales like "low-medium-high" or "green-yellow-red". These designations indicate how risky the activities are with the aid to identify

the likelihood and consequence. Then, the result is displayed in a two dimensional map. When a "1-5" rating scale is used, the likelihood an consequence can be multiplied to get a risk score.

- Weighted scores; an extension of the simple stratification methods and these uses risk indicators, with a certain weight, to obtain a weighted risk score.
- Traditional financial analysis (i.e., without using probabilities); a risk analysis within the bounds of conventional financial analysis tools. For example, there will be worked with best case and worst case scenarios for identifying the costs and benefits of the various decisions.
- A calculus of preferences; here, methods of multi-attribute utility theory, multi-criteria decision making and analytic hierarchy process are used. Methods to determine, for example, whether options of experts are internally consistent. They are more structured than the weighted scores, but they still rely on the opinions of experts. It's used to evaluate decisions according to their risks, in contract to assess and map the risks.
- Probabilistic models; advanced risk analysts used a type of probabilistic model where odds of various losses and their magnitudes are calculated. This is the basis for modeling risk in the insurance industry, one of the industries which are the furthest with the calculation of risks. Probabilistic models has its own flaws but it is the best opportunity to for continued improvement. Hubbard makes the comparison with Isaac Newton and Albert Einstein, where Newton was the starting point for Einstein. Subsequently, Hubbard indicated that the probabilistic models could use subjective inputs as do the other abovementioned methods, but it's also well-suited to accept historical data or the results of empirical measurements. Even though it's only one way to map risks, it has enough substance for a further investigation (Hubbard 2009).

3.2.6. Cost uncertainties and risks

Uncertainties and risks should be translated into cost items in the cost estimation. This is the task of the calculator together with the risk manager. In order to achieve an objective picture of the project uncertainties, it is important to make a distinction between several types of uncertainty. After which these types of uncertainties are elaborated on their own way. This is done by ranges of quantities and prices, in the item "to be determined" and/or by filling out the risk reserve item. See Figure 18. Control measures for these risks affect both the foreseen costs and risk reserve.

According to the SSK 2010 uncertainty can be subdivided into three groups:

- Decision uncertainty
- Knowledge uncertainty (also known as uncertainties under normal conditions)
- Uncertainty about the future (also known as uncertainties by means of special events)

This is shown graphically in Figure 18.

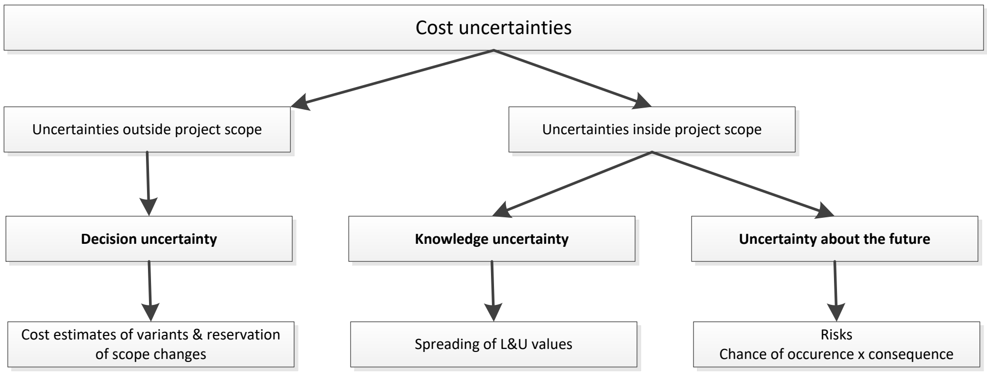

Figure 18: uncertainties inside and outside the scope (CROW 2010)

Decision uncertainty

Decision uncertainty, also known as "plan uncertainty" in the RISMAN[17] method, deals with alternatives or variants, depending on the solution space within the scope. Decision uncertainty is especially important in the design phase, when there is still no decision taken on the preferred solution. After choosing the preferred decision, the role of decision uncertainty is minimized. It is recommended to prepare a project cost estimate per alternative.

During risk assessments, it turns out many uncertainties are related to scope changes. It is important to identify these risks in the variant study, but scope changes don't belong to uncertainties in cost estimations. So, an important starting point for a cost estimate is a fixed scope (DACE 2007).

Knowledge uncertainty

Knowledge uncertainty or "normal uncertainty" deals with the interpretation of an adopted preferred solution. This uncertainty arises because the lack of information in order to an adequate description of the design, situation, scenario or system. This as a consequence of the level of elaboration or the inaccuracy of data. So, it is for 100% sure that this type of uncertainty arises.

Knowledge uncertainty is expressed in T-values[18], the most probable value. Variation of these values are possible by specifying bandwidths by granting the L (lower) and an U (upper) value. But this depends on the method of cost estimation. This is exemplified in chapter 3.4.

The bandwidths will be reduced during the design process, see Figure 21. But it also depends on the agreed, acceptable levels of detail. Bandwidths are determined on the basis of knowledge and experience (Riskineering 2014).

Uncertainty about the future

Risks, in other words "special events" are inventoried and quantified here. By means of the probability x consequence approach according to RISMAN a risk analysis can be made. This can also be by assigning a certain percentage. These events are often undesired, but they can be desirable. The probability of occurrence is less than 50%. If this value is higher, it is assumed

[17] RISicoMANagement
[18] It is based that there will be worked with bandwidths and Monte Carlo simulations. See chapter 3.4.

that the event occur. In the figure below the probability density function of this type of uncertainty is given.

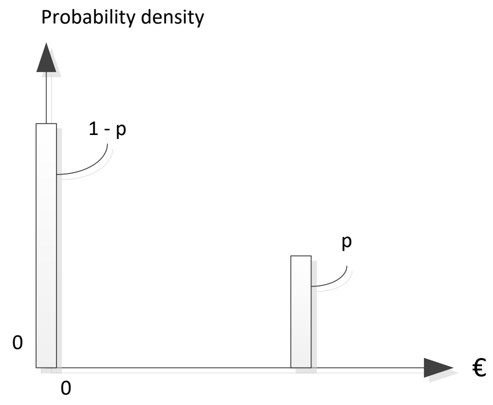

Figure 19: discrete probability density function of a special event (own figure)

Risks can occur within and outside the project scope and can be divided into the categories endogenous and exogenous.

Table 2: difference endogenous/exogenous

Endogenous	Suggestibility and responsibility is within the own organization[19]
Exogenous	Suggestibility and responsibility is outside the own organization[17]

For cost experts, the financial consequences of the endogenous risks within the scope are important. The probabilities and consequences of these type of risks are established in a risk analysis, after which there will be looked at management measures to reduce these risks. The costs of these control measures are included in the cost estimate; the residual risk is incorporated into the risk database.

Contingency reserves

In the contingency reserve, a distinction is made between identified and unidentified risks. In literature different names for these types of uncertainties are given. Identified is (almost) the same as “foreseen unforeseen” or object unforeseen (unforeseen costs associated with an object or activity). The same applies for the unidentified risks. This name is replaceable for “unforeseen unforeseen” or project unforeseen (surcharge on the base estimate to cover uncertainties about the future).

<u>Identified risks</u>
The RISMAN method is used for identified risks. This risk analysis method is used to make risks explicit, to react proactively on them and for the trade-off of associated control measures. It’s a cyclical process. The result of the risk analysis is a list of risks, sorted in order of size of the threat for the project. Possible measures are referred to reduce the probability that the risk will occur, to avoid the risk, to transfer the risk or to retain the effects of the risk. The expectation

[19] As seen from the party that reports about it

value is expressed as “probability x (financial) consequence”. These risks are added up and this creates (a part of) the financial buffer.

There are several ways to set up the risk reserve. Summing the expectation values, as mentioned above, is one method. Normally, this buffer is used when “normal” risks occur. But this method is not sufficient for risks with a low probability of occurrence with major financial consequences. To illustrate this with an example: suppose there is a risk with a probability of occurrence of 5%, with a consequential loss of €200.000,=. The expectation value is €10.000,=. In 95% of the cases there is €0,= needed; in 5% the entire €200.000,= is needed. In any case, the reserved €10.000,= will be never used.

This can be solved by means of another approach with the aid of the determination of, for example, the top two or three risks. The amount of the compensation of these three risks is intended for the risk reserve (Van der Meer 2014).

Another alternative is assigning spreads in the risk. A triangular distribution can also be used. If the costs of the risk may vary between €5.000,= and €400.000,=, L and U values can be applied. Per simulation, it is checked whether the risk occurs. If this is the case, a value between the L and U values is drawn (Van der Meer 2011). But this method have the same disadvantages as the first method.

Unidentified risks
During a project, risks occur which are not defined in risk sessions. It’s impossible to identify all project risks, hence there is an item unforeseen for contingency risks. The height of this reservation depends of the quality of the executed risk assessment and the phase in which the project is located. Which is caused by the fact that certain risks disappear over time.

It’s not scientifically proven, but a rule of thumb is that maximal 50% of the risks can be appointed in the early stages of a project. This can be increase to approximately 70% in the final phase of the design. It means that 30% to 50% of the risks are “unforeseen unforeseen” in the tender phase, see Table 3 (Stichting PostAcademisch Onderwijs 1995).

Table 3: pragmatic division between the post foreseen unforeseen (FU) and unforeseen unforeseen (UU) (Stichting PostAcademisch Onderwijs 1995)

Phase	Distribution contingencies	
	FU	UU
Planning phase	<50 %	>50%
Preparation tender	50%	50%
Design - start execution	70%	30%
End of execution	95%	5%

Another precept to estimate the contingency costs is to take a certain percentage of the construction costs. A method used by Rijkswaterstaat. In the planning phase the contingency risks are estimated between 10-15% to 3-6% in the preliminary design phase (Van der Meer 2014).

In short, identified risks are explicitly expressed in "probability x consequence". The risk reserve is established by summing the expected values and/or covering the biggest two or three risks. Unidentified risks are implicitly expressed as a percentage of the identified risks, or as a percentage of the construction costs. Table 4 summarizes the cost categories.

Table 4: summary of types of uncertainty (DACE 2007)

	Probability	Consequence	Type of uncertainty	
Normal uncertainties	100%	L,T,U for quantities and unit prices	Knowledge uncertainties	Within scope and cost estimation, endogenous
Special events	< 50%	Only T or L,T,U Object unforeseen or project unforeseen	Decision uncertainties	
			Uncertainty about the future	Outside scope, exogenous

3.3. Cost estimates in several phases

In Figure 7, the different phases in the construction process are given. They are classified in five phases. For convenience, the first two phases are considered.

Table 5:classificication of the first two project phases

Class	Project phase	
1	Program	Initiative
2		Feasibility study
3		Project definition
4	Design	Sketch plan
5		Preliminary design
6		Final design
7		Building specifications

In an idealistic situation, the course of a cost estimation look like the figure below.

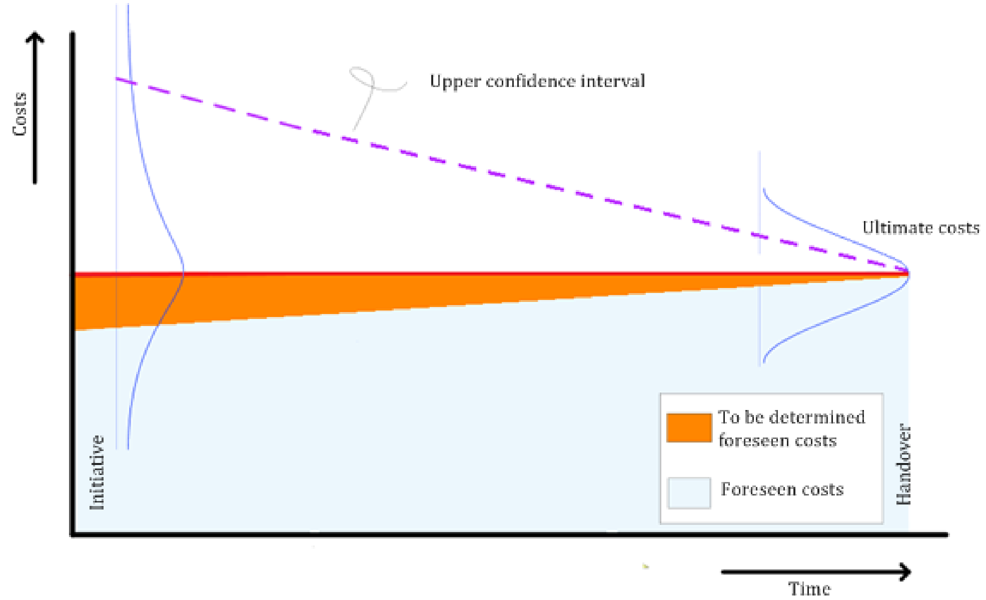

Figure 20: idealistic situation of cost estimating (own figure)

In reality, this will never happen. Various studies have addressed the issue of cost overruns in transportation projects. There are several reasons to appoint, like risks that occur, scope changes, inaccurate forecasts and the underestimating of costs (Cantarelli, Flyvbjerg et al. 2010). That's why this idealistic is never -or at least very rarely- the case.

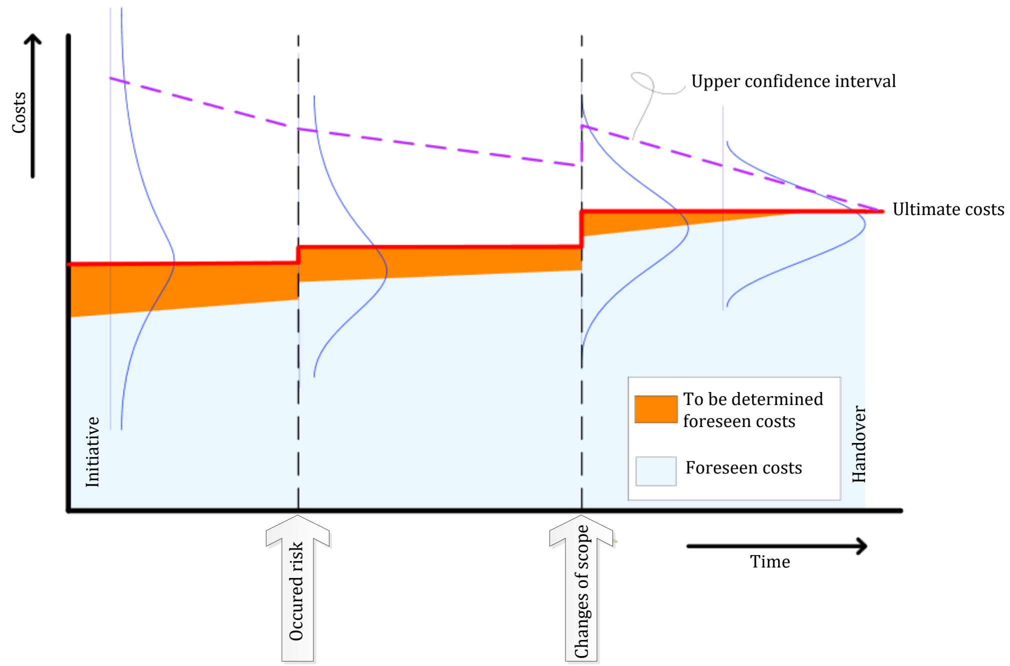

Figure 21: reliability of the cost estimation during several phases (Bots and Schilder 2007)

Depending on which stage in the construction process and the amount of information, which again depends of the level of detail of the design, the level of accuracy of the cost estimate can vary considerable.

On the basis of some examples, Vrijling and Van Gelder have clarified the different steps in the process of cost estimation in several phases (Vrijling and Van Gelder 2009).

Example of a cost estimate in the feasibility study phase. Here the estimates are worked out per object.

1 overpass	*x*	*price of 1 overpass*	=	*item overpass*	
5 km of road	*x*	*price per km of road*	=	*item road*	
1 tunnel	*x*	*price per tunnel*	=	*item tunnel*	+
				total of direct costs	
				indirect costs	+
				primary costs	
				additional costs	
				miscellaneous	+
				basic estimate	
				unforeseen	+
				estimate (ex. VAT)	
				VAT	+
				feasibility study estimate	

In the course of the construction process, parts of the cost estimates are worked out in a higher level of detail. An example of the abovementioned overpass, road and tunnel in the sketch plan phase.

800 m2 overpass	*x*	*price per m2*	=	*item overpass*	
1 km2 road	*x*	*price per m2*	=	*item road*	
3000 m2 tunnel	*x*	*price per m2*	=	*item tunnel*	+
				sketch plan estimate[20]	

Subsequently the abovementioned overpass in the preliminary design phase.

800 m3 soil	*x*	*price per m3*	=	*item "soil"*	
800 m3 concrete	*x*	*price per m3*	=	*item "concrete"*	
1 ton reinforcement	*x*	*price per ton*	=	*item "reinforcement"*	
800 m2 formwork	*x*	*price per m2*	=	*item "formwork"*	+
				subtotal overpass	

In an even more higher level of detail, a cost estimate looks like the example below. On such a level will be worked during the building specifications phase. Here the work method including

[20] For convenience the direct-, indirect costs and the remaining costs omitted.

time and material come into picture. The example is about the soil activities of the earlier mentioned overpass.

delivery at the quay by ship	*800m3*	*x*	*price per m3*	*=*	*partial item 1*
lease of an unloading plant	*80 days*	*x*	*day tariff*	*=*	*partial item 2*
transport to location (by cars)	*80 days*	*x*	*day tariff*	*=*	*partial item 3*
equipment for processing and Compaction	*85 days*	*x*	*day tariff*	*=*	*partial item 4* +
					subtotal soil

When RAW contracts were common for large infrastructural projects, cost estimations were made in this detailed way by contractors. Contractors prefer this method of estimating (Vrijling and Van Gelder 2009). Nowadays, detailed designs are not automatically the basis for cost estimates. With the use of UAC-IC contracts, functional requirements are worked out without giving a solution. It's totally not profitable to work out a tender design at this level of detail. This could be on a more abstract way. Though a systematically subdivision of the project into smaller parts to a level of detail that is manageable. With this approach, requirements, risks and documents are linked to the right part at the right level of detail. So, it is acceptable that accuracy ranges by means of bandwidths are allowed, provided that they are well founded. These indicative bandwidths are shown in Table 6. These bandwidths are about the total contract price and not about line items. It's impossible to make statements about that.

Table 6: accuracy ranges of the total contract price

Phase	Uncertainty ranges				Confidence interval
Reference	(Hamilton 2001)	(Oberlender 1993)	(DACE 2007)	(ProRail 2007)	(ProRail 2007)
Initiative/concept	-15 / +30%	-20 / +40%	-40 / +40%	-40 / +40%	50%
Preliminary design		-10 / +25%	-10-15 / +10-20%[21]	-20 / +20%	70%
Final design				-10 / +10%	70%
Building specific.				-5 / +5%	90%
Completion	-5 / +15%	-5 / +15%	-20 / +40%		

Both deterministic and probabilistic methods can support the monitoring of the project costs in time. Differences in the composition of cost estimates are explained in chapter 3.4.

3.4. Methods of cost estimation

In literature, a distinction is made between two main methods how to come to a cost estimation of tenders. It can be presented as deterministic and probabilistic values (Chou, Yang et al. 2009). These two groups not only occur in the civil engineering industry, but also in the process industry, utility construction industry (DACE 2012) and in the world of aeronautics, for example (NASA 2015). These two methods are explained below.

[21] Depending on degree of elaboration

3.4.1. Deterministic approach

A cost element is described as a random variable representing an unknown future cost. By means of the multiplication of a quantity and price, a single point estimate of the costs per object is obtained, which is called the most likely value[22]. All these cost items will be summed. In this approach there is basically no room for uncertainty, which means that the result is a single point value, derived from one quantity and one price. The next paragraph explains how these "uncertainties" still being processed.

After summing up the cost items, on the basis of expert judgment and/or a subsequent calculation, the item unforeseen is estimated. In this way the margin of the entire cost estimate is determined. This is shown, depending on the project phase, as a percentage of the base estimate. The final cost estimation is equal to the sum of these three cost items, whereby the percentage of this cost item is determined by expert judgement. Another way to determine the item unforeseen is possible with the "black box" method. There is no insight in the structure of the item unforeseen and the marge. This will depend on the project phase. Finally, the estimated sum of the costs has a probability of undershooting and exceeding of 50%.

The deterministic method, also called the conventional or traditional approach, is suitable for the calculation of cost objects/ partial components/ elements only when detailed information about the design or costs are available. With RAW contracts the quantities were exactly known in advance by the contractor. Nowadays, with integrated contracts only with functional requirements, this is dependent upon the agreed level of detail of the contractor. According to Vergara and Boyer, they are of opinion that to increase the reliability of the estimates, the level of detail involved should be increased up to an optimum level of detail at which the cost of increased reliability equals the value of the increased reliability. Because of time- and cost consuming aspects associated with this practice, they have preferred the another, probabilistic approach for cost estimations (Akintoye 2000). When there are specials[23], cost drivers and risky elements present in the design, a higher level of detail will be maintained. If it's not the case, the design can be elaborated at a more abstract level.

Due to various reasons, it appears to lose in popularity with respect to the probabilistic approach. This has various reasons:

- By introducing functional requirements in integrated contracts
- Risks and uncertainties are not explicitly expressed per item
- Because it becomes more and more required by clients like Rijkswaterstaat and other government agencies

The abovementioned description is about the deterministic cost estimation method as currently used by the organization. Zwaving has executed extensive literature research on other various deterministic cost estimation methods. She distinguishes the following three methods (Zwaving 2014):

[22] Also expressed as T-value
[23] Nonstandard constructions

- Parametric Cost Estimation method; a top-down estimating based on the logical and predictable correlation between the physical or functional characteristics of a project and its resultant cost, making use of computerized cost models.
- Comparative Cost Estimation method; where completed similar projects are compared with the current project that is tendered.
- Detailed Cost Estimation method; a bottom-up estimating, typically done at the lowest level of detail. A project will be divided into manageable tasks, operations or activities with easy calculation. During the tender, the level of detail will be higher. This is in agreement with the cost expert and the designer, depending on the need.

Abovementioned process of the organization is more or less similar to the detailed cost estimation method. But the only difference is that by the organization, there will be directly elaborated on a high level of detail. Also, the parametric and comparative cost estimation method are suitable for a quick scan of the cost estimation in an early phase of the tender; the detailed cost estimation method is suitable for a more reliable cost estimation in a later stage.

3.4.2. Probabilistic approach

The main difference between the probabilistic- and deterministic method is that in the probabilistic approach, uncertainties are explicitly modeled using statistical distributions. This way of cost estimating in the construction industry is originated in the process industry, to examine the sensitivities of investments relative to market prices. In the civil engineering industry is it mainly used for a (stronger) underpinning of uncertainties by means of Monte Carlo simulations, a risk analysis tool for this range estimating approach.

A Monte Carlo simulation is a simulation technique in which a physical process is simulated several times. Each time with different starting conditions. The result is a distribution function which shows the whole area of possible outcomes. One condition is that the variation or uncertainty of the starting condition of a quantity or a cost price, expressed as a probability distribution, is known or estimated with sufficient reliability and can be quantified.

According to Vrijling, there are different levels in the probabilistic approach (Vrijling 1994):

- The approximating probabilistic method
- The refined approximating probabilistic method
- The exact probabilistic method

The approximating probabilistic method

The approximating method is limited to two numbers: the expected value and the standard deviation. This for the determination of the estimated amount and the uncertainty, on the basis of uncertainties in the constituent parts.

Here the expectation value is linear added. If the items are independent, the standard deviations are summed quadratically. If the items are dependent, these standard deviations are also added linearly (Vrijling 1994).

The refined approximating probabilistic method

The refined approximating probabilistic method considers the quantities, prices and surcharges as a mathematical function. In all of these variables the uncertainty is modeled by a probability density function and not only by means of the expectation value and standard deviation. By a computer procedure, non-normal probability density functions are converted into normal density functions. After which the estimation amount can be determined.

In both cases, these methods are unsuitable for (discrete) special events.

The exact probabilistic method
The probabilistic method of cost estimating represents the allocating of continuous probability density functions to uncertainties, in particular for knowledge uncertainties. Unit prices, quantities and surcharge percentages are quantified via L(ower)-, T(op)- and U(pper)- values and are converted into probability density functions. Subsequently, the uncertainties about the future are added through discrete density functions. These are added to the other costs after which the whole is simulated with Monte Carlo simulations. All variables are random drawn from corresponding probability density functions. This procedure is repeated 10.000 times to reach a steady-state result (Vrijling 1994).

The result is shown as a probability distribution for the total costs. Therewith this analysis provides insight on the reliability of the estimate within the agreed scope (Willems 2011).

This research is about the last mentioned probabilistic approach. This method provides the best results, partly due to the inclusion of special events.

3.4.3. Method of probabilistic cost estimation
Assuming that the preferred solution has been chosen during the variant study, the decision uncertainty is disregarded here.

As previously mentioned in the chapter of knowledge uncertainty, the T-value is calculated on the deterministic manner[24]. There is a certain range in quantities, unit prices or surcharge percentage. The designer primarily determined quantities, the calculator primarily the cost prices. Hereby, starting point is the determination of the lowest and highest reasonable expected value, which is expressed as a probability density function. The simplest probability density function is a triangular distribution. This may be symmetrical or asymmetric, in other words skewed. See Figure 22.

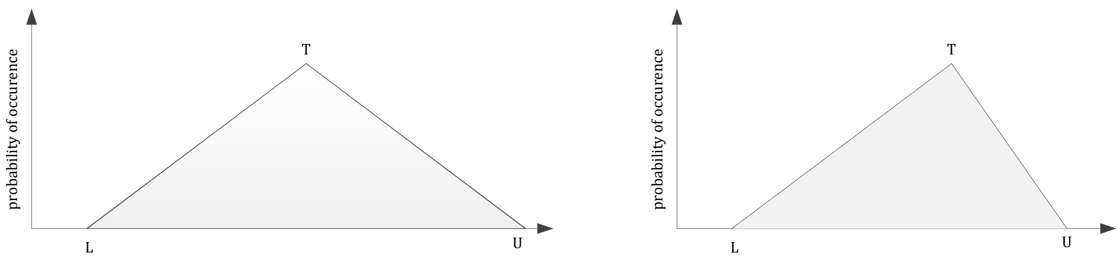

Figure 22: a symmetric and skewed probability density function (own figure)

With L and U values, the range in the design solution is given. The calculator indicates, depending on the activity with the most influential costs of the project and/or standard

[24] by means of key figures or unit prices

deviation, for which objects further elaboration is needed. With the aim to reduce the ranges of the largest uncertainties of the quantities and/or the cost prices. These depend on the construction phase and the detailing of the design. They shall be determined on the basis of:

- Knowledge of previous projects
- Subsequent costing
- Research
- Design/ assessments

The probability distribution of uncertainties in the future is discrete. During a simulation, a risk occurs or not. As a risk occurs, the consequential costs are included in the cost estimation.

After 10.000 draws the results are presented in the form of histogram, a probability distribution and some characteristic values, see Figure 23. This figure shows a solution with the normal distribution, in which the probability density is bell-shaped and is symmetric about μ. There are also other distributions like the uniform, lognormal, beta, triangular and weibull distributions.

During the simulations, a distinction is made between dependent and independent draws. Some activities have a relationship with each other, which makes them dependent. This relationship is expressed as correlation, a number between 0 (no coherence) and 1 (full coherence). To illustrate this with an example: if there is more concrete needed, more concrete must be supplied. A negative correlation is also possible.

An insight into correlation is required for a realistic standard deviation. Correlations have a major influence on the variation (σ), but a little effect on the mean value (μ) (CROW 2010).

Because the specification of individual dependencies is time consuming, it is often chosen to run two simulations, namely:

- Completely independent (correlation 0)
- Completely dependent (correlation 1)

It is assumed that the actual distribution is somewhere between these two kind of simulations.

Input

- Normal uncertainties are imported as quantity and unit prices with a triangular distribution, wherein the confidence interval for these values must be reported
- Special events are imported as probability x consequence with a discrete distribution, wherein the result of the outcome is shown as a triangular distribution and in some cases as uniform distribution

<u>Independent calculation</u>

- 10.000 numbers of drawn
- Special events and any percentage of risk reserve are considered completely independent (correlation 0)
- All quantities and unit prices are considered completely independent (correlation 0)

- Advantage: individual sensitivity analysis for each line item is possible
- Disadvantage: a too optimistic image of the bandwidth of the project estimation

Dependent calculation

- 10.000 numbers of drawn
- Special events and any percentage of risk reserve are considered completely independent[25] (correlation 0)
- Quantities and unit prices are considered completely dependent within defined groups (correlation 1)

- Advantage: better understanding of the “realistic” bandwidth of the project estimation
- Advantage: coefficient of variation is a good measure for the degree of assurance of the estimate
- Disadvantage: an individual sensitivity analysis is impossible

In accordance with the method, as defined in the SSK, risks are always calculated in an independent way. This assumes that there is no consistency between the chances of occurrence of the various risks. This is not in accordance with the reality. To demonstrate this with an example: the construction of a road section. In addition to a risk for polluted soil, there is also a risk for traffic disruption during the construction. A correlation may exist, but the correlation is one-sided. If the soil is polluted, activities are required that can cause traffic problems. Conversely, this is not true. If there is traffic nuisance, it does not lead to a higher probability of the existence of soil pollution.

Modeling the correlation between two risks is difficult in the current software; this is only possible with risks with a two-sided correlation (Van der Meer 2011).

Advice:
DACE recommends to report both the dependent and independent simulations. Here the diversity within the total estimate is important. If an estimation consists of a number of large line-items which have a direct relationship, than the diversity is small and the dependency between the line-items is large. In this case, the uncertainty will be better modeled by the dependent estimate. Similarly, if the estimate has many items which do not have a relationship, the uncertainty is better approximated by the independent estimation. (DACE 2007)

- Average value (μ)
- Standard deviation (σ)
- Variation coefficient (σ/μ)
- Contributions of the bandwidths with an 15% and 85% probability of exceedance.
- The skewness; the difference between the deterministic T-value and probabilistic μ-value[26].

[25] Special events with a common cause may be correlated
[26] Maximum value in the order of magnitude of 4% à 5%. When the skewness is larger, then the deterministic estimate is probably too optimistic

- Sensitivity analysis; by this items are arranged which make the largest contribution to the total proportion of uncertainties.
- Histogram/ normal distribution with the project estimate classes plotted against the number of draws.
- Cumulative probability density distribution of the results of the project estimate plotted against the probability of exceedance.

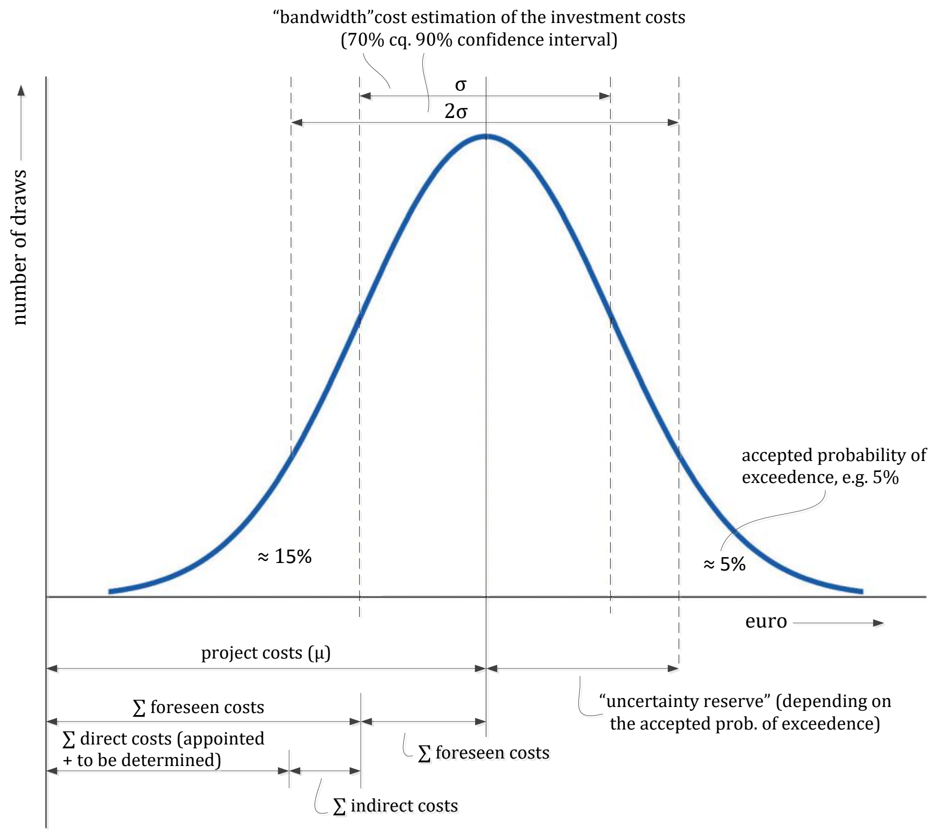

Figure 23: graphical representation of a probabilistic cost estimation by means of Monte Carlo simulations (CROW 2010)

In a graphical output the form of a normal distribution is shown. Certain terms are added which can derived from this output, as seen in Figure 23. An example of a sensitivity analysis is seen in Figure 24. This figure is an example of an outcome after the execution of a Monte Carlo simulation.

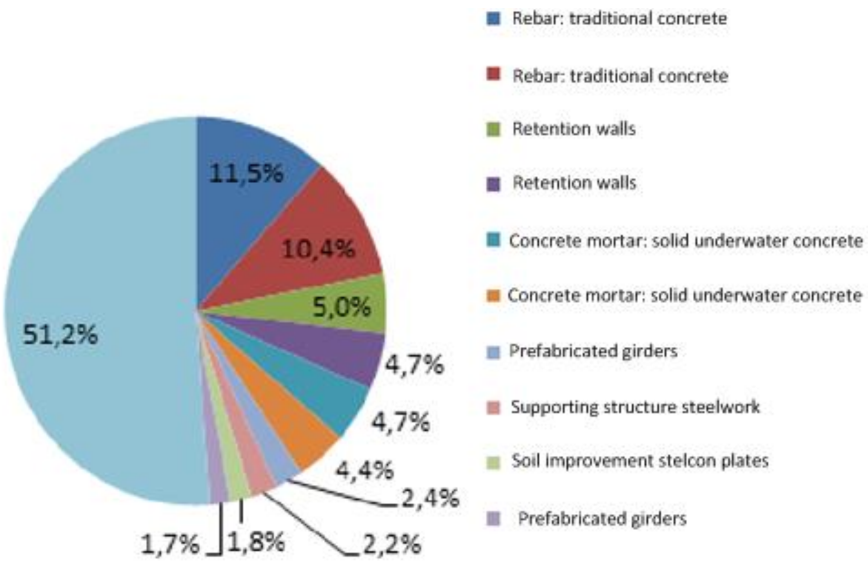

Figure 24: example of a sensitivity analysis of the direct costs (own figure)

3.4.4. The use of Monte Carlo simulations

The introduction of computers in the nineties facilitated the practicality of Monte Carlo (MC) simulations. Software companies developed simulation tools, so everybody has the opportunity to run MC simulations. There a dozens of tools that can run MC simulations. Some tools are @Risk, Chrystal Ball and Oracle Primavera Risk Analysis. There are differences in the programs.

MC simulations can be used for different purposes. The simulations are for example necessary to make business plans, IT projects, mining and oil exploration, capital investments in the steel industry, schedule and budget forecasts and competitive bidding. This has resulted in the fact that there are a lot of people that work with MC simulations from various perspectives. Unfortunately this also has a downside. Users come from different industries, sometimes without much experience with MC. Hubbard conducted a small survey with users of MC simulation tools, because he thought many users make fairly constant errors. This he described in his book The Failure of Risk Management. Data of 72 simulations have been received out of 35 people who claimed that they are fairly experienced with MC simulations. The average years of experience is more than 6. Most of the models were "simple". That means that 73% of the models had fewer than 50 variables.

His findings were that there were a lot of subjective estimates in the cost estimations. The average number of subjective variables in a model was 44%. Remarkably, no one had heard of calibration training. It's a training for a better determination of subjective odds. Research has demonstrated that a training seems to have a significant effect on the ability of users of MC simulations (Hubbard 2009). Almost all the cost estimates of uncalibrated individuals were overconfident. I.e. uncertainties are underestimated and ranges are too narrow. See Figure 25. This applies mainly when dealing with the riskiest issues: big, rare and catastrophic.

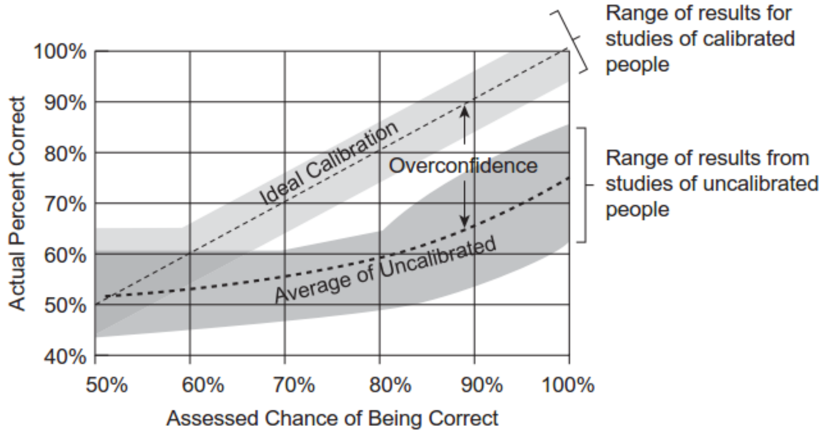

Figure 25: comparison of uncalibrated and calibrated people (Hubbard 2009)

Another notable finding of the research was that the input of the models has been verified against reality only by one person. In addition, this was not a good verification because this person offered a weak evidence for this. So, it's not checked whether the final estimates are realistic. No lessons can be drawn of the differences between the forecasts and the reality.

Last conclusion of Hubbard was that 75% of the models consist of some historical data. 35% of the models used data, specifically collected for the MC simulations. In doing so, only 4% executed additional measurements to reduce uncertainty where the model is the most sensitive. It can be said that the idea of conducting original empirical research is far removed from MC modeling (Hubbard 2009).

3.4.5. Deterministic vs. probabilistic

The deterministic and probabilistic approaches have already been explained. The main differences between them are shown in Table 7 and in Figure 26.

Table 7: main differences

Deterministic cost estimation	Probabilistic cost estimation
*Most probable amount of final costs	*Calculation of the distribution of the final costs
*Result is one price	*Outcome as a probability
*Unforeseen as a percentage	*Explicit input of risks
*Black box	*Statistically underpinned
	*Smarter choices in design and construction process
*Expert judgement	
*Knowledge from recalculations	

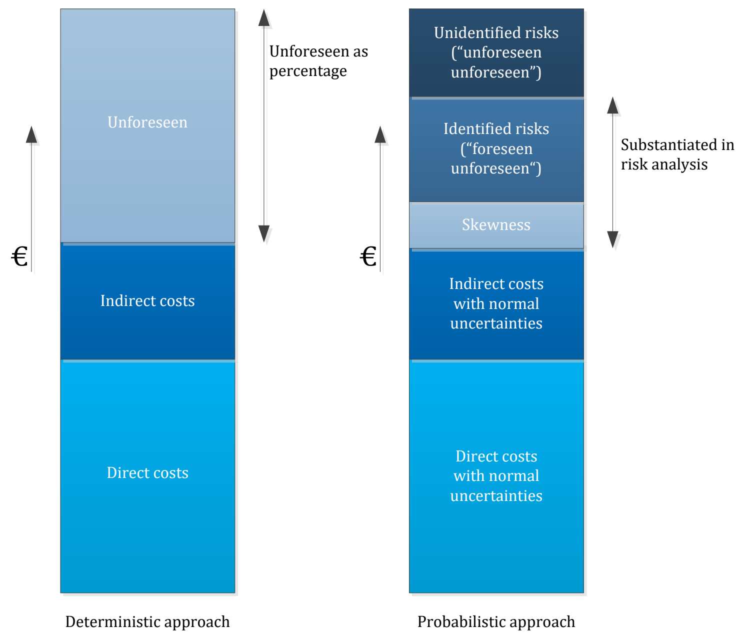

Figure 26: differences in the composition of the cost estimate (Bots and Schilder 2007)

The start principle of both methods, the bottom-up approach for the calculation of the expected T-value of the objects, is for the two different methods more or less equal. There is a difference in the level of abstraction. But the major difference is the determination of the bandwidths. This is done quite different. In deterministic cost estimations, this is done with the top-down approach through the "black box" method. In the probabilistic approach, this is also done with the bottom-up approach.

Another difference is that the probabilistic method usually need more time and budget to conduct. Disadvantage is that some agencies and most contractors are not willing to employ it on their normal projects. Only contractors engaged in procurement of highly complex projects invest in formal risk analysis (Bakhshi and Touran 2014).

This is in contrast to what is thought. Of course costs are incurred with the use of probabilistic cost estimating. There is money and time involved with, for example, the quantification of risks, the drafting of bandwidths, software acquisition, the introduction within the organization and the education of employees. These are start-up costs and permanent costs. Together with probabilistic cost estimation, the design can be made on in a more abstract way, the probabilistic design. This is one of the main advantages, together with the quantification of risks, of probabilistic cost estimation. The design costs comprise often around or more than 50% of the tender costs. So it's a big advantage when the design process can be shortened.

Furthermore, it is mentioned that contractors engaged in large complex infrastructural projects invest in formal risk analysis by means of the probabilistic approach. Somewhere there must be a break-even point if it's worthwhile to apply the probabilistic approach, depending on the complexity.

In conclusion, the advantages of a probabilistic cost estimate are the bottom-up risk control and the mathematical foundation of the entire estimate. The disadvantages are: it's a relatively new method where there is a lack of the experience of the personnel, the subjectivity in the bandwidths and more input is required for drawing up a cost estimate.

4. Literature based conclusions

The estimation of costs is crucial for the procurement of civil engineering projects. Two main streams are distinguished: the deterministic and probabilistic approach.

Probabilistic cost estimation must be understood as an integrated whole together with probabilistic design. For an optimum use for the realization of a tender bid, probabilistic cost estimating is not possible without probabilistic design and vice versa. In this process, the alignment and interaction between designers and cost experts is crucial.

As described, probabilistic cost estimating made its appearance in various sectors around last turn of the century. Also in the building industry. This method has developed further in recent years; the process is still relatively new and it's gaining in popularity. In principle, tools such as software for the use of probabilistic cost estimating is present at this time. Further, the SSK has been revised several times and has been complemented, so there is a manual how to deal with probabilistic cost estimations in the Civil Engineering industry. Yet there is the notion, both inside and outside the organization, that the methodology of probabilistic cost estimation – together with probabilistic design- is still not been fully developed. For example, the SSK is not an uniform, conclusive estimation methodology –irreverently said, it's just a good basis- so cost experts can give their own spin on among others the input parameters. And it's all about this input. Garbage in is garbage out, and garbage times garbage is garbage squared.

At this time, it's still not entirely clear how the probabilistic cost estimate should be applied in the correct manner. This is partly due to the determination of the input parameters like accuracy ranges, how to deal with (in)dependencies and correlations, how all risks and uncertainties are included and subsequently: how to interpret the output of the Monte Carlo simulations. Concerning probabilistic design it's still difficult to determine what levels of detail of objects/ sub- components/ elements of the design are acceptable for realizing a tender bid in a more abstract way. And above all: to maintain this abstract level of detail during the tender process.

How to deal with risks and uncertainties is one of the most important and difficult issues in a probabilistic cost estimation. Ultimately, the profit or loss of the organization depends on the mapping of risks. In quantitative risk sessions for reliability, availability, maintainability and safety (RAMS) can often be relied on generic statistical data. This is not the case with quantitative risk sessions of project risks. In the Civil Engineering industry, there are systematic tools such as RISMAN and the SSK, but the substantive quality of the estimate is still being determined by the cost experts himself (Kuiper and Vrijling 2005). Most organizations in the Civil Engineering sector use the SSK as guidance. However, many have given their own twist on this methodology.

Because cost estimates are often based on knowledge, experience, subsequent costings and expert opinions, cost estimates are –rudely said- dependent on a few individuals within an organization. Further, use can be made of similar projects, statistics, data from suppliers and databases.

The estimation of costs is a fairly subjective process which can be and must be more objective and more substantiated. The input obtained from expert opinions, knowledge and experience is depending on persons. Here is a weakness right away; what to do as a leading cost expert leaves the organization. They are not up for grabs in the labor market. Further, this also makes some important choices in the estimation process depending on person. To illustrate this by giving a few examples: when is an estimation of the accuracy ranges of a particular object sufficient, underpinned by the "thick thump" i.e. knowledge and experience. When should the market be contracted for more detailed cost information for smaller accuracy ranges or sharper unit prices. Why is the accuracy range 15% and not 20%? Difficult questions and not simply to answer.

One of the reasons is that projects usually are not comparable with each other. The reason for that are the various types of contract but also the different construction methods for structures. Consider also the environment and project specific risks. Furthermore, there are several ways to deal with risks. Which way is the best? Secretly there are many parameters where the costs of the structure from depend. That makes the estimation of costs an difficult affair.

The investigation is focusing whether accuracy ranges can be more reliable and underpinned.

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5. Clients and the probabilistic approach

To answer sub question 1, research has been done regarding how clients come to an accurate cost estimation to large projects.

Contractors make cost estimates, however clients do the same. They make management estimations what a project will cost to establish a correct budget. When RAW contracts were common, on the basis of a fully engineered design a management estimate could be made. Now clients specify their projects on a functional way, the process for clients has also changed.

To know how clients make their cost estimates to get inspiration, an interview is conducted with a cost expert of Rijkswaterstaat. With the aim to find out how they come to a cost estimate, in this new situation[27].

In 1992, the Project Ramingen Infrastructuur (PRI) is developed to improve the quality of cost estimates. An uniform structure of estimates was required for the cost expert itself, to compare estimates with each other and to fit cost estimates of third parties. In addition, a conceptual framework was also important in order to avoid miscommunication where cost elements are placed. This was often the case. So, it's designed as a communication tool to create more clarity. In this way, a surplus value was obtained. To give two examples: engineering costs were housed in different locations and the profit margins were housed in the risk category. So, the main aim of the PRI wasn't to specify costs in a better way.

The SSK, developed by clients, is an extention of the PRI. The SSK (3rd edition) describes the probabilistic approach of cost estimations, because it was necessary to express risks explicitly and not to entrust them in a general category of contingency budget as a certain percentage. This has created the basis to make founded pronunciations about bandwidths, exceedance frequencies and the greatest uncertainties in the cost estimates. In other words, for a better quantification of risks.

Unfortunately, there was not much information about the content and the method of probabilistic estimation and design by RWS, because RWS subcontracted these services to external parties such as engineering firms. RWS give them the message: create a design and (poss.) the calculation, so that the cost estimate has an acceptable range of a certain percentage.

In conclusion, the probabilistic approach here is primarily used as a communication tool. To obtain a uniform cost estimate and to make risks explicit. There is not mentioned in which way risks must be identified and about the objectivity of the input of the MC simulation. I.e. derived from historical data and which statistical argumentation must be used. In this case the probabilistic approach has nothing to do with the word probabilism, derived from the Greek verb προβαλλο (probálloo), which is inextricably linked with terms such as the probability theory and the likelihood.

[27] Working with integrated contracts

6. Definition of probabilistic cost estimation and design

To answer sub question 2, research has been done regarding the definition of probabilistic cost estimation and design. By interviewing employees of the organization, as seen in appendix N, it has become clear that the notion of probabilistic cost estimation and design is still unknown or unclear to many of them. It can be interpreted in several ways. This is consistent with the conclusions in chapter 5, where is explained that the main aim of the probabilistic approach is: a communication tool.

Probabilistic cost estimation and design can be interpreted in different ways. Therefore, it will be investigated whether a unambiguous concept can be created. Through concepts and definitions in literature and by representatives of the organization, with different functions and from various disciplines. Everyone has a certain picture of probabilistic design and cost estimation, both inside and outside the organization. The definition of probabilistic design and cost estimation should be clear among employees; the basis of a successful introduction and use. First the word probabilistic is scrutinized after which definitions are sought in literature. Subsequently, the point of views of employees are listed, so that there can be defined a clear definition.

<u>Probabilism</u>
The word probabilistic is used in combination with “cost estimations” and “design”. It is necessary to have this understanding clear, before there will be looked at the words probabilistic design and probabilistic cost estimations. First, the general definition of the probabilism is explained, after which the mathematical definition is explained.

In general, “probabilism” is about laws of chance. A philosophical theory which discloses that “reality” exists, but never be fully known. Probabilities are accessed through statistical knowledge and data. According to the probabilism, the truth can be better approximated by the progression of knowledge. Advancing knowledge makes it possible to make statements with a larger certainty. Statements cannot be done with absolute certainty.

The probability theory is a branch of mathematics that deals with situations in which chance plays a role. The result is that there is no certainty about all sorts of outcomes. The theory of probability originated from the social need to deal as effectively as possible with uncertainties. The probability theory attempts to provide the mathematical tools to a wide range of social activities and sciences, in order to make reasoned choices or to draw conclusions within an environment of uncertainties.

6.1. Probabilistic cost estimation in literature

Definitions that are mentioned in this paragraph are found in literature. Key words are underlined that are important to the coming of an unambiguous definition. Some key words are mentioned several times, there are underlined only once.

“***<u>Calculating</u>*** with ***<u>uncertainties</u>***; drafting a probabilistic cost estimate is a good ***<u>tool</u>*** to ***<u>identify</u>*** the ***<u>consequences</u>*** of ***<u>uncertainties</u>***” (CROW 2010). These uncertainties are: ***<u>knowledge uncertainties</u>*** and ***<u>uncertainties in future</u>***.

"A good tool for ***quantifying*** uncertainties in the cost estimate is preparing a probabilistic estimate. It distinguishes two types of uncertainties, both calculated ***individually***: normal uncertainties and unforeseen circumstances (special events)" (Van der Meer 2003).

"***Insight*** into the construction costs in an ***early project phase***, controlling the ***construction costs*** and insight of the project ***risks***" (BKS Schagen 2015).

It's a tool to translate the risks and uncertainties into the ***estimation***. The result consists of two outcomes: the ***sum of the cost items*** of the estimate and the ***bandwidth*** of the estimate. The bandwidth, together with the associated statistical reliability is a measure of the ***degree of assurance*** of the cost estimation. Probabilistic cost estimation determine the order of cost items that have the greatest impact on the bandwidth and therefore, from a financial interest, have priority in the management of risks and uncertainties (Kuiper and Vrijling 2005).

"Briefly summarized, it's the assigning of ***continuous probability density functions*** to uncertainties (normal uncertainty) about ***prices, quantities and surcharge rates***, quantified by means of ***L-T-U values***. Subsequently, the project specific risks (***special events***) are added through ***discrete*** probability density functions. After which the whole both "***completely independent***" and "***completely dependent***" is calculated by ***Monte-Carlo simulations***. With a probability distribution as the final result for the final cost" (Willems 2011).

NASA also deals with complex, one of-a-kind systems that have a lot of risk and uncertainty associated with them. "NASA embraces probabilistic cost analysis as a means of ***improving*** its delivery of projects ***within budget***. NASA leadership believes that all projects should submit budgets that are based upon a quantification of the risks that could cause the project cost more than initially anticipated. Identification and estimation of risk and accommodation of uncertainty is a key to improve NASA's cost performance, thereby helping to establish a more credible cost ***baseline***. By making use of probabilistic techniques, NASA is able to more effectively communicate the impact of changes to planned or requested resources by providing quantified effects on the probability of meeting planned cost and schedule baselines. A probabilistic analysis process helps NASA management ***understand*** the risk involved, informing decisions on the appropriate amount of risk that the Agency is ***willing to accept***" (NASA 2015).

6.2. Probabilistic design in literature

In literature probabilistic design is always related to the technical design of risks and uncertainties of constructions. Here it is about strength calculations, chances of failure, lifespan and safety philosophy. A completely different thing.

The organization has drawn up its own definition. "With probabilistic design, quantities are linked to the project information in the early stages of a project. In all quantities bandwidths are included with the consequence that designers are able to give dimensions of objects or components with minimal design effort" (Heijmans 2014).

6.3. Probabilistic cost estimation and design by employees

Department head of acquisition Wegen MK: "probabilistic estimation and design is ***appreciating*** uncertainties"

Cost expert Wegen FM: “indicate, with a certain degree of assurance, that a project can be realized for a certain cost price”. In other words: “how ***reliable*** are the direct costs”

Cost expert Civiel BB: for the design division: “with ***minimal design effort***, designers should give ***dimensions*** of ***objects, partial objects*** or ***components***”. For the calculation division: “calculators should give, based on ***knowledge***, ***key figures*** and ***unit prices***, cost estimations of objects, partial objects or components”.

Department head of acquisition Civiel TH: “for the tender A2 Maastricht (project of hundreds of millions), I have checked the map first. The question was: what is the length of the road and how many constructions does it contain. Within half a day, I could give a prize accompanied by an estimate of the minimum and maximum value. On the basis of ***experience*** and key figures a L-T-U (lower, top, upper) is obtained. If there will be designed in the first ***level of detail***, this is for me deterministic. Some people still call it probabilistic if the design is elaborated at the highest possible level of detail.”

Advisory consultant constructions LM: “Some people are struggling with this term, because everyone has a different definition for probabilistic estimation and design. In a tender, the time is usually ***limited***, with the probability that a work is not obtained. So the attention should be divided in a structured way and the ***focus*** should be on issues that matter”. This definition is supported by an example:

“Years ago, I already said that energy and effort has been put into wrong topics during a tender. An example about the calculation of the position of the points of support and the collision protection of a column. Days are spent on the design in something that will cost a little in proportion. While one day is spent on the design of a bridge deck, which has far more impact in relation to the cost”. Dus een verkeerde focus.

Department head Ontwerp Grond en Wegen AB: “It’s important what is meant by probabilistic estimation and design. I’ve not a precise definition of it, but with a team agreements must be made about the level of elaboration of the design. In the past, by means of RAW specifications the quantities were determined exactly -including every curve in a gully- but that is not the intention here. Our main question is: to what level of detail should we go? By ***risky line-items***: elaborate in high detail”.

Department head Ontwerpmanagement HIP HH: “risk-driven designing and the estimating of costs to keep the transaction costs as low as possible”

Tender manager PK: to allocate bandwidths on the deterministic defined quantities and (unit) prices, in order to simulate this with the aid of Monte-Carlo Simulations.

Design manager FN: probabilistic design is used for the determination of the ***type of solution*** and up to which level of detail this solution is worked out. The level of elaboration must be agreed which will be accepted in advance, which there should build upon.

6.4. Overview

Figure 27 provides an overview of key words concerning probabilistic cost estimation and design. Most of the words have to do with both the cost estimation and the design; some are limited to one of the two. From these key words, the notions of probabilistic cost estimating and design will emerge.

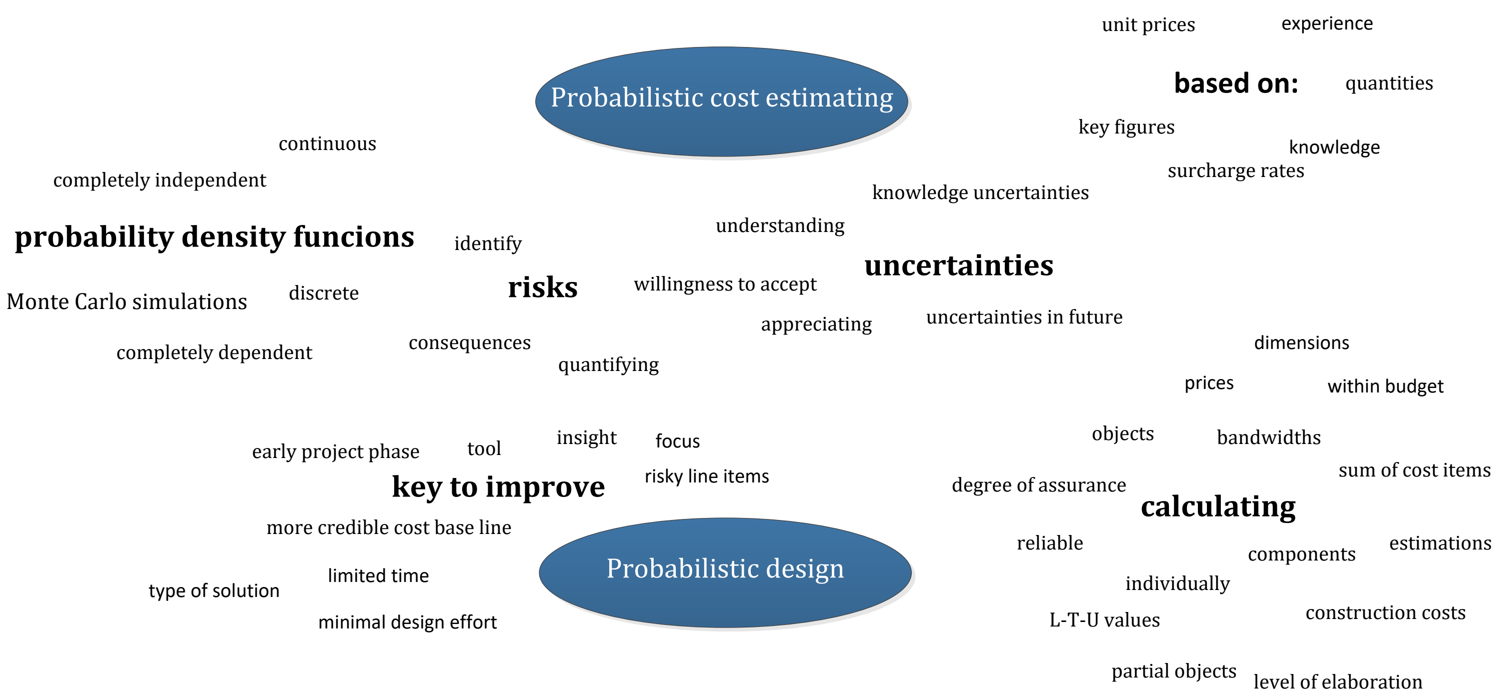

Figure 27: key words concerning probabilistic cost estimation and design (own figure)

6.5. Definition

In the paragraph below the key words in figure 27 are summarized in own definitions.

Probabilistic design

Probabilistic design is the process, starting in the variant study, continuing if the preferred design is selected to the completion of the tender bid. Through this method of risk-oriented design, it is possible for the less risky objects/ object parts/ components, with not a too high share of the total estimated amount, on a more abstract, in advance accepted level of detail. The design quantities including bandwidths are determined with less design effort, after which the cost expert can get started with the (probabilistic) cost estimation.

Probabilistic cost estimating

Probabilistic cost estimating is the process, where knowledge and future uncertainties are translated for the benefit of the cost estimate, for the calculation of the total construction costs for the tender bid. Based on knowledge, key figures and unit prices, the abovementioned uncertainties are estimated per object/ partial object/ element, depending on the level of elaboration of the design. Hereby, bandwidths are assigned. The total construction costs are simulated, optionally with the design quantities, by means of Monte Carlo Simulations. After which a mathematically-based cost estimate derives, with which a certain degree of accurance the tender budget can be determined. It is also used as a communication tool to make risks explicit.

6.6. Own interpretation

As earlier described, probabilism is about the chance of probability. To start working with probability calculations and to use this in tender phases, data should be collected from recalculations. A few years ago people in the organization started to set up a database of overpasses. The purpose of this database is to make assumptions, for example about the amount of rebar (in tons/m^3). This database is not maintained anymore and that is one of the disadvantages of starting a database. One of the requirements is that the available data should be imported consistently. Furthermore, this database should be kept up to date.

For other design activities, there are no databases available. The same applies for the costs. Recalculations are not made and not stored in a database. The explanation given by cost experts is that there are too many variables in different projects. And if works are completed, the focus on new tenders is laid instead of making recalculations. So, if little or no data will be collected, nothing is done with probabilism. Of course, quantities and costs are simulated by means of Monte Carlo simulations. This by addition of bandwidths by deterministic defined prices. This is not my definition of probabilistic cost estimation, call it pseudo-probabilistic. If bandwidths are added to deterministic defined quantities and prices and these will be simulated, the deviation with the deterministic specified price is minimal. It can only be said with how much certainty a work can be executed. Little gain of time is achieved with this method. This has to change, to use probabilistic design and cost estimation as intended. But first, obstacles in the implementation are examined, as well the methodology within the organization.

7. Implementation factors

To answer sub question 3, research has been done regarding the factors that obstruct a successful implementation of probabilistic cost estimation and design. For the organization, the implementation of probabilistic cost estimating and designing is not at all functioning as intended. The intention of Heijmans Infra was to tender all large projects in this way, beginning in 2014. During this research project one project is completely tendered with this approach. The past two years it was decided in advance to elaborate some tenders with the probabilistic approach. Due to certain factors, both technical and practical, there is (partially) slipped back on the familiar deterministic way. This chapter investigated factors which impede the implementation of the probabilistic approach.

Depending on the project

The first important factor that is decisive is the demand of the client. If a client asks for a detailed plan before the work is to be awarded, this abstract way of realizing a tender-bid makes no sense. This is often the case with smaller clients such as provinces and municipalities as compared to national authorities, but this is not always the case.

Furthermore, the application depends on the proportion of the disciplines Roads and Civil. If Roads predominate, it is more difficult to design a project in a probabilistic way. That is partly due to the variety of the underlying specialisms. These are groundworks, pavements, noise barriers, dynamic traffic management, traffic measures, drainages, surrounding roads and ecology.

What also plays a role in the discipline Roads: for relatively little costs, by some components the most comprehensive design can be obtained. For example in the cross sectional profile. It is always rewarding to elaborate this at the highest level of detail.

Unfamiliarity

What emerges from the interviews, the understanding among a part of the personnel is unknown or unclear. It is essential to have a univocal definition. In addition, this definition should be publicized in the workplace.

Dozens of design leaders and design managers are involved in tenders. Some of them have never heard of design levels and Monte Carlo simulations. They will certainly not propose to estimate and design a tender probabilistically.

Mindset

The use of probabilistic cost estimating and designing requires a certain mindset of the management board, steering committee and the level of abstraction of employees within the organization.

After the first experiences with this method, it is noted that many drawings are still too extensive. The question is: how is it ensured if a low elaboration level is agreed upon, the final product is also elaborated on this level. Because there will be, wittingly or unwittingly, continued with the further detailing of the design. Designers and calculators should be aware when objects reach an agreed elaboration level, that this is sufficient for a tender phase. A difficult task, because cost experts want to do their work as precise as possible. Most of them are struggling with this more abstract approach, because there is a kind of fear. If an estimate turn out wrong, it is feared that they are judged on their work. Despite the fact that the board wants a more abstract approach. Therefore, discipline leaders should provide more support to the cost experts.

Chosing a lower elaboration level is a matter of daring, and so it is especially important to change the mindset of the employees. They must be supported in this process by the higher authority just like children learning to ride a bike: they need a helping hand.

Administrative/ organizational

What has blocked the introduction is that this new way of tendering is not the first change in the organization. Clients move more and more responsibility and pressure to the contractor with new forms of contract. Also issues like Lean Six Sigma and BIM are recently introduced, which made it too hectic to apply the probabilistic approach. The regular work must also be executed.

It is therefore important to show the necessity to the employees. This should not be imposed, but well-motivated. Then, the willingness is higher in order to cope with changes. This is in contrast when a change is imposed without motivation.

At this time, the application depends on individuals. Whether a tender is approached on a deterministic or probabilistic way, will be agreed on project level instead of company level.

Employees

Probabilistic cost estimating and designing can’t be applied by each cost expert and constructor. Because some of them are outside their comfort zone when applying the new method. They are accustomed to calculate everything in detail. A cost expert will know everything in detail to get a sense of security with its price. This is partly because they have to defend the prices with the management. By former RAW contracts they are familiar with complete elaborated designs. So, when designing in a low level of detail, it is not certain whether the cost estimation is fully supported.

Inexperience may also play a role. An inexperienced calculator is not inclined to work with a low level of detail, because there is a chance that things are forgotten.

Per cost expert there must be viewed which persons on which projects will be used, depending on their courage, potential, knowledge and attitude towards probabilistic cost estimating. Each calculator has its own vision with regard to elaboration levels. Often they are also specialized in a number of objects, which they can manage better.

Cost experts often use the safe middle path and should gain confidence that the probabilistic approach works.

Furthermore, people should be complementary in a team. People are needed with a sense of technology, people who know the process well and creative people. Through a mix of right people, there is a bigger chance of getting awarded. Sometimes there are not the right people in a tender team because it is impossible to get the right people together. Then there will not be participated in a tender.

Finally, approximately half of the manufacturers, designers and geotechnicians are not permanently employed at the organization, but they are hired. This is a trend nowadays. It's very difficult to engage hired employees in the probabilistic design and cost estimation process. They are often unknown with this principle and are therefore no pillars whereby this method can be applied.

Efficiency
After awarding, the design should be updated and further elaborated. There should always be considered whether a little more effort in a tender is rewarding. As reported under the heading "depending on a project" with the example of the cross sectional profile. With just a little more effort objects are elaborated to the highest degree. So that after the awarding not everything has to be elaborated again.

General/ remainder

- Lack of time is probably the most important factor.
- For a better coordination between the various disciplines/ jobs in a tender team, it's worthwhile for the tender team to work at one place. If different disciplines are working in other locations, these tenders are doomed to fail. Especially if a lot of coordination is required; the first requisite for the successful implementation of the probabilistic approach.

The organization should clarify how to deal with this method and its application in a unequivocally way. That it is practiced whenever possible. At all levels within the organization, this approach should be supported. There should also be prevented that everyone is going to point out to each other. In other words: if the calculation department has no intention to apply the probabilistic approach in a more abstract way by whatever reason, it has an effect on the design department and vice versa. So they should motivate each other for the occurrence of synergy.

In addition to the abovementioned factors, there must also be well viewed whether people who work with the MC simulation tools, are suitable to cooperate with it. By this is meant: to import the parameters and run the simulations is one point, but there must be carefully examined whether the results are valid.

8. Methodology of the organization

To answer sub question 4, research has been done regarding the current experiences and methods of probabilistic design and estimating of a recent tender of the organization. This tender is fully worked out with the method of probabilistic design and cost estimation, and this never happened before on such a scale within the organization. The work consisted of a junction with four adjacent highways. A ceiling amount was known.

In Figure 1 the organizational chart of Heijmans is shown. Heijmans Integrale projecten serves for the disciplines Roads and Civil[28]. The process of a recently made tender is described whereby probabilistic cost estimation and design is applied. Between the method of Roads and Civil there are several differences which are explained.

Start tender

Via TenderNed, the online market square for procurement of the Dutch government, contractors search for interesting tenders. Interesting means tenders where the organization can distinguish themself and whether the projects match with the competences and strategy. The tender manager and director have contact about these works. One of the requirements for a "go" during a go-no go decision is about the availability and skills of potential tender team members. The director asks the head of acquisition of the departments Roads and Civil whether there is enough staff to participate a tender. If the tender team is complete and all decisions are “go”, there can be started with the participation in a tender.

Variant study

First, a start is made with the variant study. In this case, three “extreme” variants of a junction are prepared in different areas; one variant with the focus on realization, one variant with the focus on plan study and design and one variant with the focus on the traffic and the environment. The fourth variant is an extension of the reference design. The ultimate variant should be selected within these extremes. See also Figure 28.

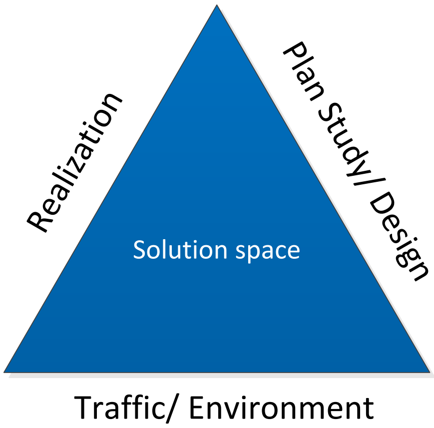

Figure 28: the solution space within three variants (own figure)

[28] All these three disciplines have been merged into Heijmans Infra since June 2015

Hereby, the junction is the point with the most different solutions, hence the most variants are made of this construction. Also for one adjacent road with enough distinguishing features, three variants are elaborated. These variants are evaluated by a trade-off matrix based on criteria such as costs, MEAT and practicability. The outcome of the variant study of the junction: one variant was too expensive, the second variant was a bit overpriced, the third variant offered less added value and the fourth option was sober (additions to the reference design). Subsequently, the slightly too expensive variant and the variant with a little added value are further developed to make them cheaper and to create more added value. Separately, these variants have been further developed. The result of these variants were virtually identical. This has become the winning[29] fifth variant.

Elaboration Civil part
The work included approximately 50 overpasses accompanied by about 20 decks. This concerns the civil section and civil is in this case the other name of the discipline which deals with concrete constructions. Instead of the traditional construction process, no drawings are used for the communication between design and calculation. Factsheets, that can be found in appendix K, are used for this purpose and replace these drawings. A factsheet is the basis for communication, for the fixation of the output and serves as input for the calculation. Initially the fact sheets are created as a concept, after which they become definitive if all relevant information is known. The factsheets are the basis for the preliminary design if the tender will be won.

For each overpass a factsheet is prepared wherein prior arrangements have been made about the level of detail of the design of the overpasses. A distinction is made in: decks, abutments, intermediate supporting points and foundations. These are defined in a memo. This memo is shown in J. and it includes all design parameters which are required for a probabilistic cost estimate. These levels of detail are prearranged between calculation and design. It is important that the definitions are clear, for example the definition of the dimensions. Hereby the question is: what is meant by a deck. Does that include boundary elements (in the width); is the length up to the joining interface or up to the imposition construction, and so on. After this arrangements, and also the arrangements about the bandwidths, no deviations are desirable anymore. This is therefore not the intention, except in deviated cases.

Starting point per construction is that the construction will be built in the open field. Hereby additional measures must be taken as, for example, a rail overpass will be built. This information is also described in the factsheets.

Design quantities can be easily imported into the calculation sheet in order to be multiplied with verified unit prices. Further, a factsheet comprises in addition to this basic information, if necessary, highlights/ special features and possibly an explanation. An example of a factsheet is shown in Appendix .

Elaboration Roads
The discipline Roads is also working with factsheets. For an example of this factsheet see appendix L. This is done only for the secondary road network, by the intersections with the

[29] The winner of the variant study

primary roads. The format is basically the same as Civil. The primary road network is drawn in 3D.

The first meeting has started with preparing the factsheets for the surrounding network. The disciplines of design, calculation, MEAT, traffic phases and definitive situation were present to determine what and how in a factsheet should stand. The project has been divided into objects that have been imported in Relatics.

The road design should be consistent with the newly build overpasses. Therefore it is important that first the department Civil has his factsheets definitive, after which the design of the road can be adjusted to this. Because of the interfaces between the sizing and alignments, first the horizontal alignments are determined. After that the vertical alignment. Arrangements will include the height/ length ratio of girders. Then cross sections are designed to see whether there can be built obstacle-free and for viewing options such as guiding rails.

From the contract the main requirements are selected (or deviating requirements, or requirements with a share in the costs). If a slope of a bicycle tunnel is normally 8%, and the requirement of the client is 2%, it will be placed in the requirements selection. Placing gulley's every 20 meters and sowing grass seed in the roadside is a matter of course. They are not indicated.

Traditional, groundwork is viewed every 50 meters with the aid of 3D drawings (only the contours). In this tender, a total of 120 profiles are created about 32 km (so an average of 267 m). Of course it depends of the equivalence of the land and the cross-section, but with the addition of bandwidths work can be saved.

The differences per discipline

The design method and the cost estimation method are different. The first difference between the disciplines Roads and Civil is that there are more underlying specialisms involved by the first mentioned discipline. These underlying specialisms are: groundwork, pavements, noise barriers, dynamic traffic management, traffic measures, drainage, surrounding roads and ecology. They all need to be involved in the design.

Secondly, the work of Civil is more factual (it's clear which elements are there in an overpass) in comparison with the discipline Roads. By Roads there are several spatial variants possible on the design of the road. For that reason the parameters and the level of elaboration for each design per construction can be determined in advance. On which the cost expert can base the cost price per construction.

This is another design- and cost estimation approach that is used by Roads. During their design phase, there was interaction between design and calculation. Here the design department did its job demand driven. More in this in next section.

The third noticeable difference is the way of forwarding to the overall cost expert. Civil simulates the costs of the structures by means of Monte Carlo simulations by themselves. After which the P-values of the constructions will be sent towards the overall cost expert. Roads supplied their quantities and unit prices with corresponding bandwidths. After which the overall cost expert will simulate this data. Finally, the board will ultimately decide which P value is chosen.

General communication
Within a tender team, several meetings are held at different times. This for a good coordination in and between different disciplines and for a good communication to the project organization during the tender phase.

- Design consultation
    - Transcends disciplines; on a weekly basis. It's about the state of affairs and a tour of the work is done here where the action list is reviewed. Participants: a permanent team consisting of a design manager, discipline leaders, design leaders and the realization manager. If necessary, specialists draws up to the table.
    - Internal consultation within the design team; on a weekly basis.
- Design atelier, it is organized according to need. During the design atelier, the junction, the surrounding roads, the noise, temporary traffic measures and cables & conductors. A delegation of all disciplines and specialties sit together to achieve an integrated design. With the aid of the Geographical Information System (GIS), everyone has access to the most recent information.
- Phasing consultation, on a weekly basis. The phasing consultations starts with a small group, consisting of the discipline leaders and the design manager. As the tender progresses, specialists of the different disciplines are involved for an accurate coordination.
- Weekly stand: with the entire tender team the planning is reviewed. Here there is viewed whether the milestones are achieved or not. The tender team also gets a complete picture of all the activities.
- Road consultation, on a weekly basis. Where the discipline leader is together with his whole discipline. A list of actions is taken by (what has been done and what needs to be done) and what information I need from whom.
- Civil consultation. The same applies here as the Road consultation.
- The core team is meeting every five to six weeks. These conversations are about the level of detail. The activities on the action- and decision list will also be reviewed. In total, four meetings have taken place, otherwise there is no workable situation (making an update of the estimate also takes a few days). One scheduled meeting is skipped, because it makes no sense to meet each time.

Three times an provisional state of affairs is defined by the overarching agency. Here an update of the cost estimate are prompted, on which they then anticipate.

Interaction
Previously, it was standard that the cost estimation was made on the basis of detailed drawings. With the use of probabilistic design and cost estimation this is done in a more abstract way (e.g. by means of fact sheets). Therefore, other activities are necessary to come to a solid cost estimation. One of these activities is an enhanced way of communication between designers and cost experts.

When applying probabilistic design, not all elements are elaborated in detail after which no communication is further required for the determination of the cost price. This is dissolved at the two different disciplines in different ways.

Because civil structures reasonably have the same structure (the basic data, the so-called building blocks, are more or less the same) there is little deviation from the agreed level of detail. During the cost estimation process, there was actually no discussion possible between the calculation and design discipline. This way of working is not possible within the discipline Roads. The design here is demand-driven, until the line items are at an acceptable level.

There is no fixed scheme to determine whether a line item is at an acceptable level. An important question to get uniformity, or to make firm commitments in this. Here the total costs per line item is decisive, as well as the standard deviation. Obviously, it also depends on the time constraints and the deployment of personnel. So, there are no fixed standards what should happen with major cost drivers with a small standard deviation, and vice versa. See figure 29.

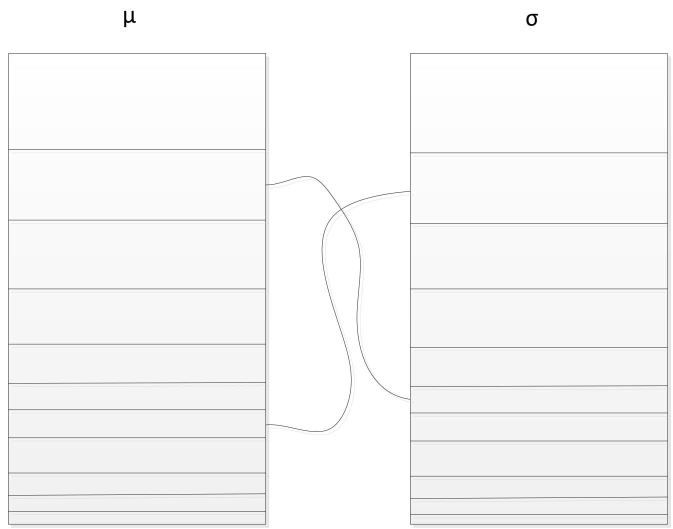

Figure 29: cost driving activities with a small standard deviation, and v.v. (own figure)

Further details

To determine the total engineering costs, the constructions are divided into families. A distinction is made in single decks, flyovers, portals, recalculations, cycling tunnels, overpasses across the railroad and overpasses across the railroad with several supporting points. These costs were calculated per family, after which these costs were multiplied by the number of that kind of constructions. The total engineering costs will normally be between 3-15%, depending on the complexity of the work.

For the determination of the contingency budget, first there is calculated with a certain percentage of the total cost estimation, after which risk sessions are started. A risk ranking system is used with numbers between 0 till 5, where each number has a certain quantitative or qualitative meaning. It stands for probability of occurrence, financial impact, impact in the planning, impact in the quality in the end product (both as opportunity as threat), impact in safety, impact in the environment (as well as opportunity, threat and infra-specific) and effects in the environment. The probability of occurrence is multiplied by the sum of the consequences, after which this amount will be offset against the financial amount sum of the opportunity or threat. See also appendix M.

Each managing director looks at risks in a different way. In any case, every risk is signed off but there is no standard method. Sometimes the financial risks or the top risks are covered and another times other previously mentioned methods are used. When working with alliance partners, they have also a say on what methods are being used.

In this tender, the MC simulation is carried out independently. An external cost expert experimented a lot in the past with correlations. His conclusions was that this make little difference.

For the planning use is made of Primavera. For the cost estimation @Risk, an add-in for Excel.

Evaluation

After speaking the two design leaders and two cost experts of this tender, there can be concluded that the process went well. By the discipline Roads, there was strictly checked of the agreed level of acceptance was maintained. There were many people who wanted more detail, but the design leader kept proper supervision.

By the discipline of Civil, the process was less iterative, because it was completely clear beforehand what should be elaborated by using factsheets.

The abovementioned findings are consistent with a brief internal evaluation of the probabilistic cost estimation process. In addition of matters that were positive, points of attention were:

- Make the probabilistic approach a more common “problem”
- Organize more comprehensive sessions to work towards the ceiling amount of the contract price

Measures which must be taken include:

- Sets demands on your team and the people. They have to cope with it and they should have the courage
- Don’t be afraid to “freeze” the design
- Determine the bandwidths through a better interaction between the disciplines design and work preparation/ calculation

The advice of the evaluation is that there should be continued with this probabilistic approach.

9. Possible improvements

To answer sub question 5, research has been done regarding issues in the probabilistic procurement process that can be further optimized. As previously mentioned, there are ways to improve the process of probabilistic cost estimation and design. The process can't be fully optimized at once, but this must be done step by step. This goal will not be achieved within a few weeks or months. It may take years to get the "desired optimal process". This only works with a broad cooperation in the organization and both sufficient time and energy should be invested by everyone who is involved.

This idea is similar to Learning by Doing (LbD), a concept which stands for the capability to increase the productivity during repetitive activities. The increase in productivity are usually achieved by gaining experience and making small improvements, in order to get the desirable long-term process. This is represented in Figure 30, where improvements lead to a possible shortening of the entire tender process.

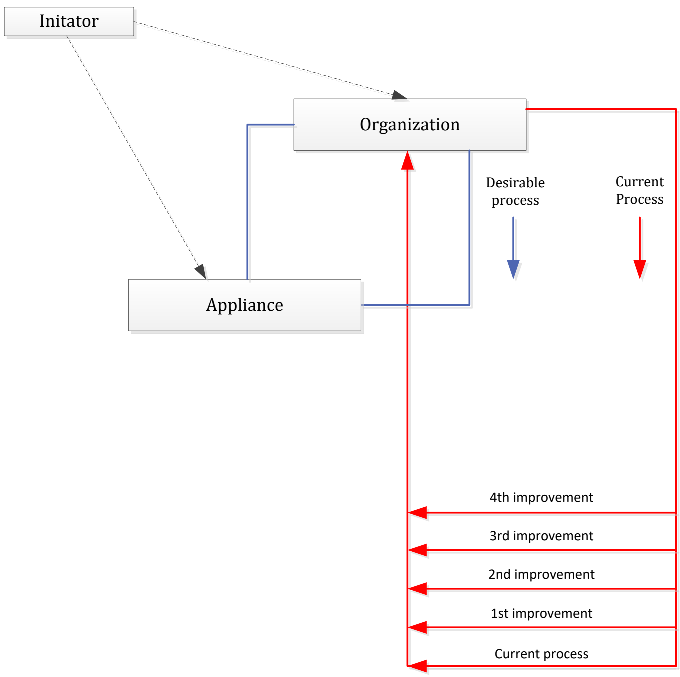

Figure 30: a representation of an improvement plan (own figure)

According to Kenneth Arrow, professor and winner of the Nobel Prize in economics, LdB and stepwise improvements are the driving force for innovation and technical change. Small changes are also responsible for the long-term growth. The basis of learning by doing is Kaizen[30], part of the lean philosophy.

9.1.Where to start

This research has demonstrated so far, that probabilistic cost estimation and design are very complex topics. Now there is a foundation within the organization that can be further optimized. Question is where to start, because this should be done gradually. Before this question can be

[30] Japanse for "change for improvement"

answered, first the purpose of the optimization must be known. Should the tender process speed up or should the tender process become more accurate[31]?

From previous observations and findings among staff there can be concluded that with fewer staff, a tender is processed, with a contract value of several hundreds of millions in a reasonably short period of time. There was a ceiling amount known, so therefore you can't compare the total contract price with the other bidders, but it can be said that -on other criteria- this tender is narrowly lost. As indicated, there are a few improvements in the current state of affairs. Hence, the emphasis here is on the accuracy of the tender bid.

9.2.Input of Monte Carlo simulations

As reported, a correct input of MC simulations is the most important part of the accuracy of the cost estimate. Within the organization, ranges are determined mainly on expert judgement. Cost experts base that ranges through, among other, experiences out of previous projects and through the inquiry of prices, but statistics out of historical data is not used. Furthermore, risks are imported as completely dependent, or completely independent. This is not the way to obtain an accurate approximation of the bandwidths and the risks as explained in the literature study. And is a probabilistic cost estimate not based on a probabilistic input, which is not intended.

Subjectivity

In addition to the matter how reliable an expert judgement is, there are other factors that can cause abnormalities in the determination of bandwidths. First of all, all respect for the knowledge and expertise of the cost experts and designers who estimate the bandwidths of all kind of uncertainties and risks in this way. But there is demonstrated that the human being is an unreliable estimator by falling into one or more cognitive pitfalls, the so called cognitive biases.

One of these pitfalls is the anchoring bias. With this psychological phenomenon it is meant that a decision is based around a reference point. People are in fact hardly capable to estimate a reasonable price for a product or service. The reason is that brains are much more sensitive for differences in relative terms than in absolute values. For that reason people always look for a reference point, the so called anchor. This reference point, the deterministic determined values, has great potential to influence an estimate.

In the context of probabilistic cost estimation it is worth remembering that anchoring may occur in the estimation of bandwidths around the price and quantities via L and U values, where the T-values are given. Many experts seem to be inclined to estimate the ranges (too) near the T-values (Willems 2011).

There are dozens of other cognitive biases, like the student syndrome (by procrastination, safety margins are poorly assessed under time pressure) and the optimism bias (experiencing of lower risk compared to others derived from, among other things, the desired end result and the overall mood). These biases are not always affected by these expert judgments, but it must be taken into account when the odds and the L-T-U values are quantified by expert judgement.

[31] Accuracy in science, technology industry and statistics is the degree of conformity of a measured or calculated quantity to its actual (true) value

To get these price- and design quantities grounded (fact-based instead of option-based) is an option to collect and store them in a database. This by means of the mapping of these quantities and costs, which arose under certain conditions and situations. By applying filters and to remove outliers, statistics can be applied to these dates. After which there must be sought for unifying factors, so that there can be worked on a micro level. Ultimately, statements can be made about average values, modes, ranges and standard deviations. See Figure 31.

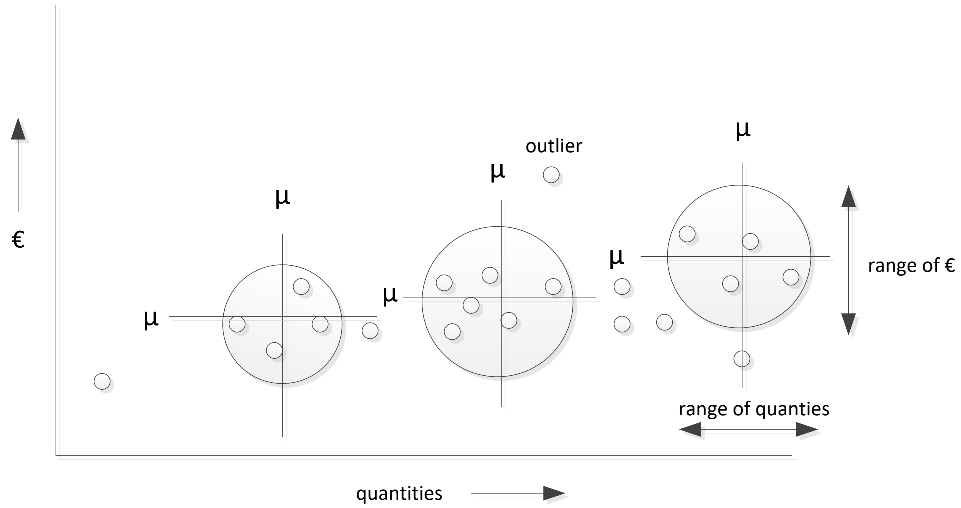

Figure 31: fictitious schematic representation of possible outcomes from collected data (own figure)

Not all parameters are meaningful and need to be saved. The 80-20 rule can be used. That is to say: 80% of the total project costs are caused by 20% of the line items.

Because of this method, the final cost estimate is better grounded in a probabilistic way. Because without historical data, there can be no probabilistic cost estimation and design.

Due to time constraints, there has been little focus on the creation of databases for both design and cost parameters. Also because of the complexity behind these parameters. There were in the past some initiatives to collect data in databases, but these were no longer maintained and complemented[32].

What also seems to be by the lack of time, and which is very crucial, is to make connections between the risks.

Correlations

Tools like Chrystal Ball and @Risk are capable to specify dependencies between any combination of variables. But one common error regarding correlations is that many modelers will ignore the possibility to indicate dependencies (Hubbard 2009). This almost always leads to a systematic underestimation of risks.

[32] In August 2015, the need to complement and maintain the existing database of design parameters of civil constructions is seen.

By the organization, correlations are approached in a different way. This is partly due to the work with alliance partners in large tenders. During the abovementioned tender of the organization, as seen in chapter 8, there is not worked with these correlations and they are often not used. This is similar like throwing a dice. With throwing with a lot of dices, the average number of eyes will come out somewhere in the middle. In this case, around the value of 3,5. It would be unlikely for a dozen of independent variables to approach an extreme value.

Subsequently, a correlation is more than a number between -1 and 1. In the figure below, the correlation coefficient is the same, but are very different as in the chart. A Monte Carlo simulation would generate a pattern like the chart on the right, when an input of 0,6 is given. See Figure 32.

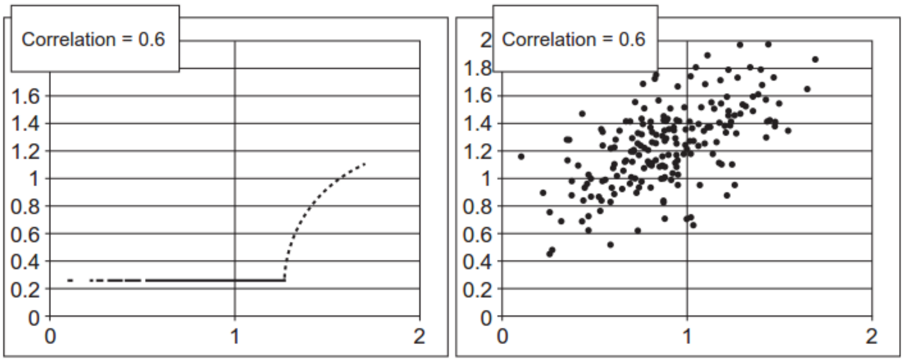

Figure 32: different patterns with the same single correlation coefficient (Hubbard 2009)

Thereby, the underlying system should be kept in mind. Sometimes it appears that there are relationships based one years of data collection, which can suddenly disappear. Therefore, the question must always be asked where the correlation is based upon, and how steadfast this relation is.

Finally, there shouldn't be thought in correlations coefficients immediately. To clarify this with an example: the uncertainty of the cost of a civil construction consist of the price of concrete, the price of other materials and labor costs. A connection can be made with the price of concrete during the time. But these line items can be better modeled explicitly without correlation coefficients. This gives a much more realistic model.

In conclusion, abovementioned errors are two very important errors that totally can't be forgotten. These are matters which are also made by experienced quantitative risk analysts and cost estimators. Together with the lack of checking the models with reality, ignoring correlations or the appliance on a kind of primitive, simplified way and ignoring common errors in subjective estimates are matters that need to be optimized to ensure the accuracy of a cost estimate.

In the next section there is looked at the complexity of parameters in the design, which has his consequences in the determination of costs. By conducting interviews it becomes clear that this would be one of the obstacles to put energy in the realization of databases. It is investigated how complex these design parameters are, for a possible addition of probabilistic cost estimation and design in the future.

9.3.Collection of data

The collection of data is something that is increasingly important in our society, Also in the construction industry. However, the data must be collected for a specific purpose. In this case it is clear: to obtain a more objective tender bid with the aid of probabilistic approach.

Uncertainties and risks inside the organization are given or people attention during a tendering process, but there is more. With the collection of data there can one can also look at the performance of subcontractors. It can be mapped whether they comply with schedules and budget. And subsequently, with which subcontractor there is more chance of a successful acquisition of work? In other words, which subcontractor is doing what he promised?

Besides probabilistic design and cost estimation, collection of data is also important for Lean Six Sigma objectives for maintenance contracts. To clarify this with a simple example: when the light of a lamppost is broken, it is wise to replace only the broken light, or is it better for the long term to replace all the other lamps along that road, because there is a high probability that all the others are going to bust in the short term? To answer this question, data is required.

Back to the complexity of parameters. Large complex infrastructural projects consist of different types of work. In order to make a start how complex the design parameters are, it is advisable to look at the one of the most relative straightforward building activities of the realization of large complex infrastructural projects. After a few conversations with experts it becomes clear that asphalt paving constructions are one of the less complex activities of all the complex activities, saying that with all due respect. Nice aspect is that asphalt pavement constructions are always cost drivers within a project. The average cost distribution of that pavement constructions is around 15%-20%. By conducting interviews with an expert of pavement constructions and a cost expert of pavement constructions, that can be seen in Appendix N (interview 12), the complexity of design and cost parameters are mapped. A small study was done in the background report of Ontwerp Instrumentarium Asfaltverhardingen, the standard program for the design of asphalt pavements. After which this knowledge is used for conducting the interview.

Complexity of asphalt pavement constructions

<u>Technical</u>

In search of factors and methods how these constructions will be designed.

Contract issues

- RAW contracts have become rare. One mainly applies DC or DBFM contracts, for both large and small projects.
- When RAW is used, it's a matter of making a price. However, an alternative design can be made but this is rarely done because of the lack of time and because design principles are often not given. These are sporadically released which is a practical hindrance for making a design alternative.
- With a DBFM, there should be dealt with a maintenance period, sometimes for 20-25 years. Here, the phasing needs to be taken into account. What if the top coat is 2 cm

thicker? Is it necessary to renew the top coat during this maintenance period and if so, what is a tactical time for that activity? Furthermore, there must be monitored and sometimes shifted in the drawn schedule, when the maintenance plan no longer corresponds with practice. Leam Rental[33] should be kept in mind for closing roads.
- The contract describes the manuals which should be used for the pavement design. These manuals are: OIA, ASCON and sometimes there is still worked with the design module CARE. If nothing is described in the contract, OIA is used by Heijmans. This method is mainly used by the market and calculates the design in a sharp way.
- If the contract documents have been received, these will be checked by means of a checklist whether all relevant documents are received. Important contract documents are about: traffic data, cone penetration tests of the subsurface and the prescribed software.
- The demand specification will be read and interfaces with other disciplines are examined. Expansion joints are often neglected.
- Formerly, RWS had a protocol six to twelve months after construction. Through thickness measurements (through drill cores) and design stiffnesses (through *valgewichtdetectiemetingen*[34]). Furthermore, a whole plan had to be written why the road should comply for a certain time. Nowadays, there will only be looked at design principles. For DC contracts, the warranty time is seven years. For DBFM contracts, this depends on the contract. After handover, the pavement must meet a certain quality.

Process

- After the developing of pavement variants, there is consultation with the cost estimation department. Together there will be looked at the most optimal foundation material, thicknesses of layers and the mixtures of the various types of asphalt, foundation and sand layers. The best variants will be further optimized. There are healthy tensions between design and calculation, because the cost estimation department challenges to come with the sharpest possible design. Until the design department reports that components become too risky or weak and there will be indicated that the design is as optimal as possible.
- Lengths, widths, alignments, junctions, roundabouts from a road are calculated by the department Road Design. The thicknesses are given by the pavement department. Geotechnicans are used for the computation of settlement differences and groundwater levels. The bearing capacity of the ground is calculated by traffic experts.

Parameters

- Censuses and forecasts of vehicles are translated into the growth and intensity in the future.
- Surface stiffness. The bearing capacity is calculated by the traffic expert in MPa, by means of cone penetration tests.
- Settlement differences are indicated by geotechnicans

[33] Contractors must pay rent to RWS when contractors must close the road for the purpose of maintenance works. This is important during DBFM contracts.
[34] Measurement method to record deflection. In this way stiffnesses can be calculated in layers.

- Phased design: will be done for constructions of residential areas. First, the road will be constructed with the exception of the coating layer. After all construction activities in the environment, the coating layer will be constructed. A phased design is also used to construction activities of highways in the winter. The coating layer, often PAC[35], shouldn't be constructed in winter. This layer will be disposed later on.
- The design criterium is almost always the *asfaltrekcriterium*. RWS will check on fatigue resistance, distortion under foundation and the surface. The latter two criteria are called *stuik*. These are almost never decisive, only for roads in a poor load bearing soil.
- Reliability of asfaltrekcriterium. Depends on the type of the road (highway, provincial road or village road). Depends between 85% on highways and 60% on village roads with less vehicles.
- *Straal contractvlak*. Is about the asphalt spectrum and the tire spectrum. This replaces the truck stress factor and the *aandeel breedband* of ASCON. There are conversion formulas for this to calculate, if prompted.
- Air temperature. Mathematically it is not important, but it is important for the execution. To give an example: it is relevant for the distance of the asphalt plant. During a cold day the asphalt cools down more quickly. Therefore, the temperature of the asphalt must be increased during the production.
- Healing. Is associated with the asphalt mixture in OIA. Healing is the phenomenon that the strength of the asphalt has partially recovered by the road itself, with the aid of kneading effects and the viscous restoring of micro-cracks (expressed in the penetration index bitumen percentage, a number between one and four).

Construction of the asphalt layer

The total paving construction consists of three layers: the asphalt layer, the foundation layer and the sand layer. In the figure below, the composition of asphalt layers for highways is shown.

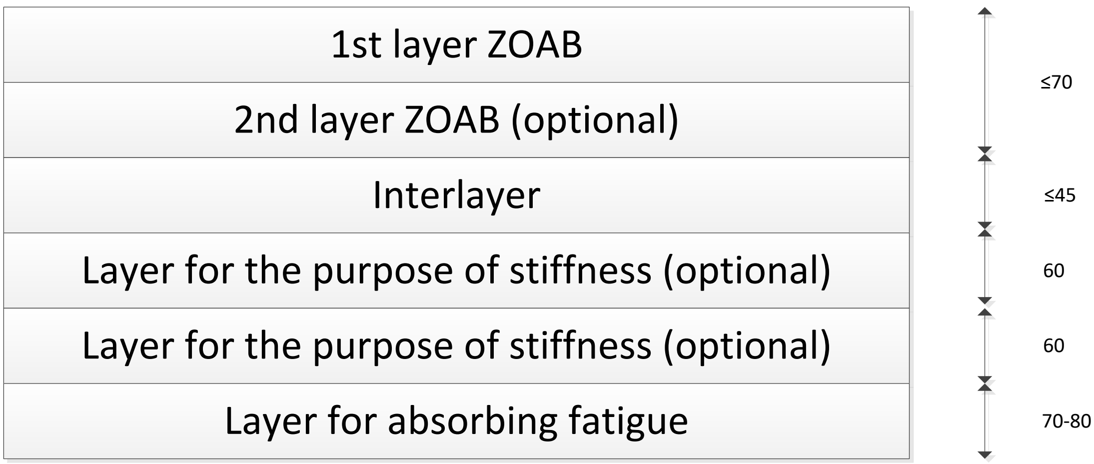

Figure 33: composition of asphalt layers (own figure)

[35] Porous Asphalt

Design starting points here are:

- One or optional two layers of porous asphalt. Two layers will be applied when modified asphalt will be applied. Porous asphalt is used if there are no accelerating, braking and wringing movements of the traffic. Otherwise, DAB of SMA[36] is often used
- Difference between modified and unmodified ZOAB is about the addition of a polymer. This polymer is for enhancing the properties against rutting and fraying. In a two-layer porous asphalt only the coating of the first layer is modified. (exceptions for DBFM contracts)
- ≥120 mm closed asphalt on an unbounded layer
- ≥140mm closed asphalt on a bounded layer (because of the probable cracking of the bounded layer)
- Grain size 0/16mm with an asphalt layer thickness ≤50mm
- Grain size 0/22mm with an asphalt layer thickness > 50mm
- The intermediate layer is the drainage layer. The ITSR[37] is high. If DAB or SMA is used as top layer, no intermediate layer is required.
- Grind-asphalt is not applied anymore.
- Alternatives for ZOAB top layers: DAB or SMA (at junctions/roundabouts)
- Material for the interlayer: STAB
- Materials for the stiffness layers and the layers for absorbing fatigue: STAB. Ranging in bitumen percentage and the amount of recycled asphalt.
- The two intermediate layers for the purpose of the stiffness sometimes omitted, depending of the loads of the road.
- The total thickness of the asphalt layer is about 20-22 cm. This does not correspond to the layer thicknesses in the figure, because these are the maximum layer thicknesses.

Construction of the foundation layer

This layer has a thickness between 25 and 35 cm, and can consist of:

- Hydraulic mixed granulate: stiffness 600-800 MPa
- Concrete mixed granulate: stiffness 600-800 MPa
- Asphalt granulate cement (AGRAC): stiffness 1200 MPa

Additional factors are:

- The foundation layer consists of one of the three abovementioned materials.
- Normal mixed granulate is not strong enough for provincial or national roads.
- *Hoogovenslakken* bind too hard, so RWS prohibits
- When using AGRAC, more time for the application of AGRAC is needed. First, the AGRAC should bind, after which the AGRAC should be free of tension. This will be done by means of refraction
- Applying the layer is done with a thickness of up to 8 cm.

[36] Respectively dense asphaltic concrete and stone mastic asphalt
[37] Ratio between indirect tensile strength of unconditioned and water conditioned drill cores, an indication against humidity

Construction of the sand layer

The construction of the sand layer consists of *zand voor zandbed*. This is sand with a proper gradation. Depending on the substrate conditions, this layer is a maximum of 50 cm. The sand bed of often more extensive than the foundation layer. Therefore, it is worthwhile to take samples in the area, so that local sand can be used if possible.

<u>Costs</u>

In this section the complexity of cost estimates is examined. Which parameters and factors are behind the line items of the cost estimations?

First, the type of contract is not decisive in the cost calculation. But with DBFM contracts there will be less design rules imposed by the client. Secondly, the level of detail of the cost estimation depends on the size of the project and the availability of suitable staff. Tradeoffs will be made on the following criteria: reliability, risks, costs and the availability of materials. A comprehensive explanation of the mentioned bullets below can be seen in interview 12 of appendix N.

- Width
- Time and phasing
- Year
- Curbs
- Length
- Foundation
- Ground water level
- Adhesive layer
- Asphalt types
- Reuse of asphalt
- Leamrental (costs for closing the highways)
- Temperature
- Distance to the asphalt plant

The complexity behind the cost and design parameters of pavement constructions are explained. In this chapter not all cost are determinant, so it is not relevant to look in detail at each parameter. As can be seen, the design and the costs are quite complex. But if every expert in a different discipline maintains its own data, and map the complexity behind its own parameters, this should not be seen as a hindrance. If the determining parameters will be filtered with for example the 80%-20% rule, there are opportunities to make the design and to calculate the costs on a more abstract level.

10. Conclusions and recommendations

This chapter contains the main conclusions and answers the general research question in chapter 10.1. In chapter 10.2, the recommendations are summarized for further development of probabilistic design and cost estimation. Chapter 10.3 is the discussion of this research and consists of the reflection in 10.3.1 and the limitations in 10.3.2.

10.1. Conclusions

This section maintains the findings of all the sub questions, which are answered in the previous chapters. Which are combined and used to answer the main research question.

> *How can the current method of probabilistic cost estimating and designing be complemented in such a way, that in a more effective way, within the entire width of the tender organization, the tender bid can be realized in a clear, systematic and objective way?*

This research consists “soft” and “hard” elements regarding probabilistic design and cost estimation, which are not yet running smoothly within the current use of this new method of tendering. This method of tendering within the organization is examined through an analysis of the first tender, which is completely done in this way.

With the soft parts of the research is meant: clarification of the concept of probabilistic cost estimation and design. Furthermore, it is about process-related factors that has resistance among employees. Hard parts have the following explanation: are the techniques which are used to obtain a valid cost estimation right and proper. Finally, it is about the gap between the current way of working –the business- and the methods as described in literature.

First can be concluded that there can be continued with the use of the probabilistic approach of tenders. The benefit is seen, and the application is currently being experienced as positive.

It is important to know what the purpose of the organization is regarding this new way of working. Is that to obtain a tender bid in a faster way, or is the purpose to obtain a more accurate cost estimation. At this time, large complex infrastructural can be processed with less commitment of staff and also in a faster way. That was the first purpose of the organization and that goal has been achieved. But there is still a lack of knowledge among staff, the concept is not clear and is different, not everyone is suitable for this way of working and some of the staff will be out of their comfort zone. Because there has been concluded that there were only a few comments at this time in this process, there is further investigated where the weaknesses are located in the current way of working. Weaknesses are surely found.

With the use of Monte Carlo simulations, the input is decisive to obtain an cost estimate of the actual cost. Garbage in, is garbage out. It has been found that this input –the determination of bandwidths- is largely based on subjectivity. This expert judgement is subjective but it has also a certain degree of objectivity. Nevertheless, it has been demonstrated that human beings are bad estimators. There are opportunities to improve this human being estimates, among other things by calibration trainings. But even then, cost estimations retain a certain degree of uncertainty, Furthermore, evaluations of earlier projects are sporadically made and otherwise, they are not available. Thus, there is no data available in order to objectify bandwidths. Without data, no probabilistic approach is possible. So this must be changed. A frequently heard comment is that the collection of data is a hopeless task because of the complexity behind line items. This kind of comments shouldn't be accepted anymore. In this research, there is begun with the identification of these complex issues behind this parameters. This is the beginning for the establishment of a database, in order to do well founded statements about bandwidths in the future. The collection of this data can be incorporated into a broader context, because on several fronts it is necessary to collect data. For example in Lean Six Sigma projects for long-term maintenance contracts. This is a must for creating maintenance schedules.

Then, probabilistic cost models that are drawn for a cost estimation should be evaluated. Without this, nothing useful can be said regarding the reliability of this models. Differences do not come to light and therefore there is a lack of an important learning process.

Another important part where certain attention should be given are the dependencies of risks, expressed in terms of correlations. At this time, risks are simulated completely dependent or completely independent. Because this risks are not mapped, the outcome of a probabilistic cost estimation is much less accurate. Pooled risks are always there, and precise correlations should certainly be laid.

In conclusion, subjectivity and correlations are components that make a tender process more effective, and in this case more accurately. It is impossible to do it all at once; this process takes time.

10.2. Recommendations

The purpose of the recommendations is explained as well as how the recommendation can be put into practice.

Let statistics-experts look into the current cost estimation process

Executing Monte Carlo simulations is not particularly hard. Anyone with a bit of knowledge of Microsoft Excel can run these kind of simulations. At this time, simulations are carried out by cost experts. There is nothing wrong with that. However, besides the fact that they have the knowledge of the costs of civil engineering projects, they don't have the necessary knowledge that is needed to fully understanding the rationale behind the statistics to understand all the possibilities of Monte Carlo simulations. This, because an expert of statistics would already realize that the input of the simulation program is not accurate enough to do reliable statements about the outcome of the simulations. Let this expert look at the subjective input of the ranges, and let them look to the ignoring of the identification of correlations.

Increasing awareness among staff

Another aspect is the unfamiliarity among the employees about this new approach to obtain a tender bid. This is also discussed in chapter 7, together with other limiting factors among employees . Without the awareness of probabilistic design and cost estimation, a successful implementation will be delayed. Thereby, it is not the intention to bring an announcement for information purposes, but the usefulness and necessity must be disclosed.

Setting up a database

To get rid of the subjective input of bandwidths of the quantities and unit prices, it should be recognized that the collection of data is unavoidable. To get started with the collection of data, start with the collection of the least complex components of a project. What is given as an example: start with asphalt pavement constructions. See this as a pilot to become familiar with this activity. This should be seen as an important component of the cost estimation process. The entering and input of data should be done, immediately when the data is known. For examples when bills are falling in the mailbox. Not only many years after a major project has been completed. So, there is a difference between ex post calculations and intermediate evaluations. The collection of data should get more attention among staff, because it can be used for more purposes than probabilistic design and cost estimation. Final note: there must be well thought out about the validity and viability of these data. Because, data is not eternally useful. And with which minimum of data reliable statements can be done.

Comparison of cost estimates

The last recommendation is the recommendation about the comparison of cost estimates. Due to a lack of time, there is little attention paid to compare the cost estimates. The estimates, prepared in advance for the benefit of the tender bid should be compared with the actual final settlement of the project. No comparison should be made at a macro level, but each line item – or at least the major, cost driven line items with a large standard deviation- should be compared with the original estimate. In this way, lessons can be learned to improve the next estimations.

10.3. Discussion

10.3.1. Reflection

With this investigation, the current practice of the contractor Heijmans Infra is reviewed and the possibilities to improve that current practice. The gap between the current practice and the practice in literature has been demonstrated.

Most of the literature that has been used was descriptive in nature and did not address issues like the subjectivity of the input of Monte Carlo simulations and the correlations like risks. The Standard systematics of cost estimations, the manual for drawing up cost estimation in the Dutch civil construction industry, has only written a small part of these two issues. Of course there is much more literature consulted about this probabilistic approach, but the focus was not placed on these items. Furtunately, there is still a book found that extensively explained a lot of risk management when use is made of Monte Carlo simulations. This was the book “The failure of risk management” written by Douglas W. Hubbard. After many years of experience in this discipline, this expert described all kinds of wrong assumptions on cost estimates.

Furthermore, there is a lot of information acquired under the employees of Heijmans Infra. They have, in spite of busy schedules, found the time to answer all the questions and explained the current practice within the organization.

The theoretical framework provided enough guidance to carry out this research, but prior to this study I did not know that this subject was so complex.

During the start of this study, I had in mind to unravel one particular topic. I also thought that there was a lot more done with this way of tendering. With the goal to do analysis of the figures and to make comparisons with cost estimations already made and the final bills in order to release statistics on the collected data and to frolic with simulation programs. Ultimately it became a descriptive study containing recommendations only. This relevant recommendations provide sufficient insights for a further optimization for tender bids.

10.3.2. Limitations

One of the limitations of this research is that during the first tender with the use of probabilistic design and cost estimation, there was only the ability to look to the process-related issues. There was no possibility to look at the content side of the cost estimation process. In this way the cost estimation process is not seen from up close. Therefore, I haven't experienced discussions with cost experts about decision making, problems that were experienced and so on. So, there was a distance and therefore I could not perceive how simulations are run and how bandwidths were defined.

Another limitation is that there was no data available for a further deepening in the investigation. I was keen to come up with a more concrete solution. Such as: through the identification of the correlations between groups of risks, the standard deviation of the cost estimate is higher. Or: due to the statistical determination of the bandwidths of certain line items, the mean of the estimated total cost is 2% higher.

10.3.3. Directions for the future

Three possible subjects for further research have been identified.

Influences of MEAT criteria

Besides the story about the importance of a competitive estimate, it is also important to look at the other award criteria: the MEAT criteria. Also mentioned is the use of certain levels of detail of the design and cost estimates of line items. When the levels of detail are not acceptable, it is necessary to increase the level of detail to obtain more accurate line items. But in recent times, MEAT criteria become increasingly important. Sometimes, works are awarded with a weighing of 60% on quality and 40% on price. Then the focus should be placed more on this MEAT criteria than on the price determination. Is it acceptable then to allow lower levels of detail in order to put the focus more on MEAT. How to deal with it, because it is an expensive business to focus on both awarding criteria, whereby tender costs will rise again.

Influences of time planning

The scope is limited to risks and uncertainties in the cost estimation. There was no further investigation in probabilistic scheduling. A schedule also has to deal with uncertainties and risks, including a cost consequence when a schedule delays or is finished earlier. This probabilistic time schedule can be coupled with the probabilistic cost estimation, to obtain a joint probability distribution. The influence of the schedule on the cost can be optimized and vice versa. So that statements can be made regarding: are measures to shorten the time planning lucrative because of potential bonuses?

Critical path

What further can be said about the time planning: how to deal with activities on the critical path? If there are activities located on the critical path, there are consequences for the subsequent activities when activities on the critical path delays. How is that translated to the bandwidths of these activities?

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12. Appendices

Appendix A Integral tender process Heijmans

Appendix B Go/ no go prior to prequalification

Appendix C Tender strategy

Appendix D Go/ no go criteria after quick scan

Appendix E Go/ no go after strategy

Appendix F Go/ no go during elaboration of the tender

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Appendix H Presentation of an uniform project estimation

Appendix I Underpinning of an object cost estimate

Appendix J Example of a memo about the level of detail of an abutment

Appendix K Factsheet used by Civil-discipline

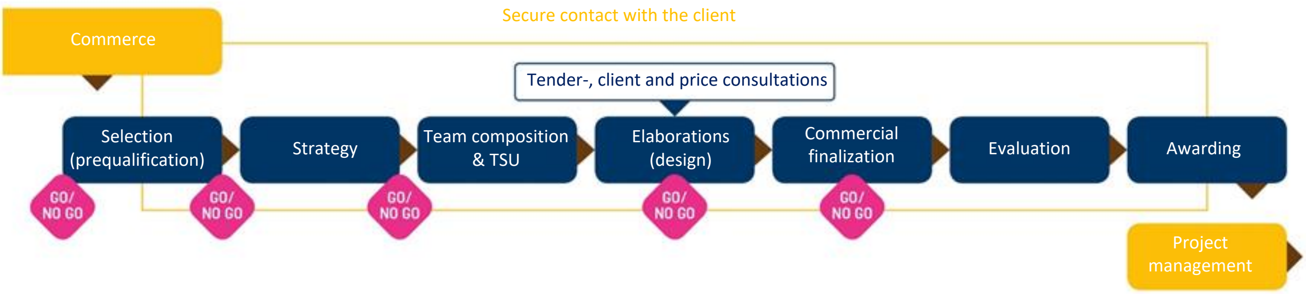
Appendix L Factsheet used by Roads-discipline

Appendix M Risk assessing method of the organization

Appendix N Interviews

Appendix A

Integral tender process Heijmans (Heijmans intraned)

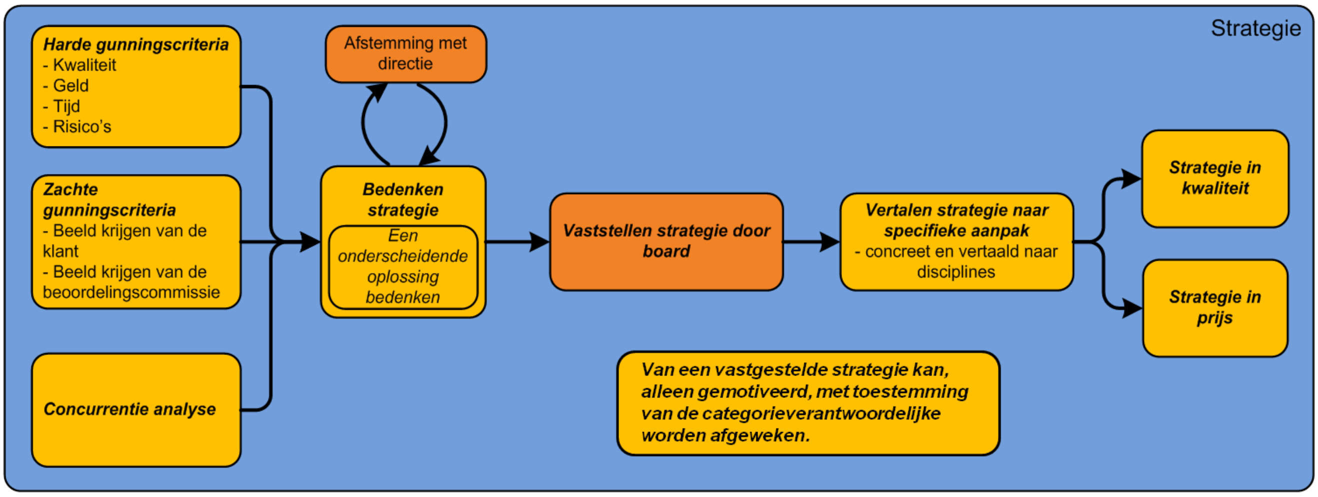


Appendix B

Go/ no go prior to prequalification (Heijmans intraned)

Past het binnen de strategie van de NV?
Partners (consortium, mede risico dragend) *Zijn er in deze fase gelijkwaardige risico dragende partners nodig waarmee gezamenlijk ingeschreven zal moeten worden?*
Hebben wij de resources? (tenderteam/uitvoeringsteam inclusief eigen adviseurs)
Hebben wij de beschikbare capaciteit/ kwaliteit in mens, middelen en tijd om deze tender te kunnen winnen c.q. het daadwerkelijk uit te voeren?
Klant (relatie)/reciprociteit **Kwalificeren van type klant.** ***1)*** *Waardevolle partner:* ***2)*** *Waardevolle kansen:* ***3)*** *Project partner:* ***4)*** *Project met mogelijkheden:* **Geschiedenis met klant en zijn adviseurs.** ***1)*** *Geen ervaringen (nieuw):* ***2)*** *Goede ervaringen:* ***3)*** *Wisselende ervaringen:* ***4)*** *Slechte ervaringen:*
Tender Prioritisering *Categoriseren op basis van onderstaande kernonderdelen in een "Must win", "Should win" of "Niet aanbieden".* *Hoe belangrijk is het om deze tender te winnen: gezien de relatie met de klant, de externe uitstraling, hoe hard hebben we het werk nodig, de strategieën of benodigd als referentie?*
Marktsegment *Past het binnen de gekozen markt strategie van de bedrijfstroom.*
Winkans *Is het een uitvraag waar we toegevoegde waarde kunnen leveren/ onderscheiden van de concurrentie? Wat zijn onze kansen om te winnen op basis van, ervaring, de markt, wie is de concurrentie en hoeveel andere aanbieders er zijn?* ***1)*** *Klein %<Concurrent* ***2)*** *Gemiddeld %=Concurrent* ***3)*** *Boven gemiddeld %> Concurrent* ***4)*** *Groot (beste)*
Integraliteit (bedrijfstroom overstijgend) *Als er sprake is van een gelijkwaardige partners uit verschillende bedrijfstromen die gezamenlijk inschrijven en een aanbieding maken.*
Contractvorm *Zodra er financiering, of exploitatiegebonden diensten in een contractvorm voorkomen is er direct sprake van een groot risico profiel en specifieke deskundigheid.*

Appendix C
Tender strategy (Heijmans intraned)



Appendix D

Go-no go criteria after quick scan (Heijmans intraned)

Past het binnen de strategie van de NV?
Partners (consortium, mede risico dragend) *Zijn er in deze fase gelijkwaardige risico dragende partners nodig waarmee gezamenlijk ingeschreven zal moeten worden?*
Hebben wij de resources? (tenderteam/uitvoeringsteam inclusief eigen adviseurs)
Hebben wij de beschikbare capaciteit/ kwaliteit in mens, middelen en tijd om deze tender te kunnen winnen c.q. het daadwerkelijk uit te voeren?
Klant (relatie)/reciprociteit **Kwalificeren van type klant.** ***1)*** *Waardevolle partner:* ***2)*** *Waardevolle kansen:* ***3)*** *Project partner:* ***4)*** *Project met mogelijkheden:* **Geschiedenis met klant en zijn adviseurs.** ***1)*** *Geen ervaringen (nieuw):* ***2)*** *Goede ervaringen:* ***3)*** *Wisselende ervaringen:* ***4)*** *Slechte ervaringen:*
Tender Prioritisering *Categoriseren op basis van onderstaande kernonderdelen in een "Must win", "Should win" of "Niet aanbieden".* *Hoe belangrijk is het om deze tender te winnen: gezien de relatie met de klant, de externe uitstraling, hoe hard hebben we het werk nodig, de strategieën of benodigd als referentie?*
Marktsegment *Past het binnen de gekozen markt strategie van de bedrijfstroom.*
Winkans *Is het een uitvraag waar we toegevoegde waarde kunnen leveren/ onderscheiden van de concurrentie? Wat zijn onze kansen om te winnen op basis van, ervaring, de markt, wie is de concurrentie en hoeveel andere aanbieders er zijn?* ***1)*** *Klein %<Concurrent* ***2)*** *Gemiddeld %=Concurrent* ***3)*** *Boven gemiddeld %> Concurrent* ***4)*** *Groot (beste)*
Integraliteit (bedrijfstroom overstijgend) *Als er sprake is van een gelijkwaardige partners uit verschillende bedrijfstromen die gezamenlijk inschrijven en een aanbieding maken.*
Contractvorm *Zodra er financiering, of exploitatiegebonden diensten in een contractvorm voorkomen is er direct sprake van een groot risico profiel en specifieke deskundigheid.*
Marge potentie (verwachte winst) *Bruto marge < 9%*
Saldo tenderbudget (kosten minus vergoedingen klant) >1% van de projectkosten met een minimum van € 50 k.
Is het project beheersbaar maakbaar?
Vermogensbeslag *Indien totale kosten gemoeid met bankgaranties en geïnvesteerd vermogen samen > € 1mio naar concerndirectie.*
Contractuele voorwaarden van de klant *indien er sprake is van:* *1. Ongelimiteerde kortingen/aansprakelijkheden.* *2. Afwijkende contractvorm.* *3. Uitsluiting retentie recht.* *4. Overname van ontwerprisico's vanaf DO niveau.* *5. Bank- en verzekeringsrisico's.*

Appendix E

Go/ no go after strategy (Heijmans intraned)

(Herijking) hebben wij nog de resources? (tenderteam/uitvoeringsteam) Na de tweede No/Go is het tenderteam bepaald en bemenst en zijn de interne en externe tenderkosten bepaald en gebudgetteerd. Nu kan daadwerkelijk bepaald worden of er voldoende resources vrijgemaakt kunnen worden om de tender op een goed kwaliteitsniveau te doorlopen. Tevens is een inschatting nodig, op basis van de verwachtte uitvoeringsperiode, of we op dat moment voldoende uitvoeringscapaciteit (en evt. kwaliteit) beschikbaar hebben. De teamsamenstelling, interne en externe kosten/budgetten worden definitief vastgelegd in het Tendermanagementplan voor dit project. Bovenstaande leidt tot een uitspraak op deze vraag: Ja of Nee. Bevoegde directeur binnen de Bedrijfsstroom beslist hier over.
(Herijking) of nieuwe Partners (consortium) De definitieve partners zijn nu ook bekend. Indien er een wijziging op is getreden in deze partners dan zal dit altijd voorgelegd moeten worden aan de Concerndirectie/RvB. De definitieve samenstelling wordt vastgelegd in het Tendermanagementplan voor dit project.
(Herijking) Tenderstrategie goed *De voorlopige strategie/strategische overwegingen wordt met alle informatie die nu bekend is beoordeeld en definitief bepaald/omschreven. Het resultaat wordt vastgelegd in het Tendermanagementplan voor dit project. Een Go/No Go wordt bepaald op basis van een inschatting dat dit een 'winnende en onderscheidende' strategie is.*
Reputatieschade bij No Go *Gevolgen voor reputatie van Heijmans bij geven van No Go hebben negatief effect op naam, relatie, imago, etc.* *Er dient altijd een advies gegeven te worden door een commercieel manager of, waarom en hoe reputatieschade voor Heijmans kan ontstaan als gevolg van een eventuele No Go beslissing.*

Appendix F

Go/ no go during elaboration of the tender (Heijmans intraned)

Overschrijding saldo tenderbudget (kosten minus vergoedingen klant) >1% van de projectkosten met een minimum van € 50 k.
Prijs plafond overschrijding *Overschrijding van door klant vastgesteld prijsplafond*
(herijking) resources? (tenderteam/uitvoeringsteam inclusief adviseurs)
Technische haalbaarheid (G.O.T.I.K): *Is het project beheersbaar maakbaar?*
Klant relatie *Kwaliteit van klantrelatie heeft (negatieve) invloed op winkans*
Verlaging margepotentie *Bruto Marge < 9%*
Scope-/procedurewijziging *Scope project en aanbestedingsprocedure wijken af van eerdere verwachting*
(herijking) Contractuele voorwaarden *Contractuele voorwaarden wijken af van eerdere verwachtingen of er zijn aanvullende eisen*
Reputatieschade bij No Go (rol commerciant) *Gevolgen voor reputatie van Heijmans bij geven van No Go hebben negatief effect op naam, relatie, imago, etc.* *Er dient altijd een advies gegeven te worden door een commercieel manager of, waarom en hoe reputatieschade voor Heijmans kan ontstaan als gevolg van een eventuele No/Go beslissing.*

Appendix G

Project cost estimation, classified on the basis of cost categories (CROW 2010)

Samenvatting projectraming: A Indeling naar categorie

Kostengroepen		*voorziene kosten*				*risico reservering*		*totaal*
Kostencategorieën	*directe kosten benoemd*	*directe kosten nader te detailleren*	*indirecte kosten*	*totaal voorziene kosten*				
Investeringskosten								
Object 1	X	X	X	Σ		X		Σ
Object 2	X	X	X	Σ		X		Σ
Object N...	X	X	X	Σ		X		Σ
Bouwkosten *(alle objecten)*	Σ	Σ	Σ	Σ		Σ		Σ
Object 1	X	X	X	Σ		X		Σ
Object 2	X	X	X	Σ		X		Σ
Object N...	X	X	X	Σ		X		Σ
Vastgoedkosten *(alle objecten)*	Σ	Σ	Σ	Σ		Σ		Σ
Object 1	X	X	X	Σ		X		Σ
Object 2	X	X	X	Σ		X		Σ
Object N...	X	X	X	Σ		X		Σ
Engineeringskosten *(alle objecten)*	Σ	Σ	Σ	Σ		Σ		Σ
Object 1	X	X	X	Σ		X		Σ
Object 2	X	X	X	Σ		X		Σ
Object N...	X	X	X	Σ		X		Σ
Overige bijkomende kosten *(alle objecten)*	Σ	Σ	Σ	Σ		Σ		Σ
Totaal investeringskosten	Σ	Σ	Σ	Σ		Σ		Σ
Levensduurkosten								
Object 1	X	X	X	Σ		X		Σ
Object 2	X	X	X	Σ		X		Σ
Object N...	X	X	X	Σ		X		Σ
Totaal levensduurkosten	Σ	Σ	Σ	Σ		Σ		Σ
Risico's en/of scheefte								
Risico's en/of scheefte investering						X		Σ
Risico's en/of scheefte levensduur						X		Σ
Totaal objectoverstijgende risico's en/of scheefte						Σ		Σ
Projectkosten								
Totale projectkosten (gemiddelde waarde inclusief btw)				Σ voorziene kst inv + levensduur	+	Σ risicoreservering	=	totaal project
Btw (belasting toegevoegde waarde)				X	+	X	=	X
Projectkosten (gemiddelde waarde inclusief btw)				Σ voorziene kst inv + levensduur	+	Σ risicoreservering	=	totaal project
Prijspeil *datum*								
Bandbreedte tussen	X	en	Y	bij trefzekerheid van 70%				
Variatiecoëfficiënt		X %						
Budgetvaststelling								
Projectkosten gemiddelde waarde (inclusief óf exclusief btw)						Σ risicoreservering		totaal project
Onzekerheidsreserve	Z	Z	Z	Z		Z		Σ
Reservering scopewijziging(en)	Z	Z	Z	Z		Z		Σ
Aan te houden risicoreservering en totaal **budget**						Σ risicoreservering		totaal **budget**

X	verantwoordelijkheid ramer, gepresenteerd resultaat volgt uit de kostenonderbouwing
Z	verantwoordelijkheid financier
Σ	rekenkundige uitkomst

Appendix H

Presentation of an uniform project estimation (CROW 2010)

Figuur 12. Objectramingen

Objectraming; investeringskosten

Kostengroepen *Kostencatogorieën*	*voorziene kosten* *directe kosten benoemd*	*directe kosten nader te detailleren*	*indirecte kosten*	*risico reservering*	*totaal*
Bouwkosten	X	X	X	X	Σ
Vastgoedkosten	X	X	X	X	Σ
Engineeringskosten	X	X	X	X	Σ
Overige bijkomende kosten	X	X	X	X	Σ
Investeringskosten object	Σ	Σ	Σ	Σ	Σ

Objectraming; levensduurkosten

Kostengroepen *Kostencategorieën*	*voorziene kosten* *directe kosten benoemd*	*directe kosten nader te detailleren*	*indirecte kosten*	*risico reservering*	*totaal*
Levensduurkosten object	X	X	X	X	Σ

Appendix I

Underpinning of an object cost estimate (CROW 2010)

Objectnaam: ....

Investeringskosten	*hoeveelheid*	*eenheid*	*eenheidsprijs*	*totaal*		*hoeveelheid*		*eenheidsprijs*		*motivatie/ onderbouwing L&U*
						L	U	L	U	
Bouwkosten					1)	3)	3)	3)	3)	
Directe kosten										
X	X	X	X	Σ		X	X	X	X	X
X	X	X	X	Σ		X	X	X	X	X
X	X	X	X	Σ		X	X	X	X	X
Totaal directe kosten benoemd				Σ						
nader te detailleren	X	%	X	Σ						
Totaal directe kosten				Σ						
eenmalige kosten	X	euro	X	Σ	2)	X	X	X	X	X
Indirecte kosten										
uitvoeringskosten & algemene bouwplaatskosten	X	tijds-eenheid (wkn)	X	Σ	2)	X	X	X	X	X
algemene kosten	X	euro	X	Σ	2)	X	X	X	X	X
winst & risico	X	euro	X	Σ	2)	X	X	X	X	X
bijdragen (RAW/ FCO)	X	euro	X	Σ	2)	X	X	X	X	X
Totaal indirecte kosten				Σ						
Totaal voorziene kosten				Σ						
Risico's										
benoemd risico ... (kans x gevolg)	X	%	X	Σ				X	X	X
benoemd risico ... (kans x gevolg)	X	%	X	Σ				X	X	X
....										
niet benoemd risico (percentage van voorziene kosten)	X	%	X	Σ		X	X			X
Totaal risico's				Σ						
Totaal bouwkosten				Σ	1)					

1) Gebruikelijk is om bedragen exclusief btw te presenteren. Berekend btw kan separaat worden gepresenteerd
2) Een onderbouwing met percentages en uitsplitsing van uitvoeringskosten en bouwplaatskosten (twee regels) is ook mogelijk
3) In te vullen als absolute bedragen of percentage ten opzichte van de T-waarde

N.B. De deelramingen van de kostencategorieën vastgoedkosten, engineeringskosten en overige bijkomende kosten, kunnen op identieke wijze worden opgebouwd als de hier gepresenteerde bouwkosten.

Appendix J
Example of a memo about the level of detail of an abutment (Heijmans intraned)

Memo

Datum	1 december 2014	Van	Bjorn van den Brand
Onderwerp	Memo Uitwerkingsniveaus kunstwerken ontwerp en calculatie	Telefoon	+31 (0)6 5324 53 41
		E-mail	bbrand@heijmans.nl

Aan	*K. Vermeij*	*T. van Hunen*
	F. Millenaar	*P. Eckhardt*

Inleiding

Voor de tender A28/A1 is besloten om de kunstwerken Probabilistisch te ontwerpen en te ramen. In deze memo wordt het uitwerkingsniveau toegelicht van het te maken ontwerp en de calculatie.

We willen d.m.v. “bouwstenen” de calculatie opstellen, waarbij de bouwstenen door ontwerp bepaald worden (afmetingen en kg/m3 wapening en voorspanning)

De kunstwerk calculaties worden benaderd alsof ze allen in het vrije veld gebouwd kunnen worden. Vervolgens zal er per kunstwerk bekeken worden wat de aanvullende maatregelen zijn die optreden.
Aanvullende maatregelen zijn NIET LIMITATIEF:

- Geotechnische opbouw grond
- Verbredingsmaatregelen kunstwerk
- Wegfaseringsmaatregelen
- Bouwen over het spoor
- Beschikbaar ruimte beslag

Deze aanvullende maatregelen zullen per kunstwerk apart begroot worden.

Calculatie heeft ramingssheets in Excel opgesteld, welke gebruikt gaan worden voor de raming/begroting. De “standaard” eenheidsprijzen in de ramingssheets zijn getoetst.
Per kunstwerk zal een eenheidsprijzen toets uitgevoerd worden of de standaard eenheidsprijzen voldoen aan het betreffende kunstwerk.
De ramingssheets, incl. prijzen kunnen vanuit Excel in IBIS gekopieerd worden.

Voor ontwerp zijn factsheets opgesteld, waarin de ontwerpuitgangspunten worden vastgelegd. Deze factsheets vormen de input voor calculatie.

Uitwerking van ontwerp- en calculatie.

ONDERBOUW:

Landhoofd:

- **Aanpak ONTWERP NIEUW KUNSTWERK KNOOP:**
  - Van één hoog- en één laaggefundeerd landhoofd, (zijnde funderingssloof, grondkerende wand en vleugelwand) onderstaande items bepalen geldend voor alle kunstwerken in de knoop:
    - Principe dwarsdoorsnede;
    - Kg/m3 wapening;
    - Betonsterkteklasse;
    - Opgave bandbreedte op kg/m3 en op afmetingen uitgedrukt in %.
- **Aanpak ONTWERP NIEUW KUNSTWERK POTEN (VERVANGEN):**
  - Van één hoog- en één laaggefundeerd landhoofd, (zijnde funderingssloof, grondkerende wand en vleugelwand) onderstaande items bepalen geldend voor alle nieuwe kunstwerken in de poten:
    - Principe dwarsdoorsnede;
    - Kg/m3 wapening;
    - Betonsterkteklasse;
    - Opgave bandbreedte op kg/m3 en op afmetingen uitgedrukt in %.
- **Aanpak ONTWERP NIEUW KUNSTWERK POTEN (NIEUW NAAST BESTAAND):**
  - Van één hoog- en één laaggefundeerd landhoofd, (zijnde funderingssloof, grondkerende wand en vleugelwand) onderstaande items bepalen geldend voor alle kunstwerken in de poten. Maatvoering dwarsdoorsnede conform bestaand kunstwerk.
    - Kg/m3 wapening;
    - Betonsterkteklasse;
    - Opgave bandbreedte op kg/m3 en op afmetingen uitgedrukt in %.
- **Aanpak ONTWERP BESTAAND KUNSTWERK POTEN (VERBREDING):**
  - Van één hoog- en één laaggefundeerd landhoofd, (zijnde funderingssloof, grondkerende wand en vleugelwand) onderstaande items bepalen geldend voor alle kunstwerken in de poten. Maatvoering dwarsdoorsnede conform bestaand kunstwerk.
    - Kg/m3 wapening;
    - Betonsterkteklasse;
    - Opgave bandbreedte op kg/m3 en op afmetingen uitgedrukt in %.
- **Aanpak CALCULATIE:**
  - Per kunstwerk het ramingssheet invullen, met de bij ontwerp bepaalde parameters.

Tussensteunpunt:

- **Aanpak ONTWERP NIEUW KUNSTWERK KNOOP:**
  - Bepalen principedoorsnede van één tussensteunpunt, zijnde funderingssloof, kolom en onderslagbalk;
  - Eenmalig bepalen kg/m3 wapening, geldend voor alle kunstwerken;
  - Eenmalig bepalen betonsterkteklasse, geldend voor alle kunstwerken;
  - Opgave bandbreedte op kg/m3 en op afmetingen uitgedrukt in %.

- **Aanpak ONTWERP NIEUW KUNSTWERK POTEN (VERVANGEN):**
  - Bepalen principedoorsnede van één tussensteunpunt, zijnde funderingssloof, kolom en onderslagbalk;
  - Eenmalig bepalen kg/m3 wapening, geldend voor alle kunstwerken;

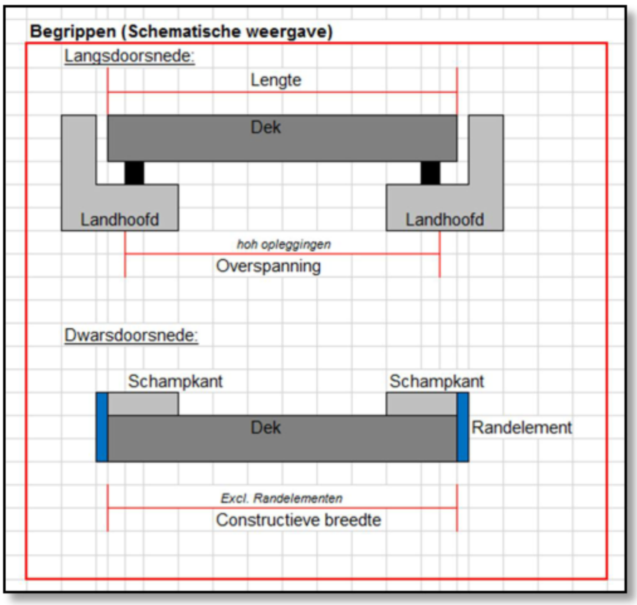
- Eenmalig bepalen betonsterkteklasse, geldend voor alle kunstwerken;
- Opgave bandbreedte op kg/m3 en op afmetingen uitgedrukt in %.

- **Aanpak ONTWERP NIEUW KUNSTWERK POTEN (NIEUW NAAST BESTAAND):**
  - Maatvoering dwarsdoorsnede conform bestaand kunstwerk;
  - Eenmalig bepalen kg/m3 wapening, geldend voor alle kunstwerken;
  - Eenmalig bepalen betonsterkteklasse, geldend voor alle kunstwerken;
  - Opgave bandbreedte op kg/m3 en op afmetingen uitgedrukt in %.
- **Aanpak ONTWERP BESTAAND KUNSTWERK POTEN (VERBREDING):**
  - Maatvoering dwarsdoorsnede conform bestaand kunstwerk;
  - Eenmalig bepalen kg/m3 wapening, geldend voor alle kunstwerken;
  - Eenmalig bepalen betonsterkteklasse, geldend voor alle kunstwerken;
  - Opgave bandbreedte op kg/m3 en op afmetingen uitgedrukt in %.
- **Aanpak CALCULATIE:**
  - Per kunstwerk het ramingssheet invullen, met de bij ontwerp bepaalde parameters.

BOVENBOUW:

Dek:

- **Aanpak ONTWERP ALGEMEEN voor alle nieuwe / te verbreden kunstwerken:**
  - Bovenaanzicht met daarop (Maatvoering conform figuur 1):
    - Constructieve breedte van het dek, bestaand en nieuw;
    - Totaal lengte dek;
    - Totaal overspanning dek (h.o.h. opleggingen);
    - Locatie (tussen)steunpunten;
    - Type voegovergang per dilatatie;
    - Aantal voegovergangen;
    - Lengte voegovergang per dilatatie.
  - Langsdoorsnede;
  - Dwarsdoorsnede;
  - Opgave bandbreedte op kg/m3 en op afmetingen uitgedrukt in %;
  - Dekverkanting wordt in de onderbouw verwerkt. (funderingssloof landhoofd en onderslagbalk tussensteunpunt).



Figuur 1

- **Aanpak ONTWERP INSITU DEK**:
  - Bepalen dek dikte per kunstwerk;
  - Eenmalig bepalen kg/m3 wapening per kunstwerk;
  - Eenmalig bepalen kg/m3 voorspanning per kunstwerk;
  - Opgave bandbreedte op kg/m3 wapening en voorspanning en op afmetingen uitgedrukt in %.
- **Aanpak ONTWERP PREFAB DEK**:
  - Per kunstwerk opgave maatgevende overspanning ter bepaling van liggerkeuze;
  - Liggerkeuze wordt bepaald door constructeur, en check door Haitsma beton;
  - Eenmalig bepalen dikte druklaag prefab dek;
  - Eenmalig bepalen kg/m2 druklaag;
  - Opgave bandbreedte op kg/m3 wapening druklaag en op afmetingen uitgedrukt in %.
- **Aanpak CALCULATIE:**
  - Per kunstwerk het ramingssheet invullen, met de bij ontwerp bepaalde parameters;
  - Prijsaanvraag liggers bij prefab leverancier o.b.v. van bovenaanzicht en maatgevende overspanning dek.

AANVULLENDE MAATREGELEN:

Funderingskeuze:

- **Aanpak ONTWERP:**
  - O.b.v. maatgevende sondering per kunstwerk de funderingswijze bepalen;
  - Keuze funderingswijze op staal of op palen;
  - Fundering op staal: afwijkende afmetingen funderingssloven landhoofd en tussensteunpunt aangeven (eenmalig);
  - Fundering op palen: (paaltype, diameter, lengte en h.o.h. afstand (lengte- en dwarsrichting);
  - Opgave bandbreedte op paallengte uitgedrukt in %.
- **Aanpak CALCULATIE:**
  - Per kunstwerk het ramingssheet invullen, met de bij ontwerp bepaalde parameters.

Dekverbreding:

- **Aanpak ONTWERP:**
  - Per kunstwerk een beschouwing van de te nemen verbredingsmaatregelen aan bestaand kunstwerk.
- **Aanpak CALCULATIE:**
  - Begroting van de te nemen verbredingsmaatregelen aan bestaand kunstwerk.

Hulpconstructies:

- **Aanpak WERKVOORBEREIDING:**
  - Bepalen benodigde hulpconstructies.
- **Aanpak ONTWERP:**
  - Per kunstwerk een beschouwing van de toe te passen hulpconstructies (damwand e.d.).
- **Aanpak CALCULATIE:**
  - Per kunstwerk het ramingssheet invullen, met de bij ontwerp bepaalde parameters.

Tender ????

heijmans

Uitwerkingsniveau ontwerp kunstwerken

Datum: 12-12-2012 Versie 1.0

Algemeen:
Niveau-indeling aan het begin van de tender afstemmen tussen ontwerp en calculatie a.d.h.v. de voorlopige raming
Aspecten: kostprijsbepalende onderdelen, risicovolle onderdelen, specifieke ervaring Heijmans/Tenderteam/persoon
Bandbreedte's bij begin tender afstemmen tussen ontwerp en calculatie

Benodigd:
Wegassen
DTM
DWM, incl kant asfalt & zichtbreedte
Bestaande KW'n
K&L
OV, DVM, Geluidschermen
Objectspecificatie?

Trefwoorden:
Prijsbepaling
Grof geometrisch ontwerp
Prijsbepalende optimalisaties
Raakvlakken afstemmen op hoofdlijnen
Multidisciplinair
Kostprijsbepalende onderdelen
Risicovolle onderdelen

Aspect	**Calculatieontwerp, eenvoudig**	**Calculatieontwerp, standaard**	**Calculatieontwerp, groot insitu dek**	**Calculatieontwerp, uitgebreid**	**3D-model fasering**
	Niveau 1	***Niveau 2***	***Niveau 3***	***Niveau 4***	
Nauwkeurigheid:			*Dek in niveau 3, overige in niveau 2*	*bv grote landtunnel*	
x,y	+/- 500mm	+/- 250mm	zie niveau 2	+/- 250mm	+/- 500mm
z	+/- 200mm	+/- 100mm	zie niveau 2	+/- 100mm	+/- 200mm
breedte, lengte	+/- 500mm	Breedte +/- 250mm, Lengte +/- 500mm	zie niveau 2	Breedte +/- 250mm, Lengte +/- 500mm	+/- 500mm
Wand/vloer/dekdikte	wordt niet bepaald	+/- 100mm, niet < dan 10%	Dek: +/- 50mm, niet < dan 5%, rest niveau 2	+/- 50mm, niet < dan 5%	+/- 200mm, niet < dan 20%
Wapeningshoeveelheden*, ook voorspanning	wordt niet bepaald	- 15% & +30%	Dek: - 5% & + 10%, rest niveau 2	-2.5% & + 5%	wordt niet bepaald
Palen, groutankers, damwanden etc., aantallen	wordt niet bepaald	+/- 10%	zie niveau 2	+/- 5%	wordt niet bepaald
Palen, groutankers, damwanden etc., afmeting	wordt niet bepaald	+/- 10%	zie niveau 2	+/- 5%	wordt niet bepaald
Palen, groutankers, damwanden etc., lengte	wordt niet bepaald	+/- 3 m	zie niveau 2	+/- 1 m	wordt niet bepaald
Funderingswijze	op staal/op palen		zie niveau 2		
Constructiehoogte incl. asfalt	nee	ja	zie niveau 2	ja	nee
Grondwaterstand	nee	ja	zie niveau 2	ja	nee
m2 dek	ja	ja	zie niveau 2	ja	ja
Codering	nee	nee	zie niveau 2	nee	ja, i.o.m. planning
Tekenen/modelleren	alleen dek in baz nieuw maaiveld bestaande maaiveld in dsn	palen poer kolom (landhoofd)balk dek (prefab ligggers niet apart, black box) vleugelwanden permanente dw'n gewapende grond?? stootplaten type voegen type opleggingen plaats HWA putten en -leidingen schampkanten nieuw maaiveld bestaande maaiveld in dsn algemene details	Wap schets dek: incl. laslengte, bgls en detaillering/stortnaden overige zie niveau 2	palen poer kolom (landhoofd)balk dek (prefab ligggers niet apart, black box) vleugelwanden permanente dw'n gewapende grond?? stootplaten type voegen type opleggingen plaats HWA putten en -leidingen schampkanten nieuw maaiveld bestaande maaiveld in dsn details tevens wap-tekening 1 moot	dek steunpunt nieuw maaiveld bestaande maaiveld in dsn
Raakvlakken	-	Voorzieningen TI (boren/itso's/sparingen/vluchtdeuren/hulpposten/waterkelders/ventilatoren etc Raakvlakken met bermbev, VRI, OV, DVM, Geluidscherm, etc.		zie niveau 2 zie niveau 2	
Niet tekenen/modelleren	alles, behalve dek in baz	specifieke details leuningen oplegblokken geluidschermen, OV, K&L asfalt	zie niveau 2 zie niveau 2 zie niveau 2 zie niveau 2 zie niveau 2	leuningen oplegblokken geluidschermen, OV, K&L asfalt	details palen vleugelwanden stootplaten schampkanten etc. leuningen oplegblokken geluidschermen, OV, K&L asfalt
Eisen aantonen	nee	ja	zie niveau 2	ja	?
Raakvlakken afstemmen	nee	ja	zie niveau 2	ja	?
In RD-coördinaten	ja	ja	zie niveau 2	ja	ja
Digitaal formaat (alles zelfde versie)	Autocad 2012 / Civil 3D 2012	Autocad 2012 / Civil 3D 2012 / Revit 2012	Autocad 2012 / Civil 3D 2012 / Revit 2012	Autocad 2012 / Civil 3D 2012 / Revit 2012	Revit 2012

* <u>Toelichting wapeningshoeveelheid:</u>
Voorspanning in aantal kabels , aantal strengen en opppervlak streng, druklagen van volstortdekken in kg/m2, overige in kg/m3
incl. las- en verankeringslengte en detaillering&stortnaden, Dus alle wapening die op de wapeningstekening komt te staan
Denk ook aan overlap van constructie elementen (bijv. balk in brugdek: totaal m3 x kg/m3 = totale hoeveelheid wapening, dus balkhoogte tot ok dek). Hier specificeren hoe de m3 beton moeten worden gezien.
excl. knip- en buigverlies, hulpwapening en VEST-toeslag

Eisen aantonen: bv: PVR, breedte berm, inspectiepad, minimale afstand tot belending, maximale/minimale hoogte, ruimte hulpvoertuig etc.

Appendix K

Factsheet used by Civil-discipline (Heijmans intraned)

Ontwerpnotitie t.b.v. calculatie Civiel

0. Revisie

nr.	Datum	Gewijzigd door?	Wat is er gewijzigd?
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

1. Bassisgegevens

Kunstwerk:	
Objectcode:	
Scope kunstwerk:	
Deeltrace:	

Omschrijving	Afbeelding

2. Geotechnische gegevens

Maaiveld niveau:		NAP (m1)
Grondwaterstand:		NAP (m1)
Grondopbouw:		

Overige aandachspunten geotechniek

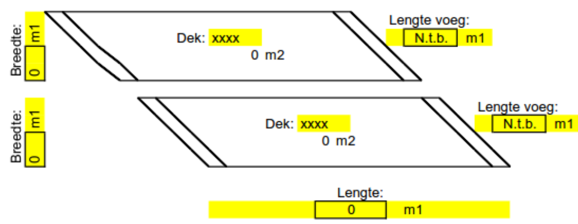
3. Ontwerp raakvlakken

Raakvlakken K&L:	
Raakvlakken NGE:	
Raakvlakken Contourgrens:	

Overige aandachspunten geotechniek

4. Algemene afmetingen

Aantal tussensteunpunten:		stk
Aantal voegovergangen:		stk



Overige aandachspunten

x
x
x
xx
x
x

5. Hulpwerk (Damwand, ondersteuning en derg.)

Landhoofd					
Damwandtype:	AZ18-700	Waarom?:			
Omschrijving:					
Lengte:		m1	Hoogte:		m1
Breedte:		m1			

Tussensteunpunt					
Damwandtype:	AZ18-700	Waarom?:			
Omschrijving:					
Lengte:		m1	Hoogte:		m1
Breedte:		m1			

Overige damwanden?					
Damwandtype:	AZ18-700	Waarom?:			
Omschrijving:					
Lengte:		m1	Hoogte:		m1
Breedte:		m1			

Overige aandachtspunten

x
x
x
xx
x
x

6. Fundering

Landhoofd					
Funderingstype:	geen	Waarom?:			
Omschrijvingspaal:					
Lengte paal:		m1	H.o.h. Lengte:		m1
Aantal rijen:		m1	H.o.h. Breedte:		m1

Tussensteunpunt					
Funderingstype:	geen	Waarom?:			
Omschrijvingspaal:					
Lengte paal:		m1	H.o.h. Lengte:		m1
Aantal rijen:		m1	H.o.h. Breedte:		m1

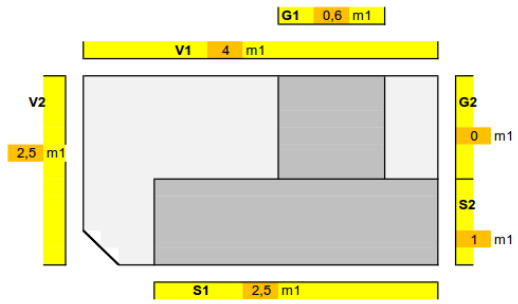
Overige aandachtspunten

x
x
x
x
x
x

7. Landhoofd

Afwijken afmetingen van het standaard landhoofd? Nee

Sloof	Strd. Afmetingen	Afwijk. Afmeting	Eenh.
Breedte (S1):	2,5	N.t.b.	m1
Hoogte (S2):	1	N.t.b.	m1
Wapening:	130	N.t.b.	m3/kg
Grondkerende wand			
Dikte (G1):	0,6	N.t.b.	m1
Hoogte (G2):		N.t.b.	m1
Wapening:	175	N.t.b.	m3/kg
Vleugelwand			
Breedte (V1):	4	N.t.b.	m1
Hoogte (V2):	2,5	N.t.b.	m1
Dikte:	0,4	N.t.b.	m1
Wapening:	150	N.t.b.	m3/kg

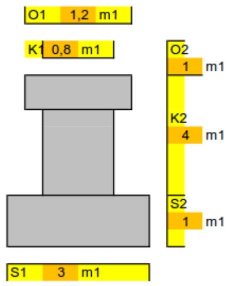


Overige aandachtspunten

8. Tussensteunpunt

Afwijken afmetingen van het standaard tussensteunpunt? Nee

Sloof	Strd. Afmetingen	Afwijk. Afmeting	Eenh.
Breedte (S1):	3	N.t.b.	m1
Hoogte (S2):	1	N.t.b.	m1
Wapening:	125	N.t.b.	kg/m3
Wand			
H.o.h. kolom:	3	N.t.b.	m1
Lengte:	0,8	N.t.b.	m1
Breedte (k1):	0,8	N.t.b.	m1
Hoogte (K2):	4	N.t.b.	m1
Wapening:	200	N.t.b.	kg/m3
Onderslagbalk			
Breedte (O1):	1,2	N.t.b.	m1
Hoogte (O2):	1	N.t.b.	m1
Wapening	150	N.t.b.	kg/m3



Overige aandachtspunten

9. Dek				
Toepassen Prefab of insitu?	Prefab	**Waarom?:**		
Maatgevende overspanning:		m1		
Insitu				
Dekdkite:		m1		
Wapening:		m3/kg		
Voorspanning:		m3/kg		
Prefab				
Type ligger:	HKO300			
Waarom:				
Overige aandachspunten				
11. Overige aspecten				

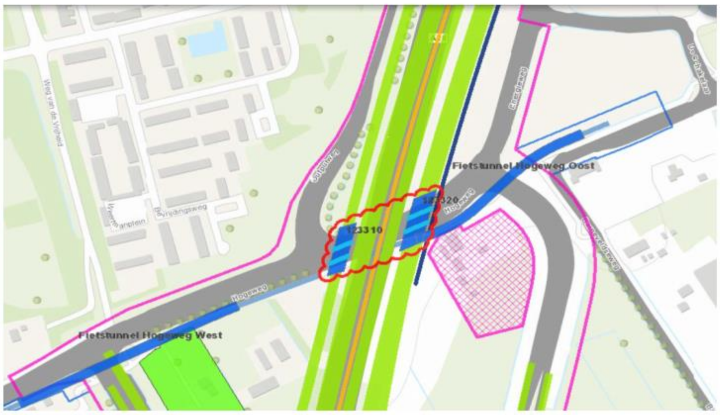
Appendix L

Factsheet used by Roads-discipline (Heijmans intraned)

Ontwerpnotitie OWN (def) t.b.v. calculatie Wegen/EMVI-plannen

1. Bassisgegevens OWN

Datum laatst aangepast:	vrijdag 30 januari 2015	**Opgesteld door:**	Frank Nijhof
OWN (objectcode):	Hogeweg (kruising A28)	123300 + 123330 + 123340 + 123350	
Scope kunstwerk:	-	-	
Deeltrace:	A28 Zuid	21.7	

Aanvullende omschrijving	**Afbeelding**
N.t.b.	
N.t.b.	
N.t.b.	
N.t.b.	
N.t.b.	
N.t.b.	
N.t.b.	
N.t.b.	
N.t.b.	
N.t.b.	
N.t.b.	
N.t.b.	
N.t.b.	
N.t.b.	
N.t.b.	
N.t.b.	
N.t.b.	
N.t.b.	
N.t.b.	

2. Analyse eisen VSE

VSE 02 Systeem Onderliggend Wegennet (belangrijkste eisen)

Object-ID	Object	EisID	Eistitel	Eistekst
123300	Hogeweg (kruising A28)	SE_02011	Ontwerpsnelheid GOW 50, binnen de bebouwde kom	De gebiedsontsluitingswegen 50 (binnen de bebouwde kom) binnen A28/A1 OWN dienen het rijden van gemotoriseerd verkeer mogelijk te maken met een ontwerpsnelheid van 50 km/uur conform "CROW-publicatie 723 ASVV 2012"
123300	Hogeweg (kruising A28)	SE_02030	Voldoen aan CROW 723 (ASVV 2012)	A28/A1 OWN, voor het gedeelte gelegen binnen de bebouwde kom, dient te voldoen aan de richtlijn "CROW-publicatie 723 ASVV 2012" uitgezonderd de situaties waar dit aantoonbaar niet ruimtelijk inpasbaar is binnen de contourlijn. (in dat geval geldt ten minste het 'stand still-principe' conform eis
123300	Hogeweg (kruising A28)	SE_03469	Aanpassing Hogeweg	De Hogeweg inclusief verkeersregelinstallaties dient tussen de aansluiting met de Energieweg en de aansluiting met de toerit richting Utrecht aangepast te zijn aan de gewijzigde functie van de Outputweg conform "Kortsluiting Outputweg - Energieweg, Wegontwerp Situatie, lengteprofielen en

Vraagspecificatie Wensen (belangrijkste eisen, naast BS)

Object-ID	Object	EisID	Eistitel	Eistekst
123340	Fietstunnel Hogeweg (2	SE_01887	Fietsverbinding Hogeweg - Fietstimuleringsplan	De fietsverbinding langs de Hogeweg dient als onderdeel van het secundair netwerk te voldoen aan de eisen zoals omschreven in het "Fietsstimuleringsplan Amersfoort 2008", (tabel 1, pagina 14), uitgezonderd de
123330	Fietstunnel Hogeweg (1)	SE_01385	Fietsverbinding Hogeweg - Langshelling en boogstralen	De langshelling en boogstralen van de fietsverbinding langs de Hogeweg dienen te voldoen aan de hellingspercentages conform "CROW-publicatie 230 Ontwerpwijzer fietsverkeer".
123340	Fietstunnel Hogeweg (2	SE_02075	Fietsverbinding Hogeweg - Ongelijkvloers kruisen	De fietsverbinding langs de Hogeweg dient respectievelijk de oostelijke en westelijke toe- en afrit van aansluiting 8 (Amersfoort) ongelijkvloers te kruisen.
123340	Fietstunnel Hogeweg (2	SE_01952	Fietsverbinding Hogeweg - Vormgeving onderdoorgang	De doorsnede van de ongelijkvloerse kruisingen in fietsverbinding Hogeweg dient overeen te komen met de vormgevingseisen zoals opgenomen in "Dossier Ruimtelijke Kwaliteit en Vormgeving Knooppunt Hoevelaken".
123340	Fietstunnel Hogeweg (2	SE_01951	Fietsverbinding Hogeweg - Wegprofiel	Het wegprofiel van de fietsverbinding langs de Hogeweg dient over de volledige lengte ten minste te voorzien in onderstaande opbouw: - voetpadbreedte ten minste 1,5m; - fietspadbreedte ten minste 4,0m; - overgangsstrook tussen fietspad en kunstwerk ten minste 0,5m (ter hoogte van ongelijkvloerse kruising)

Aandachtspunten bij deze onderliggende weg (bijv. fasering):

3. Scope vanwege verkeersdoorstroming definitieve situatie planfase (input Manus Barten)		
Hogeweg		
2 dekken ernaast HWN zonder tussensteunpunt Oostzijde, Energieweg herindeling kruising en onderdoorgang Westzijde, kruising herindeling. Knelpunt met nieuwe verbinding Outputweg-Energieweg. Moet snel zijn voor fietsfasering en ombouw Hogeweg.		
Input van RWS: informatie over huidige verkeersafwikkelingen (tellingen, verzadigingsgraad) of analyse op locatie		
Analyseren input van RWS/analyse op locatie		
Scope vanwege verkeersdoorstroming definitieve situatie planfase		
4. Maatregelenpakket OWN (op basis van 2 en 3) (Frank Nijhof)		
Wegen Verbreding huidige profiel van x naar y **Kruisingen** Extra opstelstrook x rivhting y **Fietspaden** 2 zijdig i.p.v. 1 z ***enz.***		
5. Fasering / FHU-OWN (input Rob Breman/Manus Barten)		
Functie	**Beschrijving**	**Verkeer**
Viaduct in A28	Drukste kruising in OWN. Hogeweg is verbinding tussen Hoevelaken en Amersfoort.	Verbreding aan beide zijden met extra dek voor 2 nieuwe rijbanen. Om OWN te ontzien bouwen we geen tussensteunpunten. Hierdoor geen hinder op OWN behalve bij inhijsen liggers welke in WBU-uren gebeurd vanaf A28
6. Maatregelenpakket EMVI ('procesplan', 'plan omgevingshinder', 'Beperkingverkeershinder(beleving)) (input Rob Nieuwkamer/Frank Hoekemeijer/Manus Barten)		

Appendix M

Risk assessing method of the organization (Heijmans intraned)

Score	Kans (K)	Gevolg geld (G) €	Gevolg planning (T) Kalenderdagen	Gevolg kwaliteit eindproduct (Q) Kans	Gevolg kwaliteit eindproduct (Q) Bedreiging	Gevolg Veiligheid (V)
0	0% (kan niet optreden)	0	0	Geen verbetering voor de kwaliteit	Geen gevolg voor kwaliteit	Geen gevolg voor veiligheid
1	0-1% (komt zelden voor)	< 50.000	< 1 week	Esthetische verbetering, geen toename in functionaliteit en duurzaamheid	Buiten toleranties, onzichtbaar reparabel zodanig dat eis wordt gehaald	Lichte blessure
2	2-5% (onwaarschijnlijk)	50.000 - 100.000	1 - 3 weken	Functionele verbetering t.o.v. de originele eis	Buiten toleranties, reparabel, reparatie zichtbaar, eis wordt gehaald	Licht gewond, medische assistentie benodigd
3	6-10% (kans bestaat, niet groot)	100.000 - 250.000	3 - 6 weken	Estetische en functionele verbetering t.o.v. de originele eis	Afwijking niet reparabel extra onderhoud nodig gedurende life-cycle	Gewond met kans op blijvend letsel
4	11-25% (reeele kans)	250.000 - 500.000	6 - 12 weken	Verhoogde duurzaamheid in de life-cycle, minder onderhoud t.o.v. originele eis	Afwijking niet reparabel blijvend functieverlies	Zwaar gewond, blijvend letsel
5	> 25% (grote kans)	> 500.000	> 12 weken	Estetische, functionele en duurzame verbetering t.o.v. de originele eis	Afwijking onacceptabel voor functie opnieuw uitvoeren object / activiteit	Dodelijke afloop

Gevolgen omgeving (O) Kans	Gevolgen omgeving (O) Bedreiging	Infra specifiek	Milieu (M) Milieu-effect
Geen significant gevolg voor omgeving	Geen significant gevolg voor omgeving	Geen	Geen effect
Transparantie door regelmatige communicatie	Minimale gevolgen	Niet kritisch	Licht effect
Indirecte betrokkenheid door interactie met werkzaamheden	Opgemerkt door omgeving	Hinder door vertragingen	Beperkt effect
Directe betrokkenheid door betrekking in de werkzaamheden	Klacht omgeving	Stremming 0-8 uur	Aanzienlijk effect
Omgevingvoleldig betrokken en ontzien in overlast	Groot gevolg	Stremming 8-24 uur	zeer ernstig effect
Omgeving fungeert als ambassadeur in (deel)trajecten	Blijvende klachten omgeving	Stremming > 24 uur	Milieuramp

Appendix N

Interviews

Number	Date	Job	Discipline	
1	6/10/2014	Cost expert	Civiel	Bjorn vd Brand
2	17/10/2014	Company manager	Civiel	Ton van Hunen
3	22/10/2014	Company manager	HIP, Grond & Wegen	Anton Beks
4	11/11/2014	Advisory consultant	HIP, Constructies & geotechniek	Leo Molenbroek
5	17/11/2014	Project leader	Civiel	Philip Kremers
6	27/11/2014	Company manager	Civiel	Ton van Hunen
7	2/12/2014	Company manager	HIP, ontwerpmanagement	Harm Heijmans
8	26/01/2015	Company manager	Civiel	Ton van Hunen
9	6/2/2015	Cost expert	Civiel	Bjorn vd Brand
10	26/02/2015	Company manager	Wegen	Mark Kruis
11	24/03/2015	Design leader	HIP, ontwerpmanagement	Frank Nijhof
12	24/03/2015	Road designer	HIP, ontwerpmanagement	M.M. Willemsen

Interview 1: cost expert Civiel

1. In hoeverre wordt het probabilistisch ramen gebruikt op dit moment? Op alle HIP projecten begreep ik, maar niet alles gaat probabilistisch neem ik aan. Gaat er nog veel op de traditionele, deterministische manier? Wanneer probabilistisch en wanneer deterministisch? Ligt het aan de grootte/complexiteit/innovatieve/type contract van het project of gedeeltes van projecten of zijn er nog andere factoren?

- *De tender A28/A1 knooppunt Hoevelaken wordt het eerste project binnen Heijmans Civiel waar probabilistisch ramen en ontwerpen wordt toegepast. Het staat nog echt in de startblokken. Het project Onderdoorgang Bio Science Park (OBSP) is wel probabilistisch ontworpen maar het ramen is op deterministische wijze gegaan. Er kwamen zaken bij zoals Lean, DBFM (ook niet veel voorkomend) waardoor het te hectisch werd om het probabilistische ramen ook nog eens toe te passen.*

- *Probabilistisch ramen en ontwerpen kan niet worden toegepast bij iedere calculator (en misschien ook wel constructeur). Sommige calculatoren bevinden zich buiten hun comfort zone wanneer zij PR en O toepassen, omdat zij gewend zijn alles tot in detail (moertjes- en boutjesniveau) uit te rekenen.*

- *Het vraagt een bepaalde mindset van de directie, stuurgroep en het abstractieniveau van medewerkers binnen Heijmans.*

- *Er kan worden gekozen om alles probabilistisch uit te werken. Ligt aan directie en stuurgroep met wat zij willen met de aanbesteding. Eerst wordt er een nulraming gemaakt om een orde van grootte te krijgen wat de totale kostprijs ongeveer gaat worden. Dit wil de stuurgroep weten omdat zij dan gaan bepalen of er wordt ingeschreven of niet. Een nulraming wordt verkregen door de informatie uit het Tracébesluit of overige gegevens die beschikbaar zijn.*

- *Enige reden om op de deterministische manier te doen (Thijs: ontwerpen en ramen) is: een te risicovol object of het heeft een substantieel aandeel in het totaal. Bijvoorbeeld: een viaduct gaat 50% kosten van de totale aanneemsom. Dan is het raadzaam om het niet probabilistisch uit te rekenen (Thijs: met weinig bandbreedte door een gedetailleerd ontwerp).*

- *Verder kan je geen lering trekken uit voorgaande projecten. Soms kost een dek van een viaduct €1100 euro per m^2, soms €1800/m^2. Ieder werk blijft een "special", dus is het meestal appels met peren vergelijken.*

2. Op welke manier wordt het PR toegepast? Gebruiken jullie als leidraad bijvoorbeeld het document Standaardsystematiek Kostenramingen (SKK), RISMAN? Of met een eigen methode?

- *SKK en RISMAN worden vaak gebruikt door opdrachtgevers. In het werk bij de A28/A1 is er op die manier bepaald door de opdrachtgever dat het werk €406 miljoen euro gaat kosten. Door Heijmans wordt dit niet gebruikt. Alles wat bij mij bekend is over het probabilistisch ramen en ontwerpen staat in een memo.*

3. Hoe gaat de start van een tender in zijn werk? Er komt een tenderaanvraag binnen met een programma van eisen. Hoe gaat dat na het binnenkomen van de aanvraag, en dan doel ik voornamelijk op het contact tussen calculators en constructeurs. Wordt er eerst een idee geopperd door een constructeur waarna jullie gaan calculeren, andersom, gezamenlijk? Hoe vaak hebben deze disciplines met elkaar contact gedurende een tender? Is dit ook een risico?

- *Als voorbeeld weer het project OBSP. Hierbij was de doelstelling: scoren op EMVI criteria. Dit bepaald de tendermanager met de stuurgroep. Er wordt altijd afgevraagd: waar kunnen we op scoren? Is dat goedkoop en simpel of duur met relatief hogere EMVI scores. Zo kan er gekeken worden om bij het afsluiten van een weg meerdere troepen te sturen (wat meer kost) om een weg eerder operationeel te hebben (en meer wordt terugverdient met EMVI waarde). Er wordt dus eerst een tenderstrategie uitgezet en er wordt altijd afgevraagd: hoe kunnen we het project zo (fictief) goedkoop mogelijk oplossen.*

4. Wat zijn voor jou zaken waar op dit moment tegenaan wordt gelopen met betrekking tot probabilistisch ramen en ontwerpen? Wat gaat er goed op dit moment en waar loopt het spaak?

- *Hoe de resultaten van het PR gepresenteerd moeten worden. Om een voorbeeld te noemen: alle resultaten worden verwerkt op een eindblad. Hierop staan de percentages in kolommen van verschillende disciplines zoals HIP, Civiel, Wegen en Geluidsschermen (aandeel in het totaal). Nu moet er een nieuwe factor in: de P- waarde. Alleen hoe dit te presenteren.*

- *Bij Heijmans Civiel zijn ze het meest innovatief wat PR betreft.*

5. Probabilistisch Ramen en ontwerpen is ingevoerd binnen HIP op 1 januari 2014. Maar dit is niet ineens ingevoerd neem ik aan. Die methode is in de loop van de jaren al veelvuldig gebruikt en uitgeprobeerd?

- *Zie antwoord vraag 1.*

6. Hoe zit het met het evaluaties van voorgaande tenders waarbij gebruik is gemaakt van probabilistisch ramen en ontwerpen? Zijn er rapporten beschikbaar?

- *N.v.t.*

7. Het calculeren van projecten met verschillende geïntegreerde contractvormen gaat anders in zijn werk. Er wordt veel met D&C en DBFM contracten gewerkt. Iedere contractvorm zoals D&C, DBFM(O) en E&C vereisen hun eigen aanpak en methode. Hoe gaat dat in zijn werk? Met wat voor contracten hebben jullie meestal te maken?

- *Voornamelijk D&C contracten.*

- *Bij de tender voor de A28/A1 knooppunt Hoevelaken wordt een PDC contract toegepast. In dit contract is er een plafondbedrag bepaald en bekeken wordt welke "wensen" er worden uitgewerkt. Een wens is bijvoorbeeld: het verbreden van de vluchtstrook. Als dit €10 miljoen kost en fictief levert het €15 miljoen op, moet geprobeerd worden dit uit te voeren. Doordat er een plafondbedrag is vastgesteld door overheden, kan er met deze eerste* *toepassing van het PR geen grote misser worden gemaakt. Hiervan is wel is het nadeel dat je niet kan kijken hoe concurrerend je aanbieding is voor het evaluatieproces.*

8. Zijn er duidelijke risico's wat PR met zich meeneemt? Bijvoorbeeld hogere inschrijvingen omdat er wel eens wat "vergeten kan worden"?

- *Zolang je de scope maar duidelijk hebt en alles "raakt" (niet iets mist of vergeet). Dit moet je jezelf constant blijven afvragen. Zolang er achter ieder regeltje een prijs staat.*
- *Je moet ook alles in verhouding zien. Wat is bijvoorbeeld 10.000 euro op een werk van miljoenen? Je moet natuurlijk wel alles zo volledig mogelijk invullen.*

Interview 2: company manager Civiel

1. Ik neem aan dat de meeste aanbiedingsontwerpen voor de discipline Civiel op de traditionele, deterministische methode worden ontworpen en geraamd. Toch bestaat al langer het idee om aanbiedingsontwerpen te maken door middel van de probabilistische ramen en ontwerpen. Waarom? (zien jullie veel voordelen, wordt dit door jullie opdrachtgevers gepromoot, voor het kwantificeren van risico's om deze beter in kaart te brengen?)

- *Er wordt het meest geraamd op de traditionele methode. Voor mij is probabilistisch begroten een definitie waar iedereen een andere invulling aan kan geven. Dus eerst wil ik uitleggen wat het voor mij betekent samen met een voorbeeld. Voor een bepaalde tender heb ik in eerste instantie een landkaart gepakt en gekeken hoeveel km weg het was en bepaald hoeveel kunstwerken er ongeveer moesten komen. Binnen een halve dag kon ik een prijs geven met daarbij een schatting met de minimale- en de maximale waarde. Dit is voor mij probabilistisch begroten. Aan de hand van ervaring en kengetallen op gevoel komen tot een L-T-U waarde. Als je al in het eerste detailniveau treedt, is dit voor mij al deterministisch. Maar sommige personen noemen het nog steeds probabilistisch als het wordt uitgewerkt in het meest gedetailleerde niveau.*

2. Zijn er naast de deterministische- en probabilistische methodes ook nog andere methodes om aanbiedingsontwerpen te realiseren?

- *Deze vraag heb ik eigenlijk nog nooit gehoord, maar naar mijn weten niet.*

3. Binnen HIP is afgesproken dat sinds 01/01/2014 alle projecten op deze manier worden geraamd. Maar waarom komt dit nu we bijna in 2015 zitten nog niet echt van de grond? Waar zit volgens u de oorzaak?

- *Van de disciplines Wegen, HIP en Civiel binnen Heijmans is Civiel de meest vooruitstrevende wat betreft probabilistisch ontwerp. Bij HIP en Wegen zijn ze nog niet gewend om probabilistisch te ramen en ontwerpen.*

Interview 3, company manager HIP, Grond & Wegen

1. Het begrip probabilistisch ramen en ontwerpen wordt door iedereen anders uitgelegd. Wat is uw definitie van probabilistisch ontwerpen?

- *Erg belangrijk is inderdaad wat we nu eigenlijk onder probabilistisch ramen en ontwerpen verstaan. Ik heb er nu niet echt een precieze definitie voor maar ik weet wel dat we met een team vooraf bij elkaar moeten zitten om duidelijk de detailniveaus aan te geven. De hoeveelheden kregen we vroeger bij RAW contracten exact door. Tot en met ieder bochtje van een buis in een kolkje. Op die manier hoeft het niet. Tot nu toe is onze belangrijkste vraag: tot welk detailniveau moeten we gaan. Bij een hoog risico: uitwerken tot in een hoog detailniveau.*

2. Hoe gaat bij jullie discipline het tenderproces in zijn werk? Er komt een programma van eisen binnen waarmee binnen Heijmans aan de gang wordt gegaan. Hoe gaat dat proces dan binnen Heijmans verder, met nadruk bij de ontwerpkant.

- *Dat ligt aan het type contract. Meestal komt er gezamenlijk met het programma van eisen een referentieontwerp (RFO, meestal op schetsniveau) van de opdrachtgever mee. Het wordt dan duidelijk wat voor vrijheden er zijn binnen een project. Rijkswaterstaat gaat hier losser mee om dan bijvoorbeeld gemeentes. Die laatste zijn toch banger dat er iets komt waar men niet op zit te wachten. Vragen die dan gesteld worden zijn onder andere: hoe kan EMVI het best toegepast worden.*

- *In tenderfases vindt continu overleg plaats. Wat helpt is wanneer tenderteams op dezelfde locatie werken. Als verschillende disciplines op andere locaties werken, wat er nu gebeurt bij Wegen (er werkt een gedeelte van de groep in Eindhoven) zijn deze tenders al gedoemd om te mislukken. Dat zijn mijn woorden, dus weet niet of het ook klopt. Maar zo zie ik het.*

3. Ik neem aan dat de meeste aanbiedingsontwerpen op de traditionele, deterministische methode worden ontworpen. Toch bestaat al langer het idee om aanbiedingsontwerpen te maken door middel van de probabilistische ramen en ontwerpen. Waarom?

- *Het probabilistisch begroten is er een beetje ingezogen door de calculatiekant. Vorig jaar is er bij 2 projecten gekeken of het mogelijk was om deze (gedeeltelijk) probabilistisch te ontwerpen. Hierbij is niet verder gekomen dan een eerste overleg. Dit vanwege koudwatervrees. Iedereen "wijst" naar elkaar, dat wil zeggen: als de ontwerpafdeling niet probabilistisch ontwerpt, heeft de calculatieafdeling ook weinig "trek" in een probabilistische raming v.v.*

- *Commitment van bovenaf is er wel, maar er moet dan ook support zijn om de werknemers een steun in de rug te geven om deze methode daadwerkelijk van de grond te krijgen.*

4. Hoe wordt er op dit moment omgegaan met het bepalen van de ontwerphoeveelheden? Wie bepaald er tot welk detailniveau er wordt uitgewerkt? Hoe gaat het in zijn werk met het bandbreedteformulier? Is dit voor u de gewenste gang van zaken, of wordt er soms te diep ingegaan op details?

- *Op dit moment zijn de ontwerpkosten, afhankelijk van het type contract, soms meer van 50% van de totale tenderkosten. Bij de tender A28/A1 knooppunt Hoevelaken met een PDC contract, ligt het Tracébesluit nog niet vast. Deze moet nog worden vastgelegd door middel* *van het uitfilteren van 9 à 10 varianten, naar ca. 3 varianten naar uiteindelijk 1 variant. Hierbij zijn de ontwerpkosten dus duidelijk hoger dan 50%. Dit wordt gedaan door middel van een trade-off matrix, ook een soort van probabilistische methode.*

5. Binnen HIP is afgesproken dat sinds 01/01/2014 alle projecten op deze manier worden geraamd. Maar waarom komt dit nu we bijna in 2015 zitten nog niet echt van de grond? Waar zit volgens u de oorzaak?

- *Om het in te voeren: in eerste instantie de definitie duidelijk hebben. Daarnaast bekendheid geven aan het begrip probabilistisch begroten op de werkvloer. Verder moeten ze ondersteund worden in dit proces net als kinderen die voor het eerst gaan fietsen: ze hebben een duwtje in de rug nodig.*

6. Wat verwacht u van het probabilistisch ontwerpen binnen uw afdeling; zit er toekomst in?

- *Ik ben er zelf totaal niet huiverig voor. Het is alleen niet de eerste verandering binnen Heijmans van de afgelopen tijd. Zo is BIM recentelijk ingevoerd, zo leggen opdrachtgevers steeds meer verantwoordelijkheid en druk bij de opdrachtnemer met nieuwe contractvormen en hebben de werknemers het sowieso al druk met normale werkzaamheden. De invoering van het probabilistisch ramen en ontwerpen is weer een nieuwe verandering en veranderingen zorgen weer voor een extra belasting voor het personeel. Dus het is van belang de noodzaak duidelijk door te laten schemeren aan het personeel en het zelf duidelijk te hebben wat probabilistisch begroten eigenlijk inhoudt.*

7. Hoe denkt u op welke manier het probabilistisch ramen en ontwerpen binnen het bedrijf kan worden ingevoerd?

- *Het invoeren stapsgewijs laten plaatsvinden. Wellicht wanneer er de mogelijkheid (tijd/geld) bestaat een gedeelte van een tender eerst probabilistisch te ontwerpen en te calculeren, waarna dit daarna getoetst wordt met een deterministische raming.*

8. Wat ziet u gebeuren op de markt/bij de concurrentie? Bijv. bij het gezamenlijk aanbesteden van een werk.

- *Ik kan je vertellen dat wij het zo slecht nog niet doen bij Heijmans. Doordat we een ontwerpafdeling hebben van 75 personen, dus een volledig ingenieursbureau, hebben we veel voordelen op de concurrentie. We hebben alles zelf in de hand en kunnen zelf bepalen welke koers we gaan uitzetten. Dat is anders bij de concurrentie, omdat zij vaak een ontwerpafdeling hebben van ca. 10/15 personen. Ze moeten ingenieursbureaus inhuren die graag veel uren willen maken en verantwoordelijk zijn voor de koers die wordt ingeslagen.*

9. Is er volgens u haast bij het invoeren van het probabilistische begroten?

- *Als je tenderkosten kan besparen, zijn het wel kosten die je direct terugverdient. En als het gaat functioneren binnen Heijmans, kunnen we vooruitlopen op de concurrentie. Maar om iedereen mee te krijgen binnen Heijmans, wordt een hels karwei.*

10. Een van de doelstellingen van het probabilistisch begroten is het sneller focus kunnen bepalen voor het wel/niet meedoen aan tenders. Wat zijn bij Ontwerp Grond en Wegen redenen om juist wel of niet mee te doen aan een tender?

- *Voor 80-90% zijn wij volgend: Civiel en Wegen zijn hierin bepalend of er wordt meegedaan aan tenders. Omdat vaak maar 5% van de totale kosten uitvoeringskosten zijn, dus maar een klein aandeel. Wel worden er door het ontwerpteam naar risico's gekeken en hebben zodoende een stem in een go/no go beslissing.*
  Om een voorbeeld te noemen: als wij door verschillende redenen het moeilijk/risicovol vinden dat een Tracébesluit er doorheen komt, melden wij dit uiteraard van tevoren. Vanwege de bezwaarprocedure kan dit zomaar een vertraging van 1 à 2 jaar opleveren als het TB er niet meteen doorkomt.

11. Zijn er naast de deterministische en probabilistische methodes ook nog andere methodes om aanbiedingsontwerpen te realiseren?

- *Nee eigenlijk niet. Of een referentieontwerp moet letterlijk worden overgenomen.*

Interview 4, advisory consultant HIP, Constructies & Geotechniek

1. Hoe gaat bij jullie discipline het tenderproces in zijn werk? Er komt een programma van eisen binnen waarmee binnen Heijmans aan de gang wordt gegaan. Hoe gaat dat proces dan binnen Heijmans verder, met nadruk bij de ontwerpkant.

- *Het kernteam bepaalt de onderverdeling op basis van de eerste raming.*

2. In tenders zijn de ontwerpkosten (neem aan dat daar constructies onder vallen) soms wel meer dan 50% van de totale tenderkosten. Wordt op dit moment alles op de deterministische manier ontworpen (tot in boutjes en moertjes niveau uitgewerkt)? Of gaan jullie in tenders bij sommige kunstwerken/constructies abstracter te werk?

- *Ik ben zelf voorstander van het niet helemaal uitwerken. Het is afhankelijk van de klant en het contract of de deterministische methode goed functioneert of niet. Voor een aanbesteding wilde een opdrachtgever, een provincie, een erg gedetailleerd plan hebben waarna het werk gegund werd. Bij Rijkswaterstaat wordt er meer gekeken naar "wat kost het" en EMVI en wordt er in eerste instantie geen erg uitgewerkt plan gevraagd.*

3. HIP en andere disciplines binnen Heijmans willen met het probabilistische ramen en ontwerpen van start (of zijn al deels van start hiermee). Het begrip probabilistisch ramen en ontwerpen wordt door iedereen anders uitgelegd. Wat is uw definitie van probabilistisch ontwerpen?

- *Er wordt geworsteld met deze term. Iedereen heeft een andere definitie voor probabilistisch ramen en ontwerpen. Jaren geleden heb ik al gezegd bij tenders dat energie en inspanning in verkeerde zaken wordt gestopt.*
  Bijvoorbeeld met het uitrekenen van steunpunten/aanrijden kolom: daar wordt veel tijd in het ontwerp gestopt (bijv. 1 week) met iets wat in verhouding maar weinig gaat kosten. En aan een brugdek wordt maar 1 dag besteed, terwijl dat relatief veel meer impact heeft op de uiteindelijke kostprijs.

- *In een tender heb je meestal weinig tijd, met de kans dat je een werk niet krijgt. Je aandacht moet je dus goed spreiden en leg de focus op zaken die belangrijk zijn. Hier is pas goed naar gekeken vanwege tijdnood tijdens het project A4 in Schiedam.*

4. Wat denkt en verwacht u zelf van deze manier van werken? Of heeft u hier al (veel) ervaring mee?

   Ik zie zeker het nut van de probabilistische methode, want ik ben eigenlijk samen met een collega op dit idee gekomen. Het is toen uit nood geboren.

5. Ziet u dus nut in met het werken van deze probabilistische methode of totaal niet? Wat zijn volgens u voor- en nadelen?

   Voordelen:
- *komen gedurende het interview aan bod*
  Nadelen:
- *er komt weer een processtap bij. Het aantal stappen tot op een aanbieding te komen wordt meer. Een stap extra is bijvoorbeeld het terugkijken nadat je de simulaties hebt gedaan: "ben ik niks vergeten?"*

- *waken dat het personeel hun eigen werk kan blijven doen door de administratieve last beperkt te houden*

6. Binnen HIP is afgesproken dat sinds 01/01/2014 alle projecten op deze manier worden geraamd. Maar waarom komt dit nu we bijna in 2015 zitten dit principe nog niet echt van de grond binnen Heijmans? Waar zit volgens u de oorzaak?

- *Het wordt niet uitgesproken waarom. Het gebeurt zeker nog niet op alle werken. Een van de oorzaken is dat er wordt gewerkt met tientallen ontwerpleiders en ontwerpmanagers. Ik ben er van overtuigd dat een aantal mensen nog nooit gehoord heeft van Monte Carlo simulaties.*

- *Op dit moment is het toepassen afhankelijk van de personen. Het wordt nu nog op projectniveau afgesproken i.p.v. op bedrijfsniveau. Stel een ontwerpmanager of ontwerpleider is van oorsprong een wegenbouwer met weinig ervaring met kunstwerken. Die gaat bij wijze van spreken niet zeggen dat dat viaduct probabilistisch moet worden ontworpen en geraamd. Niet alle ontwerpleiders weten van detailniveaus. "Als je zo'n persoon vraagt naar de bandbreedte van het ontwerp schrikt diegene zich waarschijnlijk rot".*

- *Ook is de helft van de constructeurs/tekenaars/geotechnici niet van Heijmans zelf maar is inhuur. Een ingehuurde constructeur zegt ja en amen en gaat niet op eigen initiatief op deze nieuwe manier aan de gang.*

- *De sleutelposities worden zoveel mogelijk ingevuld door eigen mensen, maar je kan niet op korte termijn verwachten dat deze mensen met deze methodiek aan de gang kunnen.*

- *Verder kan je van een ervaren calculator verwachten dat zij een prijs van een viaduct, met het minste detailniveau, zo een schatting kunnen maken van een verwachte prijs met de minimale- en maximale schatting daarbij. Voor een onervaren calculator is dit een shock.*

- *We moeten als bedrijf duidelijk krijgen hoe we met het principe eenduidig om moeten gaan en bekijken naar de toepassing ervan. Dat iedereen het ook waar mogelijk gaat toepassen. Ontwerpleiders/ontwerpmanagers moeten de kar hierin gaan trekken.*

- *"Het proces tussentijds monitoren/meten doe je als je je in een roze wolk begeeft".*

7. Wat ziet u gebeuren op de markt/bij de concurrentie? Bijv. bij het gezamenlijk aanbesteden van een werk.

- *ProRail heeft een bepaalde gedachte bij het probabilistisch ramen en ontwerpen. Maar geen idee wat hun drijfveer is als opdrachtgever zijnde.*

8. Is er volgens u "haast" bij het invoeren van het probabilistische begroten?

- *Haast niet, maar het zal wel een welkome aanvulling zijn.*

9. Een van de doelstellingen van het probabilistisch begroten is het sneller focus kunnen bepalen voor het wel/niet meedoen aan tenders. Wat zijn bij de afdeling ontwerp redenen om juist wel of niet mee te doen aan een tender?

- *Ons wordt eigenlijk nooit gevraagd of we dat werk wel kunnen realiseren. Dat wordt altijd geacht dat wij dat wel kunnen.*

10. Zijn er naast de deterministische en probabilistische methodes ook nog andere methodes om aanbiedingsontwerpen te realiseren?

- *Misschien niet vergelijkbaar met hetgene wat Heijmans gebruikelijk doet maar aanbesteden door middel van statistische benaderingen zoals de Maeslantkering. Waar gewerkt wordt met faalkansen en op die manier dus ook probabilistisch.*

11. Wilt u verder nog iets kwijt over probabilistisch ontwerpen?

- *Wellicht is het wat om EMVI criteria mee te nemen in de vraag. (niet/wel onderscheidend, lage/hoge bandbreedte). Als een criteria is: eerder klaar is dat niet onderscheidend en heeft het een lage bandbreedte. Daar kan je dus vanuit gaan dat de concurrentie daar ook op wil scoren. Het echte geld maar dus ook het fictieve geld meenemen in de bandbreedteanalyse.*

- *Als EMVI belangrijk is, minder focus leggen op het in detail uitwerken van het "echte geld"*

Interview 5: project leader Civiel

1. Wat verstaat u onder probabilistisch ramen?

- *Probabilistisch ramen heb je op twee manieren:*
    - *De bandbreedteanalyse (Heijmans past deze al langer toe)*
    - *Ramen op de "nieuwe manier" door middel van Monte-Carlo simulaties*

- *ProRail werkt ook met probabilistisch aanbesteden als opdrachtgever zijnde, maar dit is ook een andere methode van aanbestedingen vanuit de opdrachtgever zijnde.*

Interview 6: company manager Civiel

1. Probabilistisch tenderen (ramen en ontwerpen) is een begrip waarbij iedereen een verschillende opvatting over heeft. Allen zijn er over eens dat het risico gestuurd tenderen betreft, om de transactiekosten zo laag mogelijk te houden.

- *Naar mijn weten heb je 3 manieren van uitwerken:*
    - *Deterministisch*
    - *Probabilistisch*
        - *Bandbreedte-analyse*
        - *D.m.v. Monte-Carlo simulaties*

Interview 7: company manager HIP, Ontwerpmanagement

Vanuit ontwerp: koudwatervrees over het probabilistisch ontwerp. Wanneer wordt er een ontwerp afgeven waar volledig wordt achtergestaan? Wat je aan de voorkant zegt, hoe is dat aan de achterkant?

Op dit moment is er een statisch proces. Er wordt van te voren een "strategie" bedacht. D.w.z. we werken viaduct A op detailniveau 2, tunnel B op detailniveau 1, viaduct C op detailniveau 3. Achteraf wordt gekeken of dit de goede manier van werken is. Hoe ga je er voor zorgen dat het een dynamisch proces wordt. Op welke momenten ga je tussenpeilingen verzorgen zodat dit proces kan worden bijgestuurd zodat het een optimaal aanbestedingsproces wordt?

Interview 8: company manager, Civiel

1. Wat is het verschil met DC en DBFM contracten? Om uitleg te geven aan de scope.

- Het verschil zit hem grotendeels in de financiering en de exploitatie.

  <u>Ontwerpcomponent:</u>
  Bij het ontwerp bij een DC contract: zo goedkoop mogelijke realisatiekosten.
  Bij DBFM: kan interessant zijn om meer geld te investeren in realisatiekosten. Bijvoorbeeld dikkere laag asfalt o.i.d. Dit wordt dan afgewogen d.m.v. een business case m.b.t. de netto contante waarde. Dit is een methode om geld in de tijd uit te zetten.

  <u>Financieel component:</u>

  Voorschieten geld van de banken. Via beschikbaarheidsvergoedingen en voltooingscertificaten komt het geld na 20, 25 of 30 jaar terug.

  Via een trade off matrix wordt het uiteindelijke ontwerp bepaald. Maar het maakt voor de calculator weinig verschil, wel voor de ontwerper.

  Voor het financieringsgedeelte bij een DBFM contract: een aannemer zet er een bandbreedte op. Mochten de verschillen groter zijn: dan keert de opdrachtgever naar redelijkheid en billijkheid het verschil uit.

  Bij DBFM contracten zoekt de directie naar eventuele partners. Als de directie een Go geeft, gaan afdeling Civiel en wegen aan de gang.

2. Marche is 9% voor een go-no go beslissing. Maar winstmarches zijn vaak kleiner. Wat houdt precies die 9% in?

   BOR: Bruto omzet resultaat. Bestaat uit: algemene Kosten (AK) en Winst. Dat beslaat de marche van 9% zoals aangegeven in de go/no-go beslissing. AK zijn de kosten die moet worden afgestaan aan de NV, zoals kosten voor het kantoor etc.

3. Activiteiten in het kritieke pad: hoe wordt daar mee omgegaan?

- *Bedoel je de tenderplanning of de uitvoeringsplanning?*
  - *Tenderplanning is bijvoorbeeld: activiteit X duurt 2 weken*
  - *Uitvoeringsplanning: realistische planning voor activiteit X met bijv. 6 "subactiviteiten". Bijvoorbeeld X is een landhoofd en subactiviteiten zijn bijvoorbeeld: de vleugelwanden, langsbalken, funderingspalen etc.*

- *Met PERT master kunnen planningen probabilistisch worden uitgerekend. Hoe zeker is die 1 januari 2017 wanneer de planning moet worden afgerond? Geen zekerheid of dat binnen Heijmans gebruikt wordt, volgens mij niet. Aan de hand daarvan, mocht een planning niet gehaald worden door een bepaalde reden en boetes dreigen (of hogere bonus als het werk eerder klaar is..), kunnen versnellingsmaatregelen worden toegepast. Bijvoorbeeld inzet van extra materieel, meer bekistingen kunnen worden geplaatst, een 6e dag per week aan* *het werk etc. Hier wordt op voorhand niet ingecalculeerd. In principe wordt dus niet gekeken naar activiteiten op het kritieke pad.*

4. Hoe komen eenheidsprijzen tot stand?

- *Eenheidsprijzen volgen voornamelijk uit interne Heijmansbedrijven. Ook worden prijzen aan de hand van oude offertes gebruikt en vanuit de nacalculatie. Meer opties zijn er niet, want er worden maar zelden prijzen gebruikt vanuit databases van websites zoals GWWkosten.nl.*

5. Hoe komen bandbreedtes tot stand?

- *Op iedere activiteit volgt een bandbreedte. Deze komen tot stand door een voorstel van: ontwerpleider en calculator. Stelregel hierbij is dat er wordt afgerond op 5%. Vaak wordt de stelregel in verhoudingen gebruikt:*
    - *Bij een strekkende meter: 5% of 10%*
    - *Bij een vierkante meter: 10% of 20%*
    - *Bij een kubieke meter: 15% of 30%*

6. Wordt de SSK gebruikt binnen Heijmans?

- *De SSK is niet de systematiek die bij Heijmans wordt gebruikt. In ieder geval waren de oudere versies niet uitgewerkt genoeg. Daarom is er een "eigen methode" ontwikkeld binnen Heijmans.*
- *Wat soms wel eens vereist was bij opdrachtgevers is dat bij het inleveren van het aanbiedingsontwerp de kosten volgens de SSK methodiek werd ingevoerd. Dit was dan dubbel werk en de eindfase van een tender is toch al hectisch genoeg. Daarom wordt dit zoveel mogelijk voorkomen voorafgaand bij een aanbesteding.*
- *Verschillen bij beide methodieken zijn de plaatsing van de Engineeringskosten (bij Heijmans zijn deze te zien in de beginfase en bij de SSK in de eindfase) en zo wordt er bij de methode van Heijmans geen gebruik gemaakt van de post "onvoorzien" onvoorzien. Dit is wel het geval bij de methode van de SSK.*
- *Er zijn veel calculatiepakketten die worden gebruikt. Maar er zijn nog nooit problemen geweest met het niet gebruiken daarvan.*

7. Hoe zit het met de evaluatiemomenten van een project?

- *Ieder project wordt ieder jaar minstens 1x geëvalueerd. Daar vind de nacalculatie plaats van een onderdeel/gedeelte van het project. Niet van het gehele project, want dat is appels met peren vergelijken. Het gaat er specifiek om waarom projecten in de plus en in de min lopen.*
- *Wat een belangrijke vraag is voor je scriptie: hoe beheers je de objectiviteit van de calculatie.*

8. *Hoe worden kengetallen bijgehouden en gewaarborgd?*
- *Vanaf 2010 worden kengetallen van ieder kunstwerk in een kengetal tender rapport opgeslagen.*

Interview 9: cost expert, Civiel

Gang van zaken A28/A1:
70 kunstwerken, deze worden onderverdeeld in hoofdgroepen, de zgn. kunstwerkfamilies.

Bandbreedtes op de eenheidsprijzen moeten nog bepaald worden. Op basis van:

- Enerzijds gevoel
- Heb ik een offerte?
- Vormgeving: als er naast de functionaliteit ook wat van de vormgeving wordt verwacht
- Risicovolle onderdelen.

Bommen/archeologische vondsten worden in het kans- en risicodossier opgenomen. Daarin staan risico's betreffende tijd/geld. Deze worden gerangschikt in verschillende klassen. Hier worden ook bandbreedtes aangegeven zodoende hierover ook een Monte Carlo simulatie kan worden gedraaid.

De bandbreedtes van hoeveelheden krijg je van ontwerp.
Over de aanvoer van heistellingen moet de calculatie zelf de bandbreedtes/kosten bepalen.

Verschil DBFM/DC contracten: geen ervaring in. Dus over de verschillen kan ik niks melden.

Eenheidsprijzen zijn basisprijzen, die bepaald worden door de leidinggevende calculator.

Over activiteiten op het kritieke pad wordt weinig gesproken. Wel is het zo dat de planning probabilistisch is bij de A28/A1. Interessante vraag is: hoe wordt de probabilistische planning gekoppeld aan geld? (tijdlijn met balkjes, directe/indirecte kosten..)

Aan de hand van de nulraming wordt bepaald welke onderdelen kritiek zijn. Gedurende het traject kan dit worden bijgestuurd. In overleg met ontwerp.

Bij Heijmans Civiel worden de probabilistische ramingen onafhankelijk uitgewerkt. Wellicht bij Ontknoping wordt dit afhankelijk gedaan. Relaties tussen verschillende onderdelen worden gelegd. Ballast Nedam heeft meer ervaringen hiermee. Wordt ook met hun spreadsheet gewerkt. D.m.v. @risk.

De variantenstudies worden afgewogen: kosten zijn belangrijk maar er moet breder worden gekeken.

Ontwerp en directie nog altijd niet in comfort zone met probabilistisch ramen. Er wordt toch nog geregeld "te gedetailleerd" uitgewerkt.

Interview 10: company manager, Wegen; cost expert; Wegen

1. Ik neem aan dat de meeste aanbiedingsontwerpen voor de discipline Wegen op de traditionele, deterministische methode worden geraamd en ontworpen. Toch bestaat al langer het idee om aanbiedingsontwerpen te maken door middel van de probabilistische methode. Binnen HIP is afgesproken dat sinds 01/01/2014 alle grote projecten op deze manier worden geraamd. Maar waarom komt dit nu we bijna in 2015 zitten nog niet echt van de grond? Waar zitten de "belemmeringen" binnen Wegen? En binnen Heijmans?

- *2 tal pogingen gedaan in het verleden om probabilistisch te ramen/ontwerpen. OBSP Leiden en de A12 parallelstructuur. Alsnog zijn beide werken deterministisch uitgewerkt.*

  Door A: beschikbaarheid personeel. Calculatoren willen zekerheid en zijn niet gewend om aannames te doen. Calculatoren zijn sturend voor het ontwerp en een "ongeschikte" calculator wil uitgewerkt ontwerp hebben. Anders voelen ze zich niet in hun "comfort zone".

- *Er moet gedurfd worden om aannames te maken, en op kentallen worden geraamd. Wat we zagen bij Civiel: deterministisch uitrekenen en dan bandbreedtes aan toevoegen. Wegen probeert er naar toe te werken om alles op een hoog abstractieniveau uit te werken, door middel van begroten op basis van kentallen. Daar moet naar toe worden gegaan.*
- *A28/A1 is het eerste project op zo'n grote schaal. Het staat nog in de kinderschoenen. Tot nu toe is het echt "zoeken".*

2. Heeft probabilistisch ramen en ontwerpen meerwaarde voor Wegen? D.w.z. zien jullie heil in deze abstractere manier van aanbesteden? Wordt er volgens jullie te diep ingegaan op sommige zaken in het ontwerp of het ramen van kosten in tenderfases?

- *De waarde van het probabilistisch ramen/ontwerpen nooit ingezien op de manier zoals Civiel het uitvoert. Als je al zo nauwkeurig rekent en je gaat er dan nog eens bandbreedtes aan hangen. Je moet een tender probabilistisch gaan benaderen als je niet deterministisch kan begroten.*
- *Wij gaan de komende jaren verder niet mee met het probabilistisch ramen en ontwerpen. Dit is sowieso in de regio met de kleinere werken niet mogelijk.*

3. Wat is jullie definitie van probabilistisch ramen en ontwerpen en voor welk doel wordt het ingezet/gebruikt? Voor welke fase? Ontwerpinspanningen/ calculatie-inspanningen verminderen?

- *X: "probabilistisch ramen en ontwerpen is het waarderen van onzekerheden"*
- *Y: "met een bepaalde zekerheid kunnen zeggen dat je een werk voor een bepaalde prijs kan maken". "Hoe betrouwbaar zijn de directe kosten"*

4. A28/A1 is een pilot waarop het probabilistisch ramen en ontwerpen voor het eerst op zo'n grote schaal wordt toegepast. Er is besloten dat waar mogelijk probabilistisch wordt geraamd en ontworpen. Gaan jullie daar met Wegen ook helemaal in mee? Wat zijn ervaringen in Soest tot nu toe, nu deze tender wat betreft ontwerp en kostenbepaling op zijn eind loopt?

- *Ballast Nedam heeft zaken omtrent probabilistisch ramen en ontwerpen verder uitgewerkt. Alle calculatoren zijn op cursus geweest hoe om te gaan met dit principe*.

5. Missen jullie hulpmiddelen die het gebruik kunnen vergemakkelijken en die een bepaalde structuur/eenduidigheid kan aanbrengen in het proces van probabilistisch ramen en ontwerpen?

- *Hoe komt men tot afspraken: in samenspraak met HIP, Civiel en Wegen. Zie bestand "ontwerpuitgangspunten". Bij wegen hebben ze het over VO of DO uitwerkingsniveau, maar er zijn ook ontwerprichtlijnen voor*

6. Waarom zijn ze bij Civiel verder met het onderdeel probabilistisch ramen en ontwerpen? Krijgen jullie steun van ze?

Werkwijze bij Civiel: 1 viaduct in 5 moten. Ieder kunstwerk wordt apart gedraaid in @Risk en de P-waarde per kunstwerk komt eruit

Werkwijze bij Wegen: eenheidsprijzen worden met hoeveelheden aangeleverd inclusief bandbreedtes.

Wordt uiteindelijk bij de koepel verzameld en die gaan er verder mee aan de slag. Om uiteindelijk tot een totale kostprijs te komen.

Waken dat het behapbaar blijft. Hoe ga je er mee om, om het praktisch behapbaar te houden? Bij grote infrastructurele projecten heb je bijvoorbeeld al 70 kunstwerken. Dus al 70 regels. Als daarbij nog eens minimaal 10 bijkomen zit je al op 700 regels in een bestandje. Zie je door de bomen het bos niet meer.

7. Hoe komen bij jullie bandbreedtes tot stand en hoe worden de kostenramingen verder uitgewerkt? Op de onafhankelijke/afhankelijke manier?

Onafhankelijk uitgevoerd. Dit vanwege tijd. Natuurlijk zijn er sommige activiteiten bij wegen afhankelijk van elkaar. Zo is een asfaltpakket/ verhardingsconstructie meestal een meter dik t.b.v. de vorst. Verhardingsconstructie bestaat uit ophoogzand, zand voor zandbed, fundering, onderlaag, tussenlaag en deklaag. Als funderingslaag dikker wordt, wordt automatisch een van de andere lagen smaller.

Bij een cementgebonden fundatie wordt ook de asfaltdikte kleiner. Maar dit wordt dus niet meegenomen in de calculatie.

Hoe uit zich dat als dit afhankelijk wordt gedraaid??

Altijd anders met transportafstanden, verwerking asfalt etc.

8. Hoe wordt er omgegaan met activiteiten op het kritieke pad?

- *Kans en risicodossier: opleverdatum wordt niet gehaald*

Richtlijnen door HIP. Specials: aanvullende afspraken, uitwerkingsniveau op DO niveau. Anders uitwerkingsniveau op VO.

Vierkante meters zijn goed te bepalen. Variabele is dus de dikte, dat afhangt met de hoeveelheid tonnen.

EMVI vs. Grofmaziger bekijken

Bullshit in, Bullshit out

Wim de Nijs heeft afspraken gemaakt voor wegen

Straks na eventuele gunning weer onderbouwen

Bespaar ik daadwerkelijk tijd?

Interview 11: design leader HIP, Ontwerpmanagement

Het raamwerk van discipline Wegen is niet daarmee probabilistisch wordt ontworpen. Want probabilistisch ontwerpen is risico gestuurd uitwerken, om zodoende het risicoprofiel zo veel mogelijk terug te brengen tot een acceptabel niveau. Dit proces begint tijdens de variantenstudie (als het contract zich daarvoor leent) en gaat verder als het voorkeursontwerp is gekozen. Dit gaat met risicosessies. Tijdens overleggen worden varianten geselecteerd, deels aan de hand van robuustheid. Als er tijdens de ombouw van een rijksweg bij een variant de doorstroming niet gegarandeerd kan worden, valt die keuze gemakkelijk af. Deze risico's/bedreigingen wordt niet gekwantificeerd.
Vervolgens wordt in Relatics, een programma waarmee alle relevante projectinformatie wordt gebundeld in één systeem zoals:

- *Systems Engineering*
- *Risicobeheersing*
- *Toets- en acceptatieproces*
- *Raakvlakmanagement*

de risico's geplaatst en de RISMAN wordt gebruikt om deze risico's te kwantificeren. Dit gebeurt object/project specifiek.

Samenvattend wordt probabilistisch ontwerpen gebruikt voor de bepaling van het type oplossing en tot aan welk niveau deze oplossing wordt uitgewerkt. Het uitwerkingsniveau moet op voorhand worden afgesproken welke wordt geaccepteerd, en daar moet naartoe gewerkt worden. Risicoprofiel + dat uitwerkingsniveau = prijs tender. Deze prijs wordt op voorhand min of meer bepaald.

Bij Wegen is het uitwerken van bijvoorbeeld het dwarsprofiel altijd lonend. Voor relatief weinig kosten heb je het exacte dwarsprofiel.

Het doorrekenen van de risico's is tijdens de recente aanbesteding van de A28/A1 niet gedaan. Dit is achteraf gebeurt.

Calculatoren willen hun werk zo nauwkeurig mogelijk doen. De meeste hebben moeite met een abstractere benadering. Wellicht is er vrees dat -ondanks dat de directie het abstracter wil benaderen- dat ze "gek" worden aangekeken mocht een raming een keer verkeerd uitpakken. Een disciplineleider moet dus meer gaan sturen naar calculatoren om hen steun te bieden.

"Er is het meest te halen in procesafspraken"

Interview 12: road designer HIP, Ontwerpmanagement

Dit interview is een opsomming van de elementen welke de kosten bepalen voor het aanbrengen van een rijksweg.

- Breedte. De kosten van de breedte van een asfaltlaag zijn afhankelijk van de snelheid waarmee een asfaltmachine werkt. Hoe langzamer een asfaltmachine werkt, hoe beter een laag wordt verdicht. Dit is voornamelijk voor toplagen belangrijk. Ook kan er met meerdere machines worden gewerkt, waardoor er geen koude naad ontstaat.
- Tijd en fasering. Wordt er overdag gewerkt of 's nachts, en wordt er in bepaalde faseringen gewerkt. Dit heeft te maken met extra inzet van verlichting, personeelsbezetting van asfaltploegen en het aantal effectieve werkbare uren.
- Kantopsluiting. Deze kunnen worden ingevoerd per m^1, m^2 of per hoeveelheid. Indien er putten en kolken voorkomen, is dit bewerkelijker.
- Lengte: nachtwerk? Kunnen we effectief maar 3 uur maken en 300 ton asfalt draaien, of kunnen we op een dag 1500 ton draaien? Hoe kan ik het maken, wanneer kan ik het maken? Razen er auto's voorbij? Kan ik achter elkaar door? Bereikbaarheid. Kan je door een barrier en dan 2 km terugsteken? Echt niet. Gebruik shuttle buggy, als feeder van asfaltspreidmachine. Per keer bekijken, en levert het ook nog wat op? Alles kan ook nog kapot! Daar ook rekening mee houden. Op grotere werken staat vaak reserve materiaal. Er wordt uitgegaan van gemiddelde productie. Extremen worden niet in de eenheidsprijs gezet maar als risico neergezet.
- Ondergrond:
  - zettingen. Heb je veel tijd of weinig tijd→ zettingsversnellende maatregelen → aanbrengen tijdelijke overhoogte of verticale drainage.
  - Kom je er uberhaupt met de vrachtwagen?
  - Waar haal ik mijn zand vandaan?
- Grondwater: kan je droog werken? Een tijdelijke polder aanbrengen of damwanden slaan tot aan slecht doordringbare laag.
- Ontwerp maakt varianten, calculatie de afwegingen.
- Tussen 2 asfaltlagen moet een kleeflaag, niet kostbaar
- Wat ook kan voorkomen bij DBFM: gedifferentieerd dwarsprofielontwerp. Alleen toepasbaar bij DBFM contracten. RWS laat dit niet toe bij DC contracten
- Gemodificeerd ZOAB is 5 à 10 euro/ton duurder, relatief goedkope manier van verlengen van levensduur
- ZOAB en DAB scheelt qua kosten niet zoveel, maar ZOAB is uiteraard 20% lichter materiaal.
- Over de keuze SMA of DAB: Vaak DAB want dat is goedkoper.
- Leamrental komt steeds minder vaak voor. Het gaat nu vooral in voertuigverliesuren; als je daarboven uitkomt moet er een boetebedrag worden betaald. Voertuigverliesuur is ook wanneer de snelheid beperkt moet worden van bijvoorbeeld 120km/h naar 70 km/h. VVU worden berekend aan de hand van theoretische modellen.

- Tussenlagen: streven zoveel mogelijk recyclebaar materiaal te gebruiken. In tussenlagen zit er zo'n 50-60% recyclebaar materiaal in, het overige deel bitumen. Wat de grootste kostenpost is.
- Zand voor zandbed. Hiervoor is een vergunning nodig voor het ontgraven van zand. Als er binnen werkgrenzen zand kan worden gewonnen wat anders afgevoerd kan worden is dat prima, maar uit de buurt zand voor zandbed halen wat bedoelt is voor commerciële doeleinden, daarvoor wordt nooit een vergunning afgegeven. Dus dit wordt bijna altijd aangevoerd van elders. Voor zand voor ophoging worden wel eens staalslakken gebruikt of Avi slakken, indien dit verwerkt mag worden.
- Qua temperatuur kan er altijd wel omheen gepland worden. Maar asfaltlagen worden niet aangelegd tijdens koude weersomstandigheden. Daarom wordt er tussen november-april weinig asfaltklussen gepland. Regen is van meer invloed met de aanleg van wegen. Hierbij kan een deklaag niet worden aangebracht, wel onderliggende lagen. Bij heftige regenval moet een werk gewoon worden afgeblazen. Dit is niet erg bij nieuwbouw, maar wel bij onderhoudsklussen. Hiervoor zijn wegafzettingen gereserveerd. Waardoor onderhoud pas bijv. in het weekend 3 weken later kan plaatsvinden.
- Afstand tot molen: hoeveelheid auto's met bepaalde afstand. Transport cirkel uitrekenen oftewel de cyclustijden. Vuistregels hierbij zijn: 30-45min laadtijd, waarbij 30 minuten legen en 15 minuten volladen. En 50km/h tussen molen en locatie. Het type transport is afhankelijk van ondergrond (veen/ of kan ik over mijn eigen asfalt rijden) zijn al mijn assen aangedreven of alleen de vooras, of de verkanting (kan ik kippen of valt daardoor mijn truck om)
- 20-25% meer kosten nachtinzet personeel
- M2 per verharding, m1 bandlijn, of heel gedetailleerd (is ook weer een bepaalde vorm schijnveiligheid).
- Kort samengevat:
  - Wat moet ik maken (welke constructies)
  - Waar moet ik het maken (grondslag, geografie, water)
  - Hoe moet ik het maken (verkeer, dag, nacht, fasering)